Falkland Oil and Gas Limited

RPS Energy

Exploration Drilling
Environmental Impact Statement

Date: November 2011

Revision: 02

Falkland Oil and Gas Limited

ENVIRONMENTAL IMPACT STATEMENT
EXPLORATION DRILLING

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November 2011

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Document Details and Issue Record

Rev No.	Details	Date	Author	Checked Text	Checked Calcs.	Approved
01	Final	03/08/2011	OS / SA / JC	GC /SS	SS	MT / CM
02	Revised	24/11/2011	SS / SA / HN / SP	SS / SA / HN / SP	SS	MT
Document Reference:	Projects\Falkland Oil and Gas Limited\2148 – Environmental Support					

Project Information Sheet

Project Name	Exploration Drilling Environmental Impact Statement
Type of Project	Exploration Drilling
Undertaker Name	Falkland Oil & Gas Limited
Undertaker Address	32-34 Wigmore Street, London, W1U 2RR
Licensees/Owners	Falkland Oil and Gas Limited is the operator, with 100% ownership of 13 exploration and production licences offshore Falkland Islands.
Operational Description	Falkland Oil & Gas Limited (hereafter referred to as 'FOGL') plan a 2-well exploration drilling campaign offshore eastern and southern Falkland Basins. Five prospective well locations are under consideration with Loligo (A or NW) being a certain well number one; whereas the alternate Loligo, Vinson West, Nimrod and Scotia East D are alternatives for a second choice well. Final well locations will be discussed in the Operational Addendum, following the Environmental Impact Statement (EIS) submission. The distances from the proposed well locations to the nearest landfall vary between 155 kilometres (Vinson West) and 314 kilometres (Scotia East D) and the recorded water depths are in the range of 1,300-1,800 metres. It is anticipated that hydrocarbons, if discovered, would primarily comprise oil with an API of 18-25^{o} for all wells, apart from Scotia East D (API 30^{o}). The wells will be drilled using the semi-submersible 5th generation dynamically positioned drilling rig Leiv Eiriksson. The exploration wells are currently planned as vertical wells. Following drilling operations, the wells will be plugged and abandoned in accordance with UK Oil and Gas Guidelines. Seabed structures will be dealt with according to FIG guidelines. Water-based muds will be used to drill all wells. The vast majority (by volume) of planned chemicals have a Harmonised Offshore Chemical Notification Scheme category of 'E' (which are of low aquatic toxicity, readily biodegradable and non-bio accumulative) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable.
Anticipated Project Commencement	April- May 2012
Anticipated Project Duration	Approximately 100 days (45 to 50 days per well)
Significant Environmental Impacts Identified	FOGL is aiming to limit environmental effects to as low as reasonably practicable through project design and mitigation. During drilling it is considered that the following project activities may have an impact: atmospheric and noise emissions, discharge of water based mud and cuttings, waste disposal and the accidental spill of hydrocarbons. For all routine activities the severity of the impact is limited by the nature and composition of the environment and by the fact that these activities are short-term and affect a localised area. With mitigation measures in place, the proposed project will have minor impacts on the environment. However, in the unlikely event of a worst case scenario oil spill (i.e. blow out preventer failure leading to a long term release of liquid hydrocarbons until a capping device can be deployed or a relief well drilled), the impacts on offshore marine resources, particularly seabirds, are likely to be significant.
Statement Prepared By	RPS Energy

Non Technical Summary

Overview

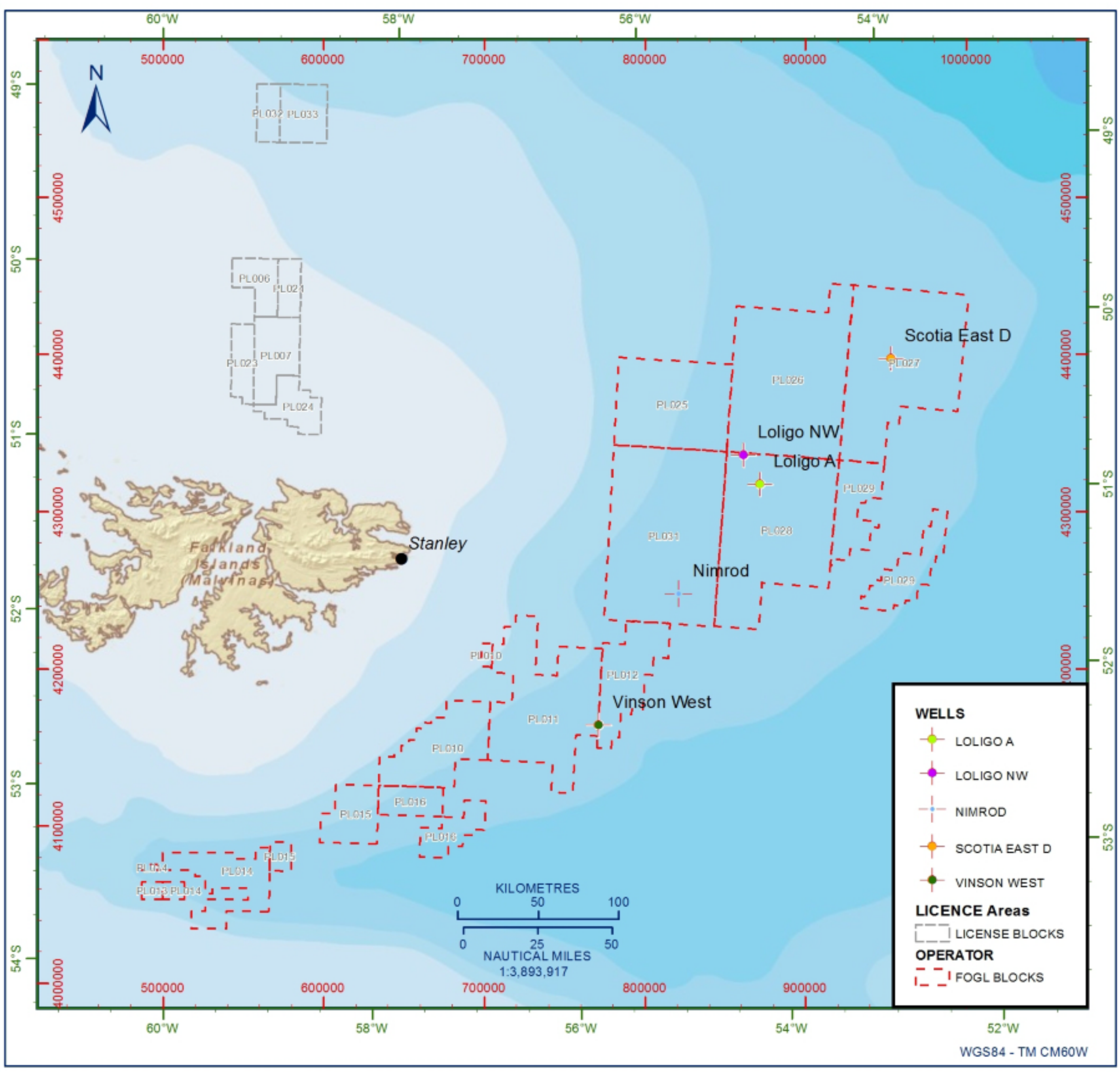
This Non Technical Summary accompanies a full report which presents the results of the Environmental Impact Assessment (EIA) undertaken for a two-well exploration drilling campaign proposed by Falkland Oil and Gas Limited (FOGL).

The purpose of the Non Technical Summary is to briefly describe the project, environmental baseline conditions, summarise potential project impacts and present recommendations on mitigation measures.

Project Background

Falklands Oil and Gas Limited (FOGL) holds 100% equity interest and operatorship of 13 exploration and production licences offshore Falkland Islands (Figure 1), a UK Overseas Territory located on the edge of the Patagonian Shelf in the south Atlantic Ocean. The exploration and production licences cover approximately 48,740 square kilometres and are located in water depths ranging from 500 to 2,000 metres.

Figure 1. FOGL Licence Area and Potential Well Locations



FOGL is a UK-based company and has been engaged in the exploration for oil and gas in the south and east Falklands Basins since 2004. The company carried out a number of seismic and site surveys and drilled their first well FI 61/05-1, on the Toroa prospect, in 2010. The evaluation of Loligo, Scotia, Nimrod and Vinson West and other key prospects continues with the current drilling programme proposed for the year 2012.

FOGL plans to drill two exploration wells. The first well will be on the Loligo prospect at location A or NW. The second well location has not been confirmed but will be on either the Vinson West, Nimrod or Scotia prospects or potentially it will be a well in the Loligo area e.g. Loligo NW (Figure 1). The proposed wells lie to the east and southeast of the Falkland Islands. The nearest well to the shore is Vinson West (155 kilometres) and the furthest is Scotia East D (314 kilometres). The water depths at these well locations vary from 1,300 to 1,800 metres.

It is anticipated that hydrocarbons, if discovered, would primarily comprise oil with an API of 18-25^{o} for all wells apart from Scotia East D (API 30^{o}). Gas with condensate is a possible alternative but not considered in this EIA as this would represent a best case scenario from the point of view of environmental impacts.

FOGL has contracted to use the Leiv Eiriksson dynamically positioned, fifth-generation semi-submersible rig, owned by Ocean Rig INC. The rig will mobilise following drilling in the neighbouring southern blocks operated by Borders & Southern. Drilling is anticipated to commence in April or May 2012 and will last for up to 100 days (45 to 50 days per well). Following drilling, the wells will be plugged and abandoned in accordance with UK Oil and Gas Guidelines. FIG guidelines for removal of obstructions from the seabed will be followed. Water-based muds will be used to drill both wells. Chemicals to be used during the drilling have been selected to minimise the potential environmental impacts as far as possible. The vast majority (by volume) of planned chemicals have a Harmonised Offshore Chemical Notification Scheme category of 'E' (which are of low aquatic toxicity, readily biodegradable and non-bio accumulative) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable.

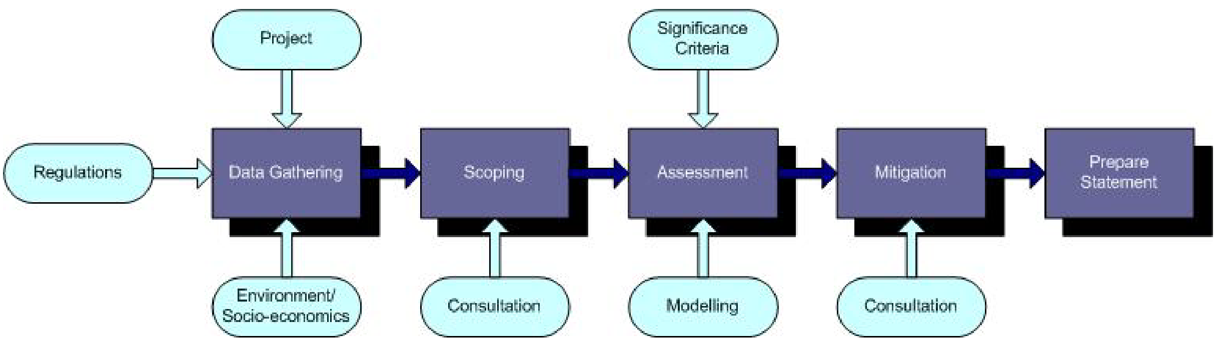
The drilling operations will be managed by AGR as drilling management contractor on behalf of FOGL. Three support vessels and two helicopters will be used throughout planned operations. Further operational details are included in Section 4.

Scope and Methodology

FOGL has commissioned RPS Energy to undertake the Environmental Impact Assessment (EIA) for the 2-well drilling programme in their southern and northern licence areas offshore Falkland Islands.

The EIA is an important management tool which ensures that environmental hazards and impacts are identified and evaluated and that appropriate control (mitigation) measures are implemented throughout all phases of the project.

Figure 2. EIA Process



The purpose of the EIA is to:

- Set EIA objectives by defining the applicable Institutional, Policy and Regulatory frameworks;
- Describe the work that the project proponent intends to undertake and how the environmental considerations have formed an essential part in the development concept, definition and selection of the activities;
- Describe the physical, biological and socio-economic components of the environment within the study area and to assess their sensitivities in the context of the intended exploration drilling programme;
- Undertake scoping exercises during the project planning stage through consultation with the Falkland Islands Government and key stakeholders, to outline key operational impacts associated with the project;
- Qualitatively and quantitatively assess the nature, significance and probability of impacts on environmental resources and receptors;
- Develop appropriate mitigation measures, together with management and monitoring procedures that will seek to avoid, minimise or reduce potential impacts to a level as low as reasonably practicable.

The EIA has been prepared to satisfy the requirements of The Offshore Minerals Ordinance 1994 (amended 1997) and other Falkland Islands' legislation pertaining to offshore exploration and production activities.

The geographical scope of this EIA includes the 13 FOGL licences together with the wider marine and coastal environment where relevant to the potential impacts of the Project (referred to as 'the project area of influence'). The focus of the EIA is on the locations where wells are likely to be drilled (see Figure 1).

Any operational details not covered by the EIS will be detailed in the Operational Addendum, which will be submitted to the Falkland Islands' Government (FIG) for review and approval, as per FOGL's agreement with FIG.

Baseline Environment

Data Collection

To provide a baseline against which potential impacts can be assessed, the EIA provides a description of the conditions that will prevail in the absence of the project. The baseline includes information on all receptors and resources identified as having the potential to be significantly affected by the proposed project. For this EIA, baseline data collection proceeded in several stages:

- Collection of available data from existing sources including:
  - Government agencies;
  - Research and academic organisations;
  - Published sources;
  - External stakeholders; and
  - Previous offshore exploration EIAs.
- In-country information gathering and stakeholder interviews.
- Benthic and geophysical surveys of the well site locations have been undertaken to inform the physical and biological components of the baseline.
- Various meteorological studies commissioned by FOGL.

- Marine Mammal Observers (MMOs) reports issued from seismic and site surveys by various operators have been analysed and incorporated to provide up-to-date information on marine mammal sightings in the area.

Overview

The Patagonian Shelf Large Marine Ecosystem, where the Falkland Islands lie, is of regional and global significance for marine resources (Croxall & Wood, 2002). Current patterns and bathymetry influence nutrient circulation and marine productivity levels. Productive waters upwell on the edge of the continental shelf, but most particularly, to the northwest of the Jason Island Group, Beauchêne Island and the Burdwood Bank (Otley *et al*., 2008). These areas are rich in plankton and fish assemblages, and are important foraging grounds for seabirds and marine mammals (White *et al*. 2002).

Key environmental sensitivities identified within the FOGL licence blocks and surrounding areas are discussed below and summarised in Table 1.

Key Physical Sensitivities

- The Falkland Islands offshore area is characterised by weather conditions with strong winds and average wave heights of 2-3 metres.
- On rare occasions, icebergs may occur within the licensed area.
- No gas hydrates have been identified during the well site surveys.

Key Biological Sensitivities

- A medium density of kelp species can be found throughout the project areas, providing food and habitat for a wide range of marine invertebrates and fish.
- The most prominent colonial epifauna encountered across the Loligo site constitutes cnidarians, including at least two species of gorgonian (soft corals) and at least one species of scleractinian (hard or stony coral). The recovered coral samples, although superficially similar to the cold water coral *Lophelia pertusa*, are believed to be analogous Antarctic species, capable of withstanding colder waters. There is insufficient evidence to conclude that recorded coral species are part of cold coral colonies/reefs classified as Annex I Habitat under the EU Habitats Directive.
- Fish species known to spawn in the vicinity of the FOGL exploration wells include Patagonian toothfish (peaks between May and July through to August), and Grenadier during March-April.
- The following species of cetacean were recorded during the austral winter around the proposed FOGL well sites: Fin whale, Long-finned pilot whale, Southern bottlenose whale, Hourglass dolphin, Peale's dolphin, Sei whale, Minke whale, Sperm whale, Killer whale, Blue whale, and Spectacled porpoise.
- Pinnipeds present in the vicinity of the FOGL sites include: South American sea lion, southern elephant seal, South American fur seal and the rare Leopard seal. All of these species except the leopard seal spend the summer months ashore on the Falkland Islands breeding. During winter, however, they have been observed undertaking long foraging trips which overlap with the FOGL blocks.
- Petrels are known to be present in the vicinity of the FOGL site, with particularly high numbers occurring during the proposed drilling period. These include; Antarctic fulmar, Kerguelen petrel, Cape petrel, and Blue petrel. Other seabird species likely to be present include: Soft-plumaged petrel, White chinned petrel, Grey-backed storm petrel, Great shearwater, Sooty shearwater, Great shearwaters, Little shearwater, Prion and Skua sp, Kelp gull, South American tern and the Arctic tern.
- Of the penguin species recorded offshore the Falkland Islands, only king penguins and gentoo penguins are likely to be present in significant quantities during the proposed drilling period; they can forage far offshore but predominantly stay near to the shore.

- It is possible that the following species of albatross will be present in the vicinity of FOGL blocks throughout the year: Southern and Northern royal albatross, Black-browed albatross and Grey-headed albatross, Light-mantled sooty albatross, Wandering albatross and Shy albatross.
- Seabird vulnerability is assumed to be high throughout the drilling period due to variability in seasonality and occurrence of various birds with protected status. Based on the JNCC study (White *et al*., 2002), seabird vulnerability to oil spills in the proximity of the project area is highest in August, and was rated as high on the vulnerability scale. During winter and spring months seabird vulnerability was rated as low, and there was no data for March and May. The JNCC data coverage is not sufficient for impact assessment purposes and was used as an indicator of seabird vulnerability for near shore areas only.
- Numerous protected areas exist on the Falkland Islands coast related to seabirds and seal colonies. The closest to the proposed FOGL well sites is the Stanley Common & Cape Pembroke Sanctuary Protected Area, located approximately 153 kilometres northwest of the Vinson West well site.

Key Socio-Economic Sensitivities

- The Patagonian Toothfish and Grenadier are the main catch throughout the FOGL licensed area, with some Rock cod fishing in the vicinity of the northern well sites. Other species caught in this region include Skates, Hake and Loligo squid.
- Low density of shipping in the general offshore area and in the vicinity of the proposed wells.
- Tourism in the Falklands is growing rapidly. However, tourist levels peak in austral summer, outside the FOGL drilling timetable.
- There is an increasing exploration interest, with a focus on the north Falklands licences. To the south and east of the Falklands, only one well (Toroa - 2010) has been drilled.

Table 1. Overview of the key seasonal environmental sensitivities for the FOGL blocks and surrounding waters (proposed drilling period outlined in red)

Species	J	F	M	A	M	J	J	A	S	O	N	D
Cetaceans												
Fin whales (*Balaenoptera physalus*)	Peak Occurrence	Peak Occurrence	Known Occurrence	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Peak Occurrence	Peak Occurrence
Sei whale (*Balaenoptera borealis*)	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Known Occurrence	Known Occurrence
Antarctic minke whale (*Balaenoptera acutorostrata*)	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Peak Occurrence
Sperm whale (*Physeter macrocephalus*)	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence
Southern bottlenose whale (*Hyperoodon planifrons*)	Known Occurrence	Known Occurrence	Known Occurrence	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence
Southern right whale (*Eubalaena australis*)	Known Occurrence	Known Occurrence	Known Occurrence	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Known Occurrence	Known Occurrence
Long – finned pilot whale (*Globicephala melas*)	Known Occurrence	Known Occurrence	Known Occurrence	Peak Occurrence	Peak Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence
Hourglass dolphin (*Lagenorhynchus cruciger*)	Peak Occurrence	Peak Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Peak Occurrence	Peak Occurrence
Peale's dolphin (*Lagenorhynchus australis*)	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence
Commerson's dolphin (*Cephalorhynchus commersonii*)	Peak Coastal Occurrence	Peak Coastal Occurrence	Peak Coastal Occurrence	Peak Coastal Occurrence	Known Coastal Occurrence	Known Coastal Occurrence	Peak Coastal Occurrence	Peak Coastal Occurrence	Peak Coastal Occurrence	Peak Coastal Occurrence	Known Coastal Occurrence	Known Coastal Occurrence
Killer whale (*Orcinus orca*)	Peak Occurrence	Peak Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Peak Occurrence	Peak Occurrence	Peak Occurrence	Peak Occurrence
Blue whale (*Balaenoptera brydei*)	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Occurrence Unlikely	Known Occurrence	Known Occurrence	Known Occurrence
Spectacled porpoise (*Phocoena dioptrica*)	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Known Occurrence	Peak Occurrence

Key *Peak Occurrence* *Known Occurrence* *Peak Coastal Occurrence* *Known Coastal Occurrence* *Occurrence Unlikely*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Pinnipeds												
South American sea lion (*Otaria flavescens*)	Peak	Peak	Known	Peak	Peak	Known	Known	Known	Known	Peak	Peak	Peak
Southern elephant seal (*Mirounga leonine*)	Peak	Peak	Known	Known	Known	Known	Known	Known	Peak	Peak	Peak	Peak
South American fur seal (*Arctocephalus australis*) australis)	Peak	Known	Known	Known	Known	Peak	Peak	Peak	Peak	Peak	Peak	Peak
Leopard seal (*Hydrurga leptonyx*)					Known	Known	Known	Known	Known			

Key: Peak Occurrence | Known Occurrence | Occurrence Unlikely

Species	J	F	M	A	M	J	J	A	S	O	N	D
Penguins*												
King penguin (*Aptenodytes patagonicus*)	Known	Known	Known	Known	Known	Peak	Peak	Peak	Peak	Known	Known	Known
Gentoo penguin (*Pygoscelis papua)*	Known	Known	Known	Peak	Peak	Peak	Peak	Peak	Peak	Known	Known	Known
Southern rockhopper penguin *(Eudyptes chrysolophus)*	Peak	Known	Known	Known	Known	Known	Known	Known	Known	Known	Peak	Peak
Macaroni penguin (*Eudyptes chrysolophys*)							Known	Peak	Peak	Known		
Magellanic penguin (*Speniscus magellanicus*)	Peak	Peak	Peak	Known	Known	Known	Known	Known	Known	Known	Peak	Peak
Chinstrap penguin *(P. Antarctica)*								Known	Known	Known		
Albatrosses*												
Black – browed albatross (*Thalassarche melanophris*)	Known	Known	Peak	Known	Known	Known	Known	Known	Known	Known	Known	Known
Grey-headed albatross (*Thalassarche chrysostoma*)	Known	Known	Known	Peak	Peak	Peak	Peak	Peak	Peak	Known	Known	Known
Light – mantled sooty albatross (*Phoebetricia palpebrata*)	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known
Northern royal albatross (*Diomedea sanfordi*)	Known	Known	Peak	Peak	Peak	Known	Known	Known	Known	Known	Known	Known
Southern royal albatross (*Diomedea exulans*)	Known	Known	Peak	Peak	Peak	Peak	Known	Known	Known	Known	Known	Known
Wandering albatross (*Diomedea exulans*)	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Peak	Known
Shy albatross (*Thalassarche cauta*)	Known	Known	Known	Known	Known							
Petrels and Shearwaters*												
Southern giant petrel (*Macronectes giganteus*)	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known
Northern giant petrel (*Macronectes halli*)	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known
Antarctic petrel (*Thalassoica antarctica*)							Known	Peak	Known			
Cape petrel (*Daption capense*)				Known	Peak	Peak	Peak	Peak	Peak	Known	Known	
Antarctic fulmar (*Fulmarus glacialoides*)	Known	Known	Known	Known	Peak	Peak	Peak	Known	Known	Known	Known	Known
Blue petrel (*Haloboena caerulea*)			Known	Known	Known	Known	Peak	Peak	Peak	Known		
Kerguelen petrel *(Lugensa brevirostris*)			Known	Known	Known	Known	Peak	Peak	Peak	Known		
Soft plumaged petrel (*Pterodroma mollis*)	Peak	Peak	Peak								Known	Peak
Atlantic petrel (*Pterodroma incerta*)			Peak	Known	Known	Known	Known	Known	Known	Peak	Peak	Known
Grey petrel (*Procellaria cinerea*)	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known	Known

Key: Peak Occurrence | Known Occurrence | Unlikely Occurrence

Species	J	F	M	A	M	J	J	A	S	O	N	D
White-chinned petrel (*Procellariaaequinoctialis*)												
Wilson's storm – petrel (*Oceanites oceanicus*)												
Grey backed storm petrel (*Garrodia nereis*)												
Diving Petrels*												
Black bellied storm petrel (*Fragetta tropica*)												
White bellied storm petrel (*Fragetta grallaria*)												
Great shearwater (*Puffinus gravis*)												
Sooty shearwater (*Puffinus griseus*)												
Little shearwater (*Puffinus assimilis*)												
Prions*												
Fairy prion (*Pachyptila turtur*)												
Rock shag (*Phalacrocorax magellanicus*)												
Imperial shag (*Phalacrocorax atriceps*)												
Swans, Geese and Ducks												
Skuas Stercorariidae*												
Catharacta skua (*Stercorarius skua*)												
Arctic skua (*Stercorarius paasiticus*)												
Long tailed skua (*Stercorarius lonicaudus*)												
Gulls Laridae*												
Dolphin gull (*Larus scoresbii*)												
Kelp gull (*Larus dominacanus*)												
Brown-hooded gull (*Larus maculipennis*)												
South American tern (*Sterna hirundinacea*)												
Arctic tern (*Sterna paradisaea*)												
Key	*Peak Occurrence*		*Known Occurrence*			*Occurrence Unlikely*						

**Indicating vulnerability only in coastal areas*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Plankton												
Key:	*Peak Bloom Period*		*Summer Bloom Period*									

Species	J	F	M	A	M	J	J	A	S	O	N	D
Patagonian toothfish (*Dissostichus eleginoides*)												
Grenadier (*Macrourus spp.*)												
Key:	*Known Spawning Period*											

Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into the summary table outputs, and therefore the table gives only a basic guide to the presence/absence of species throughout the year.

Discussion of Impacts and Mitigation

The proposed exploration activities have the potential to induce noise, atmospheric emissions, physical disturbance and a variety of discharges (routine, and non-routine; such as spills) and wastes.

A detailed study of the potential impacts, sensitivity of receptors, mitigation measures and any residual impact has been carried out and is included within this EIS report. An overview of the main areas of impact and their significance is provided in Table 2 below.

Table 2. Potential Hazards and Associated Impacts from the Proposed Drilling Operations assuming Implementation of Pollution Prevention and Mitigation Measures

Hazard	Water & Air		Flora & Fauna							Socio-economic						Other		
	Water Quality	Air Quality	Plankton	Seabed Fauna	Fish Spawning	Offshore Sea Birds	Coastal Birds	Marine Mammals	Sensitive Coastal Sites	Fishing	Shipping	Military Activity	Pipelines, Wells & Cables	Archaeology	Tourism / Leisure	Land Use	Sediments	Resource Use
Physical Presence						4				4	4	5	5		5			4
Seabed Disturbance				3									5	5			4	
Noise & Vibration					5	5	5	4										
Atmospheric Emissions		4																
Marine Discharges	5		5	4	5													
Solid Waste									5							3		
Minor Loss of Containment	4		4		5	4		5		4	5	5			5			
Major Loss of Containment	3		3	4	3	2	3	2	3	3	3	4			3		4	3

Key to Significance of Effect (see Table 6.1 for definitions)

1	Severe	2	Major	3	Moderate	4	Minor	5	Negligible		None

The risk of accidental hydrocarbon spillage to the sea is the main environmental concern associated with the proposed drilling programme. Spilled oil can have a number of environmental and economic impacts.

The greatest environmental sensitivity to oil spills would be the presence of vulnerable and protected seabird populations (i.e. penguins, petrels, albatrosses) and marine mammals (cetaceans and pinnipeds in particular). Without implementation of mitigation measures to stop or disperse a worst case scenario spill, the impact on these species is likely to have severe consequences affecting regional population count and dynamics, long term (>10 years) damage and poor potential for recovery rates. Provided that an effective and timely spill response is put in place, the overall impact is likely to be reduced to a lower significance, where medium term (>2 years) damage to ecosystem occurs with a likelihood of recovery within 10 years.

Cumulative environmental effects from the planned exploration programme are considered to be minor given the short term nature of the drilling and low level of exploration activities in the east and south Falkland Basins.

Transboundary impacts have a low probability of occurring and are assessed to be of minor significance provided the below mitigation measures are implemented. The potential impacts of these operations will be mitigated in a number of ways, including:

- Maintaining a culture of openness and ongoing consultation with the Falkland Islands Government (FIG), the public and key stakeholders;
- Applying international best practice and established UK standards to the proposed operations;
- Extensive logistical planning prior to commencing operations to ensure that no strains are placed on current onshore capacities;
- Comprehensive operational planning, risk assessment and provision of suitable specification equipment for drilling (i.e. blowout preventer) and planning for emergencies (i.e. capping device, relief well);
- Implementing a high level of environmental management offshore and applying environmental procedures for potentially impacting operations (chemical storage, bunkering, waste handling, maintenance programmes, seafloor surveys etc);
- Establishing and implementing a project specific Oil Pollution Emergency Plan and carrying out training of key personnel in spill response. FOGL will be a member of Oil Spill Response Ltd and will have access to their Tier 1, 2 and 3 response capabilities as well as a dedicated oil wildlife response capability provided by the Sea Alarm;
- Preparation of the Iceberg Management Plan covering iceberg surveillance and monitoring procedures and detailing avoidance and mitigation measures;
- Implementing a detailed waste management plan to minimise the quantity of waste going to landfill, prevent unsuitable disposal of waste, and maximise the re-use of materials. All hazardous waste will be transferred to UK for treatment and disposal;
- Using water based drilling muds and low toxicity chemicals approved under the UK Offshore Chemical Notification Scheme;
- Ensuring all discharges from the rig/supporting vessels are treated and discharged according to the MARPOL Convention;
- Preventing increased noise levels in ecologically sensitive areas, i.e. avoiding helicopter flights over seabird and pinniped colonies;
- Collecting and sharing environmental data wherever possible, for example in offshore sightings, seabed surveys and meteorological and oceanographic conditions.

Conclusions

The assessment of potential environmental impacts from the proposed drilling programme has been carried out using a conservative precautionary approach, and is based on publicly available literature, unpublished research data, inputs from stakeholder consultation combined with the expert judgement of the RPS Energy consultants and the Falklands Island Government departments, Falkland Conservation, Birdlife International and NGOs. On the basis of the assessment conducted, a wide range of preventative and mitigation measures have been proposed.

Given the current operational commitments and proposed mitigation measures, it is considered that the routine drilling activities can be undertaken without significant impacts to the Falkland Islands' environment. However, in the event of a potential blowout under worst case scenario conditions (i.e. loss of control of the well due to failure of numerous safety systems e.g. blow-out preventer; long term release of liquid hydrocarbons until a capping device can be deployed or relief well can be drilled), the impact is likely to be of major significance.

Further Studies and Recommendations

Data Gaps

EIA process is heavily reliant on the accuracy and availability of the baseline environmental data. For the current EIA, a series of data gaps have been identified which are to be considered as an element of uncertainty contributing to the final conclusions:

- Absence of reliable scientific data on fish spawning and nursery grounds around Falklands Islands. Though a number of publications discuss this subject, there is insufficient coverage, or correlation between various results, to build up regional and temporal overviews of the spawning areas;
- Sparse information on the benthic environment, including protected habitats (i.e. cold coral colonies) offshore Falkland Islands. There is therefore a need for a strategic co-ordinated survey and monitoring programme;
- Comparatively little is known about the numbers and distribution of marine mammals in the offshore environment, their use of the area and its resources. Survey effort to date is limited to fishing observations and a single 'Seabirds at Sea' programme undertaken in 1998-2001. Therefore a need for a strategic co-ordinated survey and monitoring programme based on adequate scientific approach exists. Given weather conditions offshore Falklands, a programme of acoustic monitoring is also desirable to complement such visual surveys throughout the year;
- Existing MMO reports from rig site surveys and seismic surveys have not been collated into the main body of knowledge on cetaceans. With suitable co-ordination and methods development, existing cetacean data gathering could be improved and systematised;
- Few data, including the Seabirds at Sea programme of 1998-2001, and observations from fishing vessels, currently exist to indicate foraging areas for pinniped species along the Falklands Shelf. The first attempts to determine the offshore distribution of pinnipeds using tagging and satellite telemetry methods, began in 2000. However, in most cases the sample sizes were too small to be conclusive of pinniped distribution trends. A Falkland Island wide survey to assess the abundance and distribution of pinnipeds is highly desirable due to their high vulnerability to marine noise and oil spills;
- Comparatively little is known about the numbers and seasonal distribution of seabirds in the offshore environment, and their vulnerability to surface pollution at different times of the year. Fishing vessel observations are partially biased as vessels tend to attract certain types of birds, whilst the Seabirds At Sea survey (1998-2001) effort was particularly low to the east and south of the Falkland Islands i.e. the FOGL licence areas. Seabird tracking data has been collected since 1994 and is limited to a few species of protected petrels and albatrosses.

General Recommendations- data gaps and data management

- Survey data (benthic, cetaceans, pinnipeds) collected by various operators should be designed to generate datasets that can support both strategic and site-specific approaches to environmental assessment.
- Falkland Islands marine monitoring and data gathering initiatives should be initiated and integrated across and between the various state agencies, research institutions and commercial operators.
- Environmental data (physical, chemical, biological and relating to other sea users) should be collated and held in a co-ordinated and readily accessible database at an identified location for use in future oil and gas-related environmental assessments.

Project Specific Recommendations

Project specific recommendations to enhance the knowledge of licensing area include:

- Use of marine mammal and seabird observers during drilling programme.
- Compiling and releasing seabed visual observations from ROV surveys where these provide information on seabed habitats or species.

Abbreviations

%	Percent
%Sat	Percentage Saturation
”	Inches
°	Degrees
°C	Degrees Celsius
$\mu g.g^{-1}$	Micrograms per gram
2D	Two Dimensional
ACAP	Agreement on the Conservation of Albatross and Petrels
ACC	Antarctic Circumpolar Current
ADCP	Acoustic Doppler Current Profiler
AIM	Alternative Investment Market
ALARP	As Low As Reasonably Practicable
APF	Antarctic Polar Front
API	American Petroleum Industry
ATC	Acorn Tourism Consulting
boe	Barrels of oil equivalent
BHP	Broken Hill Proprietary Company Limited
BOP	Blow-out Preventer
B&S	Borders and Southern
CBD	Convention on Biological Diversity
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEFAS	Centre for Environment Fisheries and Aquaculture Science
CHARM	Chemical Hazard Assessment and Risk Management
CITES	Convention on the International Trade of Endangered Species
$cm.s^{-1}$	Centimetres per second
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CO_2	Carbon Dioxide
CZ	Confluence Zone
DP	Dynamically Positioned
E&P	Exploration and Production
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMP	Emergency Management Plan
ERP	Emergency Response Plan
FC	Falklands Conservation
FCO	Foreign and Commonwealth Office

FICZ	Falklands Inner Conservation Zone
FIDA	Falkland Islands Designated Area
FIFD	Falkland Islands Fisheries Department
FIC	Falkland Islands Company Ltd
FIG	Falkland Islands Government
FIGAS	Falkland Islands Government Air Service
FIPASS	Falklands Interim Port and Storage System
FOC	Fractional Organic Compound
FOCZ	Falklands Outer Conservation Zone
FOGL	Falkland Oil and Gas Limited
FOSA	Falklands Offshore Sharing Agreement
FSLTD	Fugro Survey Limited
GMT	Greenwich Mean Time
HSES MS	Health, Safety, Environmental and Social Management System
HMCS	Harmonised Mandatory Control Scheme
HOCNF	Harmonised Offshore Chemical Notification Format
HQ	Hazard Quotients
HSE	Health, Safety and Environment
IPIECA	International Petroleum Industry Environmental Conservation Association
IADC	International Association of Drilling Contractors
IBA	Important Bird Area
ITOPF	The International Tanker Owners Pollution Federation
IUCN	International Union for the Conservation of Nature
JNCC	Joint Nature Conservation Committee
Kg	Kilogram
LAT	Lowest Astronomical Tide
m	Metres
m^2	Square Metres
m^3	Cubic Metres
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973,
mm	Millimetres
MMO	Marine Mammal Observer
MPC	Mount Pleasant Complex
MRAG	Marine Resources and Fisheries Consultants
ms^{-1}	Metres per second
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
$ng.g^{-1}$	Nanograms per gram

NNR	National Nature Reserves
NO_2	Nitrogen Oxide
NO_X	Nitrous Oxides
OCNS	Offshore Chemical Notification Scheme
OGP	Oil and Gas Producers
OPEP	Oil Pollution Emergency Plan
OSIS	Oil Spill Information System
OSPAR	Oslo / Paris Convention
OSRL	Oil Spill Response Limited
PAH	Polycyclic Aromatic Hydrocarbons
PLONOR	Pose Little or No Risk to the environment
PON	Petroleum Operations Notices
ppg	Parts Per Gram
ppt	Parts Per Ton
PROTEUS	Pollution Risk Offshore Technical Evaluation System
PSA	Particle Size Analysis
PSD	Particle Size Distributions
Q1-4	Quarter 1-4
RAF	Royal Air Force
ROV	Remotely Operated Vehicle
RQ's	Risk Assessments
SO_X	Sulphur Oxides
TD	Target Depth
THC	Total hydrocarbon concentrations
TOM	Total Organic Matter
TVD	Total Vertical Depth
UKOOA	United Kingdom Offshore Operators Association
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WBM	Water Based Mud
WOAD	World Offshore Accident Databank

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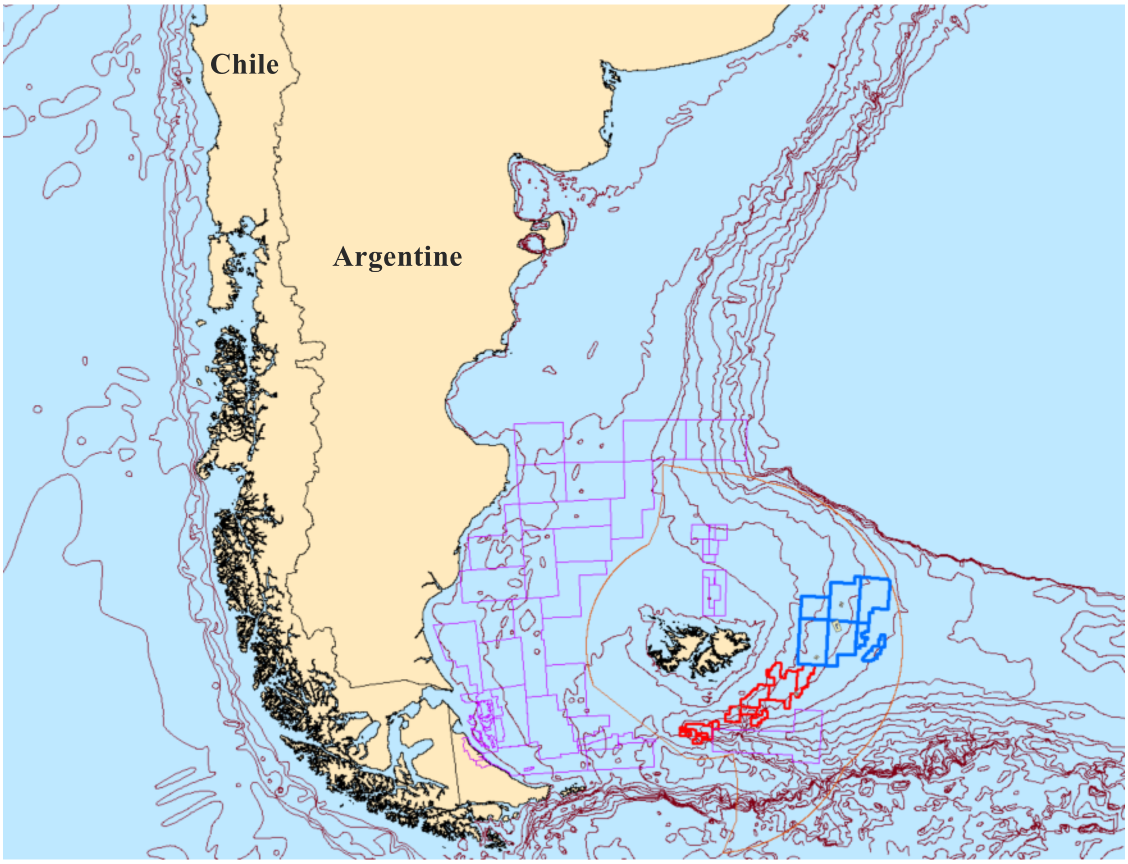
Appendices

1 Introduction

1.1 The Project

Falkland Oil and Gas Limited (FOGL) is a UK-based, oil and gas exploration company operating in the south and east Falkland Basins, a potentially new petroleum province in the south Atlantic (Figure 1.1). The company holds 100% equity interest and operatorship of 13 exploration and production licences covering approximately 48,740 square kilometres and are located in water depths ranging from 500 to 2,000 metres.

Figure 1.1 Geographical positioning of FOGL Licence Blocks (blue- east Falklands Basin; red – south Falklands Basin)



FOGL plans to drill two exploration wells. The first well will be on the Loligo prospect at location A or NW. The second well location has not been confirmed but will be on either the Vinson West, Nimrod or Scotia prospects or potentially it will be a well in the Loligo area e.g. Loligo NW (Figure 1.2). The design details for the Loligo A well are provided in this report as it is a worst case scenario well (higher mud/ cuttings discharge) to be drilled first, whereas potential second well details will be provided in the Operational Addendum following the Environmental Impact Statement (EIS) submission. The proposed wells lie to the east and southeast of the Falkland Islands. The well nearest to the shore is Vinson West (155 kilometres) and the furthest is Scotia East D (314 kilometres). The water depths at well locations vary between 1,300-1,800 metres.

It is anticipated that hydrocarbons, if discovered, would primarily comprise of oil with an API of 18-25^{o} for all wells apart from Scotia East D (API 30^{o}). Gas with condensate is a possible alternative but not considered in this EIA as this would represent a best case scenario from the point of view of environmental impacts.

Figure 1.2 Potential Well Locations

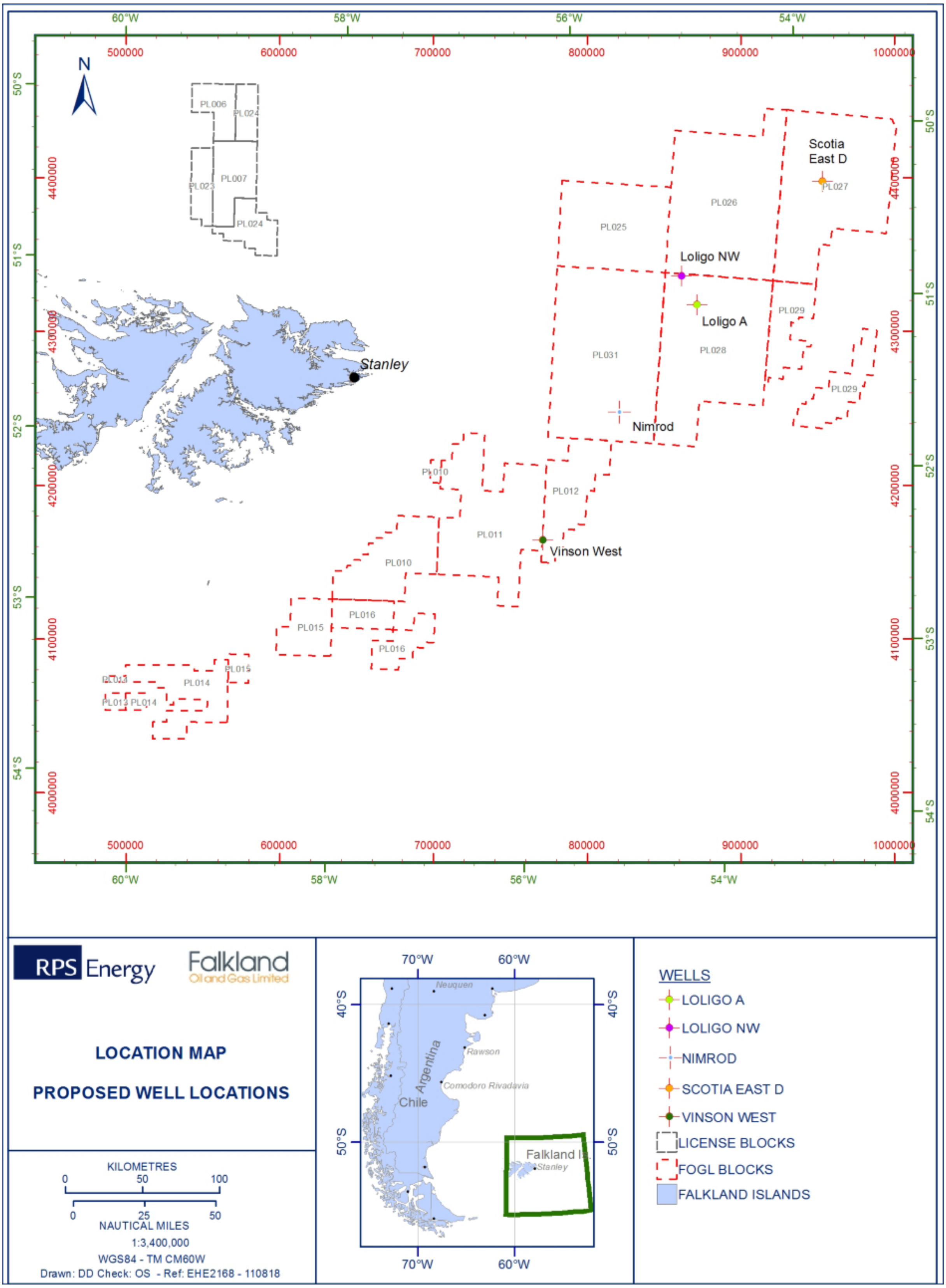
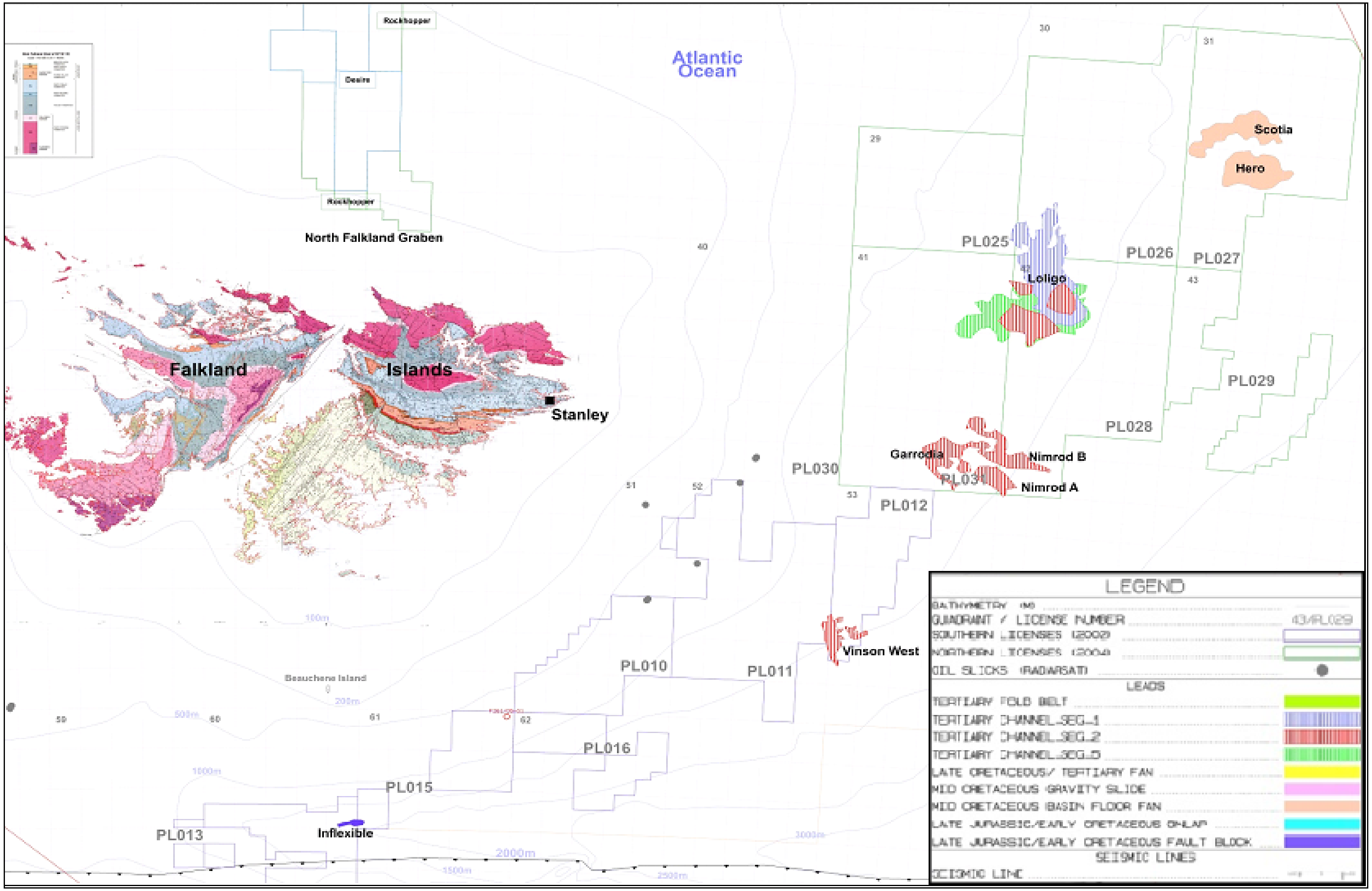


Figure 1.3 Falkland Islands Hydrocarbon Prospects Surveyed by FOGL



As part of the ongoing exploration campaign, FOGL acquired two dimensional (2D) seismic data over a number of licence blocks between 2005 and 2007, and conducted geotechnical and environmental site surveys for Loligo A, Nimrod-Garrodia, Toroa, and Endeavour prospects in 2008-2009 (Figure 1.3). The Toroa-1 (FI61/05-1) well was drilled and abandoned, as a dry hole, in mid 2010. The 2011 site survey programme has been completed for the following prospects: Inflexible, Vinson West, Scotia East, Hero and Loligo NW (Figure 1.3). The results of the 2011 surveys are being finalised and will be incorporated in the Operational Addendum. The survey results for Loligo A are presented in this Report.

FOGL has finalised a contract with the Ocean Rig drilling company for the use of the Leiv Eiriksson dynamically positioned fifth-generation semi-submersible rig. The rig will mobilise following drilling in the neighbouring southern blocks operated by Borders & Southern. Drilling is anticipated to commence in April – May 2012 and will last for approximately 100 days (45 to 50 days per well). Following drilling, the wells will be plugged and abandoned in accordance with FIG Guidelines, comparable to UK Guidelines. All obstructions will be removed from the seabed.

Water-based muds will be used to drill all wells. Chemicals to be used during the drilling have been selected to minimise the potential environmental impacts as much as possible. The vast majority (by volume) of planned chemicals have a Harmonised Offshore Chemical Notification Scheme category of 'E' (which are of low aquatic toxicity, readily biodegradable and non-bio accumulative) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable.

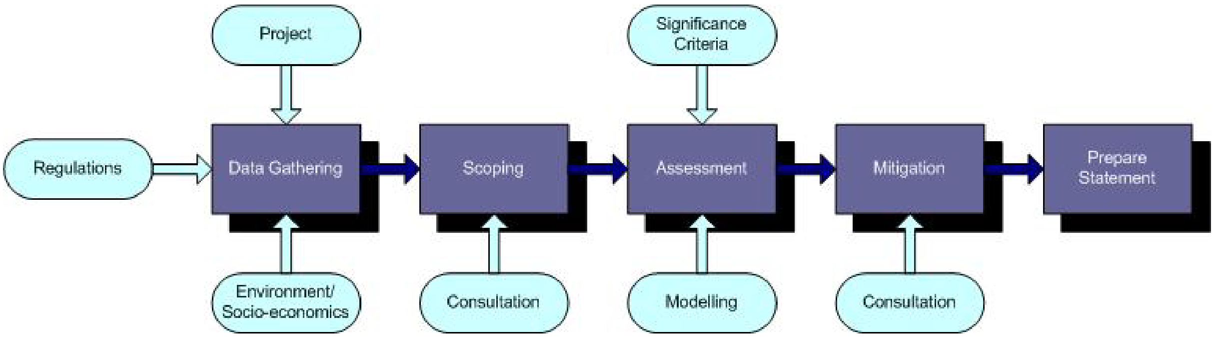
The drilling operations will be managed by AGR as drilling management contractor on behalf of FOGL. Two support vessels and two helicopters will be used throughout planned operations. Further operational details are included in Section 4.

1.2 Scope and Methodology

FOGL has commissioned RPS Energy to undertake the Environmental Impact Assessment (EIA) for a 2-well drilling programme in their southern and eastern licence areas, offshore Falkland Islands.

The EIA is an important management tool ensuring that environmental hazards and impacts are identified and evaluated and that appropriate control (mitigation) measures are implemented throughout all phases of the project.

Figure 1.4. EIA Process



The purpose of the EIA is to:

- Set EIA objectives by defining the applicable Institutional, Policy and Regulatory frameworks;
- Describe the work that the project proponent intends to undertake and how the environmental considerations have formed an essential part in the development concept, definition and selection of the activities;

- Describe the physical, biological and socio-economic components of the environment within the study area and to assess their sensitivities in the context of the intended exploration drilling programme;
- Undertake a scoping exercise during the project planning stage through the consultation with the Falkland Islands Government and key stakeholders, to outline key operational impacts associated with the project;
- Qualitatively and quantitatively assess the nature, significance and probability of impacts on environmental resources and receptors;
- Develop appropriate mitigation measures, together with management and monitoring procedures that will seek to avoid, minimise or reduce potential impacts to a level as low as reasonably practicable.

The EIA has been prepared to satisfy the requirements of The Offshore Minerals Ordinance 1994 (amended 1997) and other Falkland Islands' legislation pertaining to offshore exploration and production activities (see Section 2).

The geographical scope of the EIA includes 13 FOGL licence blocks together with the wider marine and coastal environment where relevant to the potential impacts of the project (referred to as 'the project area of influence'). The focus of the EIA is on the locations where wells are likely to be drilled (see Figure 1.2).

In preparation of this EIA, a range of existing information sources and studies have been used. A comprehensive literature review has been conducted using reports on Falkland Islands environment prepared by local and international organisations, as well as information sourced during internet research and the results of computer modelling. FOGL conducted site surveys to investigate the well specific physical and biological environment and commissioned various studies on weather patterns, icebergs and currents. Marine Mammal Observers (MMOs) reports issued from seismic and site surveys by various operators have been analysed and incorporated to provide the up-to-date information on marine mammal sightings in the area.

Any operational details not covered by the EIS will be detailed in the Operational Addendum, which will be submitted to the Falkland Islands' Government (FIG) for review and approval, as per FOGL's agreement with FIG.

1.3 The Applicant

Falkland Oil and Gas Limited (FOGL) is an AIM-listed oil and gas exploration company operating in the south and east Falkland Basins, the company holds 100% equity interest and operatorship of 13 exploration and production licences.

FOGL is the designated operator for the proposed drilling campaign and is therefore ultimately responsible for all operations. All operations will be undertaken by contractors under FOGL's management and oversight.

1.4 Consultations

Prior to submission of this EIS to the Falkland Islands' Government (FIG), FOGL representatives met with a number of Falkland Islands' entities in July 2011. The issues raised during this preliminary consultation process have been considered by FOGL and addressed, where appropriate, in the EIS (refer to Table 1.1).

Public consultation will also be undertaken, as per legislative requirements, for 42 days after the submission of this EIS to FIG.

Stakeholders have been, and will continue to be, consulted regularly throughout the proposed drilling programme.

Table 1.1. Summary of Stakeholder Consultation Responses

Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
Department of Mineral Resources	FOGL to provide technical updates and mitigation measures in line with DECC Guidance (July 2011).	Technical details have been provided in this EIS, with further details to be presented in the Operational Addendum and Basis. Mitigation measures have been proposed in line with the best UKCS and international practices.	Section 4 Section 6
Falkland Islands Government Air Service (FIGAS)	Adequate aerial surveillance can be provided by FIGAS, but no dispersant spraying capability in the event of an oil spill.	This information is included in the Oil Spill Contingency Plan (OSCP).	N/A
Environmental Planning Department	Limited waste disposal capacity on the islands; only non-hazardous waste can be accepted whereas hazardous waste must be shipped to UK. Highlighted international protection status of a number of vulnerable areas within the FI and lack of local protection measures.	FOGL notes the limited waste handling capacity on the Islands and will plan waste transfer to UK. General waste management practices are discussed in the EIS, with more details covered in the Waste Management Plan. Protected areas are discussed in this EIS.	Section 4 and 6 Section 5
Falklands Conservation and New Island Conservation Trust	Seabirds and mammals are the main vulnerability to any offshore work (through spills). Emphasised limited capabilities for Wildlife response (Tier 1) and operator's responsibility for arranging Tier 2/3 response. Need for survey programmes and research on marine wildlife to improve the knowledge on baseline environment.	This EIS has identified marine mammals and seabirds likely to be present in the region and within the licence blocks. Tier 2/3 wildlife response will be provided via membership with Oil Spill Response Limited (OSRL).	Sections 5 and 6
Fisheries and Marine Resources	Notice to Mariners via Fisheries and Marine Resources. Minimal response capability for oil spills. Emphasised operators responsibility for responding to small and large spill in cooperation with other Oil & Gas operators and FIG.	Notice to Mariners will be issued via the Fisheries and Marine Resources prior to commencing operations. FOGL's OSCP will be prepared in line with the National OSCP and submitted for review and approval by the authorities.	Section 6
Public Works Department	Waste – very limited capacity for storage, management and/or onshore processing. Some recycling available. Water resources are scarce during dry summer months and may impose restrictions on water demands for multiple drilling operations.	FOGL notes the limited waste handling capacity on the Islands and will plan waste transfer to UK. Drilling operations are planned for autumn-winter season when water shortages are unlikely.	Sections 4 and 6
Police Chief	National Emergency Response Plan	FOGL's emergency response plan and OSCP will be prepared in agreement with Falkland Islands' National ER Plan and National Oil Spill Contingency Plan.	Sections 6 and 7
Various service providers	Understanding service capabilities and logistics.	FOGL has gained an early understanding of service capabilities on the Islands and will work with the drilling rig provider and drilling management contractor to ensure that comprehensive planning is undertaken so that no strains are placed on current capacities.	N/A

1.5 Structure of the Report

This Environmental Impact Statement (EIS) presents the results of the EIA process and is prefaced by a Non-Technical Summary (NTS) and in addition to this Chapter 1, it contains the following:

Section 2	Legislative Framework – provides an overview of the Falklands' legislation relevant to this exploration drilling EIS.
Section 3	Alternatives to the Proposed Drilling Programme – provides justification of the planned drilling programme and why alternate methods were discarded.
Section 4	The Proposed Project – provides details of the proposed exploration wells including project overview and drilling operations.
Section 5	Description of the Environment – describes the background physical, biological and socio-economic characteristics of the project area of influence.
Section 6	Environmental Hazards, Effects and Mitigation Measures – identifies the potential interactions of the proposed wells with the environment and details the control and mitigation measures to limit the impacts.
Section 7	Management Framework – provides an outline of FOGL's Health, Safety and Environment Management System.
Section 8	Conclusions of the EIS.
Section 9	Further Studies and Recommendations
Section 10	Acknowledgements
Section 11	References

1.6 Contact Address

Any questions, comments or requests for additional information regarding this EIS should be addressed to:

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2 Legal Framework

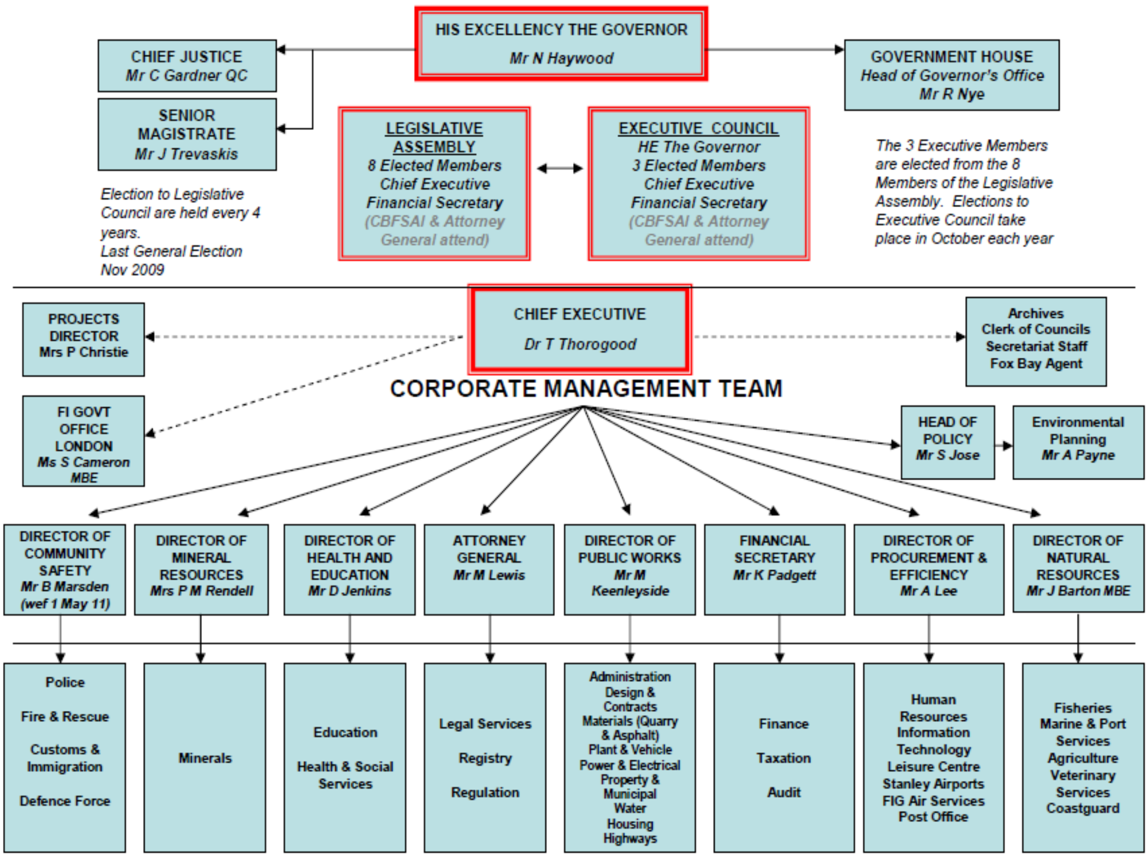
This section summarises the international and national legal context for the proposed drilling activities. It is not intended to provide a complete analysis of the wider legal framework within the Falkland Islands, but only legislation relevant to the natural environment and local stakeholders. Legislation specific to health and safety, tax and finance are outside of the scope of this study.

The Falkland Islands are a United Kingdom Overseas Territory, where supreme authority is vested in HM The Queen and exercised by a Governor on her behalf, with the advice and assistance of the Executive and Legislative Assembly, and in accordance with the Falkland Islands Constitution Order 2008. The organisational structure of the Falkland Islands Government is illustrated in Figure 2.1.

Falkland Islands' laws govern petroleum exploration and exploitation on the Falkland Islands Continental Shelf. The licensing system for offshore exploration and production activities is applicable to the Falkland Islands areas dedicated for offshore petroleum activities.

The Falkland Islands do not have any documents similar to the UK's white paper on 'Meeting the Energy Challenge', however, in the Government's Business Plan (The Islands Plan) a commitment has been made to produce a National Energy Strategy by mid 2012, which will place all on-going petroleum exploration in the Falklands' waters into context.

Figure 2.1. Falkland Islands Government organogram



2.1 International Conventions and Agreements

International conventions and agreements applicable to offshore drilling activities in the Falkland Islands are summarised in Table 2.1.

Table 2.1 International Conventions and Agreements of the Falkland Islands applicable to this Proposed Drilling Programme

Known As	Full Title	Status	Summary
Aarhus Convention	1998 Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters	In 2004, the Executive Council decided to join this at a later date	Grants the public rights and imposes on Parties and public authorities obligations regarding access to information and public participation and access to justice.
ACAP	Agreement on the Conservation of Albatross and Petrels	Ratified* April 2001	Seeks to conserve albatrosses and petrels by co-ordination of international activity to mitigate known threats. ACAP has been developed under the umbrella of the CMS (see below).
Basel Convention	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal 1992	Under consideration	Seeks to reduce the trans-boundary movements and amounts of hazardous wastes and non-hazardous wastes to a minimum, and to manage and dispose of these wastes in an environmentally sound manner. The Convention has not been extended to any of the UK's Overseas Territories; however, in the Government's Business Plan (The Islands Plan) a commitment has been made to produce a Waste Management Strategy by 2012
CBD	Convention on Biological Diversity 1992	Not yet ratified, applies through UK extension of overseas territories	Seeks to conserve biological diversity, to use biological resources sustainably and to share equitably the benefits arising from the use of genetic resources. Indirectly applies through the Overseas Territories Environment Charter
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources 1982	Ratified	Aims to protect the marine ecosystem south of 60°.
CITES or the Washington Convention	Convention on International Trade in Endangered Species	Ratified* October 1973	Ensures that international trade in specimens of wild animals and plants does not threaten their survival.
CMS or The Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals	Ratified* 1979	Seeks to conserve terrestrial, marine and avian migratory species (those that regularly cross international boundaries, including international waters). Concluded under the aegis of the United Nations Environment Programme. All cetacean and southern Hemisphere albatross species are listed in the CMS.
Environment Charter	Environment Charter	Signed 2001	Charter to protect the Falkland Islands' natural environment, with additional support from the British government through funding and expert advice.
Fisheries Agreement	Fisheries Agreement	1990, issued a joint statement	A joint statement between the British and Argentine governments to create the Falklands Outer Conservation Zone and the South Atlantic Fisheries Commission for the protection of fish stocks. Note: The South Atlantic Fisheries Commission is not operating at present as the Argentine government has withdrawn cooperation in fisheries matters.
Hydrocarbons Agreement	UK/Argentine Joint Declaration on Hydrocarbons	1995, issued a joint statement	A joint statement between the British and Argentine governments for the cooperation of

Known As	Full Title	Status	Summary
			offshore activities in the southwest Atlantic. Note: The Hydrocarbons Agreement is not operating at present as the Argentine government has withdrawn cooperation in hydrocarbon matters.
Kyoto Protocol	Kyoto Protocol to the UN Framework Convention on Climate Change	Ratified 1997	An amendment to the international treaty on climate change, assigning mandatory emission limitations for the reduction of greenhouse gas emissions to the signatory nations.
London Convention	1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.	Ratified* 1980. The 1996 Protocol does not yet extend to the Falkland Islands.	Aims to prevent pollution of the sea from dumping of waste and other matters liable to create hazards, harm living resources and marine life, damage amenities, or to interfere with other legitimate uses of the sea. The dumping of Annex I materials is prohibited, Annex II materials require a prior special permit and all other wastes require a prior general permit.
MARPOL 73/78	1973 Convention for the Prevention of Pollution from Ships, as modified by the Protocol of 1978	Annexes I, II,III and V have been extended to the Falkland Islands	Seeks to prevent pollution by oil, chemicals, and harmful substances in packaged form, sewage and garbage from ships.
Montreal Protocol	Montreal Protocol on Substances that Deplete the Ozone layer	Ratified* December 1987	Aims to protect the ozone layer by phasing out ozone depleting substances.
Ramsar Convention	1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat	Ratified* in 1976	Aims to halt the world-wide loss of wetlands and promote the conservation of wetlands through wise use and management. Wetlands can include marine waters up to a depth of 6 m at low tide.
UNCLOS (or Law of the Sea)	The United Nations Convention on the Law of the Sea (1982)	Ratified* July 1997	Legislation of the world's oceans and seas governing all uses of the oceans and their resources.
UNFCCC	United Nations Framework Convention on Climate Change	Ratified in 1992.	Aims to reduce greenhouse gas emissions to combat global warming.
World Heritage Convention	1972 Convention for the Protection of the World Cultural and Natural Heritage	Ratified* May 1984	Aims to identify protect and preserve cultural and natural heritage worldwide. No natural and cultural sites of outstanding global value have been designated within the Falkland Islands.

* - Ratified by the UK and ratification extended to the Falkland Islands

As joint-signatories of Kyoto, the Falkland Islands are expected to reduce emissions in line with UK targets, but currently do not have any formal expectations or set targets to work towards. However, the Islands are reducing emissions and reliance on fossil fuels with the recent development of a wind farm, a heat recovery system linked into the diesel power station and through the provision of subsidies towards the cost of domestic wind turbines for the farming community.

The 1992 Convention on Biological Diversity (*UNCED, 1992*), ratified by the UK but not by the Falkland Islands, includes UK dependencies within the 'UK: Biodiversity Action Plan' (*HMSO, 1994*). In connection with the UK's goals to encourage implementation of the Convention, partnerships are formalised in Environmental Charters between the UK and various Overseas Territories. The Falkland Islands Bio-Diversity Strategy (2008 to 2018) arose from the Convention on Biological Diversity and the Overseas Territories Environment Charter.

The first Environmental Charter, stating mutual responsibilities of the UK and its Overseas Territories, was signed on 26 September 2001 by the Councillor of the Falkland Islands Government, and the Minister of UK Overseas Territories.

2.2 National Legislation

This section details the regulatory framework applicable to this drilling project and the protection of the offshore environment around the Falkland Islands (Table 2.2).

The Falkland Islands Government enacted subsidiary legislation under the Offshore Minerals Ordinance 1994, designed to ensure health and safety in offshore operations. The system of Petroleum Operations Notices (PON) are not legally binding but have been adopted by the Falkland Islands Government as best practice.

Table 2.2 National Legislation of the Falkland Islands applicable to this Proposed Drilling Programme

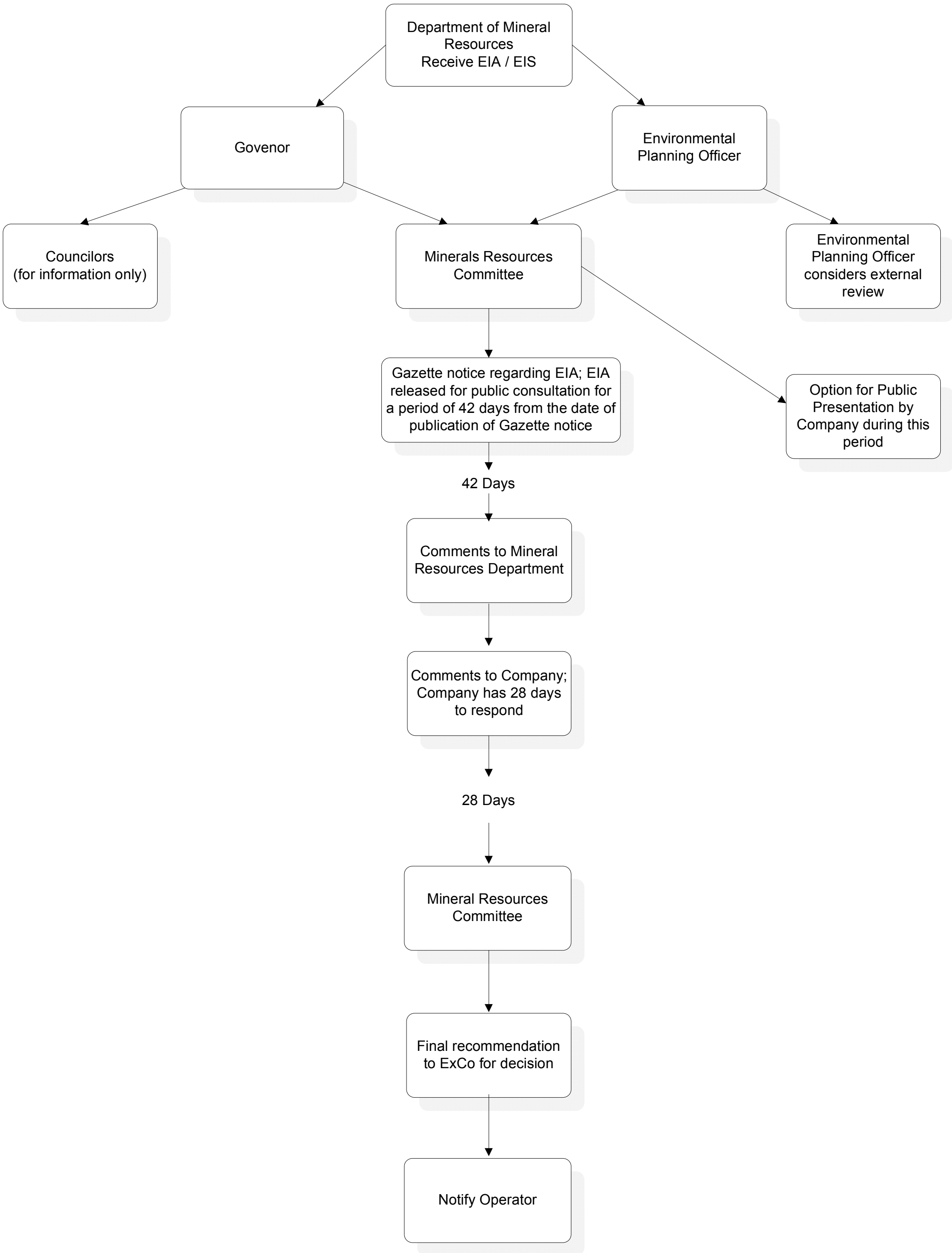
Legislation	Key Requirements / Relevance to Proposed Operations
1) Relevance to Offshore Operations	
Environment Protection (Overseas Territories) (Amendment) Order 1997	This Order extends to the Falkland Islands. The provisions of the Food and Environment Protection Act 1985 which control the deposit of substances and objects in the sea and under the sea bed (thereby implementing the 1972 London Convention on Ocean Dumping).
Merchant Shipping (Oil Pollution) Act 1971	Applied to the Falkland Islands by 1975 Order in Council (SI 1975/2167 as amended by SI 1976/2143 and SI 1981/218). This Act regulates responsibility for oil pollution from ships.
Offshore Minerals (Amendment) Ordinance 1997	Amends the Offshore Minerals Ordinance 1994 to make further provision in relation to the application of the Health and Safety at Work etc. Act 1974.
Offshore Minerals Ordinance 1994	The licensing framework for offshore exploration and production. Regulates offshore installations and pipelines, offshore health and safety, oil pollution, liability for environmental damage, and abandonment. Sets out the requirement for Environmental Impact Assessment and preparation of Environmental Impact Statements.
Offshore Petroleum (Licensing) Regulations 1995	Provides the schedule, model clauses and format for application of exploration or production licences in Falkland Islands' waters, as well as conditions for record keeping, sampling and drilling.
Offshore Petroleum (Licensing) Regulations 2000 – Invitation to apply for open door licences	Invites applications for production licences in respect of Blocks specified within Schedules 1 and 2. Specifies exploration terms, conditions, financial terms and application criteria.
Offshore Petroleum (Licensing) (Amendments) Regulations 2004	Enables applications to be made under the Offshore Petroleum (Licensing) Regulations 2000 in respect of areas formerly licensed under the Offshore Petroleum (Licensing) Regulations 1995, but to prevent applications which were formerly licensed and being considered within two years of the expiration or sooner determination of that licence.
Offshore Petroleum (Licensing) Regulations 2005	The Offshore Petroleum (Licensing) Regulations 2005 amended the 2000 Regulations by inserting a new regulation 3A enabling the operation of the open licensing system to be suspended from time to time in relation to whole or part of the controlled waters.
Offshore Petroleum (Licensing) Regulations 2009	The Offshore Petroleum (Licensing) Regulations 2009 further amended the 2000 Regulations by removing the prohibition on the licensing of part blocks; and by amending the model clauses so as to increase the maximum initial term of a production licence from 5 to 8 years, and to increase the second exploration term of a production licence from 3 to 5 years.
Petroleum Operations Notice No.1	Specifies the record and sample requirements for surveys and wells, including reporting requirements and sampling details.
Petroleum Operations Notice No.2	Specifies reporting procedures including monthly and daily reports, drilling reports and changes to the work programme.
Petroleum Operations Notice No.3	Provides guidance on the procedure to follow for notification prior to carrying out a geophysical survey.
Petroleum Operations Notice No.4	Comprises the pro-forma and accompanying guidance notes to

Legislation	Key Requirements / Relevance to Proposed Operations
	use for an application for consent to drill exploration, appraisal and development wells.
Petroleum Operations Notice No.5	Comprises the pro-forma and accompanying guidance notes to use for an application to abandon or temporarily abandon a well.
Petroleum Operations Notice No.6	Comprises the pro-forma and accompanying guidance notes to use for an application to complete and/or workover a well.
Petroleum Operations Notice No.7	Specifies the definition of a well and the system to be used for numbering a well.
Petroleum Operations Notice No.8	Specifies reporting requirements in the event of an oil spill, guidance on the use of dispersants and provides contact numbers and reporting forms to use in case of oil pollution.
Petroleum Survey Licences (Model Clauses) Regulations 1992	The regulatory framework governing offshore exploration activity, including; field observations, geological and geophysical investigations, the use of remote sensing techniques, and sea floor sampling.
2) Relevant to Environmental Protection	
Conservation of Wildlife and Nature Ordinance 1999	Replaces the Wild Animals and Birds Protection Ordinance of 1964. Protects wild birds, wild animals and wild plants, by prohibiting certain activities and making provision for National Nature Reserves. Fauna specified so far for protection are two species of trout, all species of butterflies and almost all species of wild bird. Protection of wild plants extends to 29 listed species, including those listed as threatened on the Falklands Red List (*Broughton, 2002*). National Nature Reserves can be created by designating the seabed or Crown land or, where the owner and occupiers agree, privately-owned land. Sanctuaries created under the Wild Animals and Birds Protection Ordinance 1964 and Nature Reserves created under the Nature Reserves Ordinance 1964 are automatically converted into National Nature Reserves.' Marine areas may be designated in Falkland Islands territorial waters (12 nautical miles) or 3 nautical miles beyond, but no marine areas have been designated yet.
Control of Kelp Ordinance 1970	Makes provision for the licensing of seaweed harvesting and export
Endangered Species Ordinance 2003	Upholds the CITES, and controls the import and export of species listed in the CITES.
Marine Environment Protection Ordinance 1995	Implements the conditions of the London Dumping Convention 1972 and prohibits, other than under license, the deposition or incineration of materials in Falkland Islands' waters. Is a system of licensing and licence offences with strict liability for certain loss or damage in relation to polluting incidents. The Deposits in the Sea (Exemptions) Order 1995, as approved under the Marine Environment Protection Ordinance, specifies categories of material exempt from requiring a licence for deposition. Includes sewage or domestic waste discharge from a vessel or platform, drill cuttings or muds under specific circumstances and the incineration of hydrocarbons.
Marine Mammals Protection Ordinance 1992	Prohibits the killing or taking of marine mammals (or to use explosives within the FOCZ where this is likely to cause harm to any marine mammal) on land or in internal waters, territorial sea or fishery waters of the Falkland Islands. It is unlawful to import or export marine mammals without a licence.
National Parks Ordinance 1998	Establishes the system for designation of National Parks, based on natural beauty and recreation value. No marine areas are being considered under this ordinance.
Waste Management Framework	Apart from the siting of disposal sites under the 1991 Planning Ordinance, there is no regulatory framework specifically for waste management and disposal.

2.2.1 Environmental Impact Assessment

The Offshore Minerals Ordinance 1994 PART VI 'Miscellaneous and General' provides the regulatory framework for requiring and undertaking an Environmental Impact Assessment (EIA) or EIS in the Falkland Islands. An EIA or EIS may be required if it is considered by the Governor that the environment might be substantially affected by the activity in question.

Figure 2.2 Falkland Islands Government EIA / EIS Consultation Process



An EIA is an assessment commissioned by the Governor and carried out on his behalf. An EIS is a statement prepared by, or on behalf of, the applicant. The scope and content of an EIA and EIS are specified within Schedule 4 of the Offshore Minerals Ordinance 1994 and are essentially the same. An EIA commissioned by the Governor, however, does not have to go through a public review period, whereas an EIS submitted by an applicant will generally be required to go through a 42 day public consultation period. This process is summarised in Figure 2.2.

Schedule 4 of the Ordinance specifies that the following information may be required within an EIA or EIS:

- Description of the proposed development such as the location, the design and size or scale of the development;
- Identification and assessment of the likely impacts of the development on the surrounding environment;
- Description of likely significant impacts, direct and indirect, on the surrounding environment; such as human beings, flora, fauna, seabed and subsoil, soil, water, atmosphere and air quality, climate, seascape or landscape, inter-action between any of the foregoing, material assets and cultural heritage;
- Description of management measures to avoid, reduce or remedy significant impacts; and
- Non-technical summary of the information specified above.

Where public review is required, the EIS is published in the Falkland Islands Gazette for a period of 42 days following government submission. Opportunities for public discussion, dissemination of information and feedback from stakeholders will be available. In addition, the document is also presented to the Executive Council.

2.2.2 Upcoming changes in the Oil and Gas Legislation

The Falkland Islands Government Department of Mineral Resources are currently (September 2011) approving the proposed amendments to the oil and gas legislation with respect to environmental requirements. The changes to legislation following the review and consultation are to reflect industry best practice and to bring the national requirements in line with those of the UK. The key proposed changes to the Offshore Minerals Ordinance 1994 are as follows:

Environmental Impact Assessments

- EIAs and EISs will be mandatory for companies seeking approval to drill exploration, appraisal and production wells and conduct offshore drill stem testing;
- An EIA and EIS may be required for other offshore activities such as 3D seismic surveys if they occur in an area sensitive to cetaceans and other protected species;
- The Governor of the Executive Council has powers to exempt a project from any of the Regulations with respect to environmental statements, public consultation, consultation on additional information requested, etc. For example if it is considered that the environment is unlikely to be substantially affected by the activity in question or if the activity is going to occur in an area already covered by a recent EIA concerning the same or similar activity;
- Applicants will be required to organise public consultations in respect of EIAs and EISs; and
- Details of the contents of EISs as set out in Schedule 4 of the Ordinance are to be updated.

Seismic Surveys

- Seismic surveying guidelines are to be updated so that they reflect the JNCC best practice guidelines for minimising the risk of disturbance and injury to marine mammals from seismic surveys; and
- The presence of a Marine Mammal Observer to oversee the implementation of guidelines during surveying will be mandatory.

2.3 Petroleum Industry Standards and Guidelines

The following standards and guidelines, produced by the Exploration and Production (E&P) sector are available either publicly (online) or just to members of the respective organisations. Elements of the best practice guidelines will be utilised in developing the operations specific Environmental Management Plan(s) for this project.

2.3.1 International Association of Oil and Gas Producers

Guidelines for waste management – with special focus on areas with limited infrastructure. OGP 413. 2008

These guidelines provide advice on area-specific waste management planning, and handling and treatment methods for drilling and production waste streams, and are an update on the 1993 guidelines.

2.3.2 International Association of Drilling Contractors (IADC)

The Health, Safety and Environment Reference Guide 2004 contains all the necessary guidelines for establishing a sound safety program. Guidance topics include: Equipment Safety, Personal Protective Equipment, Fire Prevention, Fire Fighting and Fire Control, Confined Space Entry Guidelines, Cold Weather Safety, Offshore Safety, Hydrogen Sulfide, Protection of the Environment, Emergency Action Plans and Fall Protection.

2.3.3 Oil and Gas UK

Guidelines for Fisheries Liaison, Issue 5 (2008)

This document provides guidance on offshore seismic and survey work and vessel operations supporting drilling campaigns.

For potential impacts on commercial fishing activities, liaison with fisheries is recommended. Guidelines state that due consideration should be given to: peak times of fishing activity, fish spawning and migration and other factors relating to fish or fishing identified through the consultation process or environmental assessments of the area.

2.3.4 E&P Forum / United Nations Environment Programme

Joint Technical Publication; Environmental Management in Oil and Gas Exploration and Production 1997

This publication provides an overview of environmental issues and technical and management approaches to achieve high environmental performance in oil and gas exploration and production.

2.3.5 IPIECA (International Petroleum Industry Environmental Conservation Association

The Oil and Gas Industry: Operating in Sensitive Environments (2003)

The case examples included in these guidelines aim to (a) demonstrate that minimal impact operations are achievable in a diverse range of environmental and social settings; (b) actively encourage exchange of company experiences and best practices and (c) provide a basis for discussion with groups outside the industry with a view to promoting ongoing improvements in industry performance.

2.3.6 FOGL Health, Safety and Environment Policy

FOGL has its own set of Health, Safety and Environmental Standards that must be complied with at all stages of petroleum project related activities. The standards have been applied to this project and have influenced the design and planned execution of the drilling programme. These standards are described in Section 7.

3 Project Alternatives

Consideration of project alternatives is an essential part of the Environmental Impact Assessment process. Many complex factors control the situation of oil wells (geology, topography, communications and engineering technology to list a few), meaning only a few viable alternatives can be considered environmentally.

Processed and interpreted seismic data are used to indicate areas where hydrocarbons may be trapped in oil or gas-filled geological structures. Without exploratory drilling, seismic data is unable to confirm whether oil and gas are present, the volume of the reservoir, whether the hydrocarbons can be commercially extracted or even the actual rock types. Hence, exploratory drilling is a necessary step in the development of commercial hydrocarbons and is a requirement under the terms of the production licence awarded to FOGL by the FIG Mineral Resources Department. Potential impacts from drilling activities and their management measures are discussed in subsequent chapters of this EIS.

Direct benefits to the region from the extraction of natural resources could be increased financial income and local business opportunities. Secondary or indirect benefits could be an increased standard of living, and better education, social services and amenities.

The implications of not proceeding mean that the potential environmental and social impacts (positive and negative) from the drilling operations will not occur. Should the drilling programme not proceed, the potential financial and social benefits of oil and gas production cannot be realised.

Alternative drilling methods and types of drill unit exist and each have their own environmental impacts. The use of a dynamically positioned (DP) semi-submersible drilling rig (FOGL plan to use the Leiv Eiriksson) for this project would minimise seafloor disturbance as anchoring would not be required. Such a unit would however require continual positioning using thrusters and both fuel consumption and underwater noise would therefore be considerably higher than for an anchored unit. DP drill units are generally larger and more expensive than anchored units; however they, or a drill ship, represent the only alternatives for deep water drilling.

Directional drilling is also possible where the well cannot be positioned over the target reservoir, for example where the drilling target lies under an inaccessible or highly sensitive area. This is not relevant for the proposed wells as they are positioned at a distance from the protected areas.

Water-based muds will be used to drill all wells. Chemicals to be used during the drilling have been selected to minimise the potential environmental impacts as much as possible. The vast majority (by volume) of planned chemicals have a Harmonised Offshore Chemical Notification Scheme category of 'E' (which are of low aquatic toxicity, readily biodegradable and non-bioaccumulative) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable.

Cuttings from the wells for this drilling campaign will be disposed of at the seafloor for the shallow section of the well. For the deeper sections cuttings will be treated and discharged to the sea through the cuttings caisson, in line with standard industry practice. Downhole injection of cuttings is not possible, as no suitable geological formation or old wells exist to store the cuttings discharge.

All equipment onboard the selected 5th generation drilling unit, Leiv Eiriksson, has been certified to Norwegian Standards and is functioning at optimum levels. The pollution prevention and waste management procedures to be deployed in the rig are in line with best industry practices.

4 Drilling Programme

4.1 Overview

FOGL plans to drill two exploration wells, one of which will be Loligo (A or NW). The second choice well is currently undecided but could be the alternate Loligo well, Vinson West, Nimrod or Scotia East D (Figure 1.2). The design details for the Loligo A well are provided in this report as it is a worst case scenario well (higher mud/ cuttings discharge) to be drilled first, whereas second well details will be provided in the Operational Addendum, following the Environmental Impact Statement (EIS) submission.

The proposed wells lie to the east and southeast of the Falkland Islands in water depths between 1,300 and 1,800 metres. The nearest well to the shore is Vinson West (155 kilometres) and the furthest well is Scotia East D (314 kilometres).

It is anticipated that hydrocarbons, if discovered, would primarily comprise oil with an API of 18^{o} - 25^{o} (the 18^{o} API is a worst case and so has been used for modelling purposes) for all wells apart from Scotia East D (where an API of 30^{o} is anticipated). Gas with some condensate is a possible alternative but not considered in this EIS as its presence would represent a best case scenario from the point of view of environmental impacts.

Following drilling, the wells will be plugged and abandoned in accordance with Oil and Gas UK Guidelines. It is planned that all obstructions will be removed from the seabed.

4.2 Target Reservoirs and Exploration Objectives

The objective of this project is to explore hydrocarbon reservoirs in the Tertiary Channel Play and Mid Cretaceous Fan Play of the south and east Falklands Basin through the drilling of two exploration wells.

The Tertiary (Eocene) Channel Play is the shallowest and youngest formation which is prospective for oil and gas. The play was developed when the Falkland Islands and surrounding region experienced a period of uplift after the end of the Cretaceous period – around 80 million years ago (Mercer H, 1983; Light *et al*, 1993). As a result of the uplift, sediments which had built up around the Falklands Plateau were shed into the basin. The sequence has been divided into 5 units, termed T1 to T5. The sediment type, total isopachs, thickness distribution and sediment transport direction are different for each unit within the gross sequence. The largest prospect in this play (Loligo) sits above an old basin high and this may act as a focussing mechanism for oil and gas which has been generated in the relatively recent past. This play is dominated by large stratigraphic traps which are supported by bright seismic signatures and Class III AVO (amplitude versus offset) responses.

There are many prospects within the Tertiary channel play but those with site surveys are: Loligo, Nimrod Complex and Vinson West. There are 4 separate site surveys on Loligo, 3 of which are down-dip over the main and southern parts of the prospect and one, up-dip to the northwest (Loligo NW).

The Loligo prospect covers an area in excess of 1000 square kilometres at the T1 horizon, in quadrants 30 and 42 (PL026, PL028). It is the largest prospect in the basin. There are multiple stacked targets within Loligo (several separate reservoir zones stacked on top of each other) and near the southern end of the prospect several independent prospects (Trigg Deep East, Three Bears, and South Loligo Deep) may be intersected with one exploration well (these additional prospects extend into quadrant 41, PL031). The Loligo target consists of sand sheets but within these layers the reservoir thickens and thins in a complex pattern due to deposition in a series of marine channels. The water depths at the potential well locations vary from about 1300 metres to 1400 metres. The deepest well currently contemplated on the Loligo prospect is Loligo A to some 2710 metres below the sea bed. The shallowest well under consideration is Loligo NW, which targets only the upper zone (T1) in an optimal location. It would reach TD at less than 1500 metres below the sea bed. The Loligo well locations lie approximately 225 kilometres east of Stanley (see Figure 1.2).

The Nimrod Complex lies at the southern end of Quadrants 41 and 42 (PL031 and PL028) and includes the Nimrod A, B and Garrodia features. The water depth at the potential well location is 1,290 metres. The targets are relatively shallow and the TD of the well would be about 200 metres below the deepest target at 2300 metres. There are many similarities between the Loligo and Nimrod prospects in terms of reservoir type, depositional style and the stacked nature of the target. Within the complex as a whole, prospective targets exist within the T1, T2, T3 and T5 units. At the selected well location (on Garrodia), the prospects are within the T2, T3 and T5 units. The Nimrod complex is the second largest prospect in the basin. Nimrod and Loligo are both in the northern area licences. The Nimrod Complex lies approximately 170 kilometres southeast of Stanley (Figure 1.2).

The Vinson West prospect is the third largest prospect in the Tertiary Channel Play. It is the only one in the southern area licences with a site survey. It straddles Quadrants 52 and 53 (PLO11 and PLO 12), although the major part of the feature is centred on Block 53/16. The water depth is 1510 metres. Like all the key Tertiary Channel Play prospects, Vinson consists of a series of stacked targets with each target zone showing different depositional geometry. The uppermost target is relatively shallow within the T1 unit but prospectivity also exists within the T2, T3 and T5 units. The planned TD of the well is within the Pre Channel sequence at about 1800 metres below the sea bed. Vinson West lies approximately 160 kilometres southeast of Stanley (Figure 1.2).

The Mid Cretaceous Fan Play is well developed in the northern part of the FOGL acreage. This geological play was developed when the Falklands were still attached to the southern part of the African continent. A large amount of sediment, sourced from the continent and the Falklands Plateau area to the north, built up in near shore shallow seas. When a drop in sea level occurred, these sediments were deeply eroded and the reworked sands were shed far offshore into deep water. Several prospects have recently been mapped in this play in the northern licences. These are Hersillia, Scotia and Hero.

The Scotia prospect is located in quadrant 31 (PL027). Although the area had been mapped on seismic data before, it was only when the entire data set was reprocessed in 2008-09 that Scotia stood out as an attractive prospect. A distinctive sandy unit on laps the base of the old shelf. The formation dips to the south, which controls the spill point of the prospect, but it relies upon the pinchout of the sands in other directions to define the trap. The prospect has a strong element of structural control and is supported by a conformable AVO anomaly. The primary target is in Albian age sands (about 100 million years old). The source rock for the oil sits just below this target and FOGL anticipates oil generation in the area. However, FOGL also recognises gas signatures on the seismic data and so either 'phase' is strictly possible. The Scotia well location sits in 1810 metres of water. The target is about 3,290 metres below the sea bed and the TD of the well is estimated to be at 3,440 metres below the sea bed. The Scotia well location lies approximately 330 kilometres east of Stanley (Figure 1.2).

4.3 Proposed Project Schedule

The provisional project schedule is to commence operations in April to May 2012, which will last for approximately 100 days (45 to 50 days per well). The mobilisation of the Leiv Eiriksson rig will take 1-2 days, following drilling in the neighbouring southern blocks operated by Borders & Southern.

No well testing that involves flowing well fluids to the surface is planned. All evaluations will be undertaken by wireline methods. Following drilling, the wells will be plugged and abandoned, and all obstructions removed from the seabed.

4.4 Drilling Operations

4.4.1 Well Details

The key characteristics of the potential wells identified as possible candidates for the 2-well drilling campaign are summarised in the Table 4.1 below. Note that final locations may differ slightly.

Table 4.1. Proposed Drilling Programme Well Characteristics

Aspect	Proposed Well Locations				
	Loligo A	Loligo NW	Vinson West	Nimrod	Scotia East D
Licence Area	PL028	PL028	PL012	PL031	PL027
Drilling Locations	51°10'23.79''S 54°40'48.29"W	51°00'45.63"S 54°50'28.90"W	52°36'09.69"S 55°59'22.58"W	51°49'44.25"S 55°20'07"W	50°23'54.50''S 53°37'11.61''W
Drill Rig	Leiv Eiriksson - 5th generation DP semi-submersible drill rig				
Support Location	Stanley				
Water Depth (m)	1,381	1,316	1,507	1,297	1,762
Depth of Well (m)	4,092	2,635	3,292	3,701	5,198
Nearest Landfall (km)	214	208	155	163	314
Anticipated Spud date	April- May 2012		May-June 2012		
Estimated time to reach TD	Range from 45-50 days				
Clean up and well testing	None Planned				
Anticipated Hydrocarbons	Oil, API 18 - 25°				Oil, API 30°
ITOPF Category	Group III				
Anticipated Weight of Cuttings (tonnes)	1312	771	925	1346	1790

4.4.2 The Drilling Rig

FOGL has finalised a contract with Ocean Rig for the use of the Leiv Eiriksson dynamically positioned fifth-generation semi-submersible rig (Figure 4.1). The rig specifications are summarised in Table 4.2 below and further detailed in Appendix A.

Figure 4.1. The Ocean Rig 'Leiv Eiriksson DP semi-submersible rig' (Appendix A)

Table 4.2. Specifications of the Leiv Eiriksson rig

Feature	Specification
Rig Type	Dynamically positioned Semi-submersible
Rig Design	Trosvik Bingo 9000
Year Built	2001
Yard Built	Dalian New Shipyard, China – baredeck Outfitted Friede Goldman Offshore, USA
Class	DP Class 3 DnV +1A1 Column Stabilised Drilling Unit (N) DYNPOS AUTRO, HELDK SH, CRANE, F-AM, DRILL
Safety Case	Norwegian AoC (SUT) and UK
Water Depth	7,500 ft
Dimensions	391.68 ft by 278.88 ft
Drilling Draft	77.9 ft
Transit Speed	6 – 7 knots
Variable Deckload Operating	7,222 mt
Variable Deckload Transit	6,534 mt
Number of Columns	6
Operating Displacement	53,393 mt
Mud Capacity	1,657 m^3
Bulk Mud / Cement Capacity	350 m^3
Bulk Cement Capacity	350 m^3
Drill Water Capacity	1,960 m^3
Potable Water Capacity	1,155 m^3
Fuel Oil Capacity	4,631 m^3
Base Oil Capacity	406 m^3
Brine Capacity	680 m^3
Drawworks	Continental Emsco Electrohoist III, 3000 hp
Derrick	Hydralift 170 ft by 40 ft by 40 ft 680 mt
Top Drive	Hydralift HPS 750 2E AC Electric Drive
Pipe Handling System	Hydralift
Fwd and Aft System	Hydralift
Rotary	Varco BJ RSTT 60 ½ inch
Mud Pumps	3 x Continental Emsco FC-2200HP, 7,500 psi
Main Engines	6 x Wartsila 18V32 diesel engines (total 61,200 hp)
Generators	6 x ABB ASG 900 XUB generators (total 43,800 kW)
Propulsion	6 x Rolls Royce UUC 7001 fixed pitch variable speed thrusters
BOP	Cameron 18 ¾ inch, 15,000 psi, H_2S service Annulars: 2 each; 10,000 psi BOP Rams: 4 each; 15,000 psi

Feature	Specification
Diverter	Vetco KFDS-CSO-500
Riser Tensioner	6 x Hydralift (Total Capacity 1,089 mt)
Motion Compensators	Hydralift 800-25 Passive/Active Crown Mounted Compensator
Crane	2 x Hydralift WOMCVC 3447; 75 mt
Accommodation	120 berths and hospital
Helideck	EH 101 Helicopter (Diameter = 22.8 metres)
Life Saving Equipment	4 x 70-person lifeboats 1 x Man Over-Board (MOB) boat Escape chute system (Selantic) with 8 life rafts (total capacity 240 men)

4.4.3 Well Construction

Wells are drilled in sections, with the diameter of each section decreasing with increasing depth. During the drilling of the upper well section the drill string (also called drill pipe) and drill bit are typically left open to the seawater. However, before drilling lower sections of the well, a lining called casing is run and cemented in the well and a riser pipe is used between the rig and the seabed with the drill string passing through the riser (from seabed back to rig) and the casing (below seabed).

Once the casing has been run, the drilling fluid can be returned to the rig in the space (annulus) between the drill string and the casing / open hole and back up the riser to the rig. The lengths and diameters of each section of the well are determined prior to drilling and are dependent on the geological conditions through which the well is to be drilled. Once each section of the well is completed, the drill string is lifted and protective steel pipe or casing lowered into the well and cemented into place. The casing helps to maintain the stability of the hole and also helps reduce fluid losses from the well bore into surrounding rock formations.

The design of Loligo A well is provided below. The details for the second choice well will be provided in the Operational Addendum.

Loligo A

The proposed Loligo well will be drilled to a total vertical depth (TVD) of 4,118 metres with the following hole sections (Table 4.3; Figure 4.2):

42" Hole with 36" Casing

Once the rig has been installed at the proposed location, a 42" hole will be drilled to 79 metres below mud line (BML). This section will be drilled with seawater. Occasional pills of viscosified water (using bentonite or guar gum as a gelling agent) will be circulated to help cleaning the hole. A 36" casing will then be run and cemented in place to provide structural integrity for the well.

26" Hole and 20" Casing

A 26" hole will be drilled vertically to approximately 719 metres BML, using seawater and gel sweeps. A 20" casing will be run and cemented in place. The rig riser system will then be run and the Blow-Out Preventor (BOP) system installed.

17 ½" Hole and 13 $^{3}/_{8}$" Casing

A 17 $^{1}/_{2}$" hole will be drilled to approximately 1,509 metres BML, using WBM with density ranging from 9.0 to 9.5 ppg. A 13 $^{3}/_{8}$" casing will be run and cemented in place.

12 ¼" Hole and 9 $^{5}/_{8}$" Casing

A 12 ¼" hole will be drilled to approximately 2,711 metres BML, using WBM with density ranging from 9.5 to 11.5 ppg. The higher density will be required to provide sufficient over-balance on the formation and prevent influx of reservoir fluids. A 9 $^{5}/_{8}$" casing will be run and cemented in place.

It should be noted that well design continues to be refined, and hole sections may be reduced in depth and size.

Figure 4.2. Proposed Loligo A Well Schematic

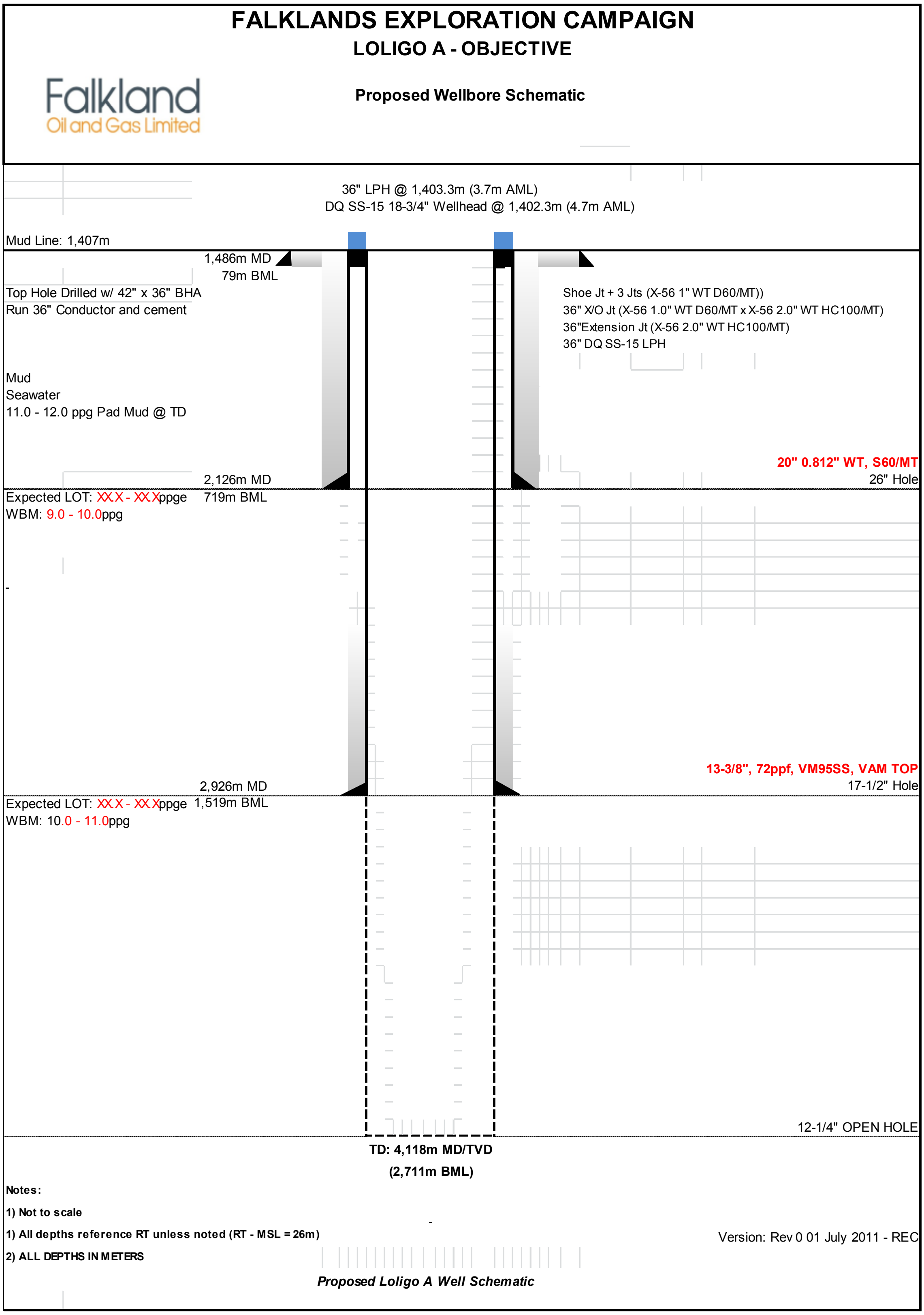


Table 4.3. Proposed Loligo Well Profile

Hole Size		Casing size		Section Length	Proposed Mud Use
Inches	Metres	Inches	Metres	Metres	
42	1.07	36	0.91	79	Seawater
26	0.66	20	0.51	640	Seawater + Gel Sweeps
17 $^{1}/_{2}$	0.44	13 $^{3}/_{8}$	0.34	800	WBM
12 ¼	0.31	9 $^{5}/_{8}$	0.24	1192	WBM
Total				2, 711Metres	

4.4.4 Disposal of Drill Cuttings

The two top hole sections will be drilled open to the seabed and the cuttings generated whilst doing so will be swept out of the hole using seawater. These will be deposited around the well bore. In the two lower sections the wells will be cased and drilled using a riser whilst circulating drilling mud to remove cuttings, to condition the well bore and provide hydrostatic pressure in the wellbore.

Whilst drilling the wells, a riser will be set between the wellhead and the rig, with a blow-out preventer fitted on the wellhead at the bottom of the riser. The mud and cuttings will be returned to the rig where they pass through the cleaning system (refer to Appendix A). This reduces the amount of drilling fluid retained on the cuttings to between 5 and 15 percent. The cuttings will be cleaned and discharged to the sea. The cuttings are variously sized particles of rock cut from the strata as the drill bit progresses down the well bore and will be comprised of sedimentary rock.

Estimated amounts of cuttings that will be generated for the proposed Loligo A well are detailed in Table 4.4.

Table 4.4. Estimate of Cuttings Generated for Proposed Loligo A Well

Hole Size (inches)	Hole Size (m)	Length (m)	Volume (m^3)	Weight (tonnes)
42	1.07	79	70.6	183.6
26	0.66	640	219.2	569.9
17 $^{1}/_{2}$	0.44	800	124.1	322.7
12 ¼	0.31	1192	90.6	235.6
Total cuttings from Loligo A well			**504.5**	**1311.8**
Discharged at Seabed			289.8	753.5
Discharged at Surface			214.7	558.3
Returned to Shore			0	0

Note: Weight of cuttings calculated assuming density of 2.6 tonnes per cubic metre

4.4.5 Drilling Mud and Casing Cement

A background to the use of drilling muds is given in Appendix A. The proposed wells will be drilled using water based mud (WBM). On the rig, the composition of the cleaned mud will be monitored and its contents adjusted to ensure that its properties remain as specified and it will be recycled through the well. No low toxicity oil based mud (LTOBM) will be used in either of the proposed wells.

The drilling mud is specifically formulated for each section of the well to suit the conditions in the strata being drilled. The selection is made according to the technical requirements for the mud and the environmental credentials of the chemical (refer to Section 4.4.8). The mud components which FOGL currently propose to use for the Loligo A well are listed in Table 4.5.

Once each section of the well has been drilled, the drill string is lifted and the casing is lowered into the hole and cemented into place (refer to Section 4.4.3). The cement is formulated specifically for each section of the well and contains small volumes of additives that are required to improve its performance (refer to Table 4.6). It is mixed into a slurry on the rig and is then pumped down the string and forced up the space between the well bore and the casing. To ensure that sufficient cement is in place and that a good seal is achieved, a certain amount of extra cement is pumped and some of this will be discharged to the seabed in the immediate vicinity of the wellhead, only in cases where cementing back to seafloor surface (e.g. the upper most section of the well). Typically, the quantity discharged is less than 10 percent of the total volume used. However, in case of contingency, the quantity discharged could double.

4.4.6 Well Testing, Completion and Abandonment

FOGL plan to plug and abandon the exploration wells drilled in the forthcoming campaign. Testing of a possible hydrocarbon discovery is not planned in this campaign.

The wells will be plugged and abandoned (P&A) in accordance with Oil and Gas UK Guidelines. A detailed P&A programme, with schematics, will be submitted to the independent Well Examiner and FIG regulator for approval prior to abandonment, taking account of final casing depths, subsurface and geological conditions encountered during drilling of the relevant well.

The objectives of the P&A programme are to:-

- Prevent the escape of subsurface fluids (water and any hydrocarbons) to the sea floor and into the sea water column.
- Remove potential seabed obstructions capable of interfering with future fishing activity.

Fluid Escape prevention

Cement plugs will be set as follows:-

- Lower open hole section (8 ½ inches or 12 ¼ inches hole size, dependent on well) – to seal off open reservoirs encountered. Dependent on the length of section and reservoir intervals encountered, more than one plug may be required. The likely length of an individual plug is anticipated to be about 150 metres. Potential cement volume per plug would be between 6 m^3 and 12 m^3 depending on hole size, making a total possible cement volume range of between 6 and 36 m^3.

- Cased hole section – plugs will be set at intervals within the cased section – from the base/seat of the last casing (9 $^5/_8$ in or 13 $^3/_8$ in casing dependent on well) to seabed/mud line. Typically, one or two 150m length plugs would be set and a plug would also be set near the seabed. Cement volume per plug would be between 6 and 12 m^3, with a total possible cement volume range of between 12 and 36 m^3.

The cement to be used would normally be Class G cement. Additives to assist cement setting may be incorporated into the cement mix. These would be drawn from a UK approved list of additives.

The above volumes are indicative and will be finalised in the formal P&A programmes. The cement plugs would be tested to ensure seal (the prior casing seat cement will have been tested during drilling).

Removal of seabed obstructions

Standard practice in areas of commercial fishing, where seabed or near seabed netting or trawling are anticipated, is to remove the well head and surface casing to below 3 metres of the seabed. This avoids damage or loss of such equipment by fishing vessels. The removal of surface casing to 3 metres below the seabed is to avoid later potential exposure, and projection above the seabed, due to scour of surrounding soft sediments by seabed currents.

At present there is no commercial fishing in the offshore Falkland Islands with nets/trawls at FOGL location depths. Experimental fishing may be carried out in the future to about 1200 metres. Long line squid fishing lines are unlikely to be affected at the well location depths of approximately 1300 to 1800 metres.

In similar water depth areas of petroleum exploration activity around the world, without commercial fishing at these depths, it is common practice to leave the wellhead in place, as it is considered very unlikely that commercial fishing could be impacted.

In UK waters, where commercial fishing activity is widespread, it is a regulatory requirement to remove the wellhead and cut the surface casing 3m below the seabed, regardless of water depth.

FOGL will comply with FIG regulator requirements on removal of wellhead and near seabed casing to 3 metres below the seabed.

4.4.7 Selection of Chemicals to be used Offshore

Drilling offshore the Falkland Islands will follow the same model of chemical use as is required in the UK. Offshore chemical use in the UK is regulated through The Offshore Chemical Regulations 2002, which apply the provisions of the Decision by the Convention for the Protection of the Marine Environment of the Northeast Atlantic (the OSPAR Convention) for a Harmonised Mandatory Control System for the use and discharge of chemicals used in the offshore oil and gas industry. The Offshore Chemical Notification Scheme (OCNS) ranks chemical products according to Hazard Quotient (HQ), i.e. the ratio of Predicted Effect Concentration against No Effect Concentration, which is calculated using the CHARM (Chemical Hazard and Risk Management) model (refer to Appendix B for further information).

In the UK, the Centre for Environment, Fisheries & Aquaculture Science (CEFAS) maintains a list of chemicals under the OCNS that have been approved for use offshore for specific functions. Only chemicals on this list may be chosen for use when selecting the components of the drilling mud, cement, completion and general rig chemicals. Chemicals are therefore selected on their technical merits and are screened so that the collateral environmental effects are minimised as far as practicable.

All of the planned chemicals, which FOGL currently propose to use for the drilling campaign, appear on this Ranked Lists of Products approved under the OCNS. The vast majority of the proposed chemicals are considered to ‘pose little or no risk’ to the environment (PLONOR) with a chemical label code ‘PLO’. The majority of chemicals also have an OCNS category of ‘E’, or have a Gold HQ band (i.e. are least toxic) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable.

Chemicals with the chemical label code ‘SUB’ have a substitution warning, and have been avoided wherever possible during chemical selection for the FOGL drilling programme. Chemicals may have a substitution warning attached due to their positional for bioaccumulation, or the presence of hazardous substances. A high Risk Quotient (RQ) may also render a chemical a candidate for substitution.

Certain chemicals will be required for specific purposes on the drilling rig, for example, lubricant for the drill string threads and detergent to periodically wash rig equipment. These chemicals will be selected to minimise any environmental impact that they might otherwise have.

Tables 4.5 to 4.7 summarise the planned chemicals to be used during drilling operations, specifically Loligo A exploration well which is the worst case well, – and the first to be drilled, based on higher chemicals use. Chemical use and discharge for the second well will be presented in the Operational Addendum. The total weight of WBM chemicals to be used and discharged for Loligo A is 1637.09 tonnes.

Other contingency chemicals may be required (Table 4.8) if problems or emergencies are encountered during drilling or cementing operations. One of the contingency chemicals, SAFE-SCAV HSB, is a hazardous class substance.

Table 4.5. Planned Loligo A WBM Mud Components

Chemical Name	Chemical Function Group	Chemical Label Code	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
42 inch section					
Caustic Soda	WB Drilling Fluid Additive	Inorganic	0.25	0.25	E
M-I BAR (All Grades)	Weighting Chemical	PLO	58.00	58.00	E
M-I GEL	Viscosifier	PLO	21.00	21.00	E
GUAR GUM	Viscosifier	PLO	0.50	0.50	E
Soda Ash	Other	PLO	0.15	0.15	E
26 inch section					
Caustic Soda	WB Drilling Fluid Additive	Inorganic	0.53	0.53	E
M-I BAR (All Grades)	Weighting Chemical	PLO	575.00	575.00	E
M-I GEL	Viscosifier	PLO	41.00	41.00	E
GUAR GUM	Viscosifier	PLO	1.90	1.90	E
POLYPAC - All Grades	Viscosifier	PLO	4.68	4.68	E
Soda Ash	Other	PLO	0.53	0.53	E
17 ½ inch section					
Potassium Chloride	WB Drilling Fluid Additive	PLO	70.00	70.00	E
M-I BAR (All Grades)	Weighting Chemical	PLO	86.00	86.00	E
SAFE-CIDE	Biocide	-	0.48	0.48	GOLD
MEG	Gas Hydrate Inhibitor	PLO	46.20	46.20	E
EMI-2224	Defoamer (Drilling)		0.48	0.48	Gold
ULTRAHIB	Shale Inhibitor / Encapsulator	-	25.52	25.52	SUB
ULTRACAP	Shale Inhibitor / Encapsulator	-	3.50	3.50	GOLD
ULTRAFREE NS	Drilling Lubricant	-	19.88	19.88	GOLD
FLO-TROL	Fluid Loss Control Chemical	PLO	4.65	4.65	E
POLYPAC - All Grades	Viscosifier	PLO	2.33	2.33	E
DUO-VIS	Viscosifier	-	1.83	1.83	GOLD
Sodium Chloride Brine	WB Drilling Fluid Additive	PLO	139.87	139.87	E
SAFE-CARB (ALL GRADES)	Weighting Control	PLO	33.00	33.00	E
12 ¼ inch section					
Potassium Chloride	WB Drilling Fluid Additive	PLO	40.00	40.00	E
M-I BAR (All Grades)	Weighting Chemical	PLO	75.00	75.00	E
SAFE-CIDE	Biocide	-	0.28	0.28	GOLD
MEG	Gas Hydrate Inhibitor	PLO	26.40	26.40	E
EMI-2224	Defoamer (Drilling)		0.275	0.28	Gold
ULTRAHIB	Shale Inhibitor / Encapsulator	-	14.74	14.74	SUB
ULTRACAP	Shale Inhibitor / Encapsulator	-	2.00	2.00	GOLD
ULTRAFREE NS	Drilling Lubricant	-	11.41	11.41	GOLD
FLO-TROL	Fluid Loss Control Chemical	PLO	2.68	2.68	E
POLYPAC - All Grades	Viscosifier	PLO	2.68	2.68	E
DUO-VIS	Viscosifier	-	1.35	1.35	GOLD
Sodium Chloride Brine	WB Drilling Fluid Additive	PLO	294.99	294.99	E
SAFE-CARB (ALL GRADES)	Weighting Control	PLO	28.00	28.00	E
TOTALS:			**1637.09**	**1637.09**	

Table 4.6. Proposed Cement Chemicals and Ratings (for each well)

Chemical Name	Chemical Function Group	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
D095 Cement Additive	Cement or Cement Additive			E
LITEFILL Extender D124	Cement or Cement Additive			E
AccuSET D197	Cement or Cement Additive			Gold
Cement Class G D907	Cement or Cement Additive			E
D600G GASBLOK* Gas Migration Control Additive	Cement or Cement Additive			Gold (sub)
Environmentally Friendly Dispersant B165	Cement or Cement Additive			E
Liquid Accelerator D77	Cement or Cement Additive			E
Liquid Antifoam B143	Cement or Cement Additive			Gold
Silicate Additive D75	Cement or Cement Additive			E
UNIFLAC-L D168	Cement or Cement Additive			Gold
Viscosifier for MUDPUSH II spacer B174	Viscosifier			E
Tros Seadye	Well Stimulation Chemical			Gold
Low Temperature Retarder D081	Well Stimulation Chemical			E
Antifoam Agent D175	Antifoam (Hydrocarbons)			Gold (sub)
Antifoam Agent D206	Cement or Cement Additive			Gold (sub)
Iron Stabilizing Agent L001	Completion Additive			E
Surfactant D191	Other			Gold
Mutual Solvent U66	Cement or Cement Additive			Gold
TOTALS:				

Table 4.7 Planned Rig Chemicals

Chemical Name	Chemical Function Group	Chemical Label Code	Estimated Use (tonnes)	Estimated Discharged (tonnes)	HQ Band / OCNS group
Jet Lube NCS-30 ECF	Pipe Dope	-	0.0162	0.01219	E
Pelagic 50 BOP Fluid Concentrate	Hydraulic Fluid	-	8.19	8.19	E
Pelagic Stack Glycol V2	Other	PLO	43	43	E
Tristar Eco Rig Wash HD-E	Detergent / Cleaning Fluid	PLO	2.497	2.497	E
TOTALS:			**53.70**	**53.70**	

Table 4.8 Contingency Chemicals

Chemical Name	Chemical Function Group	Chemical Label Code	HQ Band / OCNS group
MAGNESIUM OXIDE	Acidity Control Chemical	PLO	E
Citric Acid	Water based Drilling Fluid Additive	PLO	E
Dyna Red Seepage Control Fiber	Fluid Loss Control Chemical	PLO	E
Form-A-Blok	Lost Circulation Material	SUB	GOLD
G-Seal	Lost Circulation Material	PLO	E
Conqor 404NS	Corrosion Inhibitor	-	GOLD
Koplus LL	Pipe Release Chemical	PLO	E
KWIKSEAL	Lost Circulation Material	PLO	E
LIME	OPF Additive	PLO	E
Mica	Lost Circulation Material	PLO	E
Nutshells - All Grades	Lost Circulation Material	PLO	E
SAFE-COR EN	Corrosion Inhibitor	-	GOLD
SAFE-SCAV HSB	Hydrogen Sulphide Scavenger	-	SILVER
SAFE-SURF E	Detergent / Cleaning Fluid	SUB	GOLD
SAFE-SCAV NA	Oxygen Scavenger	PLO	E
SAPP	Water based Drilling Fluid Additive	PLO	E
Sodium Bicarbonate	Water based Drilling Fluid Additive	PLO	E
Sugar	Water based Drilling Fluid Additive	PLO	E
SUPER SWEEP	Lost Circulation Material	SUB	GOLD

4.5 Resource Use

4.5.1 Equipment and Chemicals

The remote drilling location will require sufficient materials and chemicals, equipment, spares and contingency supplies to be ordered in advance and shipped prior to rig mobilisation. These will be sourced in advance, mostly from outside the Falkland Islands.

4.5.2 Fuel

The Ocean Rig *Leiv Eiriksson* dynamically positioned semi-submersible rig is likely to consume 30 tonnes of diesel fuel a day during drilling operations. The rig will be mobilised from the neighbouring Falkland Island licence area and would take 1-2 days. Two support vessels will be used throughout the drilling campaign, each of which is estimated to consume 15 tonnes of diesel fuel a day. In total it is therefore estimated that the drilling campaign will use approximately 6,000 tonnes of diesel fuel, given that the combined campaign will last approximately 100 days (50 days per well).The fuel will be sourced from the Falkland Islands. An Emergency Response and Rescue Vessel will maintain station near to the rig.

Helicopter trips for crew changes and other *ad hoc* purposes will occur 3-4 times per week on average (30 round trips per well). The type of aircraft to be used is likely to be the Super Puma. Estimated fuel consumption is 3 tonnes per 1,000 kilometres, assuming possible use of larger helicopters, (S-92), flying between Mt. Pleasant Airport to rig with round trip estimated distances of 460 and 660 kilometres for Loligo A and Scotia East D locations, respectively. Total aviation fuel use is estimated at 100 tonnes for the 2-well campaign.

4.5.3 Water

The exploration wells will require 12,355 bbls and 15,805 bbls of fresh water for the top hole sections of Loligo A and Scotia East D, respectively. The deeper sections of the wells will be drilled with Ultradrill water based mud that utilises seawater. Availability of water has been confirmed with the Falkland Islands Government. A shortage of water may occur in dry summer seasons, but the drilling campaign is taking place during autumn/winter, therefore interference with public water consumption is unlikely.

It is estimated that 30 m^3 of sea water per day will be treated through the on-board desalination plant for galley and drinking purposes.

4.5.4 Waste Disposal

Waste disposal facilities in Falkland Islands are limited to 2 non-engineered non-hazardous landfill sites, with more than 50% capacity utilised. Therefore, only non-hazardous and inert waste streams generated during drilling will be recycled where possible and disposed of locally. All hazardous waste will be exported to the UK for treatment.

Hazardous waste is waste that is, or may be considered to be, "so dangerous or difficult to dispose of that special provision is required for its disposal". The following list provides an example of hazardous waste that may result from the proposed FOGL drilling operations (but is not considered to be an exhaustive list):

- Waste Paint and Paint thinners;
- Waste oil;
- Oiled waste, including oil filters, oily rags, etc.
- Contaminated oil;
- Spent Batteries;
- Waste Anti-freeze;
- Used Pipe dope/grease;
- Used light bulbs/tubes;
- Heli-fuel waste;
- All hazardous waste packaging.

Hazardous waste generated from wells differs greatly per well, but a typical exploration well would generate between 2 to 100 tonnes of hazardous waste (average of 65 tonnes). This estimate is based on North Sea wells. Given that no low toxicity muds will be utilised during the drilling of the proposed wells, it is assumed that the volume of hazardous waste generated per well on average would be in the range of 10 tonnes. An average volume of non-hazardous waste is estimated at 30 tonnes per well.

Specific waste handling/disposal routes and procedures will be detailed in a Waste Management Plan, to be submitted for approval.

4.6 Support Operations

The drilling rig will be supported by two Platform Supply Vessels (PSVs). The vessels will rotate between the rig and the onshore supply base in Stanley. The Emergency Response and Rescue Vessel (ERRV) at the rig will serve as a stand-by vessel and will at all times be within proximity of the drilling rig for safety purposes. It will be in close liaison with the drilling rig and will continuously monitor other vessel movements in the area. It will warn off vessels on a course that is likely to bring them into or near the safety exclusion zone around the rig. The supply vessels will provide the bulk logistics and transport materials required for drilling.

Rig crews will be transferred to and from the rig by helicopter. A helicopter from CHC Helicopters, based at Stanley Airport will be dedicated to FOGL throughout the drilling programme. Super Puma helicopters are expected to be used, but this is to be confirmed in the Operational Addendum. Helicopter crew changes are anticipated to take place once every two weeks when approximately 60 personnel will be crew changed in one day requiring 4 helicopter flights between Stanley and the Rig carrying an average of 15 personnel per flight. On arrival at Mt. Pleasant Airport, the crews will transfer by road to Stanley Airport. Crews departing the rig will arrive at Stanley Airport and transfer by road to Mt. Pleasant Airport. Each crew change flight consists of a round trip distance of 460 and 660 kilometres for Loligo A and Scotia East D, respectively.

During routine crew changes, part of the incoming crew will normally be transferred directly to the rig. However, the remainder of the crew will need to be temporarily accommodated on the Islands as they wait for their flights, later that day. It is noted that there is limited accommodation available on the Falkland Islands, although operations will take place at a low tourist season. Currently, FOGL intend to have a permanent arrangement for housing and leasing rooms in the local hotels. This accommodation will be used on a routine basis for operational personnel and management on an *ad hoc* basis. During a crew change operation if either the incoming or outgoing rig crew become stranded in Stanley, accommodation facilities outside the permanent arrangement discussed above will be utilised. The table below outlines the potential emergency accommodation currently identified. The utilisation of accommodation at the F.I.D.F. is only intended for rig emergency situations. It is not intended to be used as routine accommodation during crew change delays. During normal operations it is anticipated that 40 to 60 crew members will change out during crew change operations. Table 4.8 below summarises the crew change arrangements.

Table 4.8. Accommodation arrangements for crew change procedures

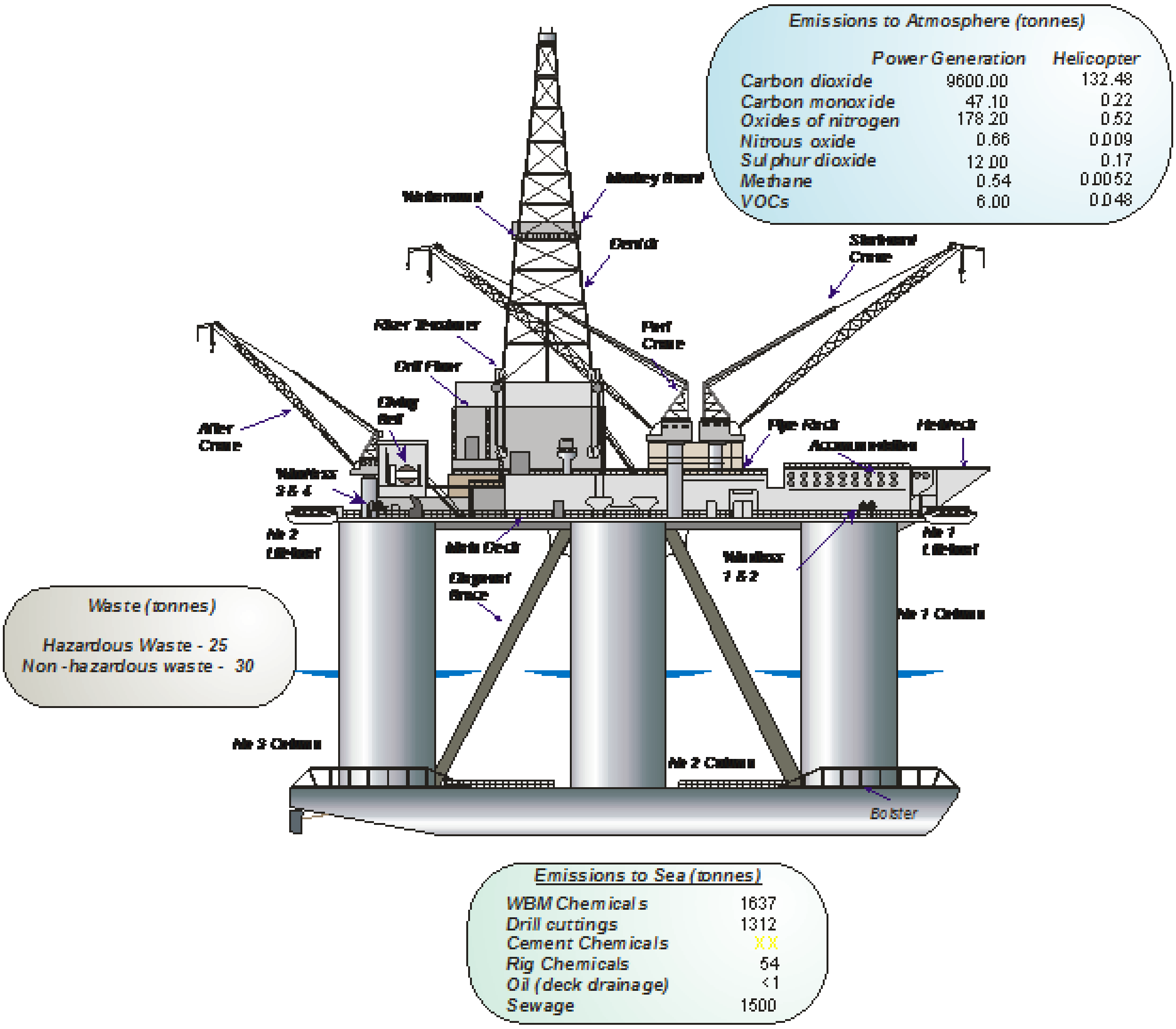
Name	Rooms	Number of Beds
Lookout Lodge	64	64
Shortys Motel	6	10
Lafone House	5	8
Bennett House	3	7
Kay's B & B	2	3
Susanna Binnie's Homestay	1	2
Waterfront Hotel	8	9
Sub Total: Number of Rooms and Beds	**89**	**103**
F.I.D.F.	Could accommodate up to 200	70 presently but could be easily increased

All routes used by vessels and aircraft will be pre-planned to avoid creating unnecessary disturbance to sensitive elements along their routes. Refer to Figure 5.76 which illustrates the 'no-go' zones for areas identified to be ecologically sensitive from aircraft and helicopter activities.

4.7 Total Emissions Summary

Figure 4.3 provides a summary of estimated maximum emissions and discharges arising from routine operations associated with the drilling of Loligo A well. The calculations are based on 50 days of the rig deployment. Similar emissions are to be expected from the second well and will be confirmed in the Operational Addendum.

Figure 4.3 Emissions Summary for Loligo A Well (best estimate only)



5. Baseline Environment

5.1 Introduction

Understanding the characteristics of the local environment is a key consideration in the planning of FOGL drilling operations, so that the potential for the exploration drilling programme to interact with the environment can be correctly identified and appropriate controls adopted to mitigate any possible negative impacts.

The physical, biological and socio-economic environments in both the immediate vicinity of the FOGL licence blocks and further afield have been reviewed. Where relevant, details of coastal, inter-tidal and terrestrial resources have also been included.

5.2 Physical Environment

5.2.1 Geography

The Falkland Islands are an archipelago of approximately 700 islands in the South Atlantic (see Figure 1.1), the largest of which are East Falkland and West Falkland. Situated some 770 kilometres northeast of Cape Horn and 480 kilometres from the nearest point on the South American mainland, the Falklands have a total land area of 12,173 km^2 and a permanent population of around 2,900 (*FCO, 2007*).

5.2.2 Bathymetry and Seabed Morphology

The Falkland Islands are situated on a projection of the Patagonian continental shelf, which is bound to the north by a steep slope (the Falklands Escarpment), separating it from the Argentine Abyssal Plain. A gently northeastward sloping area between the Falkland Islands and the Falklands Escarpment, at water depths of between 150 and 1,800 metres, is known as the north Falklands Basin. The continental shelf extends some 200 kilometres beyond the Falklands coast to the north, about 50 kilometres to the southwest, and about 50-100 kilometres offshore on the eastern side (*Otley et al., 2008*).

To the south, a deep east-west trough (the Falklands Trough) divides the Falklands Plateau from the Burdwood Bank. The Burdwood Bank is one of a number of elevated blocks bound by submarine ridges and troughs, which were formed as a result of compression during the Cenozoic era along the northern margins of the Scotia Sea (*Otley et.al., 2008*).

The bathymetry map for the region is provided in provided in Figure 5.1. A localised bathymetry map for the Loligo A exploration well is shown in Figure 5.2.

Figure 5.1. Falkland Islands Regional Bathymetry

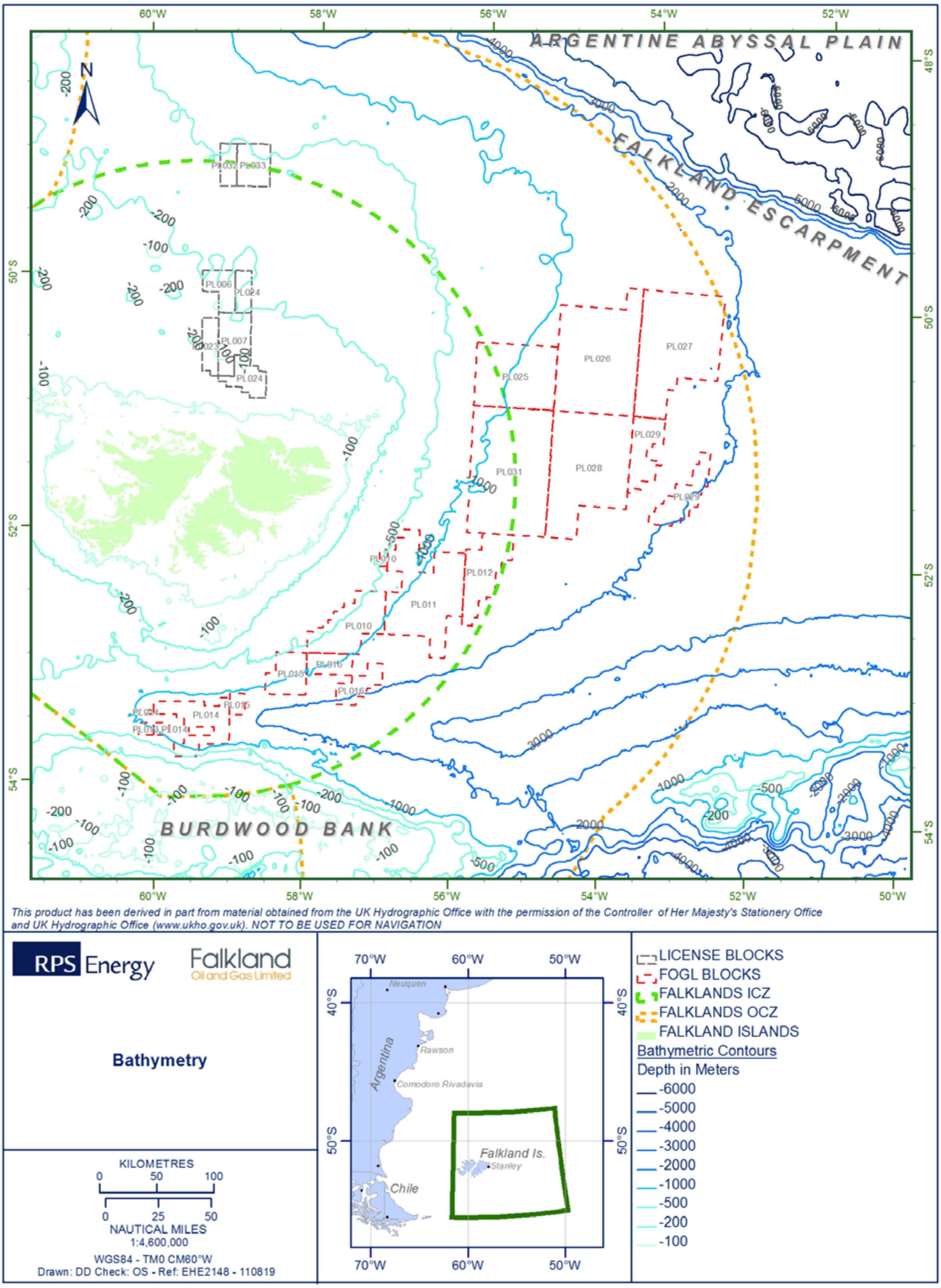
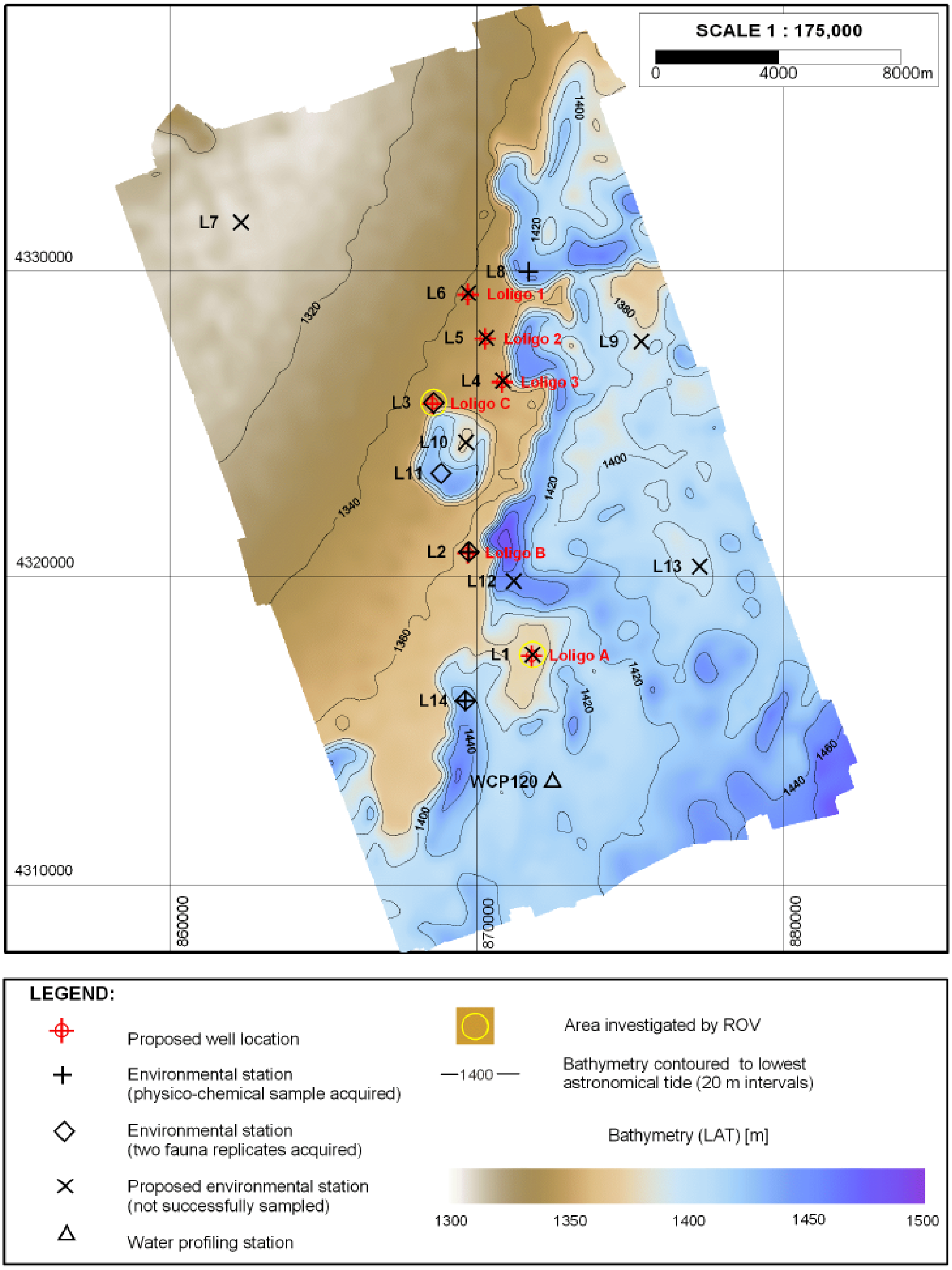


Figure 5.2. Loligo Site Survey Area: Localised Bathymetry and Sampling Stations (FSLTD, 2009a)



5.2.3 Seabed Sediments

Loligo A Site Survey Results

The evidence of the gravity coring, drilling and ROV programs suggested that seafloor materials predominantly consisted of fine to coarse sand or gravel throughout the Loligo A site survey area (Figure 5.3). These sediments may also have been cemented in parts of the area. The high-relief topographic features identified in the eastern morphologic zone may have represented un-eroded remnants of locally harder or cemented seafloor materials (refer to Appendix C for further information) (*FSLTD, 2009a*).

Figure 5.3. Screen Grabs of ROV Footage, Showing Notable Seabed Features within the Loligo A Site Survey Area (FSLTD, 2009a)

Plate 1: Homogeneous muddy fine sand in the vicinity of the proposed Loligo A location

Plate 2: Muddy fine sand with some coarse material (pebbles and gravel) in the vicinity of the proposed Loligo A location

Plate 3: Muddy fine sand with a moderate proportion of coarse material in the vicinity of the proposed Loligo A location

Plate 4: Low-relief sand covered hard material in the depression near Loligo C

Plate 5: A boulder or isolated outcrop of consolidated material in the depression near Loligo C

Plate 6: The sheer scarp of consolidated material bordering the depression near Loligo C

5.2.4 Granulometry

Particle size analysis (PSA) was performed using wet sieving techniques and laser diffraction. The Loligo A PSA results are summarised in Table 5.1, with a description of the sediment type of each sample also given based on the Wentworth Classification (*Buchanan, 1984*).

Table 5.1. Loligo A Summary of Particle Size Analysis (FSLTD, 2009a)

Station		Depth (m)	Mean (µm)	Mean Phi	Sorting	Coarse %	Sand %	Fines %	Graphical Mean/ Wentworth
L2		1365.0	178.6	2.49	1.84	1.8	79.7	18.5	Poorly Sorted fine sand
L8		1438.0	4911.9	-2.30	2.84	73.5	21.2	5.3	Very poorly sorted sand
L14		1434.0	137.4	2.86	2.19	2.0	71.7	26.3	Very poorly sorted fine sand
Comparison of Results									
Loligo A	Mean	1412.3	1742.6	1.02	2.29	25.7	57.5	16.7	Very poorly sorted medium sand
	SD	41.0	2744.8	2.88	0.51	41.3	31.7	10.6	

Granulometry definitions: coarse material: > 2 mm; sand: 63 µm. SD: Standard deviation

Of the three stations successfully sampled for particle size analysis, all showed similar levels of clay and silt particles. However only stations L2 and L4 had similar sediment types in which particles in the 1 phi unit to 3 phi unit (medium to fine sand) size range were particularly prevalent. The sediment sample acquired at L8 was observed to have a distinctly different sediment type, in which pebble particles (-2 to -4 phi units) were dominant. This sample had substantially lower proportions of both sand and fine material than stations L2 and L14. This would suggest similar oceanographic regimes at all stations.

Organic Carbon, Hydrocarbon and Heavy/Trace Metal Analysis

Both fractionated organic carbon (FOC) and total organic matter by loss on ignition (TOM by LOI) concentrations appeared relatively consistent across the Loligo A sampling stations, the former ranging from 0.24% to 0.31% (stations L8 and L2, respectively) and the latter from 4.8% to 5.7% (stations L14 and L8, respectively).

Total hydrocarbon concentrations (THC) were low at all stations, ranging from 2.3 $\mu g.g^{-1}$ to 4.2 $\mu g.g^{-1}$ (stations L2 and L14, respectively).

Total n-alkane and individual aliphatic concentrations reflected THC in being low, but were at their greatest at station L14. The lack of carbon-number preference in the n-alkanes (all stations having CPIs close to unity) was thought to be due to natural processes.

Total Polycyclic Aromatic Hydrocarbons (PAH) concentrations were low and showed the same general pattern as was observed for total hydrocarbons, with higher concentrations being recorded from stations L2 and L14 (133 $ng.g^{-1}$ and 162 $ng.g^{-1}$, respectively) than from station L8 (61 $ng.g^{-1}$). These levels of PAHs were lower than typical levels found in the North Sea and, given the remoteness of the region, these concentrations fall within expected levels.

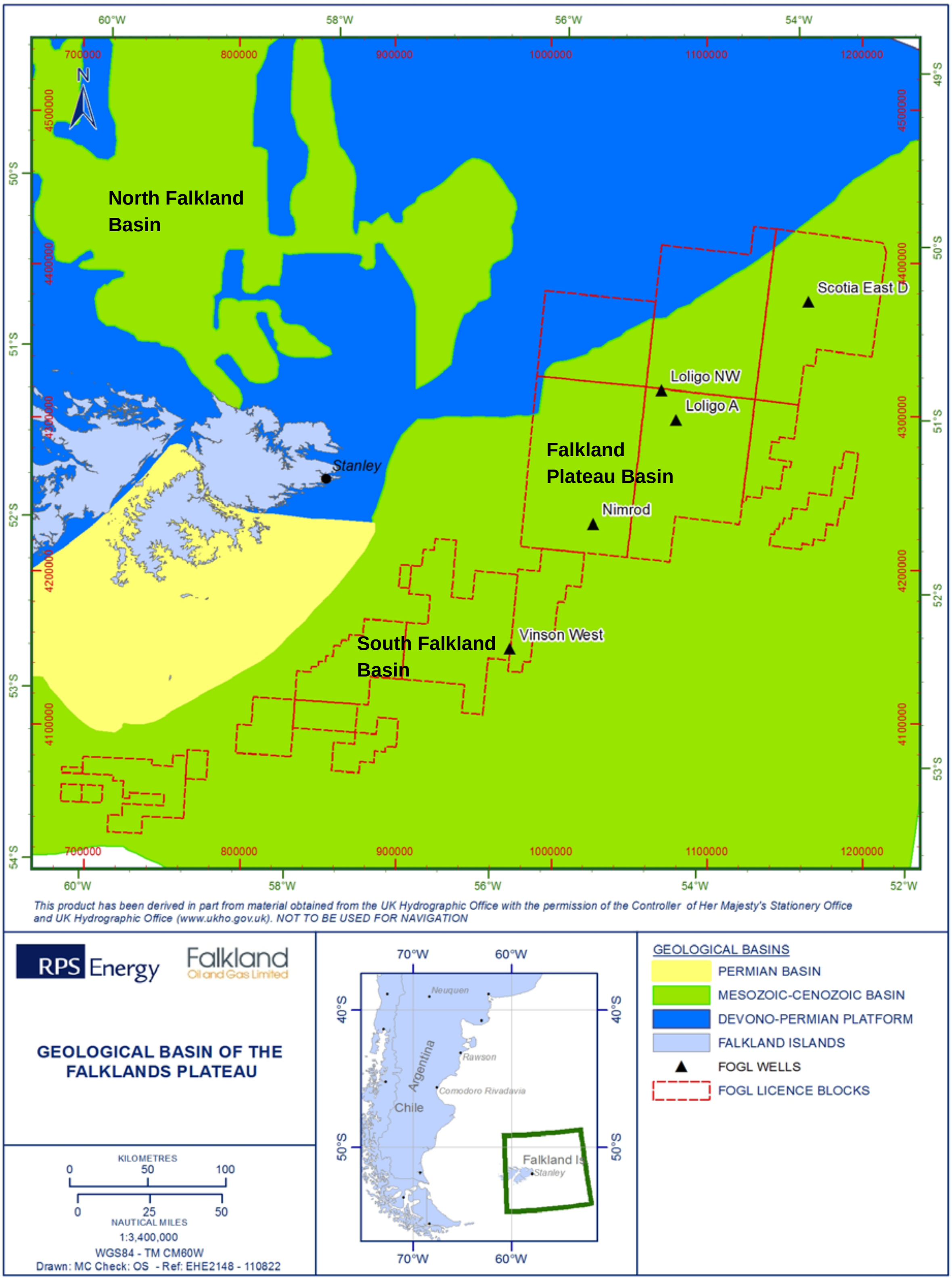
The concentrations of heavy and trace metals were measured using inductively coupled plasma mass spectrometry following extraction by separate aqua regia and hydrofluoric acid (HF) digests. As would be expected given the differing stringency of the two extraction procedures, the concentrations measured by aqua regia digestion may suggest, to an extent, the level of biologically available metals, while concentrations measured by HF relate more to the total levels of metals present within the sediment.

The concentrations of heavy and trace metals at each station were lower than North Sea UKO&G values, indicating typical background levels for an unimpacted environment (*FSLTD, 2009a*).

5.2.5 Geology

The Falkland Islands lie at the western end of the Falklands Plateau and the South American continental crust that extends to South Georgia. The islands are positioned over Permian, Mesozoic-Cenozoic and Devono-Permian Platform basins (Figure 5.4).

Figure 5.4. Petroleum Basins of the Falklands Plateau



Petroleum exploration in the region is in its infancy and is focused on the North Falklands Basin, South Falklands Basin and Falkland Plateau Basin, all within a wider Mesozoic-Cenozoic Basin. Four of the proposed alternative wells are located in the Falkland Plateau Basin, while Vinson West lies within the South Falklands Basin.

The geologic history of the East Falklands Plateau is one dominated by the creation of the surrounding oceanic crust. These are:- the opening of the Weddell Sea in the Triassic through Jurassic; the opening of the Atlantic in the late Jurassic through Cretaceous; and the evolution of the Scotia Sea/Burdwood Bank from the late Cretaceous to present. Before these events, the Falklands were part of the Gondwana super-continent attached to southeast South Africa. These units form the basement to the stratigraphy of the offshore which encompasses the petroleum system.

The area beneath the acreage forms the flexural margin to the asymmetric rift opening of the Weddell Sea. As such it does not contain major faults or associated rotational blocks. The basal stratigraphy (syn-rift) shares affinities to the fill of the Roca Verdes seaway of the Magallanes and Malvinas basins and as such is interpreted as the volcaniclastic dominated Tobifera Formation of mid Jurassic age. From this point on, until the late Cretaceous, the history of the margin is one of increasing transgression interspersed by major phases of sediment input.

It is during the late Jurassic and early Cretaceous that the couplets of source rock and fringing reservoirs of the Springhill are deposited. These provide a continuum of the established plays of the Magallanes and Malvinas Basins. In the mid-Cretaceous, a period of uplift in the Falklands hinterland results in the build out of a series of southeasterly prograding deltaic complexes with associated basin floor fans (‘Mid Cretaceous Fan Play’ reservoirs). These units are analogous with the scale of the linked fan-delta complexes of the Palaeocene/Eocene in the North Sea. The deltas become increasingly mud rich reflecting the overall denudation of the hinterland and its submergence. Indeed by the Coniacian, the Falkland Islands are thought to be almost completely submerged, with a broad shallow shelf established.

During the Santonian through Maastrictian, renewed uplift results in rejuvenation of the Falklands sourced clastic systems. However, unlike the previous mid-Cretaceous deltas where a well developed shelf edge was established, these coastal systems are much more in keeping with deposition on a ramp margin. A thick moderate to deep water claystone section was deposited in the basinal areas in the Late Cretaceous. Subsequent uplift in the Early Tertiary resulted in erosion of the Falkland Islands area. The fringing clastic systems developed on low accommodation strandplains, from which hyperpycnally generated turbidite fan channel systems (‘The Tertiary (Eocene) Channel Play’ reservoirs) were deposited in the basin. Ultimately, the oceanic thermal subsidence associated with the expanding oceanic Scotian plate, drowns these systems in the middle Eocene. This resulted in the establishment of the present, very fine grained to ooze dominated system. The presence of sand size sediment on the seabed at the Loligo location probably reflects the winnowing effect of currents, in removing finer material.

5.2.6 Oceanography

Water Circulation and Tidal Currents

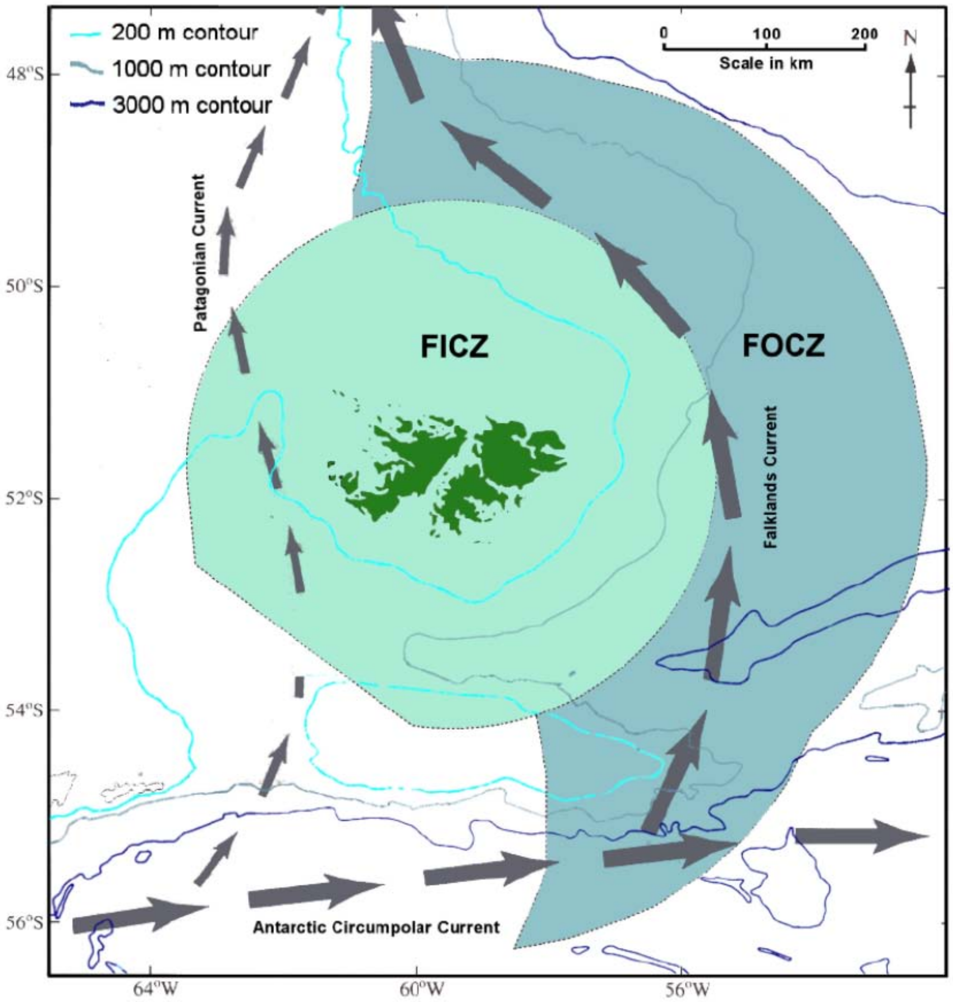
The Falkland Islands lie to the north of the Antarctic Polar Front or Antarctic Convergence, where cool surface waters from the south meet warmer surface waters from the north. The Antarctic Polar Front (APF) is ecologically important (*Munro, 2004*) and occurs between 50°S and 60°S (*Laws, 1984*).

The Antarctic Circumpolar Current is a surface current that intensifies and deviates northwards as it flows around Cape Horn, and splits to either side of the Falkland Islands (Figure 5.5). The 'Patagonian' or 'West Falklands Current' flows north on the west side of the Falklands, whereas the stronger east Falklands current runs north, then swings west to re-converge with the 'West Falklands Current', continuing northwards in a 100 kilometres wide band towards the warm south flowing Brazil Current (*Munro, 2004; Glorioso and Flather, 1995*).Average diverging current speeds are less than 25 $cm.s^{-1}$ (0.5 knots) to the west and 25 – 50 $cm.s^{-1}$ (0.5 – 1 knots) to the east of the Falklands (*Hydrographer of the Navy, 1993*).

Tidal cycles around the Falkland Islands are semi-diurnal (twice daily), with tides ranging from 0.3–3.5 m above local datum (*Brown and Root, 1997*).

The 1997 Proudman Oceanographic Laboratory current model for the Patagonian Shelf area showed the Falklands Current at depths below 200 metres flowing north, closely following the shape of the Continental Shelf slope. In the shallower water, closer to the Falklands, residual current flow is negligible and water movement is dominated by tidal flows.

Figure 5.5. Current System around the Falkland Islands



From 6th December 2008 to the 26th April 2009 (Phase 1), one metocean buoy was deployed at the Loligo A well location by Fugro Survey Limited. The aim of the deployments was to gather data on current speed and direction throughout the water profile between these times. The metocean buoy, deployed in a 1,421 metres water depth, consisted of a Long Ranger RDI 75kHz Acoustic Doppler Current Profiler (ADCP) and five single-point Aanderaa Recording Current Meters - version 7 (RCM 7) (Figure 5.6). Table 5.2 lists the maximum observed current speeds at each of the metocean buoys. The maximum observed current speed was 0.75 ms^{-1}, measured by the LR ADCP, at 41 metres below the sea surface on 26 January 2009 at 03:00 GMT. The corresponding direction was 257° (true). At 641 metres below the surface, the maximum speeds were 0.64 ms^{-1} on 17 January 2009 10:20 (GMT). Maximum speeds observed below this depth (1000–1400 metres depth range) reached speeds above 0.5 ms^{-1}.

At the Loligo location, the raw data from data bin 25 (the closest to the sea surface, at 41 metres below sea level) was obtained. From this, the residual current speed and direction from the period 6th December 2008 to the 26th April 2009 was calculated. This was found to be 0.14ms^{-1}

in the direction of 010°. This is broadly consistent with the general current pattern observed in the area (Figure 5.7). Phase 2 data were collected between 01 May 2009 and 21 October 2009.

Figure 5.6. Metocean buoy deployed at the proposed Loligo A well location (FSLTD, 2009c)

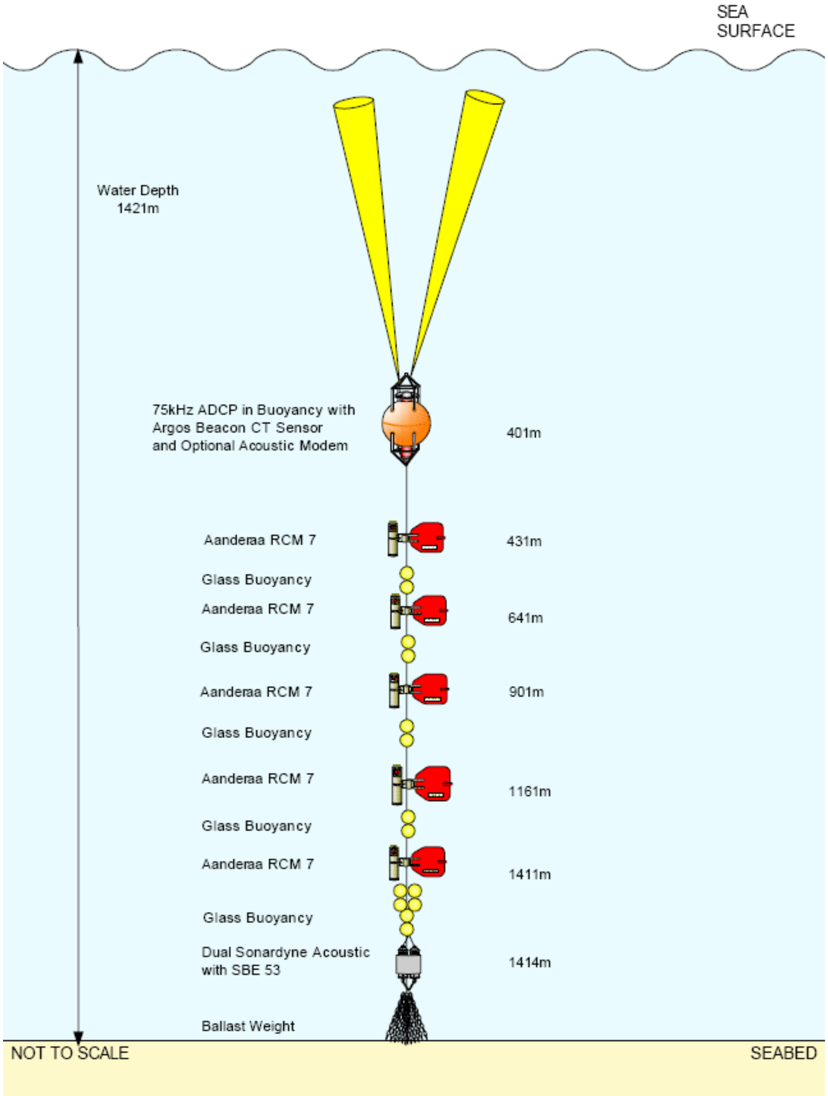
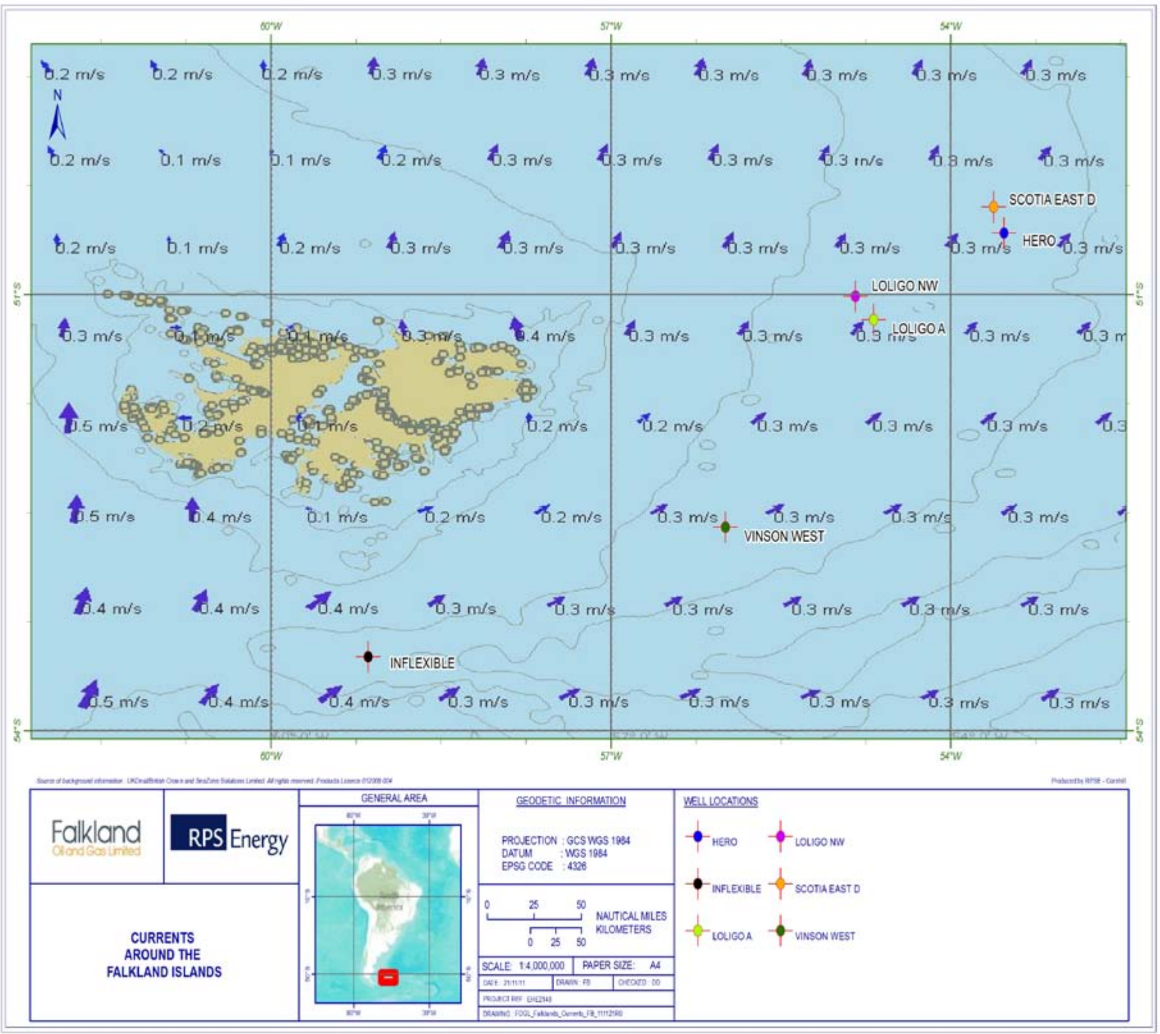


Table 5.2. Maximum observed current speeds and directions from the instruments from metocean buoy (FSLTD, 2009c)

Data Bin No.	Depth Below MSL	Current Speed (ms^{-1})		Direction of Current Maximum
	Metres	Maximum	Mean	(° True)
Loligo Bin 25	41	0.75	0.22	257
Loligo Bin 12	249	0.63	0.19	266
Loligo RCM1	431	0.59	0.19	282
Loligo RCM2	641	0.64	0.19	001
Loligo RCM3	901	0.58	0.15	006
Loligo RCM4	1161	0.51	0.16	034

Figure 5.7. Currents around the Falkland Islands. (hydrodynamic hindcast database, OSIS 4.1).



Water Column Characteristics

Four water profiling attempts were made at the Loligo site, two of which were successful. The results of which are presented in Figure 5.8; this profile was acquired over the course of approximately one hour from 1113 on February 2nd 2009 (*FUGRO, 2009*).

The surface temperature at the time of data collection was approximately 8.2°C and this remained relatively constant in the well mixed upper layers of the water column (between the surface and approximately 50 metres depth). Below this well mixed layer there was a distinct thermocline over which the water temperature rapidly descended to 5.3°C at approximately 90 metres depth. Below the thermocline the temperature declines gradually to a depth of approximately 760 metres, where there is a slight temperature inversion, over which the temperature increases from 3.6°C to 3.8°C. Below this inversion temperature generally declines, although there are a series of slight temperature increases and decreases that suggested some mixing and / or stratification. These effects may indicate the influence of a different water body below this depth. The minimum temperature of 2.9°C was recorded just above the seabed (1217 metres depth). There was very little seasonal variation in water temperature at the Loligo A site – temperatures remained low throughout the deployment period (December 2008 – October 2009). The maximum temperature observed was 4.9°C between 400 – 401 m below MSL (mean sea level) on 7th May 2009. The minimum temperature recorded was 1.9°C in October 2009 between 1411 – 1415 metres below MSL (*FUGRO, 2009a*)

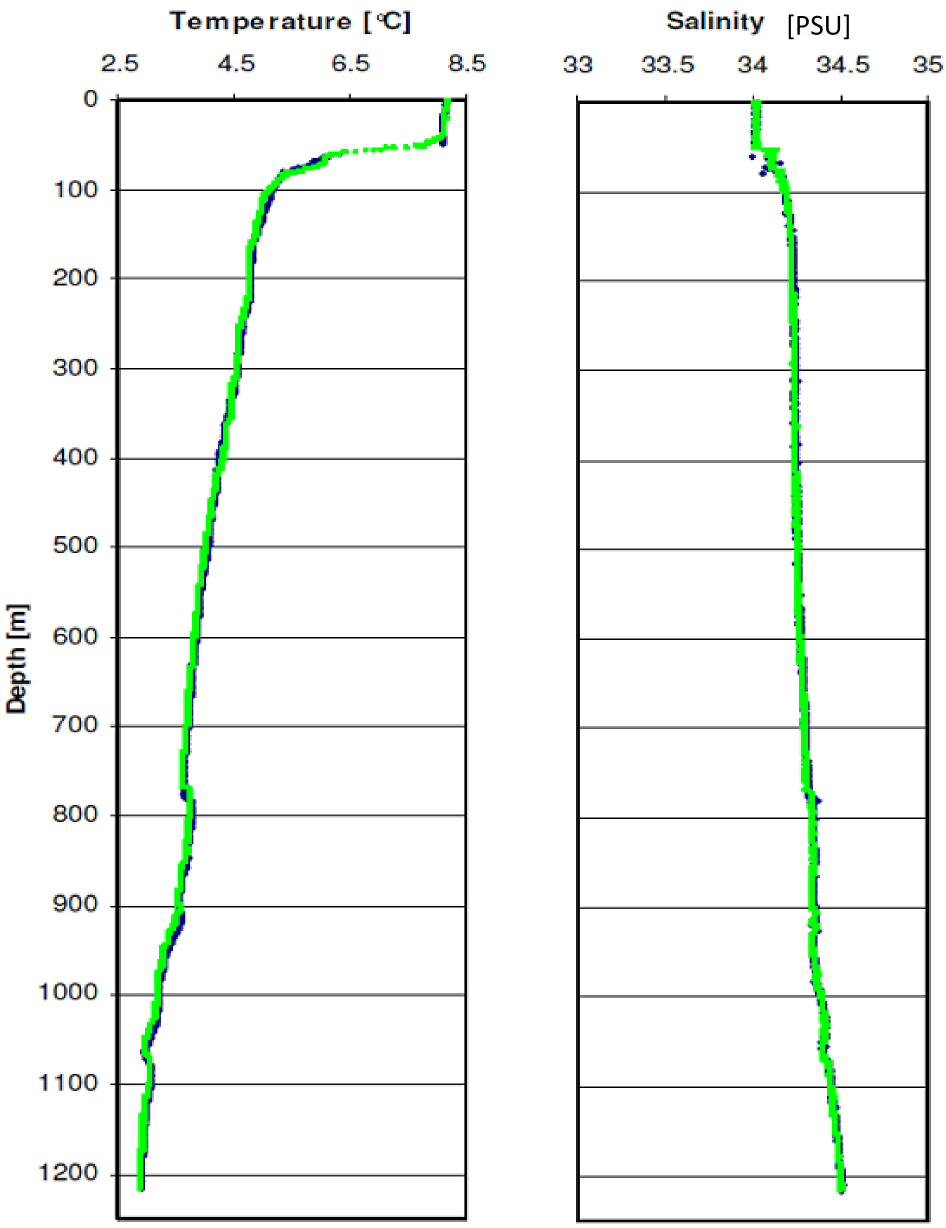
Although salinity showed minimal variation throughout the water column, ranging from a minimum of 34.0 at the surface to 34.5 at the seabed, it appeared to have a strong negative relationship with temperature. In the well mixed surface layers salinity remained constant; it then showed a small but distinct decrease over the course of the thermocline to approximately 34.2. From here it increased gradually to the temperature inversion at approximately 760 metres depth, where it showed a sharp stepped increase, before fluctuating slightly but showing a general trend of increase to the seabed. The slight increase of salinity at the temperature inversion suggested inflow of a slightly more saline (and thereby denser) water body below this depth.

The pH level showed minimal variation throughout the water column, decreasing from approximately pH 8.3 at the surface to pH 8.1 at the seabed. The decrease was gradual from the surface to the thermal inversion, where it showed a slight, but sharply stepped decrease. After this it showed a general trend of decrease, with some degree of fluctuation, to the seabed.

Dissolved oxygen (DO) increased from a surface saturation of approximately 100% (100%sat.) to its maximum of 123.2%sat. at around 50 metres depth. It then decreased rapidly over the course of the thermocline, before gradually decreasing to the seabed (minimum concentration of 47.3%sat.)

Turbidity was uniformly low throughout the water column, with the majority of measurements being either 0 FTU (formazin turbidity units) or 0.003 FTU.

Figure 5.8. Water Column Profiles Recorded in February 2009 at Loligo site (FUGRO, 2009)



5.2.7 Meteorology

Meteorological data for offshore the Falkland Islands is sparse relative to other explored offshore areas, although the following available data has been reviewed:

- UK Meteorological Office data from vessel observations and weather station locations on the Islands;
- Baseline surveys, 1997 (*Brown and Root*) and 2004 (*Falklands Conservation*);
- Hydrographer of the Navy pilot information (*1993*);
- Published article in Aquatic Conservation Journal (*Upton and Shaw, 2002*);

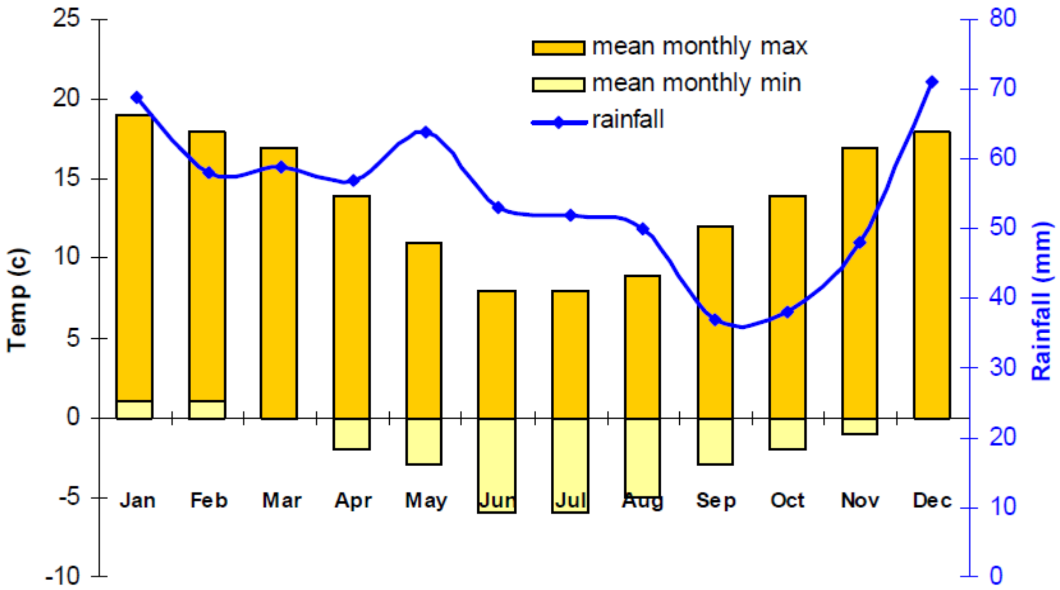
- Falklands Wind and Wave Operational Criteria report (*2005*) prepared for FOGL by Fugro GEOS Ltd.

The Falkland Islands have a cool temperate oceanic climate, dominated by westerly winds. As the Falklands lie to the north of the Antarctic Polar Front (APF) (also known as the Antarctic Convergence), where cool surface waters to the south meet warmer surface waters from the north, the climate is moderate preventing prolonged snow and ice cover (*Munro, 2004*). The region is exposed to an almost unbroken series of meteorological depressions and anticyclones that move across the area (*Hydrographer of the Navy, 1993*).

Temperature

The Falklands have a narrow terrestrial temperature range with mean annual maximum temperature of approximately 10°C, mean annual minimum temperature of approximately 3°C, and the mean monthly temperatures range from 19°C between January and December to -5°C between June and July (Figure 5.9). Temperatures over the open sea will be slightly less variable than on land at Stanley Harbour.

Figure 5.9. Climate Averages for Stanley Harbour



Precipitation

Figure 5.9 shows the average monthly rainfall for Stanley Harbour, the proposed supply base for offshore drilling operations. Average annual rainfall at Stanley is around 650 millimetres and average annual rainfall for the Falklands is consistently low, due to their location in the 'rain shadow' of the Andean cordillera (*Munro, 2004*).

The Falklands experience approximately 11 days of snow a year, most frequently in August. Weather conditions become more extreme further south, with the frequency of both violent storms and squalls increasing south of 50°S (*Hydrographer of the Navy, 1993*). There is no clear seasonal variation in atmospheric pressure with maximum pressures ranging between 1,003 and 1,035 millibars (*Upton and Shaw, 2002*).

Winds

Metrological frequency analysis data has been acquired from the UK Met Office for the area 48S to 54S and 62W to 53W. This data provides a breakdown of wave height and direction by month for the period 1978 to 2007, together with wind speed and direction by month for the period 1978 to 2007. The figures have been averaged over this period to provide annual summaries of prevailing wind direction (Figure 5.10) and annual wave exceedance (see below).

The prevailing wind direction spans from southwest to northwest (Figure 5.10). Winds predominantly range between 11 to 21 knots (Beaufort scale 4 to 5) or below. Strong gales and storms (Beaufort scale 7+) are rare in the area, but may occur in winter from a westerly direction.

Another set of wind data was analysed by Fugro (*Fugro, 2005*) for a grid point at 52.5°S, 57°W, for a period of 1992-2002. It was derived from WAM model performed by the European Centre for Medium-range Weather Forecasting (ECMWF), calibrated against satellite data and in-situ observations by Fugro Oceanor. The monthly wind roses obtained from this database for March through to August (a wider time window assumed for FOGL drilling) indicate similar wind trends, with stronger and more persistent westerly and southwesterly winds between May and June compared to other months (see Figure 5.11). Easterly winds were consistently low.

Figure 5.10. Annual Average Wind Direction and Speed in knots (Data Source: UK Met Office, 1978-2007)

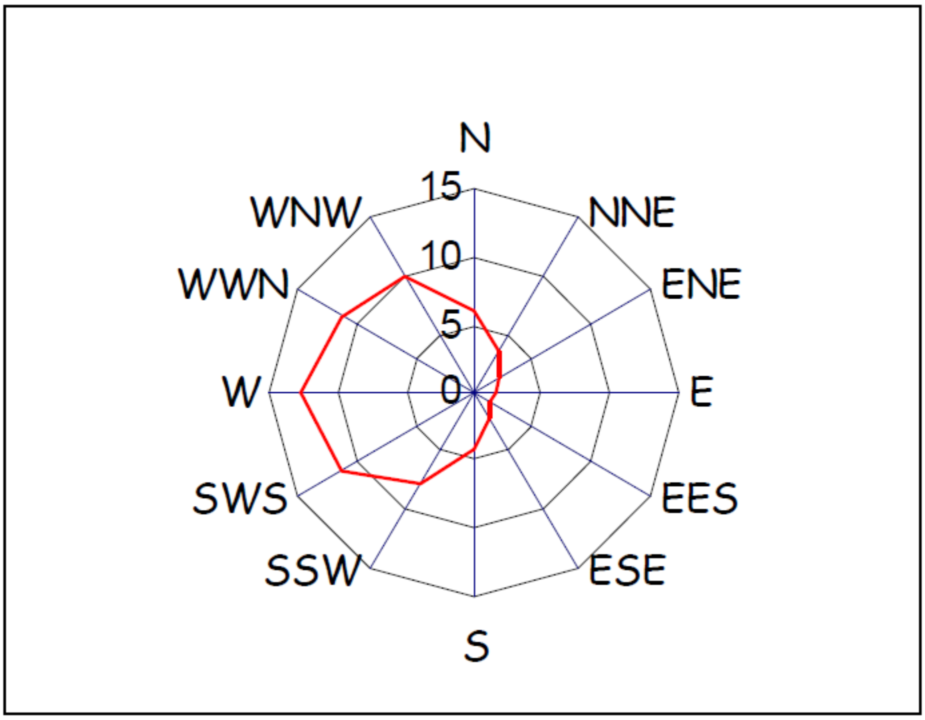
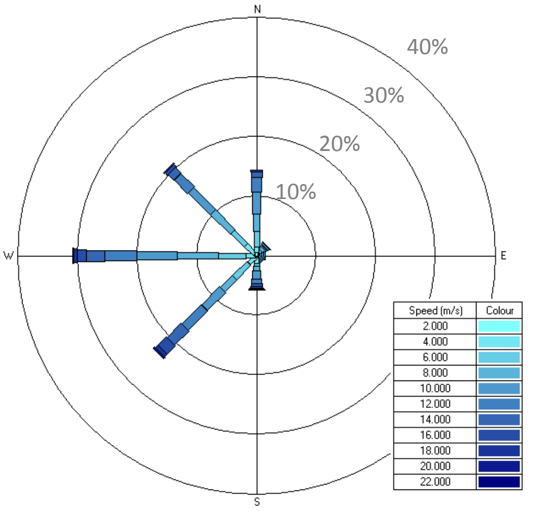
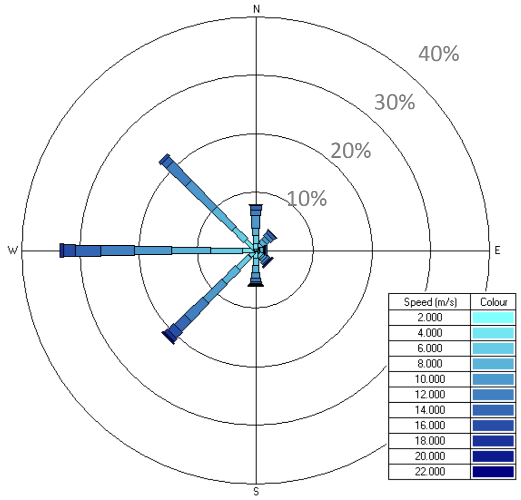


Figure 5.11. Monthly Wind Rose and Percentage Occurrence by direction between 1992-2002 (Fugro, 2005).

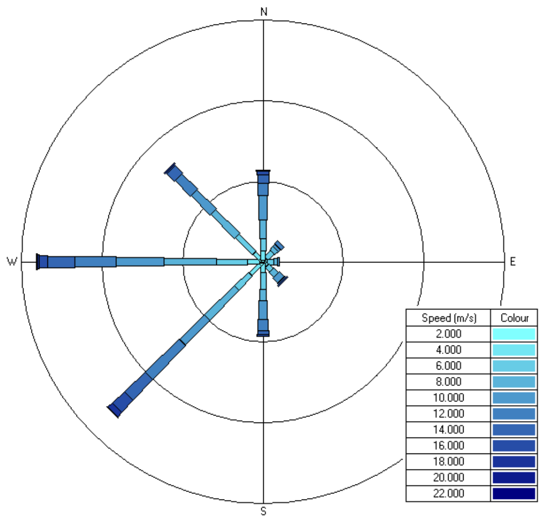
March



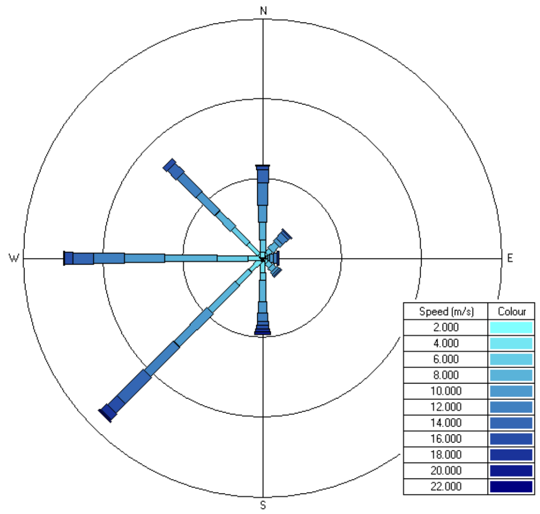
April



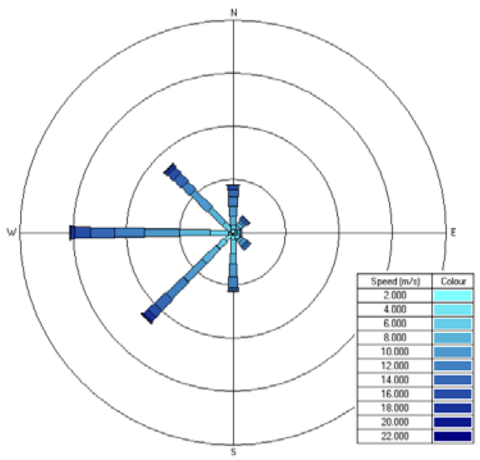
May



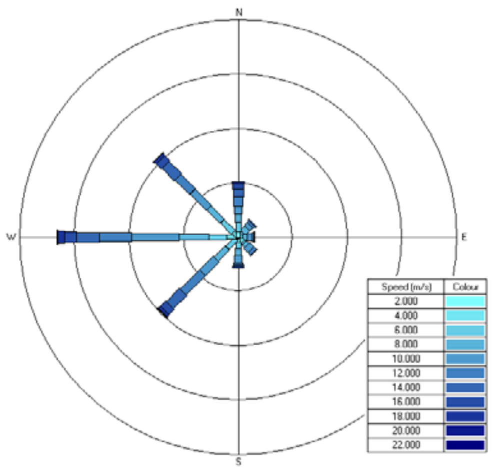
June



July



August



Waves

Winds can generate rough sea conditions with waves of variable direction and height. The wind and wave criteria in this report were derived using data extracted from the Fugro Oceanor WorldWaves product from a grid point at 52.5ºS, 57ºW (*FUGRO, 2005*). These in turn derive from operational runs of the WAM model performed by the European Centre for Medium-range Weather Forecasting (ECMWF), calibrated against satellite data and in-situ observations by Fugro Oceanor.

Average wave heights vary between 2-3 metres and one year return wave heights can reach 11 metres (Figures 5.12 and 5.13). Seasonality in wave height showed a more energetic wave environment between June and September, corresponding to the southern Hemisphere winter. The direction of wave approach was predominantly west to southwest (*FUGRO, 2005*).

Figure 5.12. Wave Height and Exceedance, offshore Falkland Islands (FUGRO, 2005)

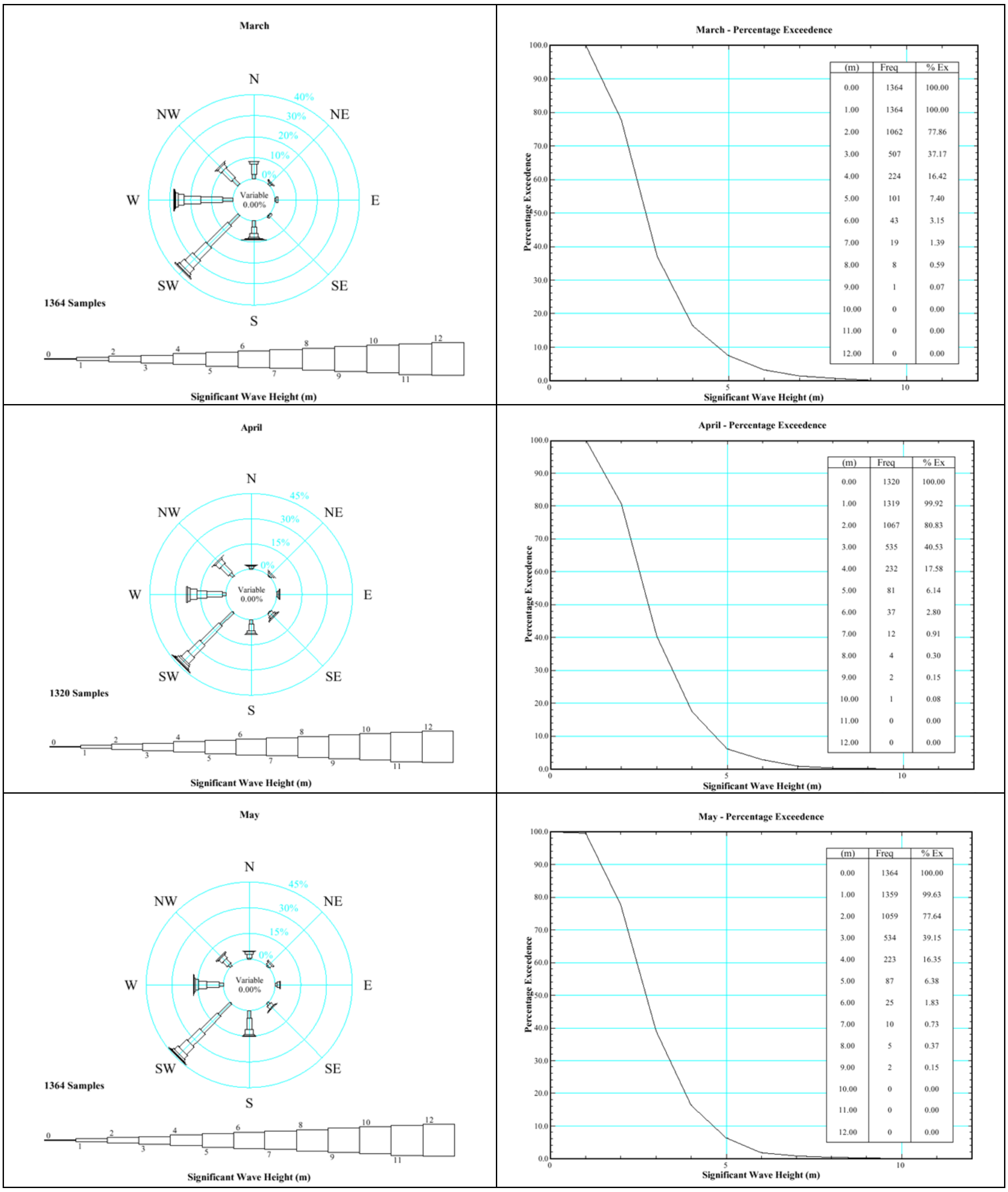
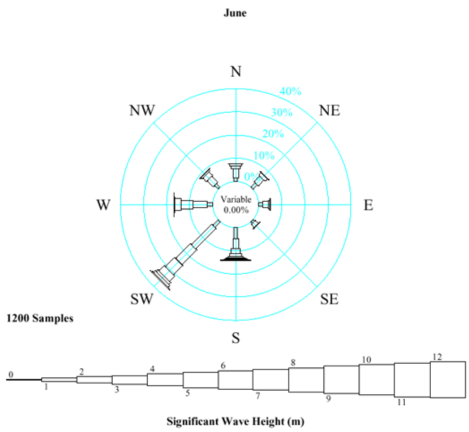
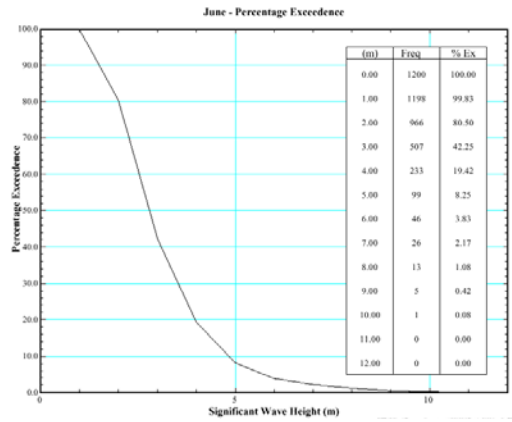
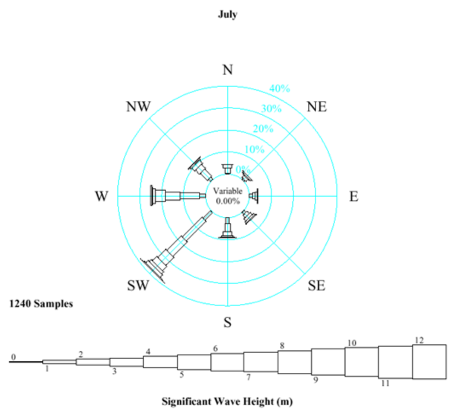


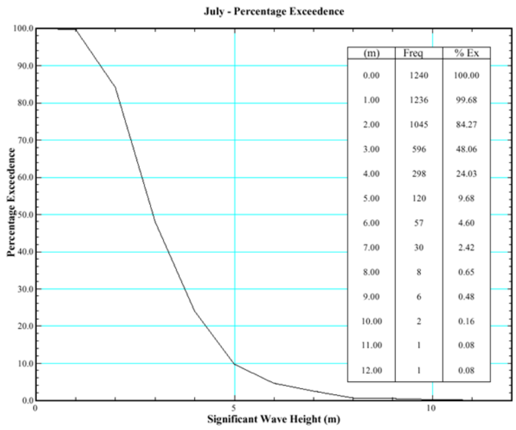
Figure 5.12 Continued



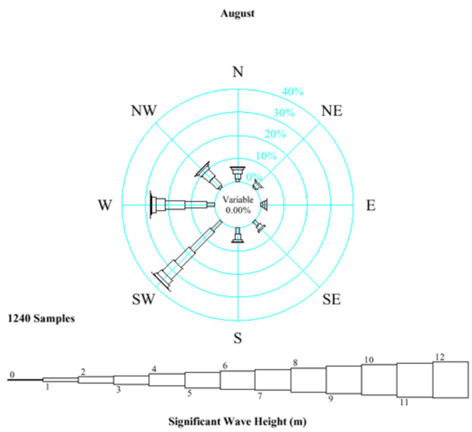


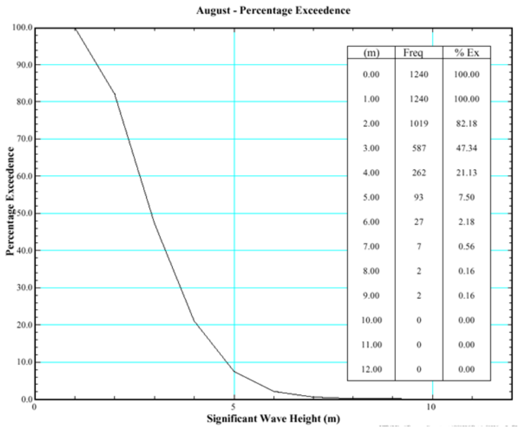
(m)	Freq	% Ex
0.00	1200	100.00
1.00	1198	99.83
2.00	966	80.50
3.00	507	42.25
4.00	233	19.42
5.00	99	8.25
6.00	46	3.83
7.00	26	2.17
8.00	13	1.08
9.00	5	0.42
10.00	1	0.08
11.00	0	0.00
12.00	0	0.00





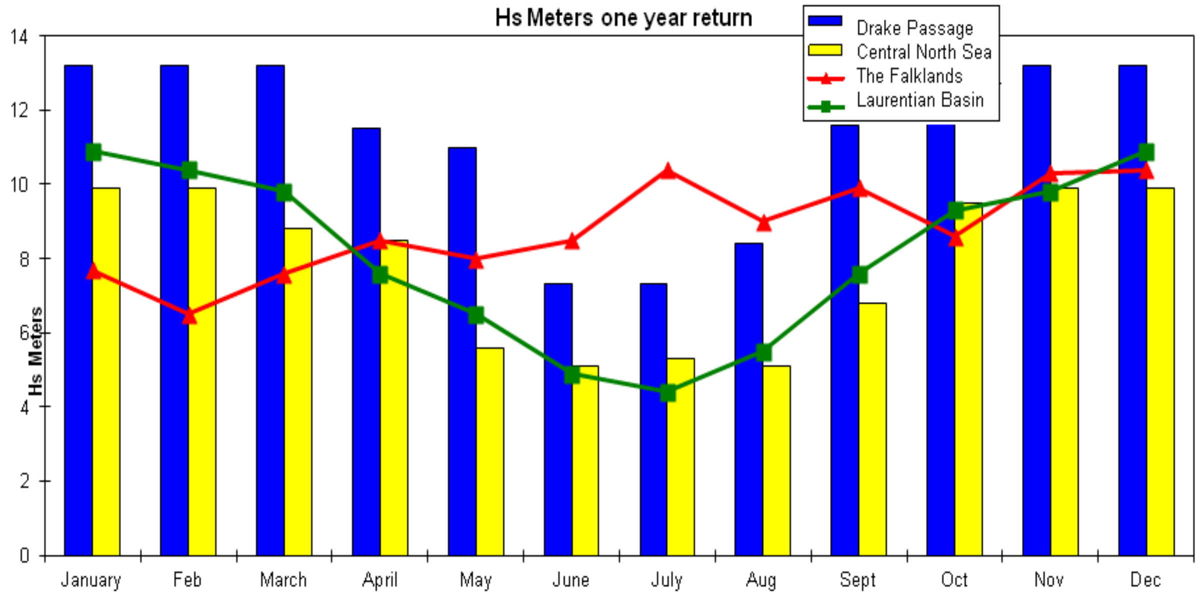
(m)	Freq	% Ex
0.00	1240	100.00
1.00	1236	99.68
2.00	1045	84.27
3.00	596	48.06
4.00	298	24.03
5.00	120	9.68
6.00	57	4.60
7.00	30	2.42
8.00	8	0.65
9.00	6	0.48
10.00	2	0.16
11.00	1	0.08
12.00	1	0.08





(m)	Freq	% Ex
0.00	1240	100.00
1.00	1240	100.00
2.00	1019	82.18
3.00	587	47.34
4.00	262	21.13
5.00	93	7.50
6.00	27	2.18
7.00	7	0.56
8.00	2	0.16
9.00	2	0.16
10.00	0	0.00
11.00	0	0.00
12.00	0	0.00

Figure 5.13. One Year Return Significant Wave Height (Ht) offshore Falklands in Comparison with other Harsh Environment Locations (Fugro, 2005)



FUGRO, 2005, Report for FOGL: Falkland Wind and Wave Operational Criteria, GEOS Reference No: C50336/3534/R0

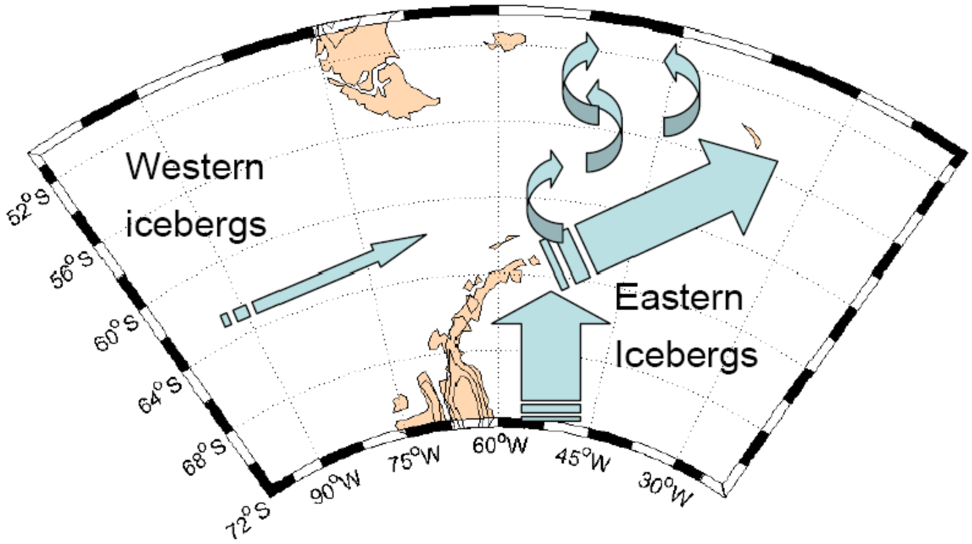
5.2.8 Icebergs

The oceanography of the region between the South American and the Antarctic Peninsula (the Drake Passage) plays a fundamental role in the movement of icebergs into the Falklands region. The polar front, within the Antarctic Circumpolar Current (ACC), separates the cold polar waters from the warmer northern waters, coinciding with the path of the maximum westerly winds. In the Drake Passage, the convergence of fronts within the ACC creates strong eddies. The size and duration of these eddies is extremely variable, subjecting the area to the east of the Drake Passage, and south of the Falkland Islands, to a significant variation in currents, thus influencing the number of icebergs approaching the Falkland Islands (*Partington, 2006*).

Icebergs occurring in the vicinity of the Falkland Islands are likely to be derived from floating ice shelves and streams where icebergs of significant sizes may be calved. Approximately 50% of the coast of Antarctica is fringed by ice shelves. These shelves are thought to discharge approximately 2000 Gt of icebergs into the Southern Ocean of varying thickness each year.

A desktop assessment of icebergs in the Falklands (*Partington, 2006*) indicates that icebergs floating through the licence areas come from two sources – primary and secondary (Figure 5.14).

Figure 5.14. Sources and Movements of Icebergs in the Falklands Region



The primary source is known as the 'eastern' icebergs, which are transported along the western edge of the Weddell Sea and originate from east of the Antarctic Peninsula. All but one of the 70 large icebergs (>18.5 kilometres diameter) recorded floating north of 60°N and west of 40°W between 1992 and 2005 are classified as 'eastern' icebergs following an anti-clockwise route around the Antarctic. The majority of the icebergs (large and medium sized) following this route pass far to east of the Falkland Islands, outside of the licence areas. In late 2005, however, a stronger current from the south resulted in a greater quantity of icebergs entering the Falklands region.

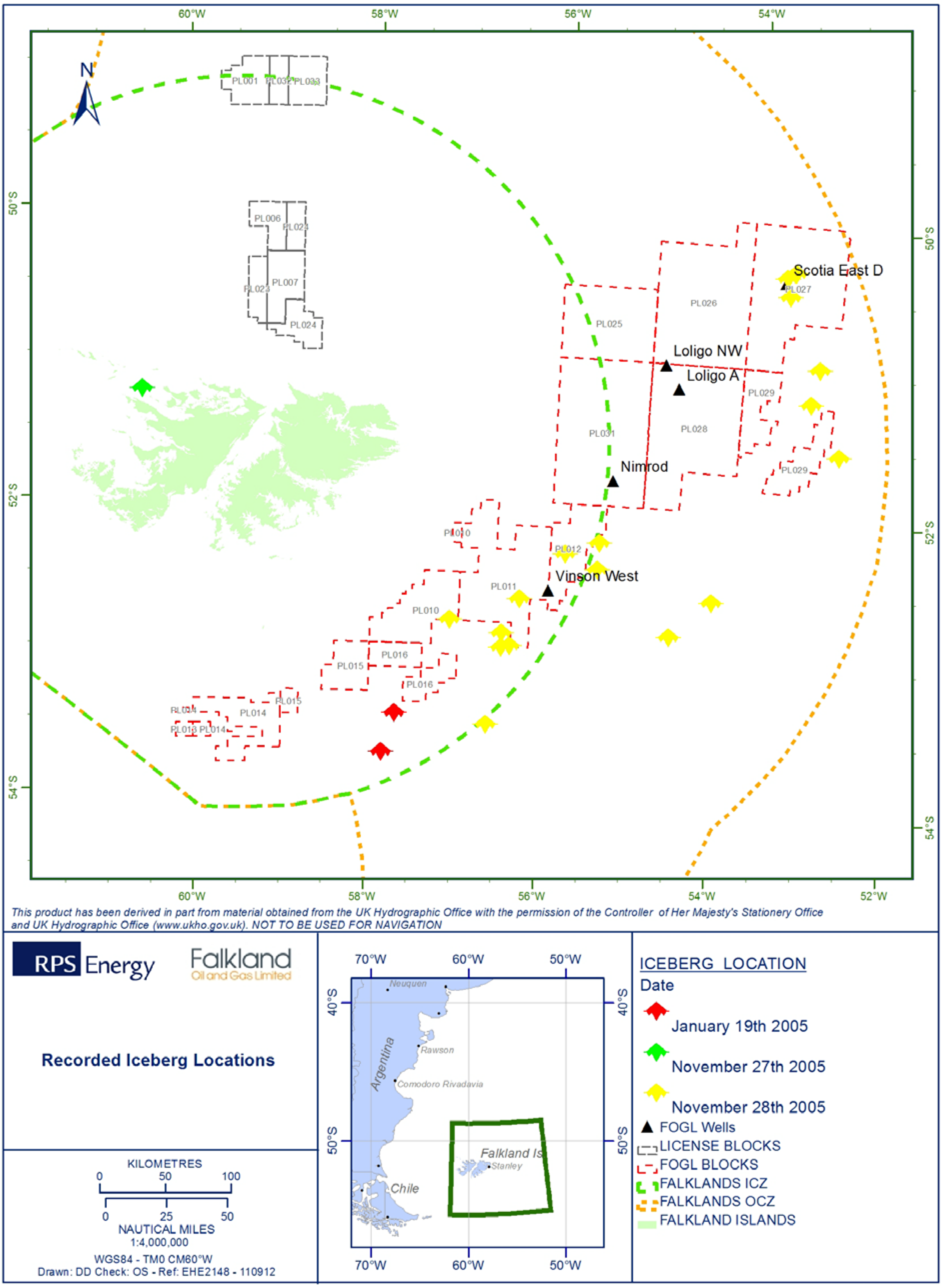
The secondary source is the 'western' icebergs that are advected northeast, away from the Antarctic coast predominantly in the Ross Sea and Bellingshausen Sea. The icebergs, drawn into the Antarctic Circumpolar Current, are transported through the Drake Passage to approach the Falklands from the southwest. In comparison to the primary icebergs, the secondary source icebergs are rare, with only one instance recorded in the large iceberg database out of 70 occurrences. The Antarctic Circumpolar Current has rough weather conditions which are expected to lead to rapid disintegration of icebergs and modelling work by *Gladstone et al*. (*2001*) suggests that most icebergs disintegrate before reaching the Drake Passage.

The highest probability of iceberg occurrence is in the eastern portion of the licence area as it is closer to the main export route for icebergs from the Antarctic. It is possible for icebergs to approach and enter the lease areas from the south, but the risk reduces to the west. In the extreme west of the area, west of 59°W, the probability of icebergs is considered low. However, due to the strong eddy activity in the Drake Passage, the presence of icebergs in any of the licence areas cannot be ruled out.

Small icebergs (0.1 – 100 kilometres in diameter) are the most likely to occur in and around the license blocks. In November 2005, 23 icebergs were detected to the northeast and east of the Falklands. One was recorded in the vicinity of the Scotia East well and 2 more were observed to the northwest of this (Figure 5.15). Little evidence exists for any seasonal behaviour in iceberg drifts or populations. There are fewer recordings of large iceberg calving during winter (summer melt plays a role in calving), but as icebergs can take months or even years to reach the Falklands region, any pattern in seasonal calving of icebergs no longer remains by the time they arrive in FOGL licence block areas.

There is no evidence that the 2002 peak in icebergs exiting the Weddell Sea was followed by an iceberg outbreak in the Falkland Islands area. It may be that the oceanographic conditions were not appropriate at the time to transport a significant number of these icebergs north into the Falklands region, suggesting an oceanographic rather than source population control exists on the icebergs found in the lease areas.

Figure 5.15. Icebergs detected by air and surface observations during October and November 2005. (Source: FOGL communications)



5.3 Biological Environment

5.3.1 Overview

The Patagonian Shelf, on which the Falkland Islands are located, is of regional and global significance for marine resources (*Croxall and Wood, 2002*). Current patterns and bathymetry (particularly continental shelf, undersea ridges and islands) influence nutrient circulation and marine productivity levels. The continental shelf of the Falkland Islands extends some 200 kilometres beyond the Falklands coast to the north, about 50 kilometres to the southwest, and about 50-100 kilometres offshore on the eastern side. Nutrient rich waters upwell on the edge of the continental shelf, but most particularly to northwest of the Jason Island group, Beauchêne Island and the Burdwood Bank (Otley *et al*., 2008). These areas are and rich in plankton and fish assemblages, and are important foraging grounds for seabirds and marine mammals (White *et al*. 2002).

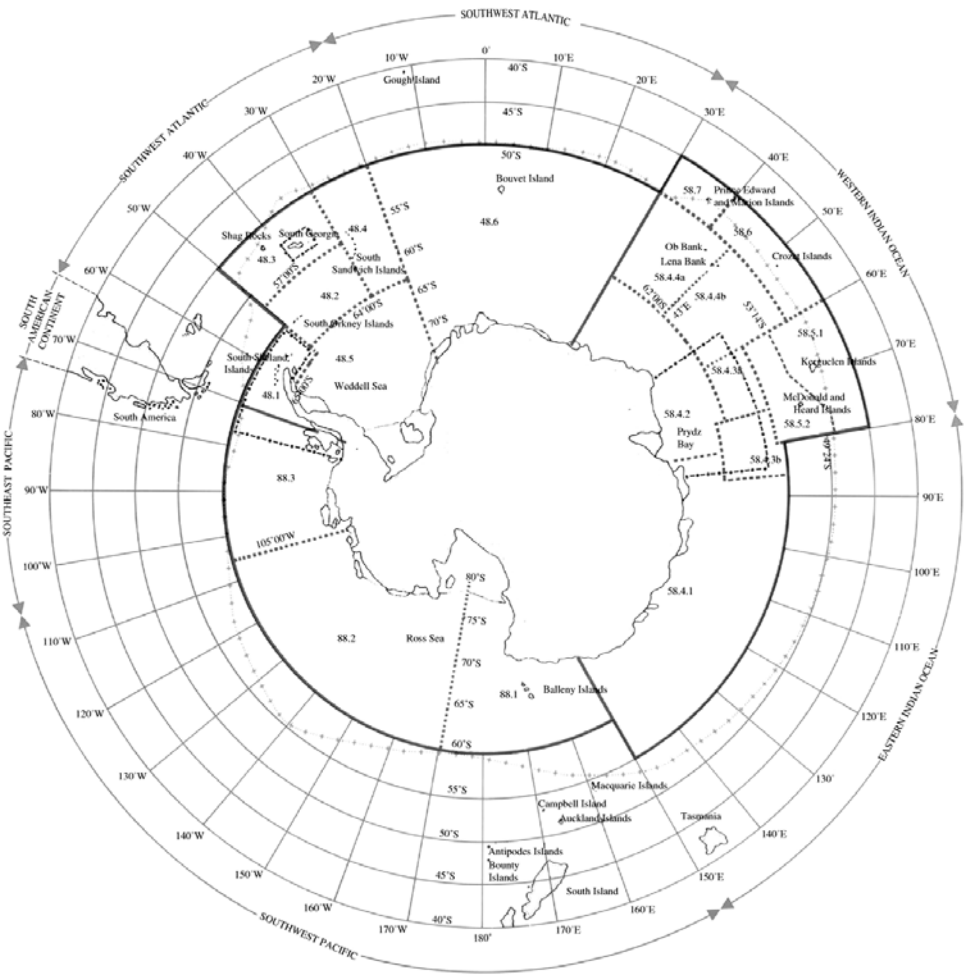
The following sub-sections outline the existing biological resources known to occur around the Falkland Islands and within the vicinity of FOGL licence blocks. The proposed well locations lie mostly outside the upwelling zone, yet are closely associated with it.

5.3.2 Patagonian Shelf Large Marine Ecosystem

Tierra del Fuego and the Falkland Islands lie within the Patagonian Shelf Large Marine Ecosystem (LME), described by Heileman (2009) as a Class I, highly productive (>300 $gC.m^{2\text{-}yr}$) ecosystem based on SeaWiFS global primary production estimates. This ecosystem is influenced by two major wind-driven currents: the northward flowing Falklands/Malvinas Current and the southward flowing Brazil Current. The two currents provide the LME with a distinctive ecological boundary to the east. While the southward flowing Brazil Current is warm and saline, the northward flowing Falklands/Malvinas Current carries cool, less saline, nutrient-rich sub-Antarctic water towards the equator. The two currents mix at a Confluence Zone (CZ). The CZ is a wide area characterized by intense horizontal and vertical mixing. It is situated on average at the approximate latitude of 39 degrees south, but is displaced to the north in the winter. The exchange of water masses of different temperatures and salinity affects biological productivity of the region. The LME is rich in a variety of biological resources.

The Patagonian Shelf LME is located north of the Antarctic Convergence zone. The cold Antarctic water mass that circulates clockwise around the Antarctic continental landmass forms the ACC. Although the ACC is relatively unconstrained by land masses, compared to the Arctic region, the current is strongly constrained by landforms and bathymetric features. The Burdwood Bank forms a significant bathymetric barrier rising from the floor of the Scotia Sea at a depth of 2,200 metres to just 200 metres below sea level. The barrier prevents northward migration of the Antarctic Convergence. The ACC passes west to east along the southern boundary of the Burdwood bank and eventually breaks north between the eastern end of the bank and the western side of Shag Rocks in the region of Aurora Bank. The Antarctic Convergence not only separates two hydrological regions, but also separates areas of distinctive marine life associations. The position of the Antarctic Convergence has been used to define the area of the Convention for the Conservation of Antarctic Marine Living Resources (Figure 5.16).

Figure 5.16. The area of the Convention of the Conservation of Antarctic Marine Living Resources (Figure from Kock et al., 2007)



5.3.3 Marine and Intertidal Vegetation

Seaweed is an important biological resource in the Falkland Islands. By providing food and habitat for a wide range of marine invertebrates and fish, seaweed plays an integral part of the health and biodiversity of the natural ecosystem. It is also an important resource in this area for extraction and use in commercial products, such as fertiliser. However, commercial exploitation is not well developed.

Giant and Tree kelp are the most common macroalgae species in offshore zones of the Falkland Islands.

Giant Kelp

Giant kelp (*Macrocystis pyrifera*) is a species of marine brown algae and is one of the largest known 'seaweeds'. It is able to grow to lengths of 60 metres with its upper fronds forming a dense canopy at the surface. *M. pyrifera* provides food and habitat for a wide range of marine invertebrates and fish.

Giant kelp species prefer depths of less than 40 metres, temperatures less than 20°C and hard substrate, such as rocky bottoms, for attachment. The nutrient rich waters of the Falklands are particularly conducive for kelp development. Studies suggest that kelp fronds may grow at rates of up to 300 – 600 millimetres per day. Fronds of mature kelp plants start to deteriorate about six months after they are produced. Mature fronds continually develop, then die and break away in a process known as sloughing, giving way to new fronds.

Giant kelp has a bipolar distribution, occurring both in the southern and northern hemispheres. Giant kelp is ubiquitous around the shores of the Falklands and is the most widespread and common marine algae found around the Falkland Islands (*Munro, 2004*). Although it is typically found in inter-tidal areas to a depth of between 3 to 6 metres it may also be found up to 1 kilometre from the shore. It has been suggested that the Falkland Islands *Macrocystis pyrifera* population is more stable than most other giant kelp beds at higher latitudes, due to the absence of winter storms.

Tree Kelp

Tree kelp (*Lessonia sp.*) is found in most open coastal areas. Three species of *Lessonia* have been distinguished: *L. flavicans, L. frutescens* and *L. nigrescens. L. flavicans* is the most common, although the distribution and status of individual species is reported to be unclear (*Strange, 1992*).

Few studies have been undertaken on these species in the Falkland Islands. *Lessonia* plants are likely to be found entwined with the giant kelp canopy in depths of 3 to 20 metres, either in sub-tidal inshore or deep water offshore areas (*Searles, 1978*), where they form a fringing zone between the low water mark and the beginning of the offshore zone occupied by Giant kelp. The Tree kelp provides a valuable habitat for shorebirds, seabirds, coastal dolphin species, and other marine creatures as feeding grounds and spawning/nursery areas (*Munro, 2004*).

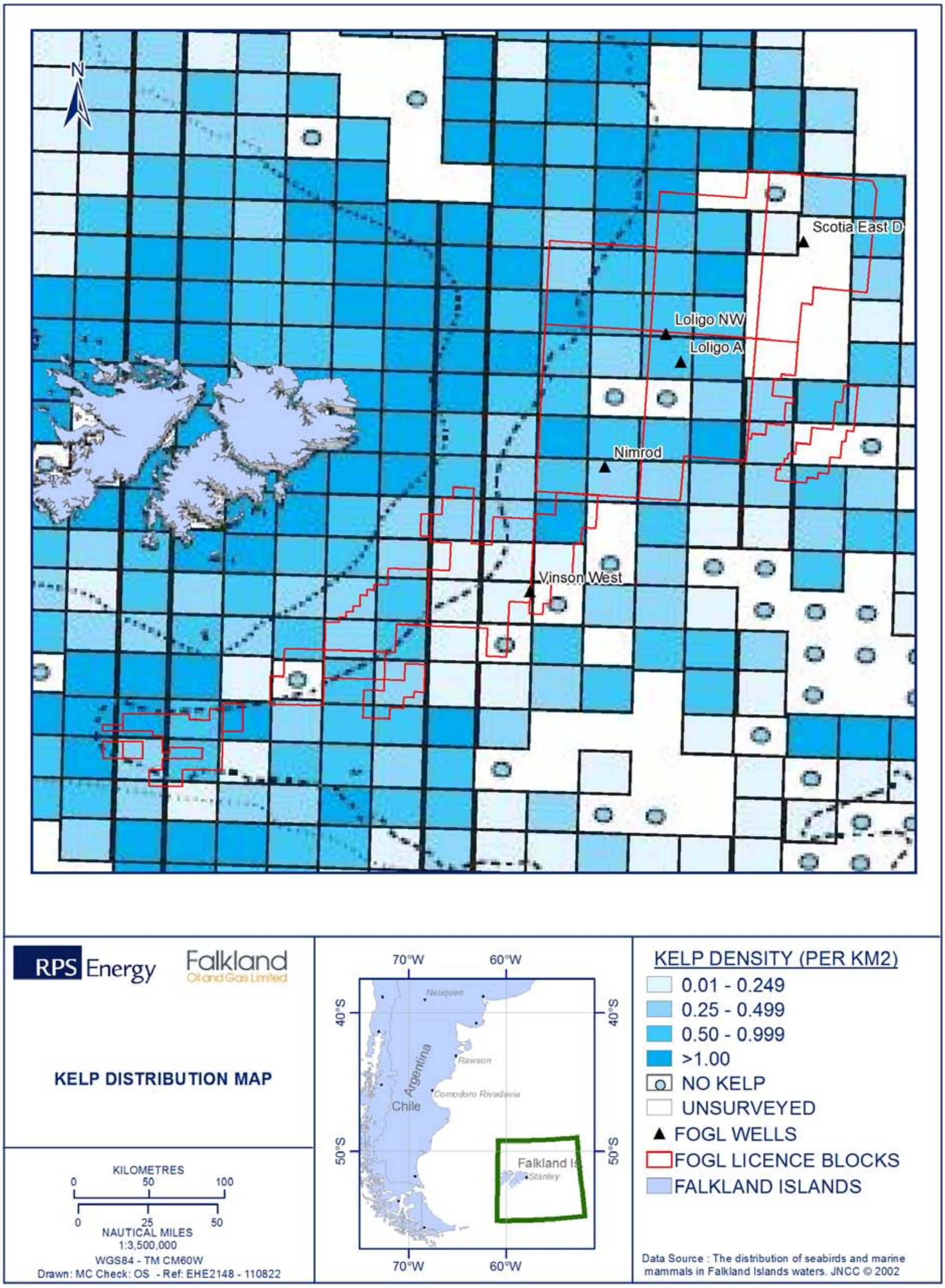
Kelp Distribution

Given the water depths at the FOGL sites, kelp species are only likely to be found as free-floating patches in the area. Distribution of free-floating kelp patches in Falkland Islands waters was reported from the 'Seabirds at Sea' surveys carried out between February 1998 and January 2001 (*White et al., 2002*) (Figure 5.17). Kelp density specific to the FOGL well sites is shown in the accompanying table (Table 5.3). These areas are important for 22 seabird species recorded as associating with free-floating patches of kelp (*White et al. 2002*).

Table 5.3. Approximated Kelp Density at the proposed well locations (Source: White et al. 200)).

Well Location	Kelp Density Range (fraction surface coverage per km^2)
Scotia East	0.01 – 0.249
Loligo NW	0.5 – 0.999
Loligo E	0.5 – 0.999
Nimrod	0.25 – 0.499
Vinson West	0.01 – 0.249

Figure 5.17. Free floating kelp distribution offshore Falkland Islands (Source: White et al., 2002)



5.3.4 Plankton

Plankton consists of marine and freshwater organisms with limited swimming capabilities that drift with the prevailing currents. It represents an integral part of the marine ecosystem and provides a crucial source of food to higher trophic levels (i.e. fish, cetaceans). Plankton is divided into two broad groups: Phytoplankton (autotrophic) and Zooplankton (heterotrophic).

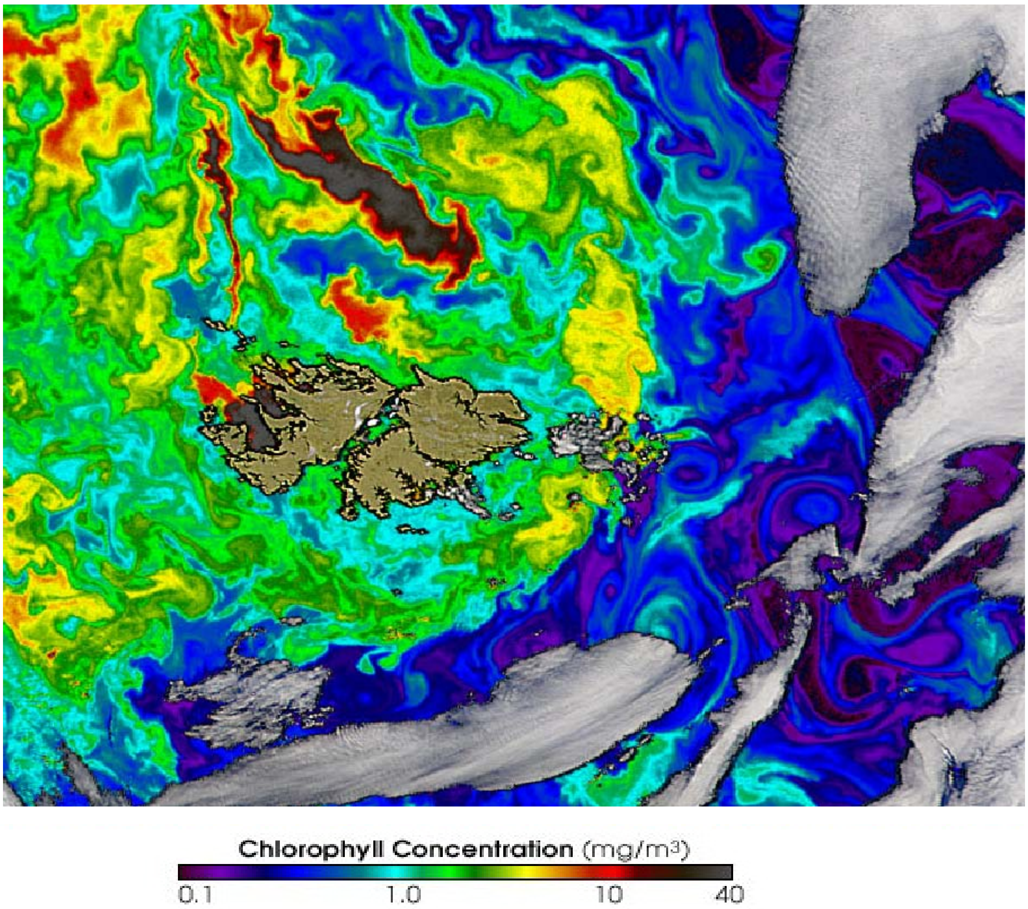
Phytoplankton

Phytoplankton is reliant on the availability of sunlight and nutrients for their photosynthetic processes. Phytoplankton exists in the photic zone of the ocean and increases in concentration during warmer seasons, particularly in polar and sub-polar regions. There may be as many as 5,000 species of marine phytoplankton with diatoms, cyanobacteria and dinoflagellates amongst the most prominent groups.

The results of the Discovery expedition, focusing on diatoms, are found in the Discovery Report Vol. XVI (*Ingram Hendley, 1937*). At the nearest sampling station to the Falkland Islands, approximately 2 to 4 kilometres offshore, 10 species of diatom were recorded. South of 44°S there were relatively few species and a marked increase in diatoms, in comparison to the dominance of dinoflagellates and ciliates further north. This is supported by more recent trends suggesting that diatoms comprise a significant component of the phytoplankton population in higher latitudes, compared to tropical waters (*Barnes and Hughes, 1988*).

NASA photographed a large phytoplankton bloom in December 2002 surrounding the Falkland Islands (Figure 5.18), including areas to the south and east of the islands. The image shows large chlorophyll concentrations, illustrating a phytoplankton rich region – partly due to the convergence of the Malvinas and Brazil ocean currents. The perennial W to SW may generate waves which bring the nutrient rich waters to the surface. The location of FOGL's licence area is predominantly outside this area.

Figure 5.88. Phytoplankton Bloom near the Falkland Islands (NASA SeaWiFS, 2002)



Zooplankton

Zooplankton is a heterotrophic species of plankton represented by small floating or weakly swimming animals that drift with the water current. Alongside phytoplankton, zooplankton makes up the planktonic food supply on which almost all oceanic organisms ultimately depend. It also plays a vital role in marine ecosystems via nutrient recycling and grazing. Zooplankton includes various species, ranging from single-celled radiolarians to the eggs or larvae of herrings, crabs, and lobsters. Permanent zooplankton (holoplankton), such as protozoans and copepods, spend their lives as plankton. Temporary zooplankton (meroplankton), such as young starfish, clams, worms and other bottom dwelling animals live and feed as plankton until they become adults.

The complex current patterns around the Falklands, with the rising bathymetry and the extensive shelf area, create stable areas to the north, where high salinity and nutrient-rich waters enhance plankton activity and so support high levels of zooplankton (*Agnew, 2002*). As with phytoplankton, zooplankton numbers appear to rise sharply during austral spring and summer months. Ciechomski and Sanchez (*1983*) noted that total zooplankton around the Falkland Islands does not peak until January / February when it is dense to the north of the Falklands, along the shelf break.

Important zooplankton species offshore Falkland Islands include the swarming epipelagic 'krill' species such as *Munida gregaria* (Lobster krill), *Euphausia lucens*, *E. vallentini* and *Thysanoessa gregaria*. *T. gregaria* is most abundant in the southern part of the continental shelf; *E. lucens* is more common on the northern shelf area, whilst *E. vallentini* is most common in the cold Falklands Current (*Agnew, 2002*). Amphipods, particularly of genus *Themisto*, such as *T. gaudichaudi*, also occur in Falkland Islands waters. Certain krill species are a key component in the food chain, consumed by squid, fish, seals, baleen whales and seabirds (particularly the black-browed albatross and penguins) in the Falklands (*Agnew, 2002*).

5.3.5 Benthos

To characterise benthic communities within the project and wider area, primary data sources, including observer and survey benthos data (*FIFD database, 2000-2011*) as well site specific surveys conducted for the proposed well locations, were analysed.

5.3.5.1 Regional Benthic Data

The access to the benthic data collected between 2000-2011 by fishing and survey vessels, was obtained from the Falkland Islands Fisheries Department (FIFD). The total observer effort by gear type is shown in Figure 5.19.

During fishing operations, observers record all catches made on the vessels, including bycatch which the vessel may otherwise not record, including benthic species. Although many different species were identified, some were only recovered in small quantities. Hence, for analysis purposes, these species have been grouped into a number of different taxonomic categories, where possible to order level, but otherwise to family or phylum. The categories used were based on those in the CCAMLR Vulnerable Marine Ecosystem classification guide, developed for observers operating on long-line vessels in the CCAMLR area to identify potentially benthic organisms that may indicate a vulnerable area. The classifications used are given below (where classified below phylum level, the phylum is specified):

- *Anemone (order)* – Phylum Cnidaria, rubbery bottom with single polyp.
- Annelid (phylum) – Segmented worms, includes *Priapulidae* and *Chaetopterus variopedatus.*
- *Anthozoa (class)* – Phylum Cnidaria. Covers corals and Anemones; *Pennatulacea*, types of stone coral, *Alcyoniina*, *Paragorgia sp.* and *Octocorallia* were grouped under this category.
- *Ascidiacea (class)* – Phylum Chordata, sea squirts.
- Bryozoan (pylum) – Lace corals.
- Echinoderm (phylum) – A large group that includes starfish, sea urchins, basket stars and crinoides.
- *Gorgonacea (order)* – Phylum Cnidaria.
- *Hydrozoa (class)* - Phylum Cnidaria. Related to jellyfish and corals.
- Mixed – Observer has recorded mixed invertebrates

- Porifera (phylum) – Sponges.

Figure 5.20 shows a relative abundance of benthic species identified by observers operating on different types of fishing vessels. The effort in this case is the amount of sampling stations within each grid square so the data presented is the average weight of benthos observed (kg) per sampling station. It can be seen that benthos was mostly recovered by trawl vessels operating at depths less than 1000 metres rather than deep water long-lines. Within the FOGL licence blocks, anthozoa species were recorded in deeper waters towards Loligo and Scotia prospects, whereas by-catch of sponges (porifera), echinoderms, and hydrozoa were more characteristic for shallower areas (<1000 metres) and shelf waters in general. These observed distributions undoubtedly reflect the selectivity of the fishing gear which will produce biased results. Hence it is important to interpret the data correctly, for what is seen on the vessel, does not necessary reflect what is on the seabed. This is particularly true of long-lining, the combination of using hooks and operating in deeper water will mean that less benthos species get caught, and that which does will probably fall off before it reaches the surface. The data however gives a relative indication of the distribution of certain types of benthos species and can highlight areas for further investigation.

In addition to the above, benthos data was collected by two scientific survey vessels between 2000 and 2011. Effort in this case has been measured in hours trawled (this would not be possible with observer data given the different gear types. Benthic data is aggregated and classified in same way and presented as kilograms caught per 10 hours trawled (Figure 5.21). Similarly, the results of the scientific surveys reflect the selectivity of bottom trawl gear, which is expected to retain broader, more diverse samples than long-lines. A greater number of species groups were recovered in the southern area, with the overall predominance of hydrozoa, echinoderm within the eastern and southern area of the Falkland Islands and close towards the western boundary of the FOGL licence area.

Figure 5.99. Total observer effort by gear type (FIFD database; 2000-2011)

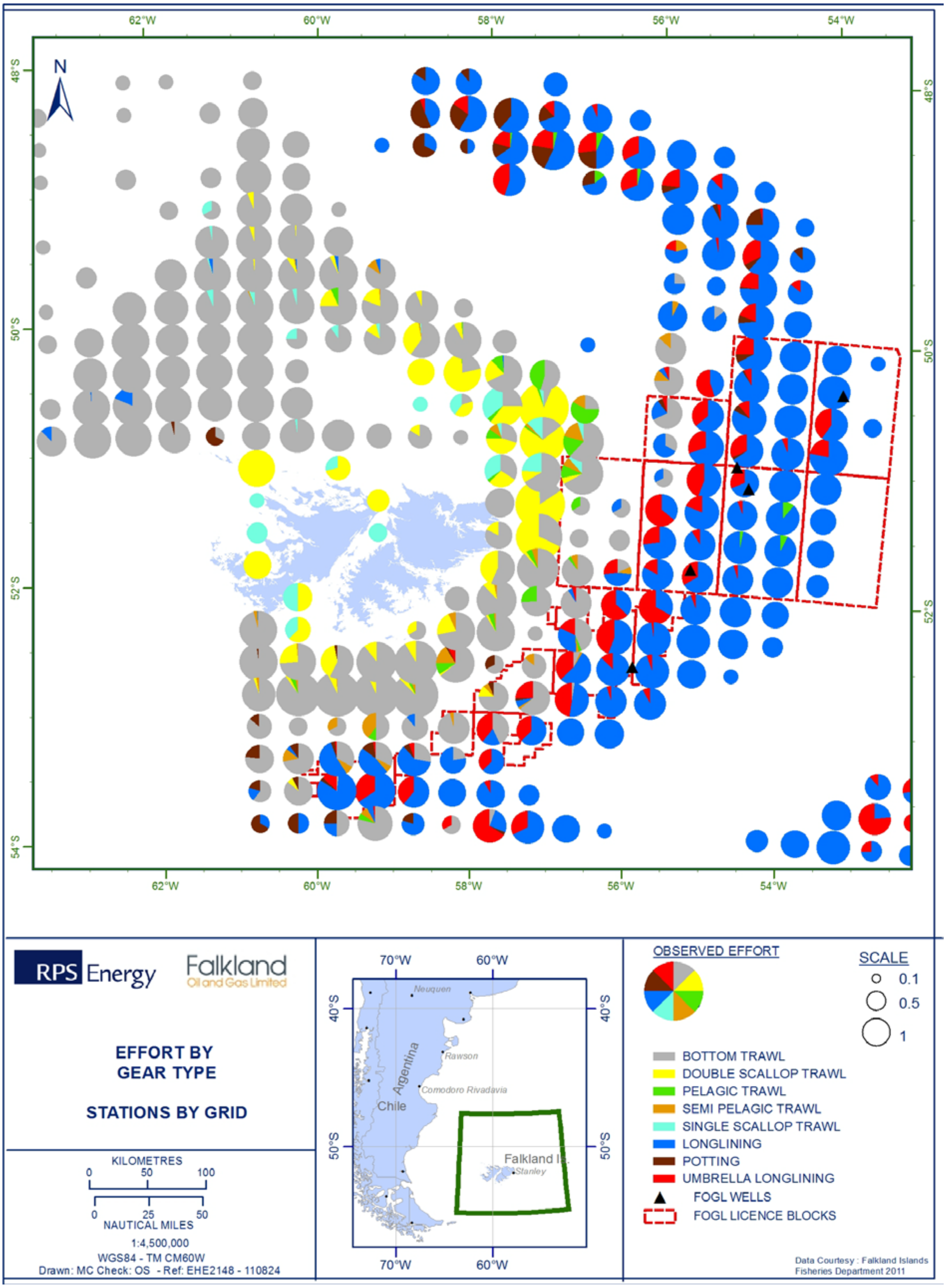


Figure 5.20. Benthos bycatch observed on fishing vessels (FIFD database; 2000-2011)

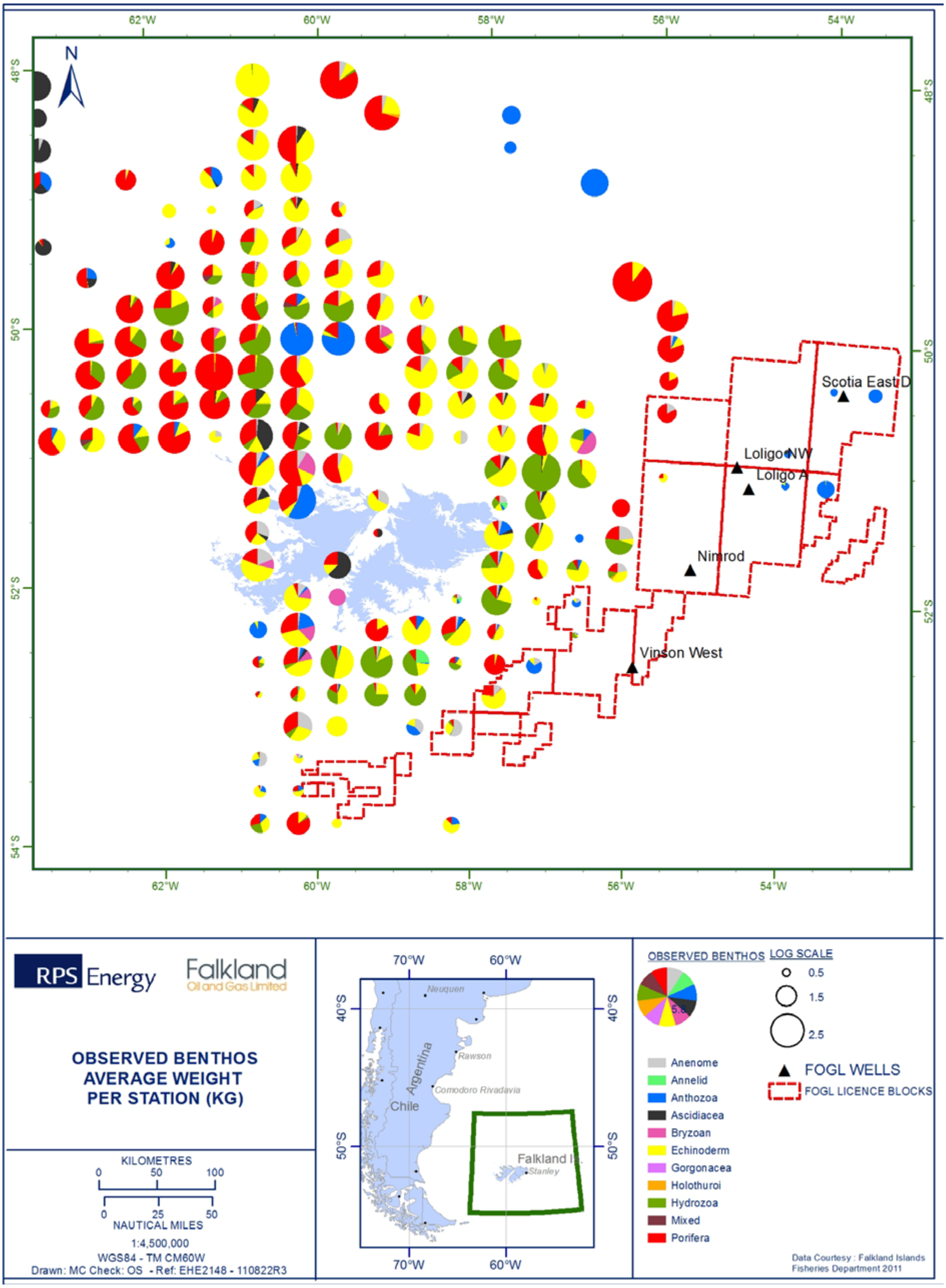
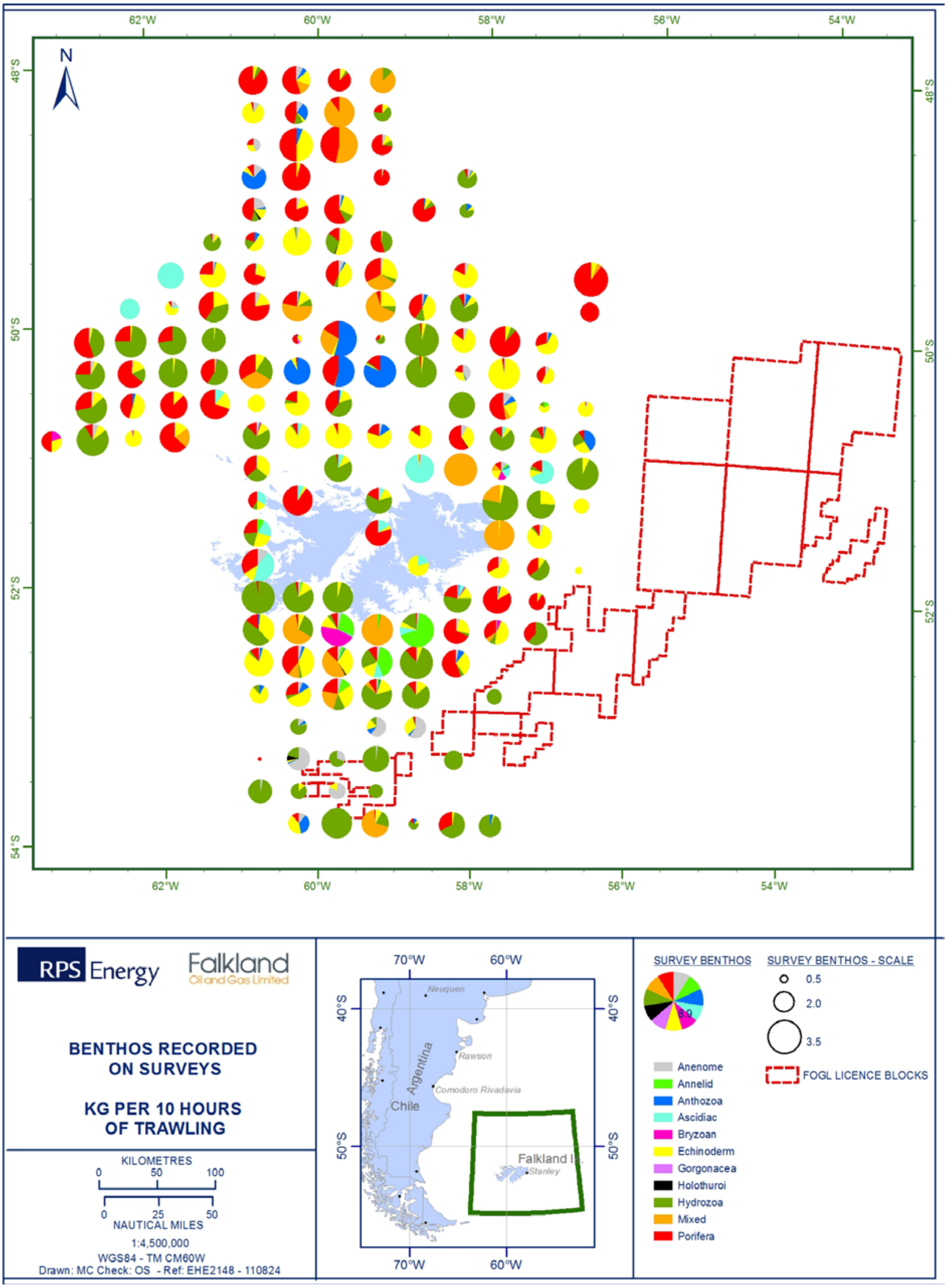


Figure 5.21. Benthos recorded on scientific bottom trawl survey vessels (FIFD database; 2000-2011)



5.3.5.2 Site Specific Benthic Data

Benthic site surveys were commissioned by FOGL and carried out by Fugro and Gardline at all five prospective well locations between 2008 and 2011. The surveys comprised sampling with a 0.1 m^2 box corer for benthic physico-chemical and macrofaunal analysis. ROV acquired seabed video data was also analysed to assist with characterisation of the benthic environment.

Benthic data collected within Loligo prospect (*FSLTD, 2009a*) is summarised below and detailed in Appendix C. Benthic data for the 2nd well will be provided in the Operational Addendum.

Epifauna/ Pelagic Fauna

ROV Video footage obtained at the Loligo site was analysed to assess the epifaunal communities at this location.

The most prominent colonial epifauna encountered across the site were Cnidarians, including at least two species of gorgonian (soft corals) and at least one species of scleractinian (hard or stony coral). The gorgonians included a characteristic “sea fan” form, which was found throughout the site on both isolated cobbles and boulders (Figure 5.22- Plates 3 and 4) and on outcrops of consolidated sediment (Figure 5.22- Plate 6). A less frequently encountered gorgonian form were “sea whips”, which tended to be restricted to consolidated sediment areas (with or without a veneer of sand) (Figure 5.22- Plates 4 and 5). While not as widely distributed as the gorgonians, scleractinians were occasionally seen in considerable density, forming low thickets over the consolidated sediments of the scarp seen to the south of Loligo (Figure 5.22- Plate 1) (*FSLTD, 2009a*).

Live tissue from stony corals was only found in one specimen in one sample. Branched hard corals are of conservation importance as they can form extensive biogenic reefs which produce complex habitats for a variety of species. However, as suspension feeders living in cold deep waters, they are much more susceptible to damage than soft corals. Order Madrepora (*Scleractina*) are azooxanthellate corals which do not possess the symbiotic relationship with photosynthetic algae residing in the ghost coral’s epidermic tissues that many shallow tropical water corals possess. Since they do not require sunlight to grow, these species are unrestricted with regards to depth. Existing in cold deep waters means that growth in these corals is extremely slow, meaning that the corals are unable to recover quickly from damage. During this study, only a small example of this species and other stony corals were recorded. It is possible to speculate that larger more extensive and developed reefs could exist elsewhere within the general survey area. However, there is no evidence for this hypothesis, in part due to the epifauna being limited to areas of hard standing. This seabed type was limited and patchy in the areas surveyed. It is equally possible that the development seen is representative of the wider area, or that it could be a relatively denser occurrence area, in a very sparse wider area. Existing information for *Lophelia pertusa* would suggest that its presence would not extend to the Falkland slope due to the low seabed temperatures recorded (2.9°C). (*FSLTD, 2009a*).

In addition to Cnidaria, the Phylum Porifera (sponges) was also well represented at a number of sites (Figure 5.22. Plates 3 and 5). Hexactinellidae were recorded only in fragmentary form, although the presence of numerous spicules in the sediments belonging to this class indicates that they are more common than indicated from the samples. This also applied to the Tetraxonida, where only one species was recorded, with one specimen of Tetilla. Also of interest was the lithistid sponge *Gastropharella* sp. These sponges, a polyphyletic group, have a virtually solid skeleton of “Desmas” with a compliment of other spicules, in this case Tylota.

A common sponge genus throughout the deeper waters of the Atlantic is *Asbestopluma* sp, which was well represented in the current study. These sponges are upright branching forms without the normal canal system and rely on a carnivorous mode of feeding. Their microscleres (anisochelae) catch small crustaceans which are then surrounded by tissue and digested.

Of the free-living taxa recorded, the most abundant were brittle stars (class Ophiuroidea), which sometimes formed dense aggregations on consolidated sediment outcrops (Figure 5.22. - Plate 1). Shrimps (presumably members of the Caridea) were occasionally seen in the ROV footage, as were small fish (*FSLTD, 2009a*).

Figure 5.22. Screen Grabs of ROV Footage, Showing Examples of Epifaunal Taxa at Loligo prospect (FSLTD, 2009a)

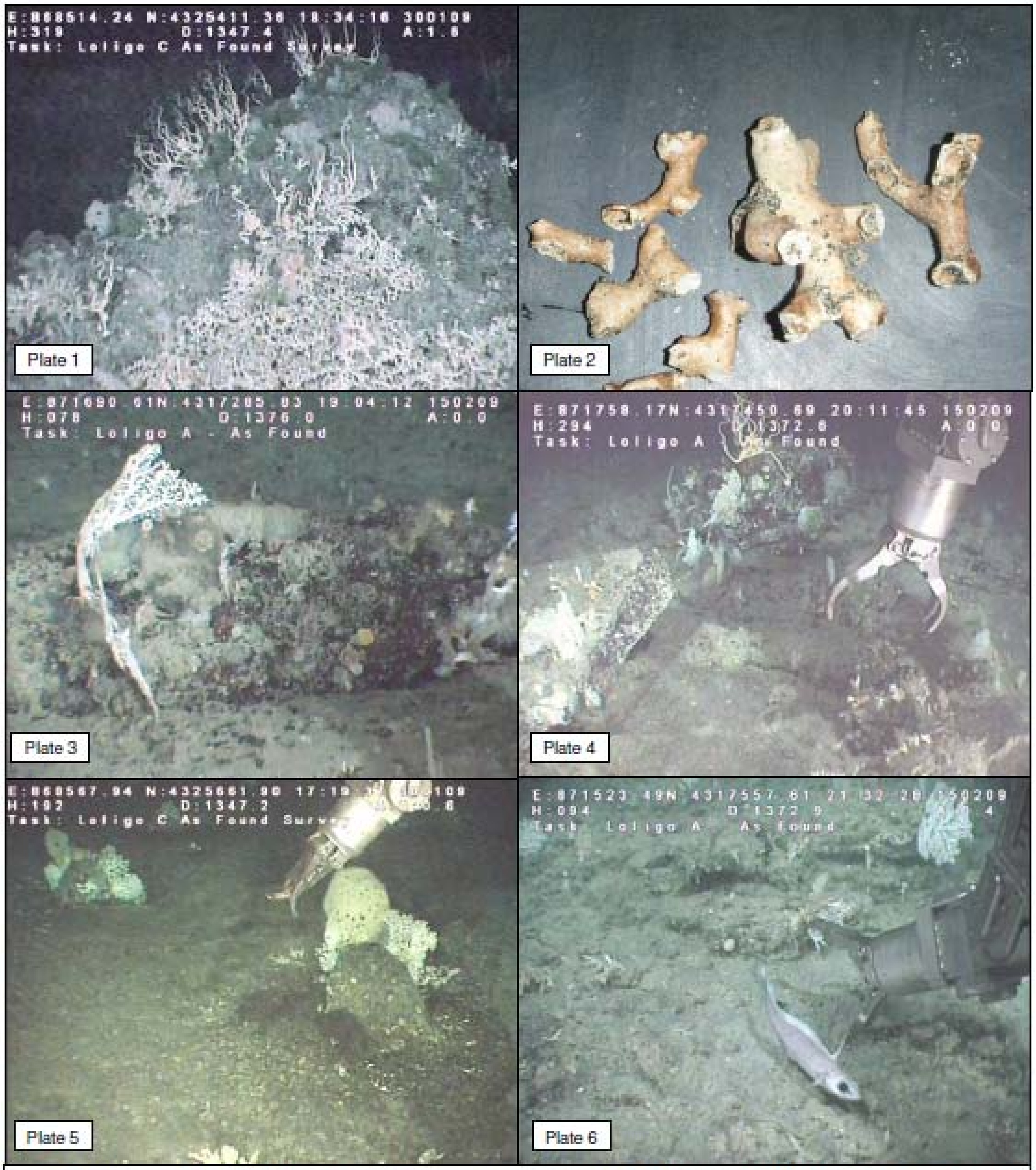


Plate 1: Dense coverage of a hard coral (possibly *Lophelia pertusa*) with filter-feeding brittle-stars (Ophiuroidea) on a consolidated sediment outcrop in the depression near Loligo C

Plate 2: Fragments of dead hard coral (possibly *L. pertusa*) taken in a box corer sample

Plate 3: A gorgonian and a faunal turf comprising Hydrozoa / Bryozoa and sponges (Porifera)

Plate 4: A sea fan (Gorgonacea), brittle-star (Ophiuroidea) and a faunal turf comprising Hydrozoa / Bryozoa and juvenile hard coral colonies seen near Loligo A

Plate 5: Sponges (Porifera) and hard corals on cobbles near Loligo C

Plate 6: A fish (possibly the threadfin rockling *Gaidropsarus ensis*), with sea fans (Gorgonacea) and hard corals on a consolidated sediment outcrop near Loligo A

Note: The fish shown in plate 6 is *Antimora rostrata*

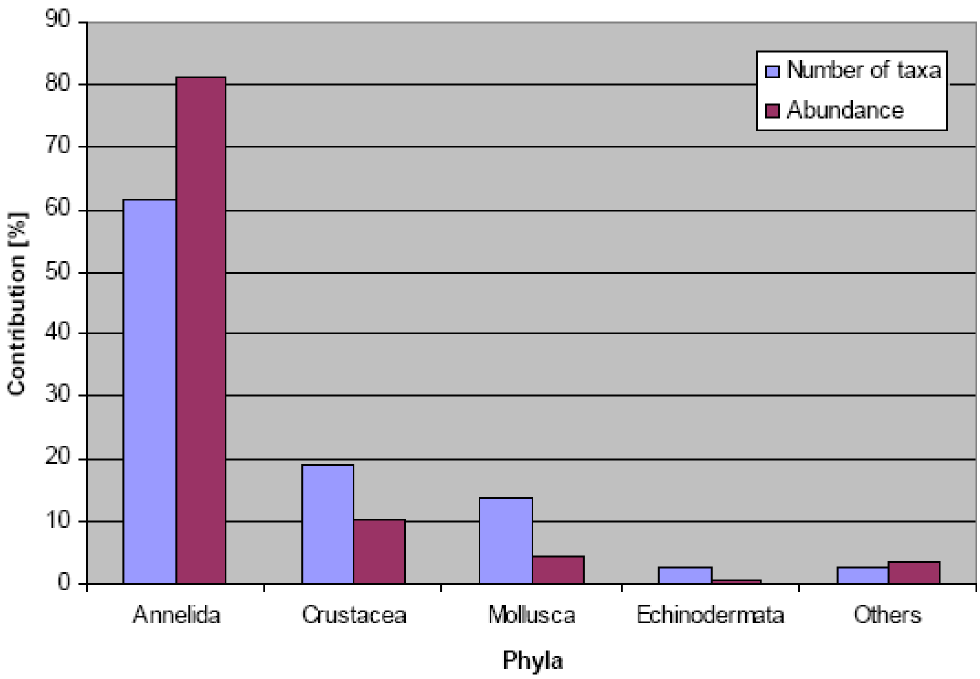
Infauna

Two 0.1 m^2 macrofaunal grab samples were analysed from four stations around the Loligo A site, giving a total of eight samples. Macrofaunal data was derived from the taxonomic analysis of all of these samples, with individuals of macrofaunal taxa being identified, enumerated and expressed as abundance per sample (0.1 m^2) and per station (0.2 m^2).

A total of 73 discrete macrofaunal taxa were found during the course of this survey, excluding the two juvenile and three indeterminate taxa, records for which were not included in the analysis.

Of the taxa recorded 61.6% were annelid, 20.5% were crustacean, 13.7% were molluscan and 2.7% were echinoderm (Figure 5.23). In terms of abundance the Annelida were overwhelmingly dominant, representing 81.1% of the 312 individuals recorded in total from the samples (*FSLTD, 2009a*).

Figure 5.23. Abundance of taxonomic groups for Loligo area (FSLTD, 2009a)



The dominant taxa recorded from the survey area are shown in Table 5.4. As would be expected given the predominance of the phylum overall, the majority of the dominant taxa belonged to the Annelida. All but two of the taxa shown (sipunculans and the tanaid crustacean *Apseudes? sp. 1*) were polychaetous annelids. The most abundant species overall was the onuphid polychaete *Kinbergonuphis oligobranchiata*, which was recorded at a mean abundance of 9.3 individuals per sample. The second most abundant species the ampharetid polychaete *Melinna sp. 1* was recorded at a mean abundance of 6.6 individuals per sample.

Crude abundance / dominance and univariate analyses of the infaunal data suggested that a single community occurred throughout the survey area. These findings were corroborated by the multivariate CLUSTER and SIMPROF analyses, which showed that all sample data could be grouped within a single statistically undifferentiated cluster (*FSLTD, 2009a*).

Table 5.4. Dominant Taxa by Abundance and Dominance Rank for Samples [0.1m^2] (FSLTD, 2009a)

Taxon	Rank	Mean	Frequency (%)	Rank
Kinbergonuphis oligobranchiata	1	9.3	100.0	1
Melinna sp. 1	2	6.6	75.0	2
Caulleriella? sp. 1	3	1.4	50.0	4
Sipuncula indet.	4	1.3	62.5	3
Chone / jasmineira sp. 1	4	1.3	75.0	5
Cirrophorus cf. forticirratus	6	0.9	37.5	6
Euchone sp. 1	6	0.9	62.5	9
Nothria anoculata	8	0.8	62.5	8
Spiochaetopterus typicus	8	0.8	62.5	29
Apseudes? Sp. 1	8	0.8	25.0	7
Aphelochaeta sp. 1	12	0.5	12.5	9
Aricidea (Allia) cf . hatmani	12	0.5	37.5	9
Notoproctus	12	0.5	25.0	9

Summary

Essentially, the conspicuous epifauna observed from the ROV footage acquired at the Loligo prospect were dominated by Cnidarians. Gorgonians (sea fans and sea whips) were widely distributed and a hard coral, at least superficially similar to the cold water species *Lophelia pertusa*, was present as patchily distributed low relief thickets on consolidated sediment outcrops and scarps. Insufficient data exist to classify the coral colonies as an Annex I habitat protected under the EU Habitats Directive (1972). There is no evidence for, or against, potential reef development elsewhere within the general survey area. This data correlates with the FIFD observer data (Figure 5.24) showing the presence of *Anthozoa,* which include corals.

Of the dominant macrofaunal taxa identified from grab sample data, the vast majority were polychaetous annelids.

The results of the dedicated site survey at the Loligo area were more informative and relevant for interpretation in the context of this EIS, compared to the observer data from the fishing vessels. This is particularly true for deep waters outside trawling zones.

5.3.6 Fish, Squid and Shellfish

5.3.6.1 Overview

Much of the information sourced for this section is based on the work undertaken by the Falkland Islands Fisheries Department (FIFD) and taken from their annual Fishery Statistics Bulletins. Additional information has been sourced from the 2008 State of the Environment Report (*Otley et al., 2008*). Although fisheries data does provide a sufficient overview of fish species in the region, it is important to note that actual fish abundance and distribution is likely to differ from the below description.

In addition to the harvest of commercial fisheries, fish stocks are a major component of many seabirds and marine mammal diets, and any impacts on fish stocks are likely to affect these species. At least 80 species of fish have been recorded in Falkland Islands waters ranging from small fish such as the rock cod to larger fish including tuna and sharks (*Strange, 1992*).

Coggan et al. (*2006*) sampled twenty deep-water stations to the east and south of the Falkland Islands by commercial bottom trawl deployed in upper, middle and lower benthopelagic zones (depth range of approximately 500-1000 metres). Forty-one species of teleost fish were recorded, 10 species of elasmobranch and one species of agnathan. Different assemblages of fish were found to characterize each depth zone (e.g. *Moridae* in deeper waters, *Bothidae* and *Rajidae* in shallower waters), with diversity being greatest in the mid-zone and biomass greatest in the upper and lower zones. Four species, namely the grenadiers *Macrourus carinutus* and *Coelorhynchus fasciatus*, the southern blue whiting *Micromesistius australis*, and the Patagonian toothfish *Dissostichus eleginoides*, accounted for 85 percent by weight of all fish caught. *Coggan et al.* (*2006*) suggests that further studies may be needed in the light of the developing oil and gas industry in the Falkland waters.

Commercial fishing is described from a socio-economic perspective in Section 5.5.3. The Falklands Interim Conservation and Management Zone (FICZ) was introduced in February 1987 to reduce uncontrolled fishing offshore the Falkland Islands. Continuing conservation problems led to the declaration of the Falkland Islands Outer Conservation Zone (FOCZ) in December 1990, 200 nautical miles from coastal baselines. The proposed drilling locations lie within these zones.

The main fisheries resources are the squid species *Illex argentinus* and *Loligo gahi*, although during 2009 *illex* stocks crashed with only a slight increase during 2010. The existing finfish fishery targets predominantly hake, hoki, red cod and blue whiting. Rock cod (*Patagonotothen ramsayi*) has provided the highest finfish catches on an annual basis since 2007: in the 2010 catch of 76,411 tonnes was the highest in the Falkland Island's history. A specialised small ray fishery exists, and a small long-line fishery operates targeting Patagonian toothfish. An experimental fishery also exists, targeting grenadier (*Macrourous spp.*) with a view to establishing a commercial fishery in the future.

Shellfish are not an important component of the commercial fishery although several species of crab are found around the Falkland Islands including the false king crab (*Paralomis granulosa*) and the larger southern king crab (*Lithodes santolla*). A small-scale scallop (*Zygochlamys patagonica*) fishery was developed in the FICZ, mainly to the northeast of Stanley, with approximately 920 tonnes (green weight) of scallops taken in 2003 and 2004 (*Munro, 2004*). However in recent years there has been no directed fishery for scallops, with only 3 tonnes being caught in 2010 as bycatch in the Loligo and finfish fleets (*FIG, 2011*). Some previous exploratory work, together with reports from other fisheries, has suggested that scallops might be more widely spread around the Falklands, although it remains to be seen whether there are significant concentrations elsewhere (*ICSF, 2010*).

5.3.6.2 Commercial Finfish

Some 11 species of finfish are caught in significant quantities in the Falkland Islands region. Fisheries catch statistics for the 2008 - 2010 period are displayed in Figures 5.24 - 5.26. It can be seen that the southern blue whiting is predominantly found to the southwest and northeast of the Falkland Islands. Hoki, rays, rock cod are caught widely around the Falklands in the FICZ. Within the FOCZ, limited amounts of these species are caught to the north of the Falklands only. Long-line fishing within the FOCZ primarily targets Patagonian toothfish with some blue antimora (violet cod), skate and grenadier also being caught, all in the north eastern and southeastern areas.

The distribution of migratory species such as hake may be affected by fluctuations in spawning success and external environmental affects. Many of the commercially caught demersal species are likely to spawn in deep water and have planktonic eggs and larvae. Immature stages of some species may occur inshore; however, there is little information on specific nursery areas.

Figure 5.24. Daily Average Fishing Catches Excluding Longline Fisheries (FIFD database, 2008-2010)

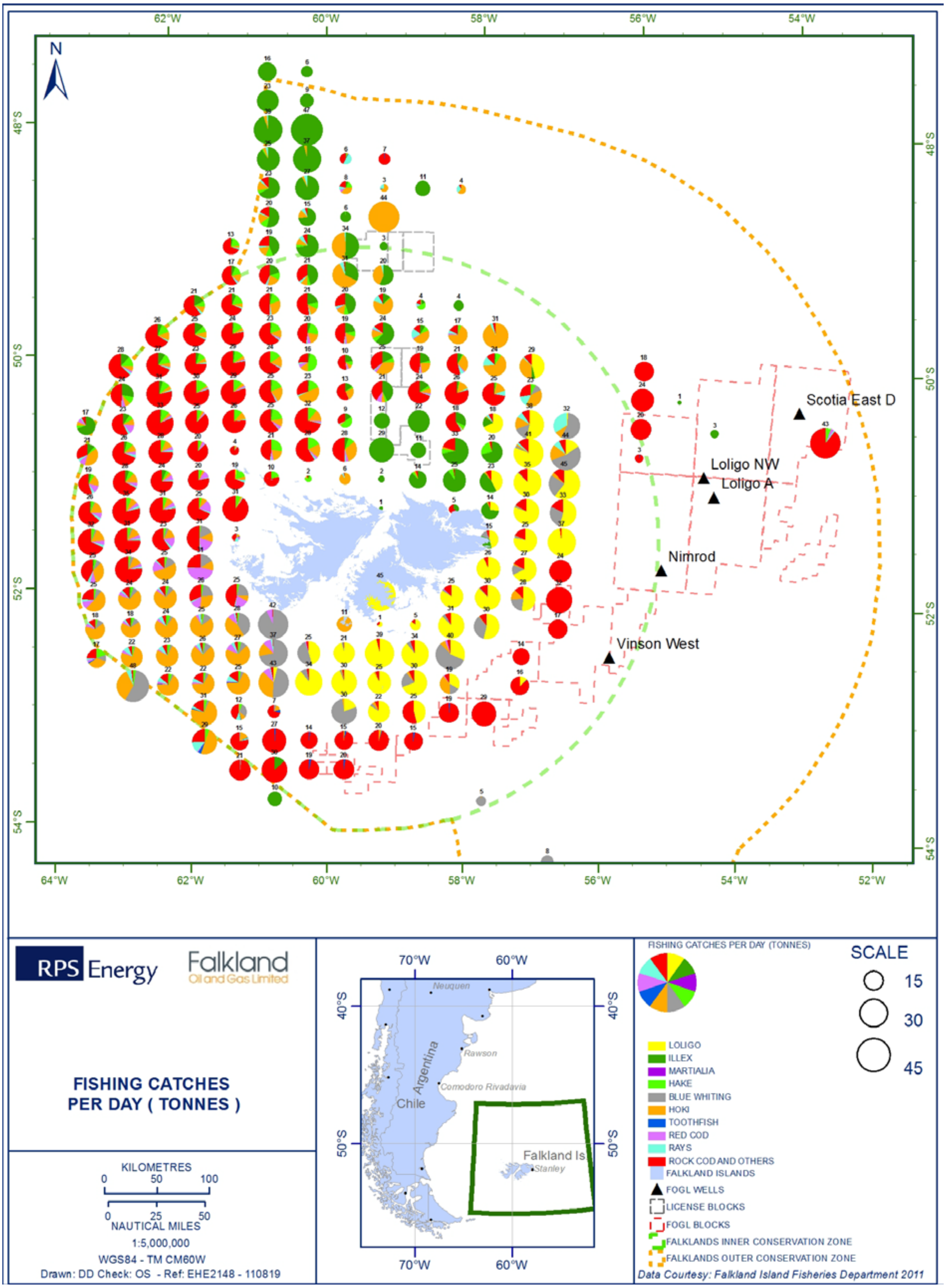


Figure 5.25. Fishing Effort by Licence Type Excluding Longline Fisheries (FIFD database, 2008-2010)

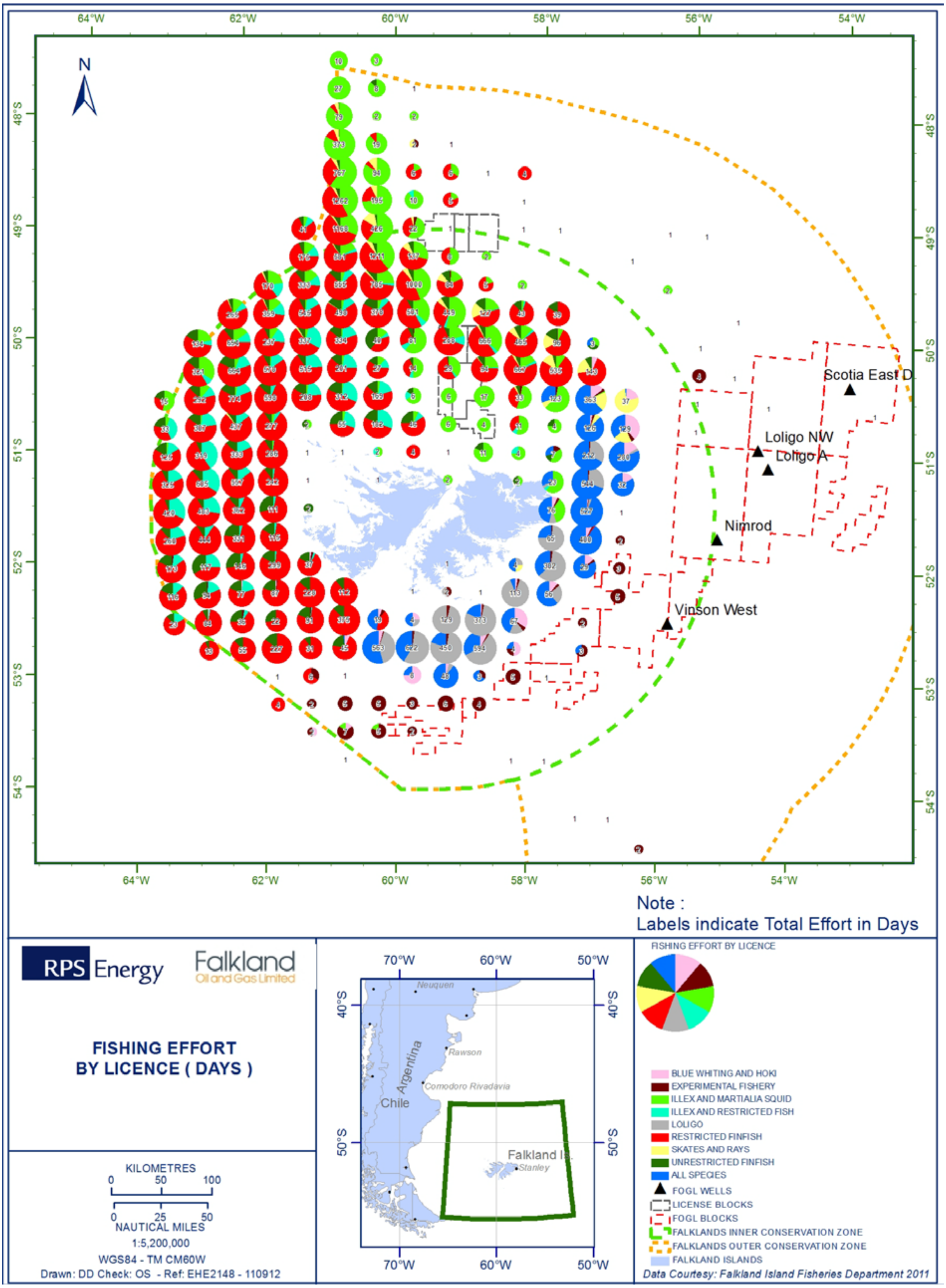
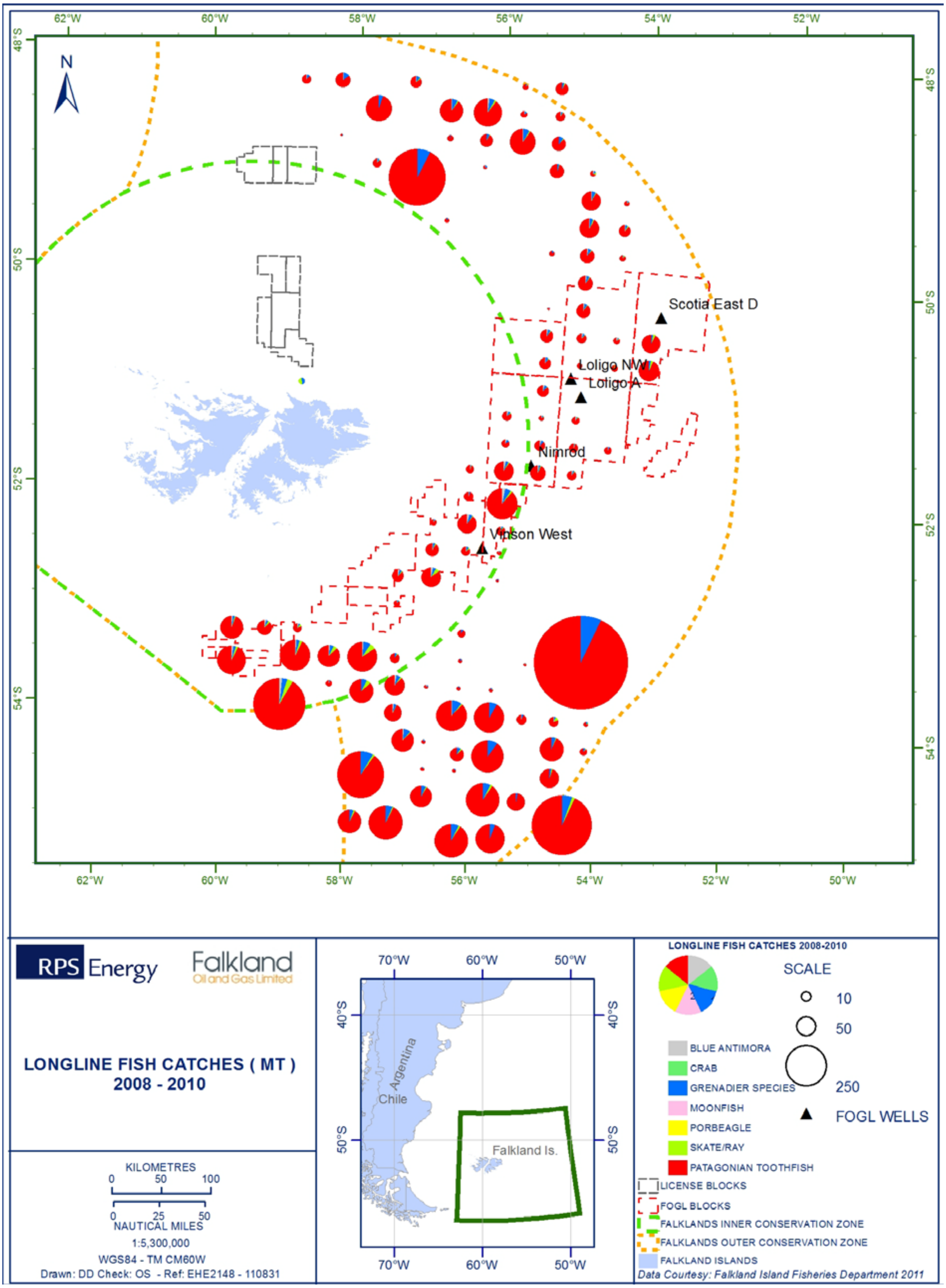


Figure 5.26. Cumulative Longline Fisheries Catches for 2008 - 2010 period (FIFD database, 2008-2010)



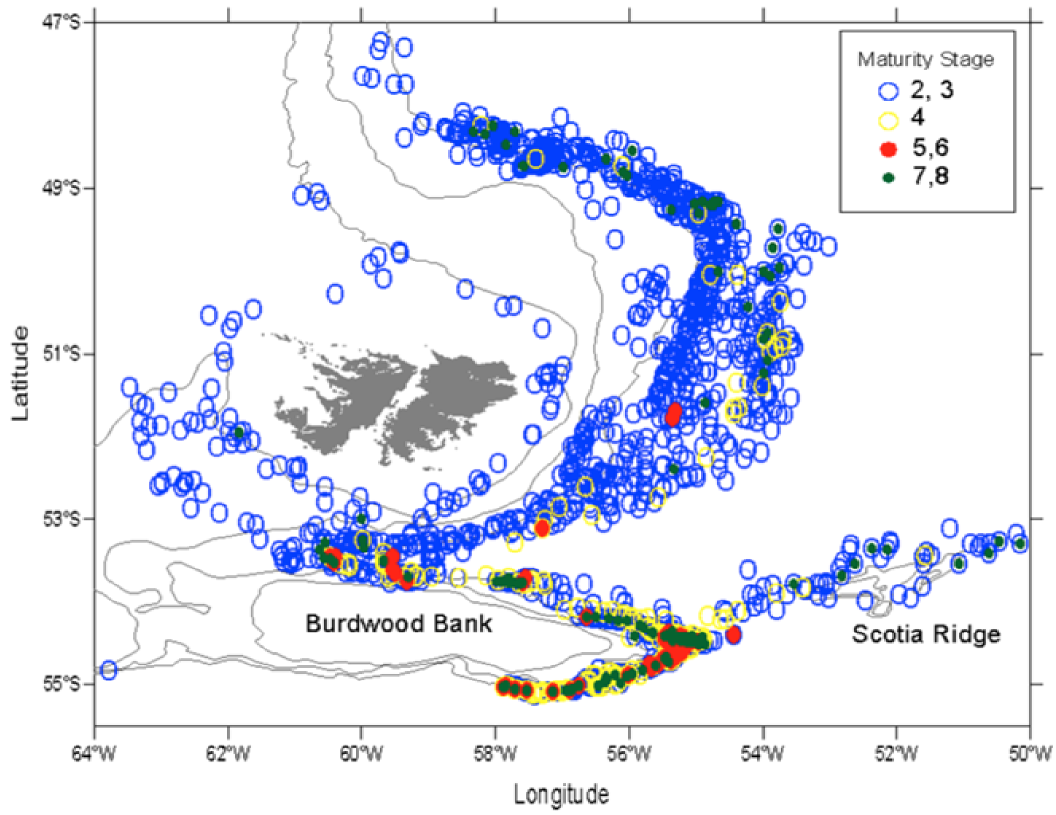
Patagonian Toothfish (*Dissostichus eleginoides*)

The Patagonian toothfish (*Dissostichus eleginoides*) is a slow growing, long lived notothenid (Antarctic cod), typically reaching maturity at around 8-10 years and living to over 40 years (*Collins et al. 2010*). They have a wide distribution and are found as far north as 30°S on the Patagonian shelf and slope to the sub-Antarctic islands of the Southern Ocean (*Evseenko et al., 1995*). Although originally thought that fish from the Patagonian region and South Georgia may only be a single population (*SC-CAMLR 1994*), it has since been found through genetic studies that they are in fact two distinct populations within the Antarctic Polar Front (APF), with deepwater troughs acting as natural barriers to genetic exchange (*Shaw et al., 2004*).

The distribution and total catches of the toothfish, between 2008 and 2010, is shown in Figure 5.24.

The Falkland's population has been found to spawn on the drop off near the Burdwood Bank at about 1,000 metres depth (*Laptikhovsky et al. 2006*). Two peaks occur; a minor peak occurring in May and a major peak in July to August. The timings of these peaks are also similar to other populations of *D. eleginoides* at South Georgia and Shag Rocks (*Laptikhovsky et al., 2006; Agnew et al., 1999*). The main spawning area for toothfish has been found to occur around the Burdwood Bank (Figure 5.13182727). Males arrive at the spawning grounds first, with both sexes remaining around the Burdwood Bank between spawning peaks. Males were consistently found at greater depths than females. Following spawning, *D. eleginoides* juveniles at the Falkland Islands have a long juvenile and sub-adult period which is spent in the relatively shallow and relatively warmer waters of the upper slope and outer shelf of the Burdwood Bank (*Laptikhovsky et al. 2006*). It is possible that two migrations occur within this population. Seasonal migration of adults from foraging grounds around the Falkland and Patagonian Shelf to the Burdwood Bank to breed; and an ontogenic migration from the shelf waters into bathyal waters upon maturity (*Laptikhovsky et al. 2006*). It is therefore likely that part of the southern FOGL licensed areas may coincide with toothfish spawning and seasonal migration patterns.

Figure 5.27. Toothfish maturity map showing the main spawning areas around the islands (Source: Brown, J. 2010, with data from FIFD).



Hake *(Merluccius spp.)*

Two species of hake are found in the southwest Atlantic: common hake *Merluccius hubbsi* and Patagonian (sometimes referred to as 'austral' or 'southern') hake *Merluccius australis*. The species are spatially and temporally separated within Falkland Island waters, with *M. hubbsi* most abundant in the northwest of the region at depths of 200-300 metres and *M. australis* in the southwest region at depths of 400-500 metres (*Arkhipkin et al., 2003*). The two species both undertake seasonal migration from inshore spawning grounds to offshore feeding grounds (*Bezzi et al., 1995*). The waters surrounding the Falkland Islands are primarily used as feeding grounds for both species, and they have different, non-overlapping spawning seasons in which they are absent from Falkland waters – austral summer (Dec-Feb) for *M. hubbsi* and austral winter (Jun-Aug) for *M. australis* (*Arkhipkin et al., 2003*).

During austral autumn and spring, both species are present but remain spatially segregated as *M.australis* occurs primarily in the southwest of the FICZ and *M. hubbsi* everywhere else (*Arkhipkin et al., 2003*). A scheme of possible migrations of *M.hubbsi* has been proposed using CPUE data from 1988-2000 (*Portela et al., 2002*). It predicted that adult fish migrate to the south and east of the Falkland Islands in austral winter, up to approximately the 500 metre contour, just outside the FOGL licensed area. Hake are generally known to migrate diurnally, being found near the seabed during the day and migrating further up the water column to feed at night.

Fishing effort concentrates in the far west of the FICZ where the highest abundance of hake are found, and also to the north (*Tingley et al., 1995*), but may extend around Beauchene Island to the south (*Lisovenko et al., 1982; Tingley et al., 1995*). The distribution and total catches of hake between 2008 and 2010 are shown in Figure 5.24.

Southern Blue Whiting *(Micromesistius australis)*

Southern blue whiting (*Micromesistius australis*) is a mesopelagic species with a wide distribution in the Southern Hemisphere (*Macchi et al., 2005*). There are two distinct populations. One population, (*M.a. australis*), is found from about 38°S to nearly 62°S around the Falkland Islands (FI) and Argentine Patagonia in the western South Atlantic, as well as off South Georgia, South Shetland and South Orkney Islands and in the Southeastern Pacific, off Chile (*Cohen et al., 1990*). The other population (*M.a. pallidus*), lives around the south island of New Zealand. The *M.a. australis* population inhabits the continental slope at 100-700 metre depths between 38°S and 47°S, and from 47°S to 55°S it is distributed within the Patagonian continental shelf (*Cassia, 2000*). It is most abundant at about 200 metres depth around the Falkland Islands (*Inada and Nakamura, 1975; Cohen et al., 1990*). The distribution and total catches of the southern blue whiting between 2008 and 2010 are shown in Figure 5.24.

Reproductive activity of this population takes place mainly south of the Falkland Islands where they aggregate to spawn (*Madirolas, 1999*). The spawning period typically takes place from August to October, with a peak in September (*Pajaro and Macchi, 2001*). Both eggs and larvae are pelagic (*Agnew, 2002*). Pre-spawning fish congregate south of West Falklands during July (*Patterson, 1986*) and post-spawning fish disperse to feed over the shelf (*Agnew, 2002*). Southern blue whiting is not expected to spawn over FOGL licensed area.

Whiptail Hake / Hoki *(Macruronus magellanicus)*

Whiptail hake, or hoki, is a benthopelagic schooling species with a depth range of 30-500m (*Cohen et al., 1990*) and exist as a wider, highly migratory population across the Southwestern Atlantic (*Amato and Carvalo, 2005*). Migration patterns are attributed to the fluctuations in the Falkland current along the Patagonian platform and edge (*Giuss, 1996*). *M. magellanicus* migrates diurnally between deeper pelagic water by day and shallower water by night (*Amato and Carvalo, 2005*). Sexual maturity is attained around 3-4 years old (*Giussi and Wöhler, 2001*) and individuals may live up to 16 years (*Giussi, 1996*).

Falkland's waters function primarily as a feeding ground for this species in the north and west of the FICZ. Most individuals of this species will migrate north to Argentina to spawn and then to Chile for austral winter (*Middleton et al., 2001*). However some individuals will remain within the FICZ (*FIG, 2011*). Diet consists primarily of fish (particularly herring, anchovies and lantern fishes) and also mysids, cephalopods, euphausiids and amphipods (*Cohen et al., 1990*). Stomach content analysis proved them to be an important prey item for large hake (*Merluccius australis polylepsis*) (*Payá, 1992*).

The distribution and total catches of the hoki between 2008 and 2010 are shown in Figure 5.24. The uniform distribution of *M. magellanicus* as a proportion of daily catch suggests that the species is taken as a part of a mixed finfish fishery rather than specifically targeted.

Skates and Rays

Over 20 species of Rajidae are known to occur within the FOCZ. Four key species account for more than two thirds of commercially exploited catch as part of a mixed fishery: *Bathyraja griseocauda*, *B. albomaculata*, *B. brachyurops* and *Raja flavirostris*. The distribution and total catches of the skate and rays between 2008 and 2010 are shown in Figure 5.24.

B. griseocauda was formerly the dominant ray species, particularly in the south where it comprised 70% of catch, but this fell to less than 5% between 1993 and 1995 (*Agnew et al., 2000*) with CPUE reporting it to still be in decline (*Wakeford et al., 2004*). Since 2007, *B. griseocauda* has been listed as endangered on the IUCN Red List. *B. albomaculata* experienced a serious decline in the Falkland region following overexploitation in the early 1990s (*Agnew et al., 1999*), but are presently more abundant throughout the Falkland shelf after replacing the former dominant species, *B. griseocauda*, in the northern fishery between 1993 and 1997 (*Agnew et al., 2000*). *B. albomaculata* has a comparably low fecundity compared to other ray species, as well as slow growth and late maturity indicative of a higher vulnerability to overexploitation, and is consequently listed as vulnerable on the IUCN Red List. *B. brachyurops* are distributed throughout the FICZ but have a concentrated population around the eastern shallow part of the shelf (*Arkhipkin et al., 2011*). Spawning aggregations can be found on the northeast Falkland Shelf between 100-200 metres. They spawn throughout the year, with periods of less spawning in the austral winter months. *R. flavirsotris* is widespread throughout the Southwest Atlantic area, which encompasses both the FICZ and FOCZ (*Wakeford et al., 2004*). Larger individuals are generally found at deeper depths and females represent over 83% of the commercial catch. No juveniles have ever been caught in the Falkland waters suggesting adult seasonal migration onto the Patagonian shelf (*Wakeford et al., 2004*).

Rays are also commercially important as bycatch within the well-developed *Loligo gahi* fishery. In addition, species that dwell in the deeper water of the Falklands Outer Conservation and Management Zone may be taken as bycatch in the Patagonian toothfish (*Dissostichus eleginoides*) fishery (*Wakeford et al., 2004*) such as *Bathyraja papilionifera* and *B. meidionalis*.

While *B. griseocauda* has been listed as an endangered species, the broad distribution and diversity of skate and ray species throughout the Patagonian shelf suggests that the FOGL licensed area is unlikely to impact significantly on the skate and ray populations. The main species found in the FOGL area are the Antarctic skate (*Raja georgiana*), butterfly skate (*Bathyraja papilionifera*) and the darkbelly skate (*Bathyraja meridionalis*); the endangered greytail skate is found more to the north and west.

Rock Cod *(Patagonotothen ramsayi)*

Rock cod (*P. ramsayi*) is the most abundant of the 14 species of its genus that inhabit the shelf waters of South America (*Ekau, 1982*). *P. ramsayi* occurs on the Patagonian Shelf from 35°S to the Burdwood Bank and from the Straits of Magellan to the west to the shelf edge of the Falkland Islands (*Winter et al., 2010*). Recent analyses have shown the density of *P. Ramsayi* to be substantially lower in the southeast than to the north with estimated biomasses of 25,000 tonnes and 481,000 tonnes respectively (*Winter et al., 2010*). The distribution and total catches of the rock cod between 2008 and 2010 are shown in Figure 5.24.

Commercial aggregations occur in the western region of the FICZ in January–March, northward in April, northwest in May-June, northwest in September and then evenly distributed along the northwestern shelf between November and December (*FIG, 2011*). Spawning has been reported to occur in the austral autumn on the Argentinean shelf at 42°S and in the austral spring on the Burdwood Bank (*Ekau, 1982*). In addition, length frequency distributions and sex ratios of mature male fish from the spawning season indicate possible nest guarding behaviour, although there is no further analysis (*Brickle et. al., 2006b*). It is therefore likely that part of the southern FOGL licensed areas may coincide with rock cod spawning areas.

P. ramsayi has only recently been targeted commercially since 2007 and prior to this did not have a high market value. Commercial activity is concentrated in the northwestern FICZ along the border between 100 and 300m, with optimum catches occurring at 150-200m. It is currently the most important region for rock cod (*Winter et al., 2010*).

Red Cod *(Salilota australis)*

Red cod is a shallow water demersal species inhabiting the Patagonian Shelf and SW Atlantic Oceans between 30-1,000 metres, with a preferred range of 152-452 metres (*Cohen et al. 1990, Nakamura et al. 1986*). *S. australis* is also found in the Pacific Ocean up to approximately 44°S. The distribution and total catches of the red cod around Falkland Islands between 2008 and 2010 are shown in Figure 5.24.

S. australis is known to spawn in batches to the south and southwest of Falkland Islands between August and October (*Brickle et al., 2011*). It is therefore unlikely that the FOGL licensed areas will coincide with rock cod spawning areas.

They are retained within the Falkland Island finfish fishery, which caught 3,133 tonnes in 2010, the lowest in 5 years (*FIG, 2011*). This decline however, was attributed to the closure of part of the fishing ground during October to protect the spawning and post-spawning stock, which is historically the period of highest catches (*FIG, 2011*). These precautionary measures were put in place due to the results of a recent stock assessment that suggested a regional decline in abundance (*FIG, 2011*).

Grenadier (Macrourus spp)

The grenadiers, or rattails, are bentho-pelagic fish that belong to the Macrouridae family which comprise more than 300 species distributed globally (*Smith et al., 2011*). There are three species found in the Southern Ocean: *Macrourus carinatus, M. holotrachys* and *M. whitsoni,* but recent research using DNA sequencing suggests that one more species may be present (*Smith et al. 2011*). *M. carinatus* and *M. holotrachys* are the two main species found around the southwest Atlantic Ocean and have also been reported within the Falkland Islands (*Laptikhovsky 2005*). They live at depths between 150-1800 metres (*Morley et al. 2004, Smith et al. 2011*). Within the region, they are thought to occur in high abundance and to have important ecological roles in the deep-sea bottom fish and deep water slope fish communities (*Morley et al. 2004, Laptikhovsky 2005*).

Within the Falkland Islands they are mainly taken as bycatch in the commercial long-line and trawl fisheries with 450 tonnes being taken in 2010. Surveys and exploratory fisheries have been undertaken around the Falklands in recent years with the view to starting a commercial fishery. During 2009, when an exploratory deep sea trawl fishery was conducted between 50°05'S and 53°38'S to the east of the Falklands between depths of 512 and 931 metres, 733 tonnes were caught. Spatial distribution was found to be relatively even throughout the survey period in the summer, but the population began to migrate north to the Autumn spawning grounds north of 51°S. It is possible there may be some overlap with the FOGL area for both fishing and spawning areas (*FIG, 2010*).

The distribution and total catches of the grenadier between 2008 and 2010 are shown in Figure 5.26.

5.3.6.3 Commercial Cephalopods

Cephalopods include species from the squid and octopus families. Squid provide economic benefits through commercial exploitation and are also a food source for a variety of marine vertebrate predators (*Munro, 2004*). Adult squid are active predators positioned near the top of the food chain, consuming fish, crustaceans and other cephalopods (*Hatfield, 1990*). Squid stock varies annually, influenced by success of the spawning season based on favourable environmental conditions. Octopi, found in kelp beds and crevices in rocks, are common prey for sea lions.

Distribution of cephalopods is dependent on temperature preference and influence of currents. Larval phases concentrate on the Patagonian shelf and shelf break area, and the adult phases utilise the currents for migration between feeding and spawning grounds (*Rodhouse et al., 1992*).

From cephalopod larvae and juveniles sampled in the southwest Atlantic Ocean, it was found that the sub-Antarctic surface waters of the Falklands Current contain the richest assemblage of species, including the sub-tropical/sub-Antarctic *Histioteuthis atlantica*, the sub-Antarctic *Batoteuthis skolops*, *H. eltaninae*, *H. macrohista* and the sub-Antarctic/Antarctic *Gonatus antarcticus*. In comparison, with the exception of some small *Gonatus antarcticus*, the polar frontal zone water of the Falklands Current was relatively poor in species (*Rodhouse et al., 1992*). Cephalopod species recorded on the Falkland Islands shelf included *Loligo gahi*, *Gonatus antarcticus*, *Martialia hyadesi*, *Moroteuthis knipovitchi*, *Batoteuthis skolops*, *Semirossia patagonica* and one species of Octopus (*Rodhouse et al., 1992*).

An evaluation of the distribution of *Loligo gahi* paralarvae and *Gonatus antarcticus* found the greatest concentrations to be around East Falkland (*Rodhouse et al., 1992*) and at the offshore stations sampled, particularly to the south of East Falkland, respectively. Octopus sp. was reported to be the most widely distributed.

Argentine Shortfin Squid *(Illex argentinus)*

The Argentine shortfin squid (*Illex argentinus*) is a common neritic-oceanic species within the Southwest Atlantic from 22°S and 54°S and is most abundant between 35°S and 52°S (*Brunetti 1981, 1988*). It is found at depths between 80 and 800 metres where it plays a significant role in the ecosystem (*Arkhipkin, 2000*). The life-cycle of *Illex argentinus* is associated with the subtropical confluence of the Brazil and Falkland Currents during reproduction and the early life stages (*Hatanaka, 1988; Brunetti and Ivanovic, 1992; Rodhouse et al. 1995; Haimovici et al. 1998*) and with the Falkland Current over the Southern Patagonian shelf during maturation, feeding and growth (*Rodhouse et al. 1995*).

Three main spawning stocks have been identified in the southern range of the distribution (*Brunetti 1988*): summer-spawning stock (SSS); South Patagonian stock (SPS); Bonaerensis-northpatagonic stock (BNS). The stock associated with the Falkland Islands is referred to as the South Patagonian stock. Concentrations of immature *Illex argentinus* migrate southwards over the Patagonian shelf and slope heading towards the Falkland Islands. During this long pattern of migration, the shortfin squid grow rapidly and reach their feeding grounds at the southern end of the Patagonian shelf, within the Falkland Islands Interim Conservation and Management Zone (FICZ) between March and May. The waters to the south of the Islands represent the southernmost extent of the distribution of *Illex argentinus* (*Csirke, 1987; Arkhipkin 1993; Basson et al. 1996*). Adults then start migrating northward to spawn and die around July or August.

In general, the FOGL licensed area is not known to be popular for fishing of *Illex argentinus*, and therefore high populations of *Illex* are not expected across the area. The distribution and total catches of *Illex argentinus* between 2008 and 2010 are shown in Figure 5.24.

Patagonian Squid *(Loligo gahi)*

The Patagonian longfin squid, *Loligo gahi* is a demersal, schooling species found mainly within Falkland Island waters, but also extends across both the Argentinean and Patagonian shelves in the Southwest Atlantic (*FIG, 2011*). On the Falklands shelf, *Loligo* undertakes spatial ontogenetic migrations, with small juveniles moving from the shallow inshore spawning grounds (20-50 metres) to feeding grounds near the shelf edge (200-350 metres) (*Boyle, 1983; Hatfield and Rodhouse, 1994; Arkhipkin et al. 2001*).

Loligo form dense feeding aggregations, with larger squid separated by sex and by depth, with females occurring deeper (250-300 metres) than males (170-250 metres) (*Arkhipkin and Middleton, 2002*). Feeding grounds are deeper in the northern areas (200-350 metres) than in the south (150-250 metres) and both are subject to a commercial fishery, an area known as the '*Loligo* box'.

On maturation, adults return to inshore kelp beds to spawn, laying their egg masses from 0.5–2.5 metres off the bottom at 8–20 metres (*Hatfield et al. 1990*). More recently, studies have shown *L. gahi* can spawn in much deeper water than previously thought for this species, with adult specimens caught as deep as 626 metres and egg masses found attached to empty polychaete tubes from 61–71 metres (*Laptikhovsky, 2008*). Spawning of the adult population is thought to occur throughout the year, with distinct peaks during the austral late winter to spring (July–September) and autumn (February – April), which form the two major fishing seasons (*Patterson, 1988; Agnew et al. 2005*). Recruitment variability and ontogenetic migrations have been linked to seasonal environmental conditions. Low sea surface temperatures during October with moderate stock sizes lead to higher recruitment in the following year (*Agnew et al. 2000*), whilst the distribution of the isotherm at 5.5°C marked the limit of squid penetration into deeper waters in all seasons (*Arkhipkin et al. 2001*).

Patagonian squid forms an important commercial species within the region, although annual catches are highly variable dependent on annual recruitment patterns (23,700 tonnes – 66,500 tonnes; (*FIG, 2011*). The fishery operates within the 'Loligo Box'. This is a fisheries statistical area positioned about 100 nm to the south and east of the Islands, where licensed vessels are permitted to fish during two fishing seasons. The FOGL licensed areas are situated to the south and east of the *Loligo* box and are therefore not thought to impact the main fishing operations for Patagonian squid situated in shallower waters. The distribution and total catches of *Loligo gahi* between 2008 and 2010 are shown in Figure 5.24.

5.3.6.4 Non-Commercial Finfish and Squid Species

The majority of finfish and squid species found on the Patagonian Shelf have low abundance and therefore are of little commercial interest. Limited information on non-commercial species found in the shallow and offshore waters of the Falkland Islands can be derived from fisheries observer reports and FIFD research surveys, in addition to other research data such as surveys or diet studies within the Southwest Atlantic. A comprehensive list of non-commercial species is provided in Table 5.5.55.5.35. A summary of these data are provided in the following sections.

Pelagic

The greater hooked squid (*Moroteuthis ingens*) is the most abundant non-commercial species in Falkland waters catch (*FIG, 2010*) but because of the erratic and unpredictable catch, has no direct commercial interest (*Agnew, 2004*). *M. ingens* is an important prey item for many species of birds, mammals and fish (*Cheung and Pitcher, 2005*), particularly the commercially important species the Patagonian toothfish (*Dissostichus eleginoides*) (*Phillips et al, 2003*).

Antimora rostrata are globally distributed and migrate further offshore as they mature and spawn in the deeper water. It is speculated that the Falklands population remain there to feed and actually spawn to the north (*Cohen et al., 1990*).

Unique to the Falkland Islands, southern opah (*Lampris immaculatus*) was considered rare until the Falkland Government Fisheries recorded sizeable numbers of bycatch in a number of fisheries in the late twentieth century (*Jackson et al., 2000*). A tonne was caught in 2010. They were found to have a surprisingly narrow prey item range of Moroteuthis ingens (93% of species eaten) and the commercially important *Loligo gahi* (*Jackson et al., 2000*).

A tonne of Falkland Island herring (*Sprattus fuegensis*) was recorded to have been caught in 2011 (*FIG, 2010*). This fish is an important prey item for hake, sea birds and seals in the Falkland waters (*Nakamura et al., 1986*).

Smaller penguins feed intensively on juvenile *Gonatus antarcticus* which are known to be found on the shelf as juveniles in spring and summer (*Laptikhovsky et al., 2010*). Smaller penguins rarely forage beyond the shelf edge and the juvenile *Gonatus antarcticus* distribution may account for this. Hoki are also known to feed on *G. antarcticus* (*Laptikhovsky et al., 2010*).

Another species commonly found in the diet of top predators is the smalleye moray cod (*Muraenolepis microps*), a small pelagic species (*Cheung and Pitcher, 2005*).

Demersal

The frogmouth (*Cottoperca gobio*), a demersal species of fish, feeds on the commercially important species of rock cod throughout the year. They are also known to predate on *Loligo gahi* during their seasonal offshore migration in June and August (*Laptikhovsky and Arkhipkin, 2003*).

The only fish species reported to be endemic to the Falklands is a demersal species known the crested spiny plunderfish (*Harpagifer palliolatus*). It is commonly found in the littoral zone (40-50 metres) and feeds on small crustaceans (*Hureau, 1990*). As with most other non-commercial fish species in this region, little else is known about the species.

Deepwater species

There are 41 species of deep sea finfish and squid that have been recorded within the Falkland Islands region. Further details are presented in Table 5.5. Because of the previous lack of data on deep sea fish and squid and related fishing activity, new species are being discovered more recently for the Falkland Islands. Additionally, the majority of deep sea species recorded in the Falkland Islands has circumglobal distribution due to the relatively homogenous environment they live in. Data on their general biology and distribution are lacking, particularly for those below depths of 300-400 metres (*Brickle and Laptikhovsky, 2002*). The deep-sea cephalopod, *Opisthoteuthis hardyi*, was initially described from one male caught on Shag Rocks to the northwest of South Georgia but recent deep water trawls caught 33 conspecifics on the Patagonian slope that were confirmed through molecular analysis. 24 were caught in one trawl indicating schooling behaviour. Other deep sea species recently found within the Falklands region through exploratory observation include: the giant grenadier (*Albatrossia pectoralis*), the deepwater squid (*Asperoteuthis nesisi*) found on the Burdwood Bank, the manefish (*Caristius groenlandicus*), the cutthroat eel (*Diastobranchus capensis*), the spiny eel (*Notacanthus sexspinis*), and the southern driftfish (*Pseudoicichthys australis*) (*Brickle and Laptikhovsky, 2002; Arkhipkin and Laptikhovsky, 2008*).

5.3.6.5 Shellfish

Data on shellfish found in the shallow and offshore waters of the Falkland Islands are scarce. Lobster krill is abundant in Falkland's waters. Crabs found in the shallow inshore waters of the Falklands include red crab (*Paralomis granulosa*) and, to a lesser extent, the king crab (*Lithodes antarcticus*). Trawling to the south of the Falklands has also shown there to be a probable significant population of sub-Antarctic stone crab (*Neolithodes* spp.). In addition, an experimental pot fishery for king crabs on the southern and western Falkland shelves from the Burdwood Bank to Jason Islands was carried out from during 2010. No commercial aggregations were found. The primary catch species was *Neolithodes diomedea*.

Red Crab *(Paralomis granulosa)*

The red crab fishery utilises a small inshore vessel operating in Choiseul Sound. The operation is licensed by the Department of Fisheries with restrictions on minimum crab size. *Paralomis granulosa* is typically found in relatively shallow water of 10 to 40 metres depth and within sheltered inshore waters. The highest concentrations of *P. granulosa* are found around the southeast of the Falklands. Juveniles and adults are found at the edges of kelp beds (*Hoggarth, 1993*).

Patagonian Scallop *(Zygochlamys patagonica)*

A small commercial fishery has existed for the Patagonian Scallop in the northeast of the FICZ at depths of 130 and 142 metres. No directed fishing occurred in 2010, but a small amount was taken as bycatch in the *Loligo* and finfish fleets. Stock assessment estimates a standing biomass in these beds of 18,000–27,000 tonnes. Distribution is mainly along the northeastern, eastern and southern edge of the Falklands shelf. Distribution is thought to be determined by three main factors: the Falklands currents, bottom morphology and suitable depth. Scallops have not been found on areas of hard rocky bottom, nor in waters greater than 145 metres deep. In Falklands waters, no inshore scallop beds have yet been found (*Munro, 2004*).

Table 5.5. A selection of key non-commercial finfish and squid species in Falkland's waters.

Common name	Latin Name	Distribution	Diet	Information	IUCN Red List
Antarctic Starry Skate	*Amblyraja Georgiana*	Most abundant >600m in depth to the south and east of the Falkland Islands (FIs) including Burdwood Bank	Gadoid fish (including *Antimora rostrata*) and deep water crayfish (*Thymops birsteini*, shrimps, crabs and squid)	One of the most abundant deep water rays found around the FI's taken as deep water bycatch in the longline fishery	VU
Blue antimora	*Antimora rostrata*	Bathypelagic, global but found in abundance throughout the FIs in deep water	Benthic invertebrates	12 tonnes caught in FIs, 2011 (FIGF). Speculated that they use this region as a feeding ground and spawn to the north.	NE
White dotted skate	*Bathyraja albomaculata*	Distributed over the entire Falkland shelf between 72-945m, most abundant at 200-300m depth	Polychaetes, amphipods and isopods	One of the key species in the mixed skate and ray fishery. High abundance of small individuals in deeper catch suggests they spawn at around 400m.	VU
Blonde (Broadnose) skate	*Bathyraja brachyurops*	Widespread around the FIs but concentrated on the eastern shallow part of the shelf between 100-200m.	Squid, fish and crustaceans including rock cod and *Loligo sp.*	One of the key species in the mixed skate and ray fishery. They spawn above the shelf break throughout the year with weaker spawning periods in December-January.	LC
Graytail skate	*Bathyraja griseocauda*	Concentrated population on the western deep water region around the FIs	Juveniles: amphipods and isopods; adults: squid, whelks isopods as well as fish. Predominantly piscivorous in adulthood	Larger rays are caught with juveniles in deeper water beneath the shelf break (400-500m) indicating they spawn here. Periods of weaker spawning in December-January.	EN
Grey skate	*Bathyraja magellanica*	Widespread through the FIs with depth range of 58-150m	Juveniles: amphipods; >25cm DW: polychaetes	Never occurs in large numbers despite being widespread over the Falklands shelf so of low commercial importance.	DD
Dark-belly Skate	*Bathyraja meridionalis*	Found on the east Falkland shelf and Burdwood bank at depths greater than 600m	Not Known	Often taken as bycatch by longline fishermen.	DD
Multispine skate	*Bathyraja multispinis*	Widespread throughout the FIs but concentrated in the northwest; depth range: 72-84m being most common at 200-350m	Specialised crabeater particularly Peltarion spinosulu.	Moderate commercial importance. Ventral cavity often heavily infected with the digenean parasite *Otodistemum plunketi.*	NT
Butterfly Skate	*Bathyraja*	Found on the eastern slope and on	Crayfish, crabs, shrimps and	Often taken as bycatch in the toothfish longlining	DD

Common name	Latin Name	Distribution	Diet	Information	IUCN Red List
	papilionifera	Burdwood bank; depth range: 827-1550m	benthic fish	fishery	
(Cuphead skate) Glassy nose ray	*Bathyraja scaphiops*	Widespread over the Falkland shelf between depths of 102-925m with a concentrated population in the northeast between 250-300m	Juveniles: small crustaceans; >25cm: active predators feeding on fish especially *Patagonotothen ramsayi* and Myctophidae	Important in the mixed species ray and skate fishery, juveniles escape capture as they inhabit shallower water than the trawling range	VU
Marginate snailfish	*Careproctus aureomarginatus*	Recorded south of the FIs	Not Known	Not Known	LC
Thornfish	*Cottoperca gobio*	Demersal	Feed on rock cod throughout the year and *Loligo gahi* during their seasonal offshore migration (June - August)	Not Known	NE
Roughskin skate (Large black skate)	*Dipturus trachydermus (Raja trachyderma)*	Depth range of 158-314m, population concentrated on the north of FIs at 250-300m	Not Known	Considered rare	VU
Lanternfish	*Electrona sp., Protomictophum spp., Gymnoscopelus spp., Lampinictus spp., Myctophid spp.*	A large number of species widespread throughout the FIs	Not Known	Not Known	Not Known
Crested spiny plunderfish	*Harpagifer palliolatus*	Demersal	Not Known	Endemic	NE
Southern opah	*Lampris immaculatus*	Pelagic	Narrow range of prey items: *Moroteuthis ingens* (93%) and also *Loligo gahi, Gymnosocephalus nicholsi, Micromesistius australis.* High level of plastic ingestion also.	Considered rare in other regions, bycatch was recorded in a number of fisheries in the late twentieth century	NE

Common name	Latin Name	Distribution	Diet	Information	IUCN Red List
Flat fish	*Mancopsetta spp.*	Demersal, a large number of species can be found throughout the FIs	Not Known	Not Known	Not Known
Greater hooked squid	*Moroteuthis ingens*	Pelagic, widely distributed throughout the FIs	Not Known	36 tonnes caught in 2010 (*FIGF),* an important prey item for many birds, mammals and fish	NE
Smalleye Moray cod	*Muraenolepis microps*	Widely distributed throughout the FIs	Not Known	important in the diet of top predators	NE
Hagfish	*Myxinidae*	Bathydemersal, a large number of species exist throughout the FIs	Not Known	Not Known	Not Known
Yellowfin notothen	*Patagonotothen guntheri*	Not Known	Not Known	Found in the diet of the *D. eleginoides* (*Collins et al., 2010*)	NE
Smalltail sandskate	*Psammobatis parvacauda*	Not Known	Not Known	Endemic, only individuals found to the north of the FIs at 120m in depth. Because of the nature of the mixed species fishery it is difficult to determine its distribution throughout the FIs	DD
Southern driftfish	*Pseudoicichthys australis*	Pelagic	Not Known	Considered rare	NE
Patagonian bobtail squid	*Semirossia patagonica*	Demersal; widespread throughout the FIs but found mostly on the southern shelf	Not Known	Movement patterns remain unknown but it is likely they do not reproduce in Falkland waters as hatchlings could be easily transported from the northern shelf into open oceanic waters by the Falkland Current.	NE
Falkland herring	*Sprattus fuegensis*	Pelagic, neritic	Not Known	Common prey to hakes, sea birds and seals in the Falkland waters. Schooling species.	NE
Scaly dragonfish	*Stomias sp.*	A large number of species widespread throughout the FIs	Not Known	Not Known	Not Known
Yellownose skate	*Zearaja chilensis (Dipturus chilensis)*	Widespread throughout the FIs with a concentrated population in the north. Likely that there is no resident population but instead a broadly distributed population in the Southwest Atlantic that encompasses	Not Known	One of the key species in the mixed skate and ray fishery which has increased in abundance following management implementation in the mid-1990s. Research indicates westward movements to spawning grounds.	VU

Common name	Latin Name	Distribution	Diet	Information	IUCN Red List
		the FICZ and FOCZ			
Picked dogfish	*Squalus acanthias*	Demersal, W Atl: Greenland to Argentina, E. Atl, Med & Black Sea. Continental and insular shelf and upper slopes.	Not Known	Ovoviviparous species high in relative abundance, broad commercial uses including food and liver oil.	VU
Snoek	*Thyrsites atun*	Benthopelagic.	Pelagic crustaceans, cephalopods and fishes	Global; reside on continental shelves, form schools near bottom. Some market interest.	Not Known

Note
IUCN Red List Categories;

EX – Extinct
EW – Extinct in the wild
CR – Critically Endangered
VU – Vulnerable
NT – Near Threatened
LC – Least Concern
DD – Data Deficient
NE – Not Evaluated

5.3.7 Marine Mammals

5.3.7.1 Overview

The information on the population, distribution and habits of marine mammals occurring in offshore waters of the Falkland Islands is scarce and incomplete, particularly for deeper waters to the south and east (*Munro, 2004*). It is estimated that more than 20 species of marine mammal reside or visit the Falkland Islands, but possibly only two or three are permanent residents. It is thought that Commerson's Dolphins and Peale's Dolphins are among those who stay around the islands year round (*Otley et al., 2008).*

Following the award of the initial round of hydrocarbon exploration licenses in 1996, the threat of oil pollution to seabird and marine mammal populations was recognized, and in the view of the lack of published data available the Joint Nature Conservation Committee (JNCC) and Falklands Conservation (FC) conducted a 'Seabirds at Sea' survey (referred to as the JNCC survey) between February 1998 and January 2001 (*White et al., 2002*). As part of this survey, marine mammals were also observed. In most cases single observers were on board with the remainder being conducted with two observers. All mammals within a 300 metre transect to one side of a survey vessel with known position, speed and heading were counted (as per methods by *Tasker et al., 1984; Webb and Durinck, 1992*).

The JNCC survey programme was conducted throughout the Southwest Atlantic – as far north as 35°S (*Black, 1999*), and south to 65°S east to 28°W (*White and Gillon, 2000*) and west to 70°W (*Gillon et al., 2000*). Over 82% of survey effort was conducted within Falkland Island waters. Analysis of the data by *White et al.* (*2002*) includes all survey effort within a rectangle defined by southwest co-ordinates 56°S 64°W and northeast co-ordinates 47°S 52°W (Figure 5.28). A total of 20, 907 km^2 of survey effort was conducted within the 3-year period (Figure 5.29). Monthly survey effort ranged from as low as 262.2 km^2 to 1278.8 km^2, with little survey effort made in the vicinity of the FOGL blocks in June or August, when survey effort was concentrated predominantly in northwestern regions (Figure 5.29). The survey effort in the south and eastern areas, particularly within the FOGL licence area, is generally low.

Figure 5.28. Total Survey Effort (km 2) between 1998 and 2001 of the 'Seabirds at Sea' Survey, (Source: White et al., 2002)

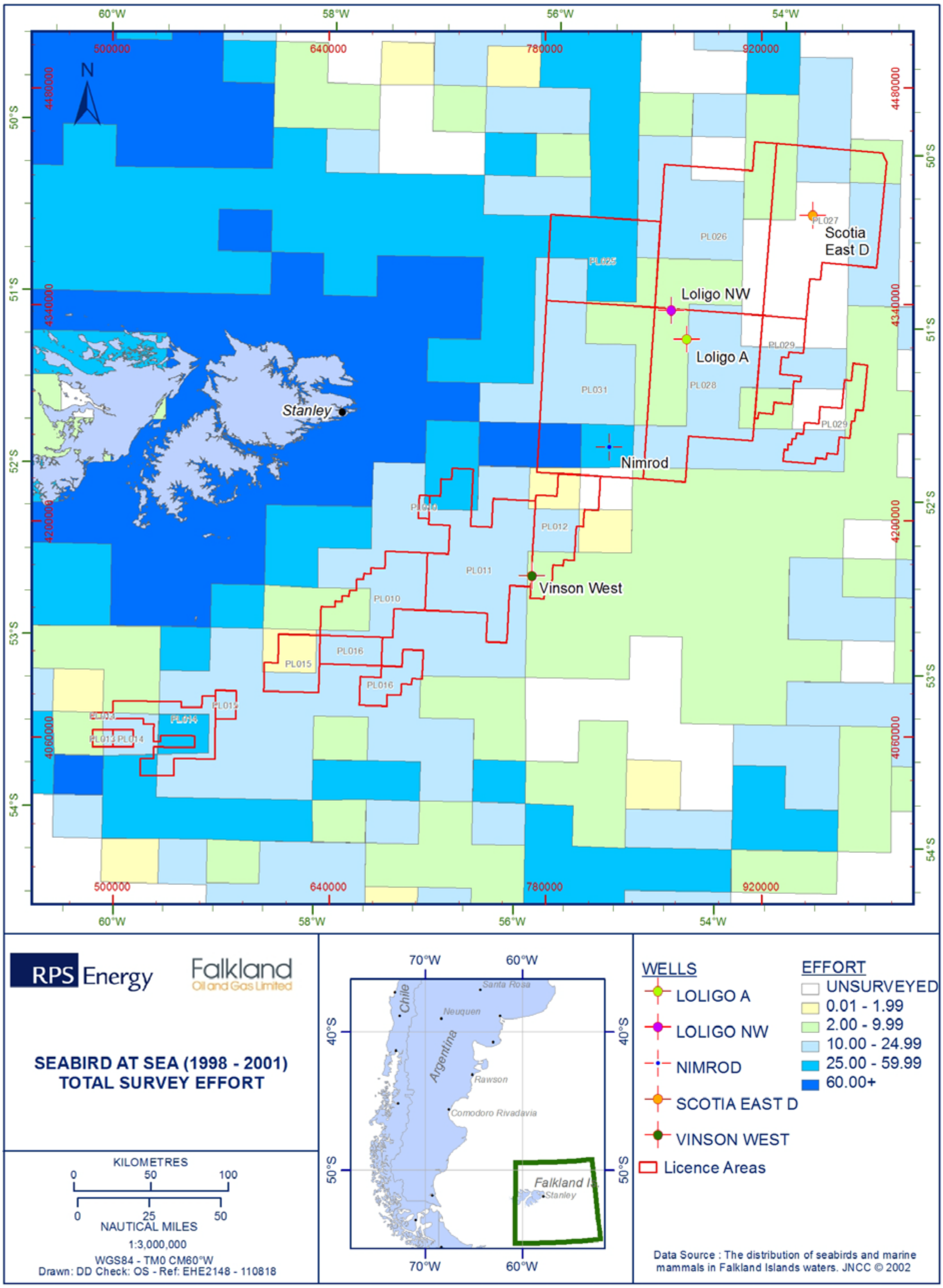
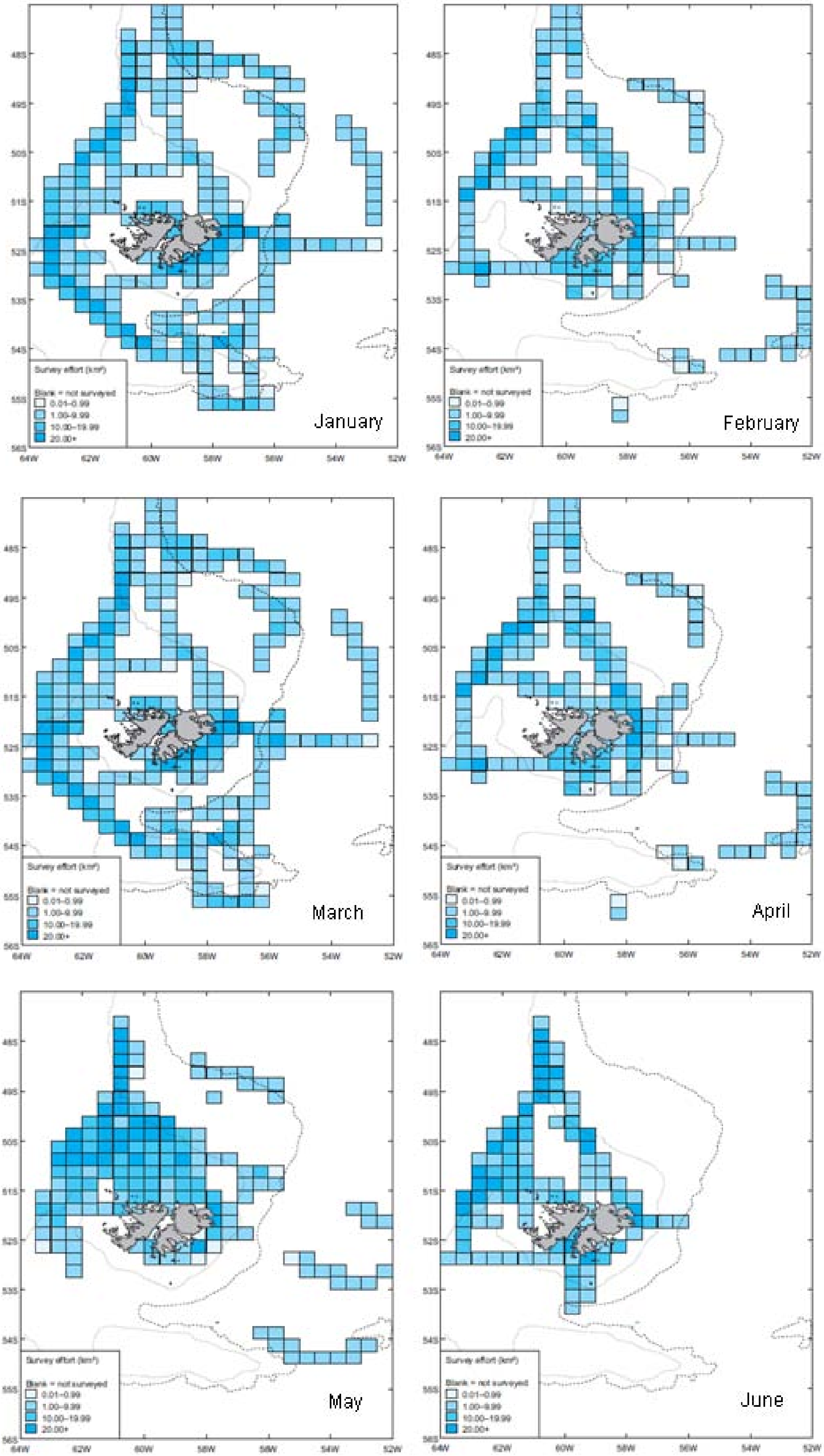
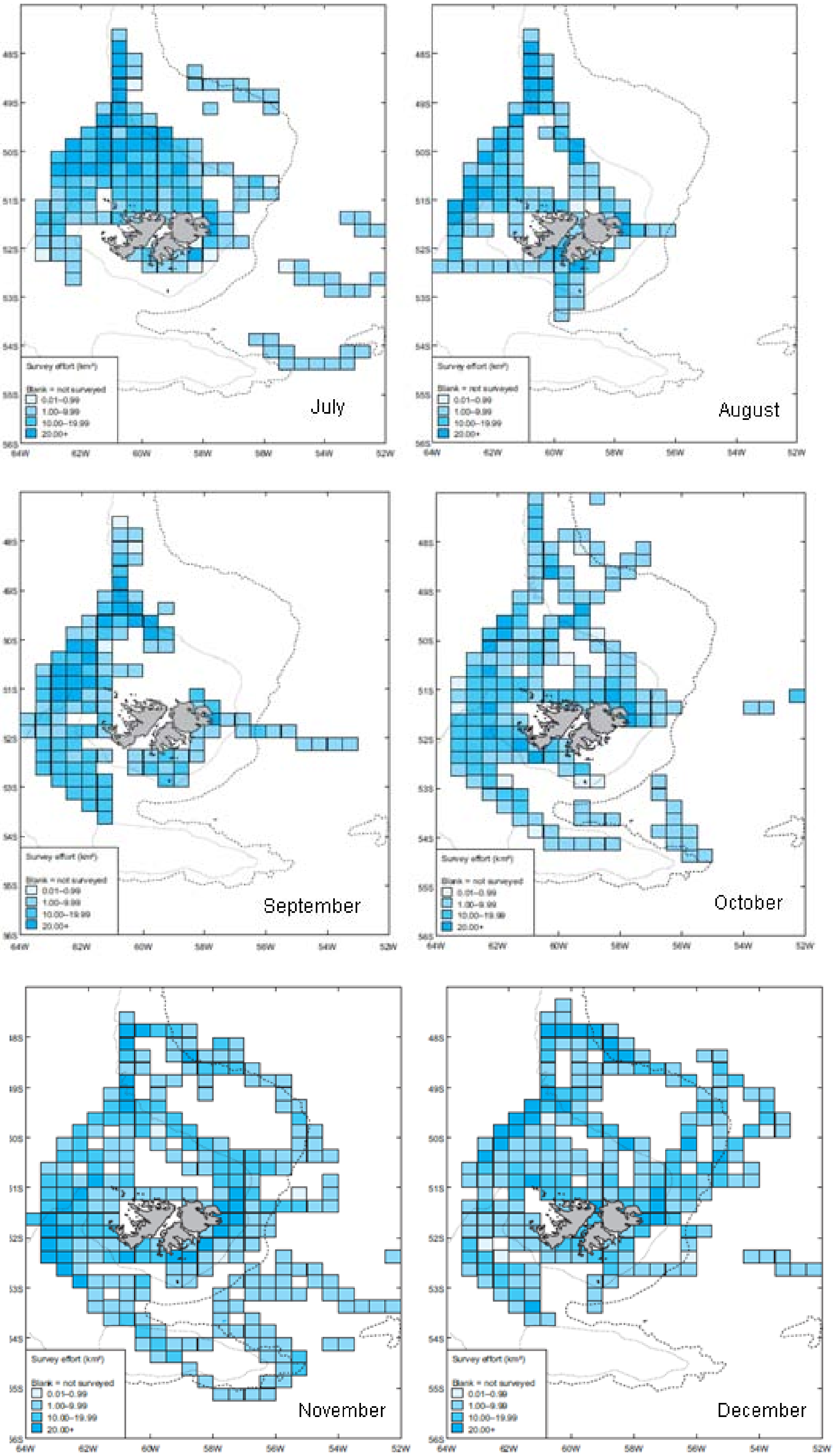


Figure 5.29. Monthly Survey Effort between 1998 and 2001 (km 2) of the 'Seabirds at Sea' survey, (Source: White et al., 2002)




July
August
September
October
November
December
Survey effort (km²)
Blank = not surveyed
0.01–0.99
1.00–9.99
10.00–19.99
20.00+
48S
49S
50S
51S
52S
53S
54S
55S
56S
64W
62W
60W
58W
56W
54W
52W

Other research of cetaceans around the Falkland Islands is limited to a few publications, including published results from the aerial survey of killer whale (*Orcinus orca*) in the region (*Yates and Palavecino, 2006*).

The marine mammal observer data collected on long-line fishing vessels during 2000-2011 was also obtained from the Falkland Islands Fisheries Department (FIFD). The observer effort can be seen in Figure 5.19. Observers on long-line vessels are required to record a 'snapshot' of the birds and marine mammals seen within 500m radius. This data were aggregated by a 0.25° x 0.5° square with the average number of mammals seen per observation period and normalised by the number of stations within each grid square to give average number of mammals within each station within each grid square.

Marine Mammal Observers (MMOs) data are also available from various seismic and site surveys conducted by exploration companies as discussed below. FOGL commissioned MMOs on their site survey and seismic vessels. The most recent observations were carried out between February and June 2011 for offshore areas around Loligo, Inflexible, Vinson West, Hero, Scotia and Blocks 30/31 and 32. Records were also taken along the transit to these sites from Port Stanley. Passive Acoustic Monitoring, using hydrophones to monitor the presence of vocalising marine mammals, was also used during hours of darkness, or during periods of poor visibility.

FOGL employed MMOs during their seismic survey in 2007, as did BHP during site surveys in December 2008 - February 2009 period. (These observations are combined in the relevant Figures and labelled BHP). Survey effort was 12 hours per day while at sea.

Borders and Southern Petroleum Plc (further referred to as B&S) employed MMOs on their survey vessels between October 2007 and February 2008. Survey effort ranged from 14 hours to 50.5 hours per week. Most of the results from November have been discarded for this evaluation due to a poor record of data.

A review of results from the JNCC surveys and MMOs records reveals a seasonal presence for some marine mammals, with several migrating away from the Falklands during Austral winter (May – September) and returning to feed and breed in Austral Summer (November – February). Some marine mammals displayed no clear seasonality and were observed year round.

Limitations of Marine Mammal Surveys

Marine mammal surveys have a number of significant limitations associated with their implementation and interpretation. The Beaufort sea state, wind speed and direction, swell height and direction, rain, fog, and the horizontal and vertical sun angle all have a direct impact on the overall visibility during the survey, and therefore the reliability of data gathered (*WHOI, 2006*). For example, the reflection of light on the sea surface increases glare during the first and final hours of the day, inhibiting sightings of marine mammals.

Variation in visibility may result in a lower number of marine mammals being observed, which may not necessarily be a true indication of the full extent of their presence within the survey area (*Thurman, 1997*). In order to draw more accurate and informed conclusions regarding presence and distribution, the ecology of individual species must also be considered, for example, the fact that some species are more cryptic than others, or the fact that some species may migrate during the year.

Ship or aerial surveys rely on human observers to detect marine mammals, but these records are limited to daylight hours only, and the experience of observers is a very important factor in their detection and correct identification. Moreover, the efficiency of this method is dependent on working conditions on the vessel (e.g. the regularity of breaks) (*Richardson et al., 1995*). In any case, *Richardson et al.* (*1995*) notes that even with conscientious and well trained observers in good weather conditions, it is unlikely that all mammals present will be detected. As a result, surveys such as the 1998 to 2001 at sea surveys (*White et al., 2002*) are often rendered time-consuming, expensive, and largely ineffective if the aforementioned meteorological, oceanographic and ecological variables are not fully considered and incorporated into survey outputs and conclusions (*Leite Parente and Elisabeth de Araújo, 2011*).

Surveys conducted from fishing vessels or during seismic surveys, whilst still valuable for providing information regarding species presence in a data deficient environment, are opportunistic and biased, representing occurrence over a small area at a given time of year. Such surveys cannot then provide reliable information regarding species presence or distribution within the larger area or throughout the year.

In addition, large parts of the south and east Falklands Basins remain unsurveyed, and the level of survey effort in the areas already covered during the 1998 to 2001 at sea surveys (*White et al., 2002*) could be improved upon. The survey is based on just three years of available data, and there is no current assessment of inter-annual variation in the patterns of marine mammal distribution. The data contained in the 1998 to 2001 at sea surveys (*White et al., 2002*) is, however, the most widespread and complete marine mammal dataset for the Falkland Islands at present, on which much of this report is based.

5.3.7.2 Cetaceans

Prior to the 'Seabirds at Sea' Survey in 1998-2001 (referred to as the JNCC survey below; *White et al., 2002*) the knowledge of Falkland Island cetacean fauna was largely based on coastal observations and records of stranded animals. The results of the 1998-2001 survey represent the most recent and systematic research of cetaceans around the Falkland Islands (refer to Figures 5.28 and 5.329. The complementary observer data from long-line fishing vessels is presented in Figure 5.44, as well as exploration companies' MMO records, which are summarised in Figure 5.41

The above data is discussed in the context of each cetacean species accounted in the project area and its vicinity:

Fin Whales (*Balaenoptera physalus*)

IUCN Status: *Endangered*

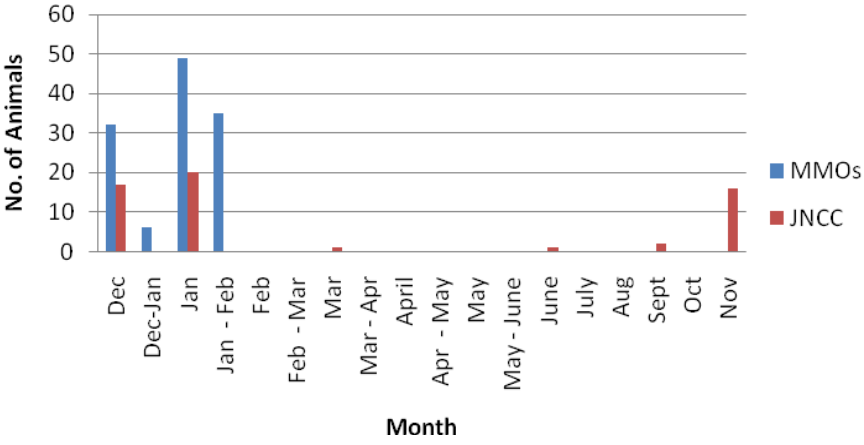
Fin whales migrate to subtropical waters for mating and calving during winter months and to the colder areas of the Antarctic for feeding during summer months (*ACS, 2011*). They tend to travel alone, although have been observed in pods (*Mackintosh, 1966*). Fin whales feed mainly on *euphausiids* and schooling fish.

During the JNCC survey 57 individual whales were recorded on 27 occasions (*White et al., 2002*). Of these over half were to the east of 60°W with several concentrated over the Burdwood Bank to the south of the Falkland Islands. There were also some reported sightings to the northeast and southeast, particularly in the vicinity of the Loligo prospect (Figure 5.42). Group size ranged from one to twelve individuals. A small number of sightings were recorded over the Burdwood Bank. During the study, *B. physalus* was most common between November and January. Very few species were sighted from February to September, and this is partially explained by the fact that fin whales tend to migrate to warmer northern waters during austral winter (*WWF, 2011*). This is also in line with the MMO records, which indicate a high presence of fin whales during austral spring/summer months (Figures 5.47 and 5.49), and no records for austral autumn/winter month (Figure 5.45).

MMOs reported higher numbers of Fin Whales than *White et al.* (*2002*). 122 sightings were recorded overall, mainly between December and February, peaking in January with 49 species. This is in contrast to no observations in February during the JNCC survey. The higher overall count of fin whales, when compared to *White et al.* (*2002*), indicate the importance of increased survey effort in spotting these species. The location of MMO sightings of *B. physalus* was similar to the JNCC survey, with a high abundance around the Loligo sites to the northeast, as well as southern areas. A few whales were also recorded around the Nimrod site.

Observer data from long-line vessels recorded fin whales near Nimrod and Vinson West areas are displayed in Figure 5.44.

Figure 5.30. Annual sightings of Fin whales



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Balaenoptera physalus* throughout the year.

Sei Whales (*Balaenoptera borealis*)

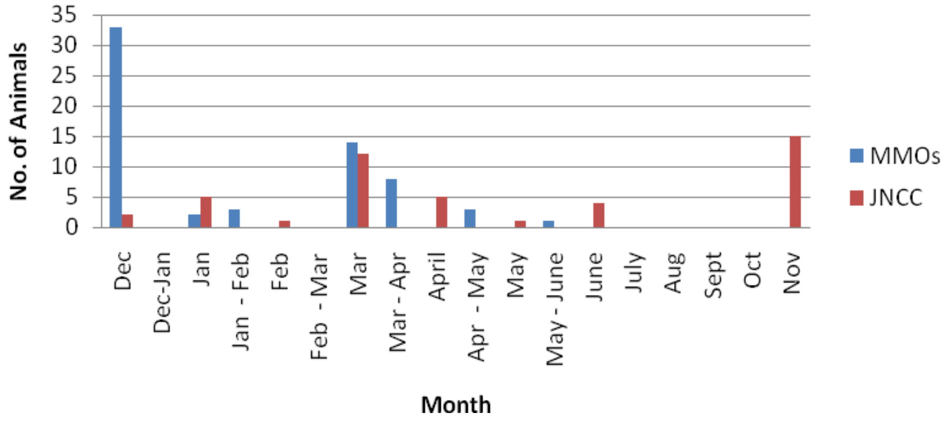
IUCN Status: *Endangered*

Sei Whales occur in the north Atlantic and Pacific, throughout the Southern Hemisphere and occasionally in the Mediterranean (*IUCN, 2011*). Although they have been known to associate with other whales occasionally, Sei Whales are mainly solitary animals. (*ACS, 2011*). During winter months, Sei whales have been recorded migrating to warmer waters (*Bonner, 1986 cited by Otley et al., 2008*). Mating occurs between May and July and calves are born about one year later (*Mizroch et al., 1985*). The diet constitute of *euphausiids*, copepods, and amphipods (*Nemoto and Kawamura, 1977 cited by IUCN, 2011*).

During the JNCC survey, 45 individual whales were recorded on 31 occasions (*White et al., 2002*), predominantly in coastal areas and towards the west and south of the Islands (Figure 5.42). Group size ranged from one to three individuals. Sightings were highest during the austral summer between November and March, peaking at either end of the season (Figure 5.31). The majority of records occurred in the eastern coastal waters, mainly between MacBride Head and the Sea Lion Islands (*White et al., 2002*). Again, this trend may be indicative of reduced survey effort during this time or Sei Whales migrating to and from the survey site over the study period (*Bonner, 1986 cited by Otley et al., 2008*).

MMOs reported 64 sightings overall, peaking in December. Low numbers were recorded in all other months, except for March when 14 individuals were observed. B&S and FOGL/BHP MMOs observed Sei Whales around the Burdwood Bank area (Figures 5.47 and 5.49). In contrast, only few sightings at the Burdwood Bank were made during JNCC survey. FOGL and BHP MMOs also spotted Sei Whales in the area around the northeastern FOGL sites as well as to the east, near the Nimrod and Vinson West well locations (Figures 5.45 and 5.49). No sei whales were sighted from long-line fishing vessels (Figure 5.44).

Figure 5.31. Annual sightings of Sei Whales



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Balaenoptera borealis* throughout the year.

Antarctic Minke Whales (*Balaenoptera bonaerensis*)

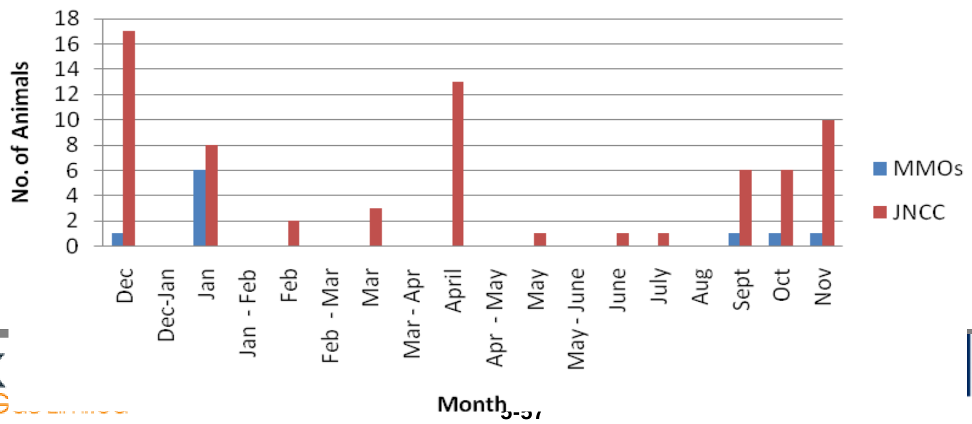
IUCN Status: *Data Deficient*

Antarctic Minke Whales are found in all oceans, except for the Black and Red Seas. They are mainly solitary animals, although have been known to associate with other whales occasionally. Mating occurs during summer with calves being born approximately 11 months later (*ACS, 2011*). *B. bonaerensis*) feed almost exclusively on krill, primarily *Euphausia superba*, but also *E. crystallorophias, E. frigid* and *Thysanoessa macura* (*Tamura and Konishi, 2006 cited by IUCN, 2011*).

During the JNCC survey 68 individual whales were recorded on 60 occasions (*White et al., 2002*). The majority of records occurred between September and April, with only three records outside this period (Figure 5.32). Most minke whales were sighted in Patagonian Shelf waters around east and northwest of the Falkland Islands, although there were records throughout the survey area (Figure 5.42). Minke whales were present in the vicinity of the Loligo prospect and in the southern FOGL blocks.

MMOs recorded only 10 Minke Whales, with a peak record of 6 in January. This contrasts with the numbers recorded during JNCC survey. It is important to note, however, that this is not necessarily indicative of low numbers of *B. bonaerensis*) in the area generally, just that they were not visible on survey days, potentially due to less advantageous weather conditions. This is corroborated by the fact that the only survey to record these whales was the BHP survey which was the most comprehensive. Whales were observed around the southeastern coast of the Falklands, occurring around Vinson West and Nimrod wells (Figure 5.49). This is in agreement with the observer data from long-line fishing vessels, which spotted Minke Whales around the same wells (Figure 5.44).

Figure 5.32. Annual sightings of Antarctic Minke Whales



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Balaenoptera bonaerensis* throughout the year.

Sperm Whale (*Physeter macrocephalus*)

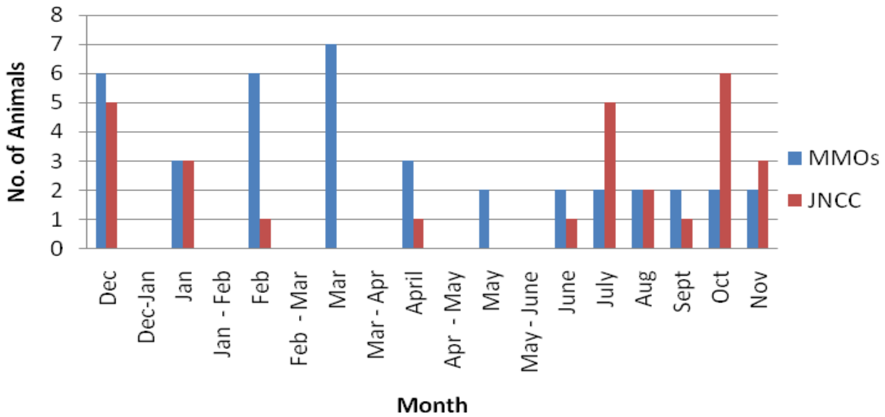
IUCN Status: *Vulnerable*

Sperm whales are thought to be present in all marine waters deeper than 1000 metres that are not covered in ice, except the Black and Red Seas. They tend to feed mainly on medium sized deep water squid. Other food sources include fish, skate, octopus and small squid (*ACS, 2011*). Calving occurs during winter after a gestation period of 12 months (*Mizroch, Rice and Breiwick, 1985*).

During JNCC survey 28 individual whales were recorded on 21 occasions, with group size ranging from one to four animals (*White et al., 2002*). Records occurred in all seasons but there were none in March or May (Figure 5.33). *White et al.* (*2002*) noted that this was likely to be due to low survey effort during these months. Populations appeared to be isolated to two distinct regions; one to the extreme north of the Falklands Outer Conservation Zone (FOCZ) and one to the south over the Burdwood Bank (*White et al., 2002*). Both these regions are used extensively by fisheries so it is likely that this separation is related to this (*Munro, 2004*). These results are mirrored by observations made by *Purves et al., 2004* (cited by *Yates and Brickle, 2007*) who recorded a high density of sperm whales to the south of the Falkland Islands over the Burdwood Bank and to the north of the FOCZ. However their results also showed sperm whales in between these two areas to the east of the Islands. This data is also strongly supported by the sightings from long-line fishing vessels, which recorded a high occurrence of sperm whales to the northeast and south of the islands, but also throughout the deep water fishing area (Figure 5.44). *Yates and Brickle (2007)* also reported that Sperm Whales appear to be present around the Falklands year round. To reach this conclusion, *Yates and Brickle (2007)* combined data from scientific observers and long line fishing vessels.

MMOs reported 39 sightings overall, peaking in March with 7. Between May and June two were also seen. Sightings were only in the Burdwood Bank area (southern FOGL blocks) and to the northeast of the Falkland Islands near the northeastern FOGL sites (Figures 5.45, 5.47 and 5.49).

Figure 5.33. Annual sightings of Sperm whale



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Physeter macrocephalus* throughout the year.

Southern Bottlenose Whales (Hyperoodon planifrons)

IUCN Status: *Least Concern*

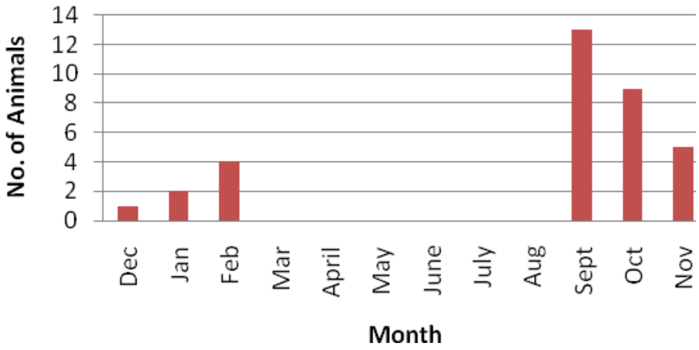
Southern Bottlenose Whales are common in the southern hemisphere beyond the continental shelf and over submarine canyons, typically in waters less than 200 m deep (*IUCN, 2011*). They predominantly eat cephalopods and occasionally fish (*MacLeod et al., 2003 cited by CMS, 2011*). Migration of

Southern bottlenose whales to Antarctic waters during summer has been reported (*Jefferson et al., 1993 cited by CMS, 2011*). During this time *H. planifrons* are commonly seen within 100 km of the Antarctic ice edge (*IUCN, 2011*).

During the JNCC survey 34 individual whales were recorded on 18 occasions, with group size ranging from one to five animals (*White et al., 2002*). All of these sightings occurred between September and February (Figure 5.34) to the east of the Falkland Islands, with many occurring around the FOGL well sites. *White et al.* (*2002*) noted that although a reduction in survey effort in deeper waters during winter may account for this apparent seasonality, it is likely that this is also due to *H. planifrons* migrating to the region in summer and away in winter.

There were no sightings of *H. planifrons* on long-line fishing vessels as well as seismic and site survey vessels by independent MMOs. Again this does not suggest that there are no individuals in the area, just that they were not visible on survey days.

Figure 5.34. Annual sightings of Southern bottlenose whales



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Hyperoodon planifrons* throughout the year.

Long Finned Pilot Whales (Globicephala melas)

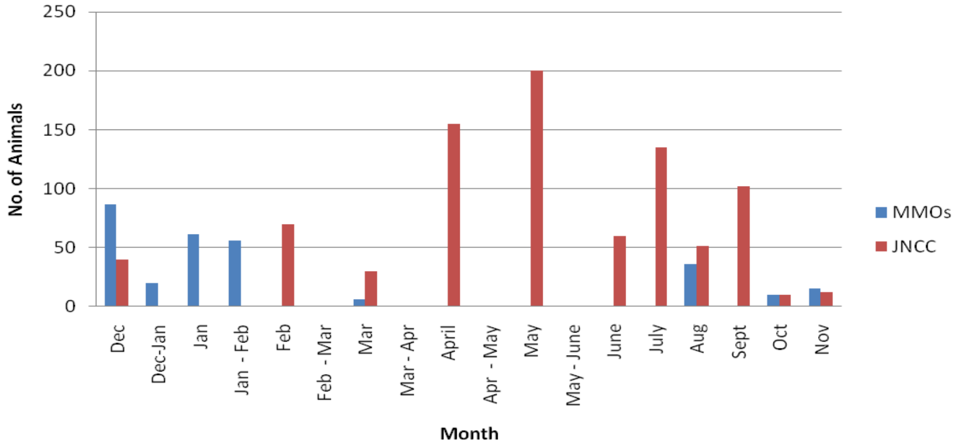
IUCN Status: *Data Deficient*

Long finned pilot whales are mostly found in offshore waters, although they do occasionally appear inshore. Near the Falkland Islands, they have been known to congregate over continental shelf where productivity is high (*CMS, 2011).* *G. melas* is often seen in groups of 20 – 90 individuals. Calving occurs year round, but most female pilot whales give birth during the summer months (ACS*, 2011*). Long finned pilot whales mostly eat squid, but have also been observed eating medium sized fish such as mackerel, cod, turbot, herring hake and dogfish when available (*IUCN, 2010*).

During the JNCC survey 872 individual whales were recorded on 27 occasions, with group size ranging from 2 to 200 animals (*White et al., 2002*). *G. melas* displayed no clear seasonality during this study, with numbers peaking in May (late austral autumn) and none being observed in January (Figure 5.35). *White et al.* (*2002*) note that the relatively high winter abundance is particularly significant against limited survey effort during these months. *G. melas* was observed around the Falkland Islands, displaying no clear preference for coastal or deeper waters. Sightings occurred in the vicinity of the northeastern FOGL sites and near the Burdwood Bank (Figure 5.43).

Long Finned Pilot Whales were the most commonly observed species by MMOs with a total of 292 records, peaking in December with 87 individuals. There were several large sightings of between 30 and 50 individuals during B&S surveys over the Burdwood Bank (Figure 5.45; referred to as Pilot Whales). High numbers of *G. melas* were recorded in the waters around the northeastern FOGL well sites and near Vinson West (Figure 5.47; referred to as Pilot Whales). Observer data from long-line fishing vessels also indicated the presence of *G. melas* to the south of the Falklands, near the Burdwood Bank, and to the east and northeast (Figure 5.43). However, none of these sightings recorded particularly high numbers of pilot whales.

Figure 5.35. Annual sightings of Long finned pilot whales



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Globicephala melas* throughout the year.

Hourglass Dolphins *(Lagenorhynchus cruciger)*

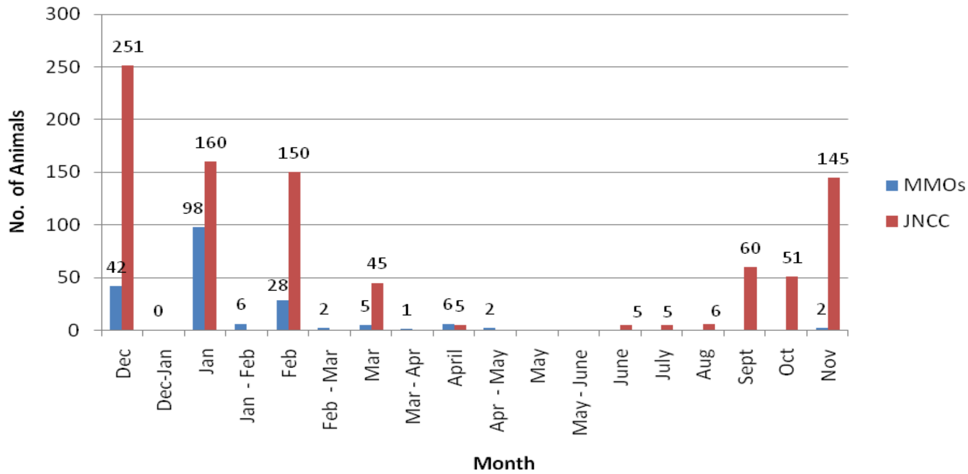
IUCN Status: *Least Concern*

Hourglass dolphins are small, oceanic dolphins that occur in the cold, circumpolar waters of the Sub Antarctic and Antarctic seas. They are usually observed in deep waters far from the coast (*FOGL, 2011*). Diet consists of small fish, squids, and crustaceans (*Goodall, 2002* cited by *IUCN, 2010*). Calving occurs in winter, although the reproductive habits of *L. cruciger* are not immediately clear since mothers are thought to actively avoid research vessels when they are with their young (*marinebio, 2011*).

During the JNCC survey 886 individual dolphins were recorded on 177 occasions to the east, southeast and far north of the Falklands (*White et al., 2002*). The majority of sightings were in waters deeper than 200 metres during the austral spring and summer (September to March). Only six records were taken outside of this time (Figure 5.36). *White et al.* (*2002*) conclude that this is due to seasonality rather than low survey effort during this time. *Munro (2004)* noted that hourglass dolphin numbers in the area may have been underestimated since they are known to be wary of shipping activity. High density of hourglass dolphins was observed around the northeastern FOGL sites (Figure 5.43).

L. cruciger were seen 192 times by independent MMOs, peaking in January with 98 sightings. There were 28 recorded in February and several observed each month between March and May. This may confirm *White et al.'s (2002)* assertion that this species are seasonal. Similar to *White et al.* (*2002*), Hourglass dolphins were spotted to the northeast and eastern offshore areas, within FOGL licence blocks (Figures 5.45, 5.46 and 5.48), but also in the southern area. Observer data from long-line fishing vessels also indicated the presence of *L. cruciger* around the Loligo prospect as well as in the vicinity of the southern FOGL blocks (Figure 5.44).

Figure 5.36. Annual sightings of Hourglass dolphins



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Lagenorhynchus cruciger* throughout the year.

Peale's Dolphins (Lagenorhynchus australis)

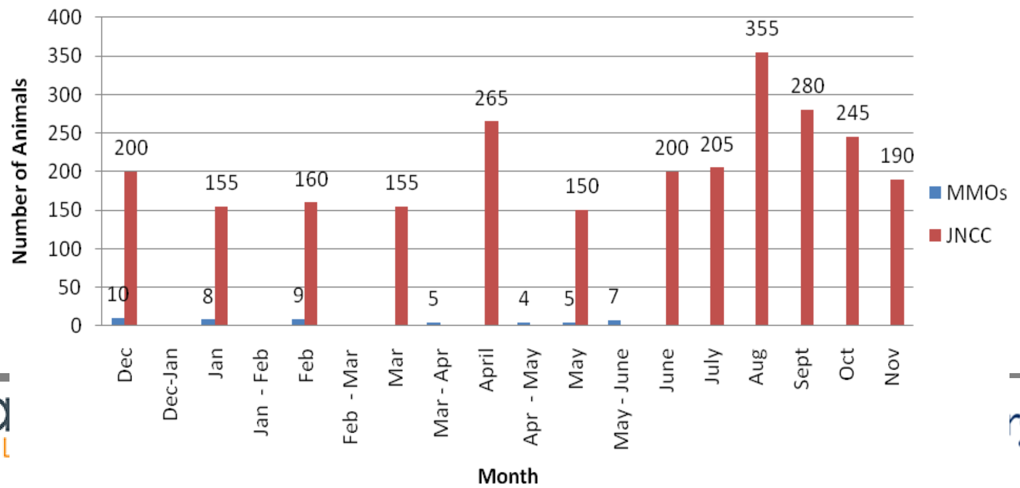
IUCN Status: Data Deficient

Peale's dolphins have been observed in waters deeper than 300 m, but prefer shallower coastal waters and spend most of their time feeding and swimming in kelp forests (*IUCN, 2011*). *L. australis* feed on small cephalopods, crustaceans and bottom dwelling fish. Adults can reach a maximum length of 2.2 metres (*Shirihai and Jarrett, 2009 cited by FOGL, 2011*). Calving occurs from spring to autumn.

L. australis was the most commonly observed species during the JNCC survey, with 2,617 individuals recorded on 864 occasions (*White et al., 2002*). Sightings occurred in every month, peaking in August, (Figure 5.37) and group size ranged from one to fifteen. Although there was a tendency for more sightings in the winter months, *White et al.* (*2002*) observed no clear seasonality. It should also be noted that high sightings in winter are significant despite the reduced survey effort. The particularly high sightings of *L. australis* may be due to their inquisitive nature and tendency to approach vessels to bow ride (*White et al., 2002*). No sightings however occurred in the vicinity of all the FOGL well sites (Figure 5.43).

MMOs only recorded 48 *L. australis* individuals, peaking in December with 10. This is a significant contrast to the numbers recorded during the JNCC survey, and most likely due to predominantly shallower areas of *L. australis* habitats, not surveyed by exploration companies. Deep water sightings occurred to the south, east and northeast of the Falkland Islands (Figures 5.45, 5.46 and 5.48). A few individuals were also spotted around Loligo area from long-line fishing vessels (Figure 5.44).

Figure 5.37. Annual sightings of Peale's dolphins



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Lagenorhynchus australis* throughout the year.

Commerson's Dolphins (*Cephalorhynchus commersonii*)

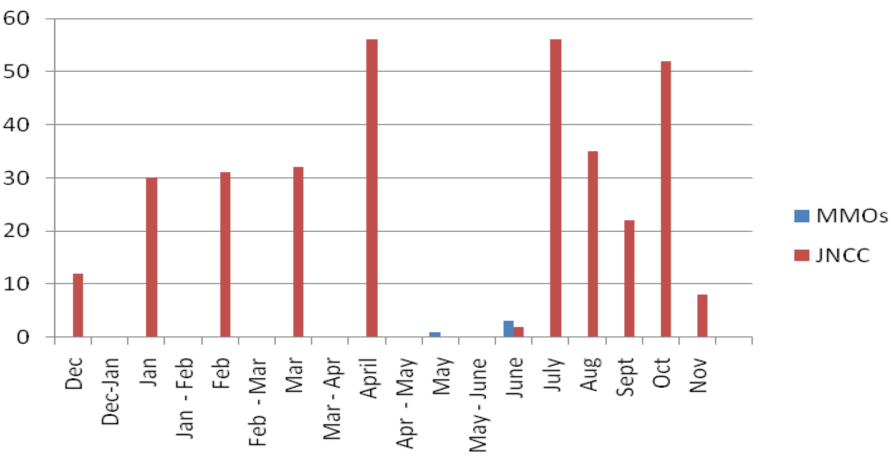
IUCN Status: Data Deficient

Commerson's dolphins are small species, predominantly found in cold inshore waters along open coasts or in sheltered fjords, bays, harbours and river mouths. Around the Falklands they have been sighted at the edge of kelp beds. *C. commersonii* appears to be an opportunistic feeder, targeting various species of fish, cephalopods, crustaceans, and benthic invertebrates in kelp beds. They have also been known to target pelagic schooling fish in more open areas (*IUCN, 2011*). The breeding season of *C. commersonii* is in the austral spring and summer, running from September to February, although little more is known about this (*marinebio., 2011*).

During the JNCC survey, 336 individual dolphins were recorded on 100 occasions (*White et al., 2002*). *C. commersonii* was observed in every month except May and June (Figure 5.38). *White et al. (2002)* speculates that this is likely due to reduced survey effort during these months, as opposed to seasonality by the dolphins. *White et al.* (*2002*) noted that the species have a highly coastal distribution, with 98.8% of sightings occurring within 10 km of the coast and none after 25 km. *White et al.* (*2002*) suggests that owing to the apparent low seasonality of Commerson's dolphins, it is likely that these species are resident around the Falkland Islands. *Otely et al.* (*2008*) and *Munro* (*2004*) corroborate this by noting that *C. commersonii* are generally sighted in waters less than 100 metres deep.

Only 4 *C. commersonii* individuals were spotted by MMOs on two separate occasions during FOGL survey, three of which were near the port of Stanley. This strongly supports the fact that *C. commersonii* are predominantly coastal species. Since *C. commersonii* appears to prefer coastal habitats, it is highly unlikely they will be encountered at any of the FOGL well sites.

Figure 5.38. Annual sightings of Commerson's dolphins



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Cephalorhynchus commersonii* throughout the year.

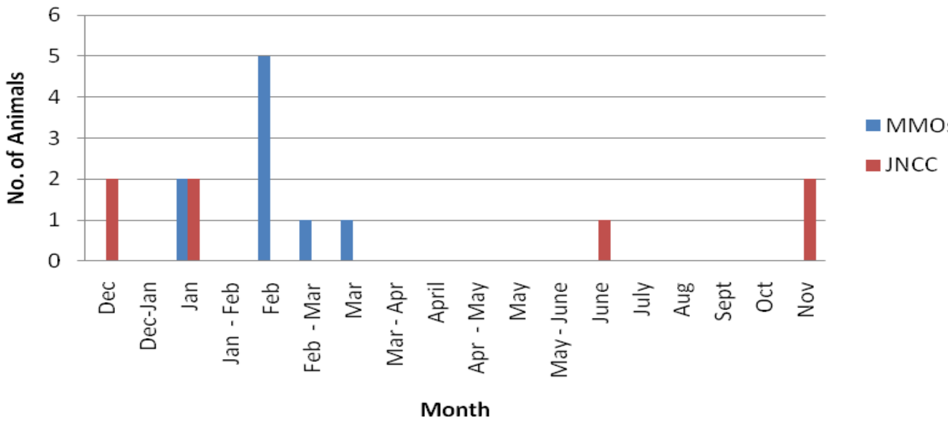
Southern Right Whales (Eubalaena australis)

IUCN Status: Least Concern

Southern right whales have a circumpolar distribution in the Southern Hemisphere. They are migratory, inhabiting colder waters for feeding, then moving to warmer waters for breeding and calving. Females produce calves at 3 – 5 year intervals throughout summer and autumn. *E. australis* are considered as "grazers of the sea", and mainly eat euphausiids and copepods (*IUCN, 2011; ACS, 2011*).

During the JNCC survey only 7 individual whales were recorded (*White et al., 2002*), and 9 sightings by MMOs (Figure 5.39). Several individuals were recorded in the north of Falkland Islands (Figure 5.42) and towards the southeast, within the FOGL licence area (Figures 5.45 and 5.49). The numbers are very low and this is believed to be due to extensive whaling in the 19th century (*Townsend, 1935 cited by Richards, 2011*). *E. australis* are thought to still use this area as winter breeding grounds (*IUCN, 2011*).

Figure 5.39. Annual sightings of Southern right whales



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Eubalaena australis* throughout the year.

Killer Whales (Orcinus orca)

IUCN Status: Data Deficient

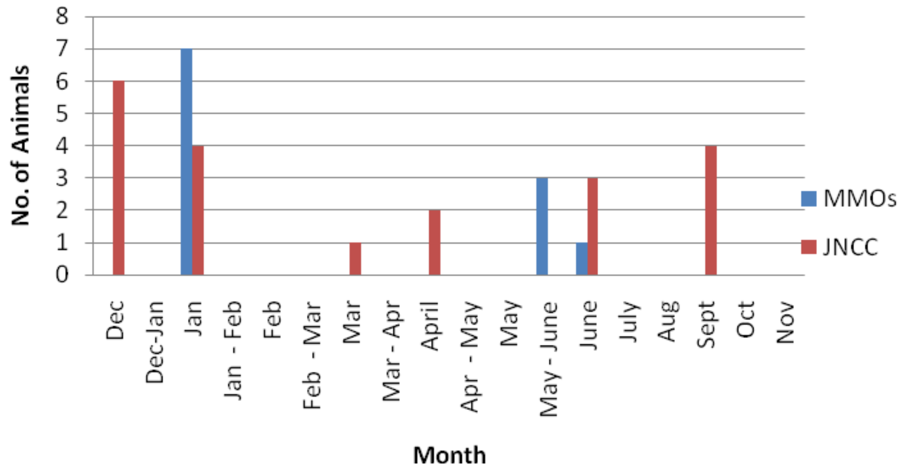
Killer whales are common in coastal regions of high productivity where their prey congregates. This prey includes; sea birds, sea turtles, fish (including sharks and rays), cephalopods and most other marine mammals (*Dahlheim and Heyning 1999; Ford and Ellis 1999; Ford 2002 cited by IUCN, 2011*). Killer Whales have also been spotted in deeper waters (*IUCN, 2011*).

In Falkland Island waters, Killer Whales have been recorded congregating near Sea Lion Island during the breeding times of elephant seals and sea lions on the island, presumably in order to target weaning pups (*Yates and Palavencino, 2006*). Killer Whales around the Falklands also target Minke Whales (*Pitman and Ensor 2003 cited by IUCN, 2011*). Little is known about the reproductive habits of Killer Whales, although since calves have been spotted all year round is assumed that reproduction and calving must occur throughout the year (*ACS, 2011*).

During JNCC survey 18 Killer Whales were sighted, predominantly in coastal and Patagonian Shelf waters throughout the austral summer of 1998 – 1999 (Figure 5.40) (*White et al., 2002*). Independent

MMOs also recorded killer whales around the Burdwood Bank and to the northeast of the Falkland Islands around Scotia East D well (Figures 5.45, 5.46 and 5.48). These findings correspond with *Yates and Palavecino's (2006)* study which recorded a pod of killer whales around the Sea Lion Islands to the south. The observer data from long-line fishing vessels indicate restricted occurrence of Killer Whales to the northeast of the Islands (Figure 5.44).

Figure 5.40. Annual sightings of Killer whales



Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into either the JNCC or MMO survey outputs, and therefore the graph gives only a basic indication of the presence/absence of *Orcinus orca* throughout the year.

Other Cetaceans

Several species were recorded by the independent MMOs that were not encountered by *White et al.* (*2002*). During the BHP survey, MMOs spotted two Bryde's Whales (*Balaenoptera brydei*) in December to the north of the FOCZ. According to the *IUCN* (*2011*) *B. brydei* distribution does not spread any further south than the coastal waters around Brazil, hence these sightings are unusual. One Blue whale (*B. musculus*), categorised as "Endangered" by the *IUCN* (*2011*) was observed during B&S survey in January around the Burdwood Bank. 19 unidentified species of baleen whale were spotted during the BHP and B&S surveys, peaking in February with 15 observations on the BHP survey. One spectacled porpoise (*Phocoena dioptrica*) was spotted in December by BHP MMOs to the northeast of the Falkland Islands near the Loligo well sites. This species is known to inhabit waters around the Falkland Islands but is rarely seen; only a few dozen live sightings have ever been reported (*eoearth, 2011*).

A total of 41 unidentified dolphin species were also spotted during independent MMOs, peaking in December with 19 sightings. These sightings were made to the south of the Falkland Islands over the Burdwood Bank as well as to the southeast and northeast of the Islands. These dolphins were sighted throughout the study period, except for February and March, when none were spotted.

During the JNCC survey twelve humpback whales (*Megaptera novaeangliae*) were recorded (*White et al., 2002*). All were observed between October and March in the Patagonian Shelf waters. 231 Southern right whale dolphins (*Lissodelphis peronii*) were also recorded during the JNCC survey in deep waters to the east of the Falkland Islands. Records of *L. peronii* were taken in September, February, and July. Neither of these species was observed by independent MMOs.

Unidentified whales

During JNCC survey 44 large whales were recorded on 40 occasions (*White et al., 2002*). 18 of these whales were thought to be fin or sei, while the rest were completely unidentifiable. Unidentified whales were spotted around the Falklands in both deep and shallow waters.

MMOs spotted 58 unidentified whales, peaking in January with 13. They were also spotted between December and June, and two were recorded in August and October. The location of sightings was around the Burdwood Bank and to the northeast (Figures 5.45, 5.47 and 5.49). Observers on long-line fishing vessels recorded unidentified whales in the vicinity of Nimrod and Vinson West wells (Figure 5.44).

Figure 5.41. Annual sightings of unidentified whales

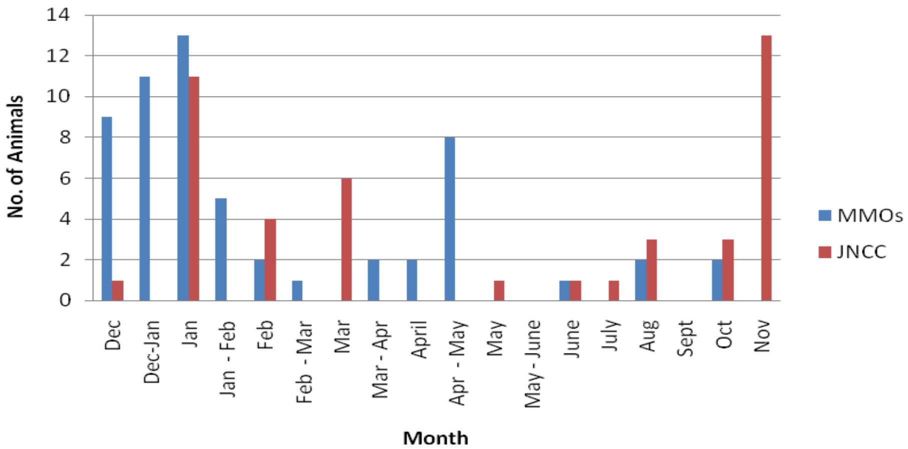


Figure 5.42. Cetacean Sightings during 'Seabirds at Sea' Survey, 1998-2001 (Source: White et al., 2002)

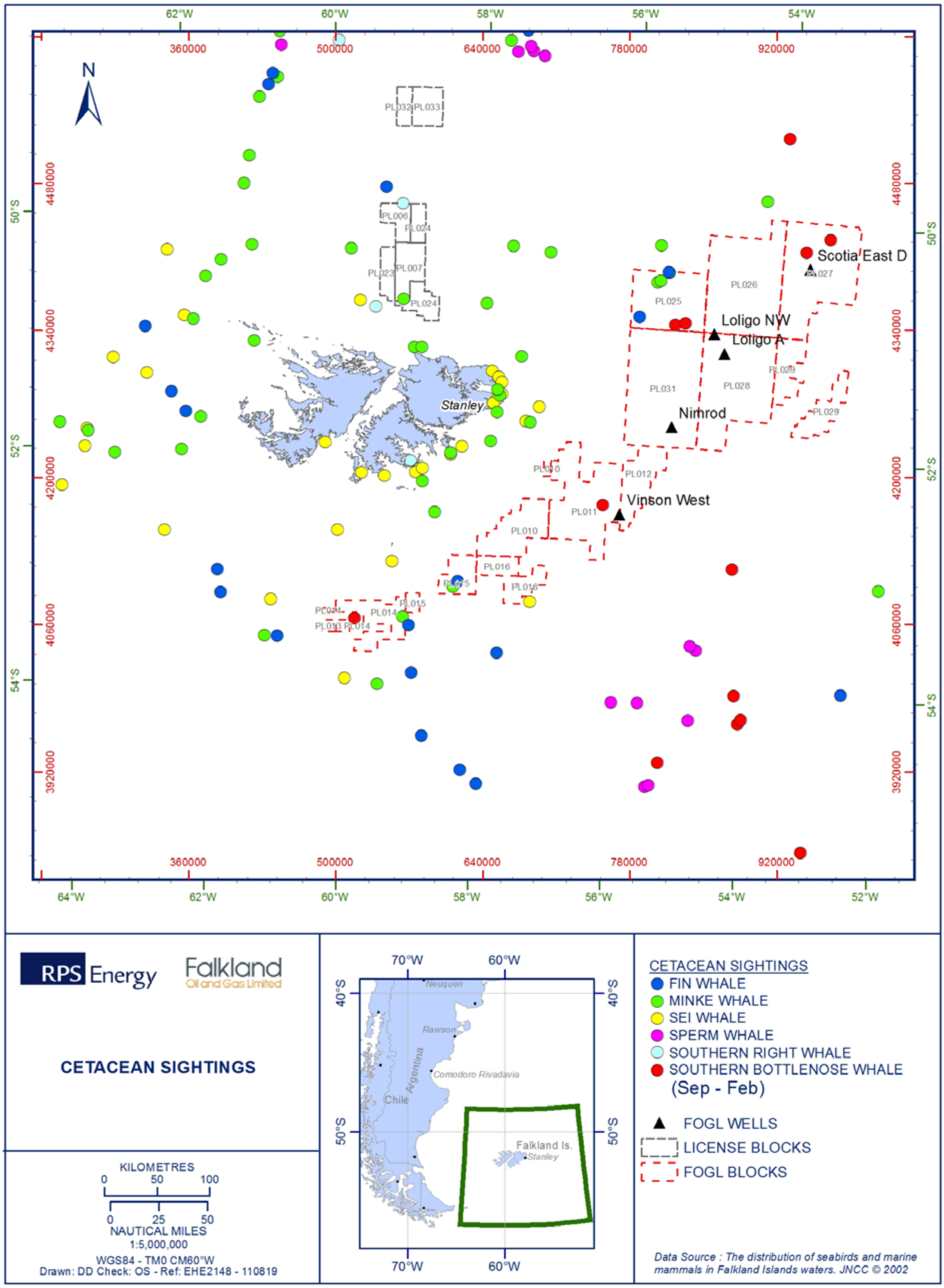


Figure 5.43. Cetacean Density, 'Seabirds at Sea' Survey, 1998-2001 (Source: White et al., 2002)

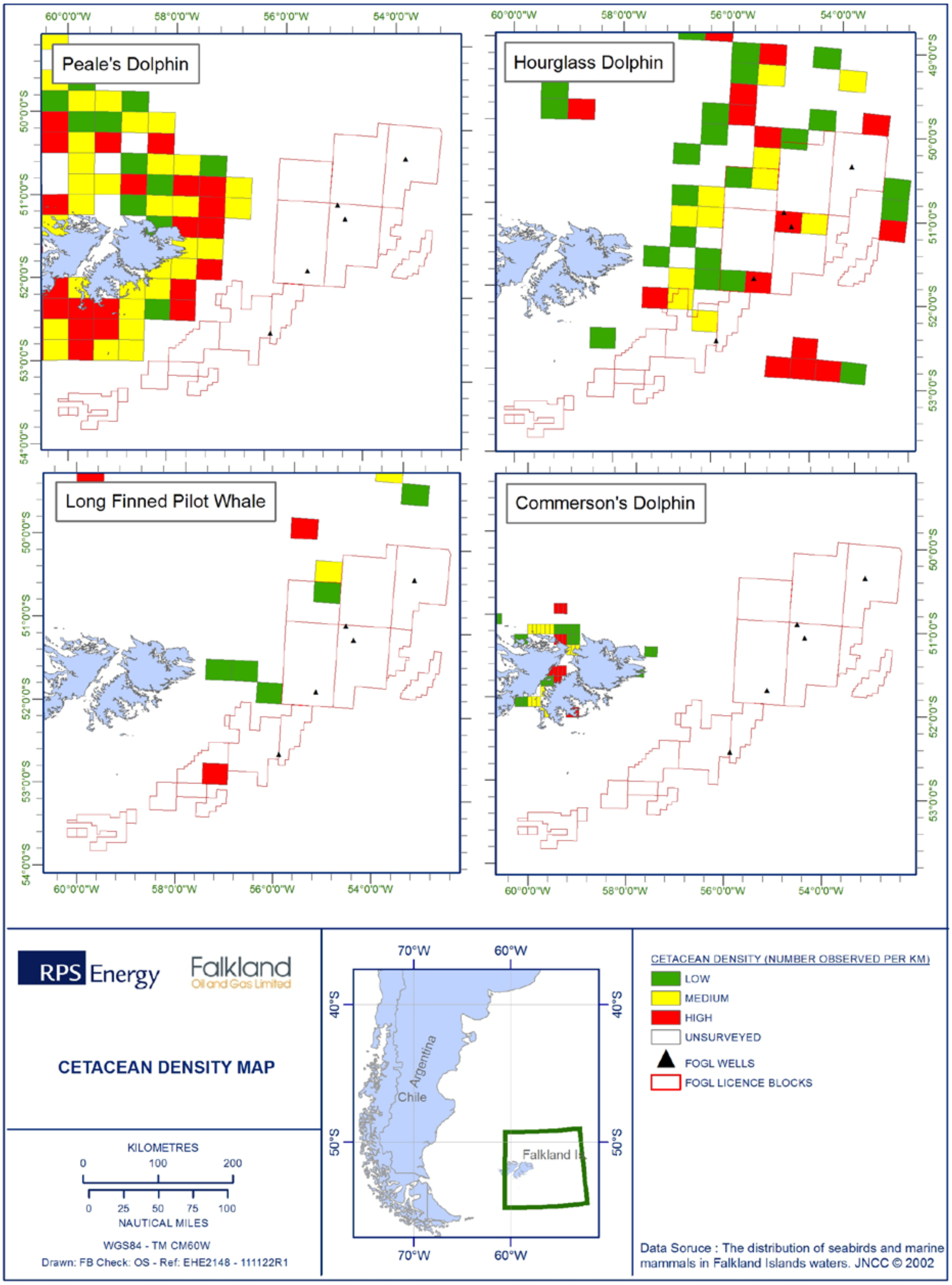


Figure 5.44. Cetacean Sightings on Longline Fishing Vessels (Source: FIFD database, 2000-2011)

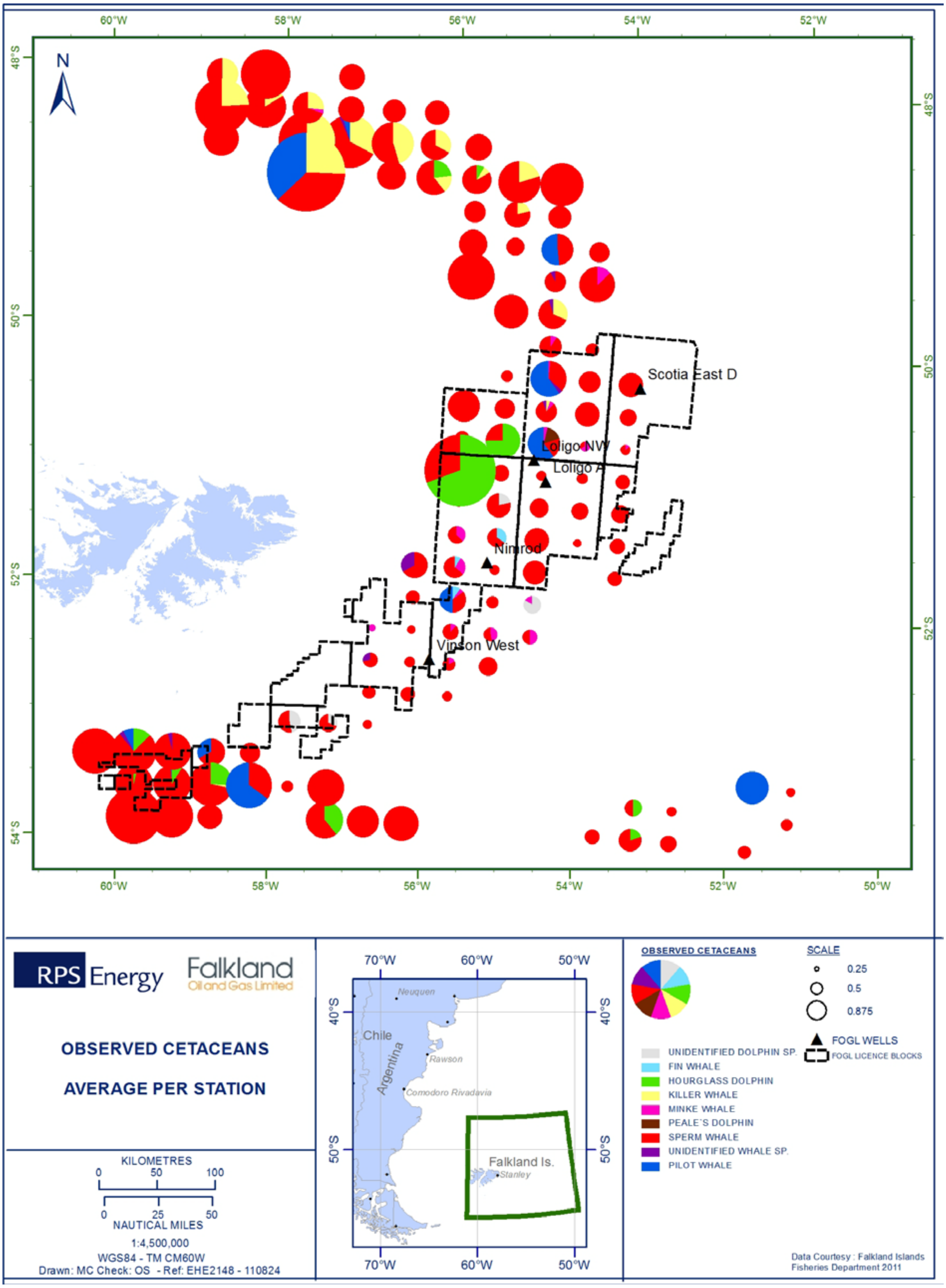
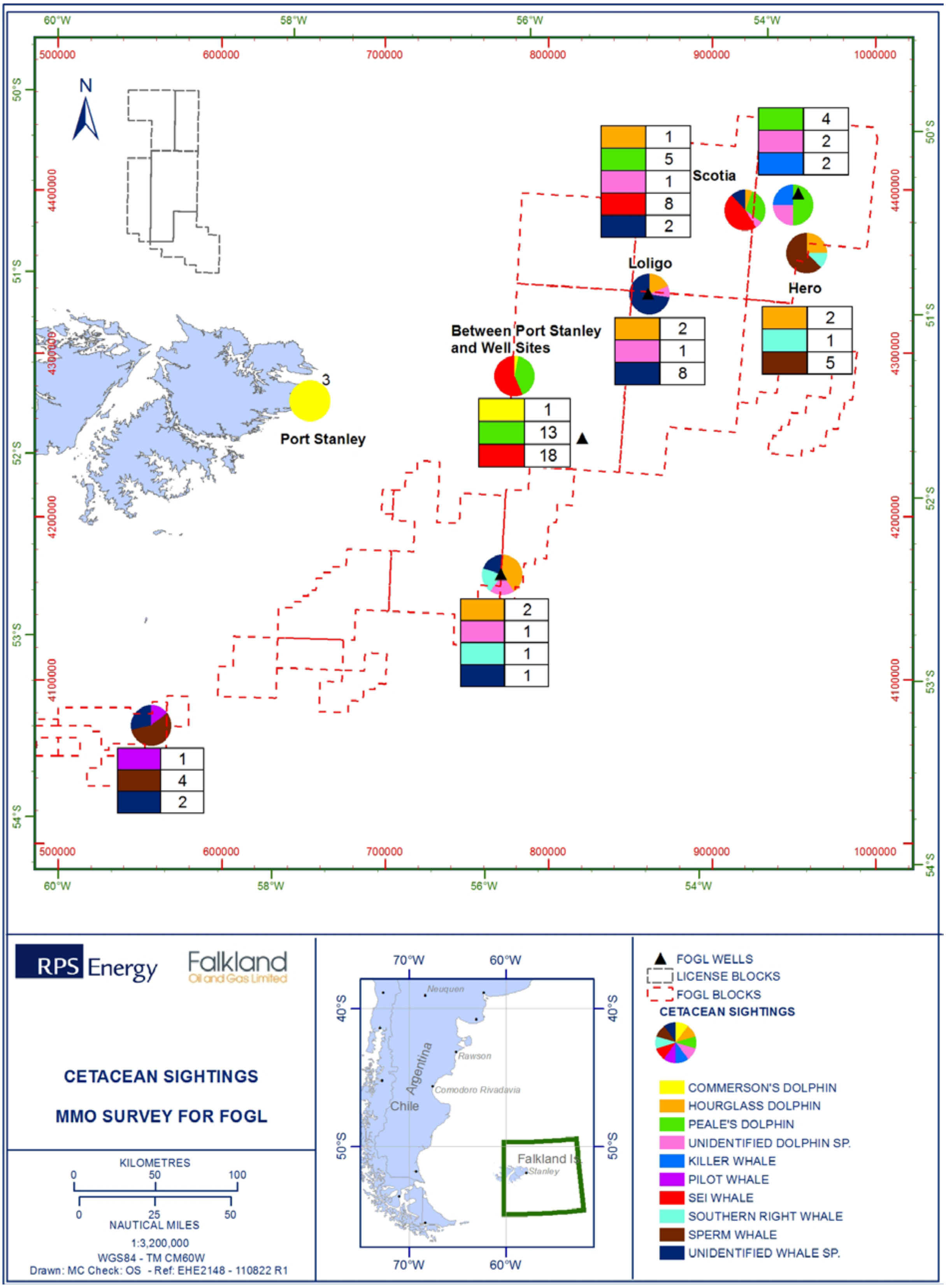
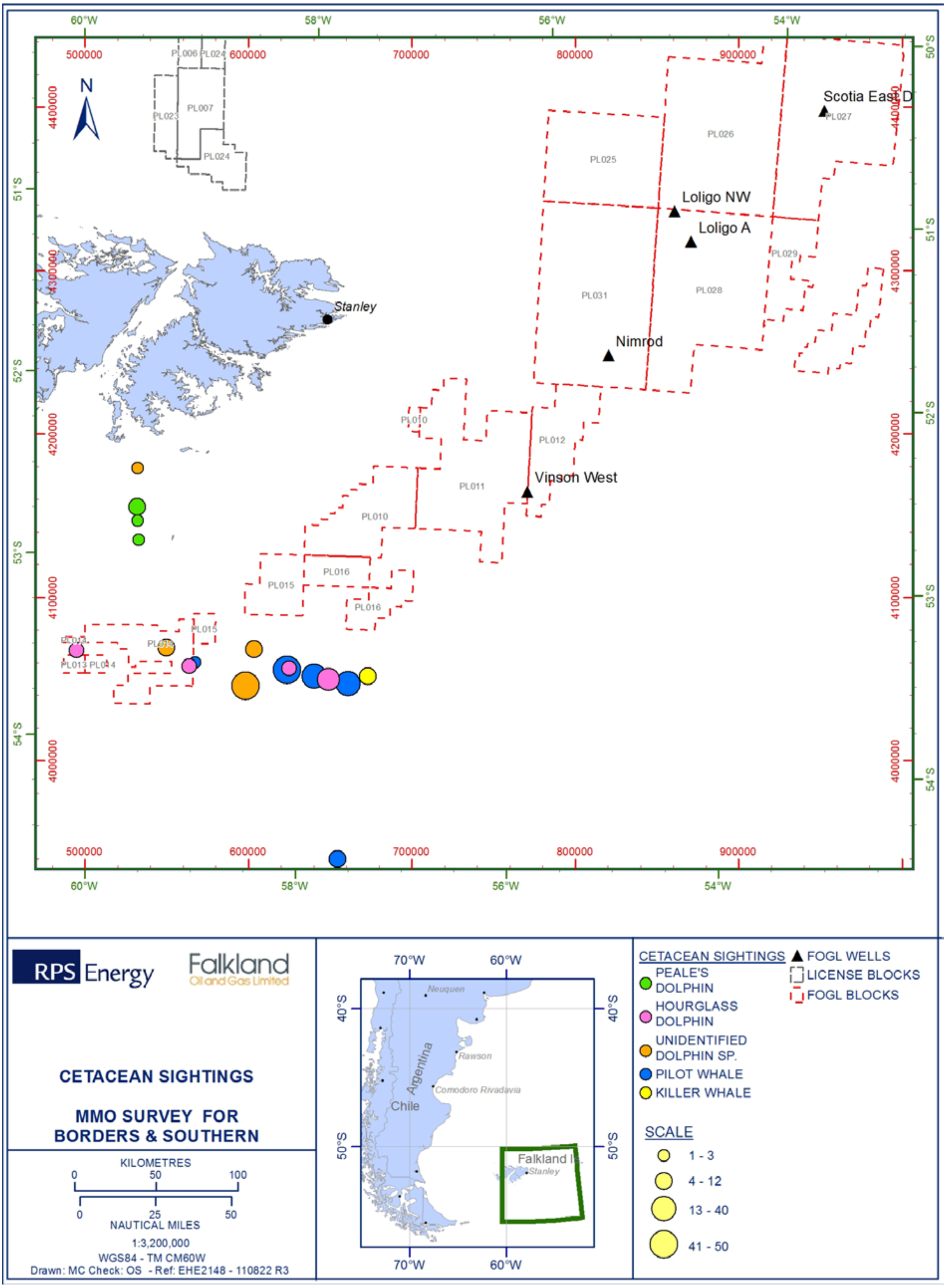


Figure 5.45. Cetaceans Recorded during FOGL surveys (Feb –June 2011)*



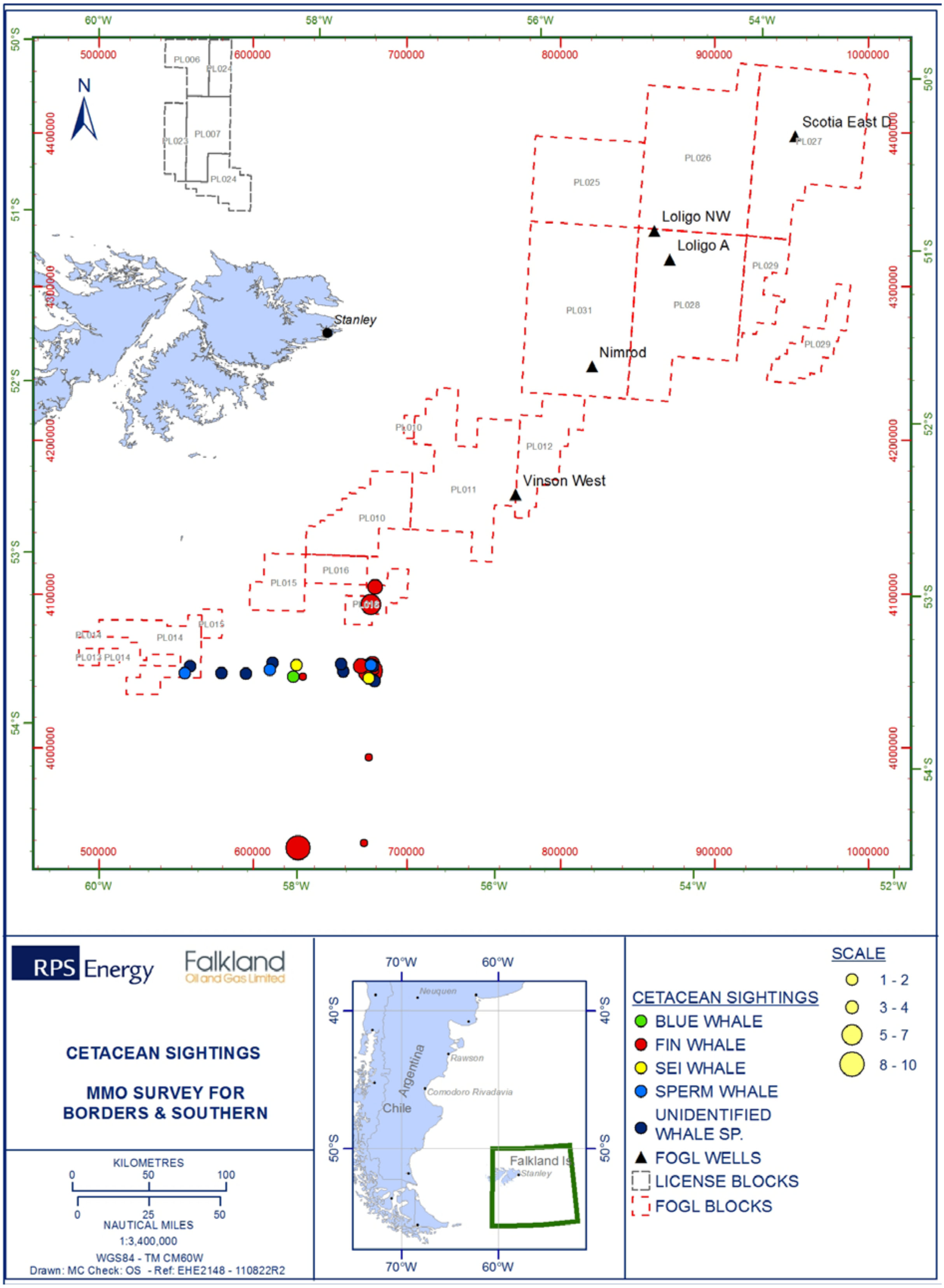
**Please note the different colour coding of the species from the Figures derived from FIFD data*

Figure 5.46. Delphinidae sp. Recorded during B&S Surveys (Oct 2007 –Feb 2008)*



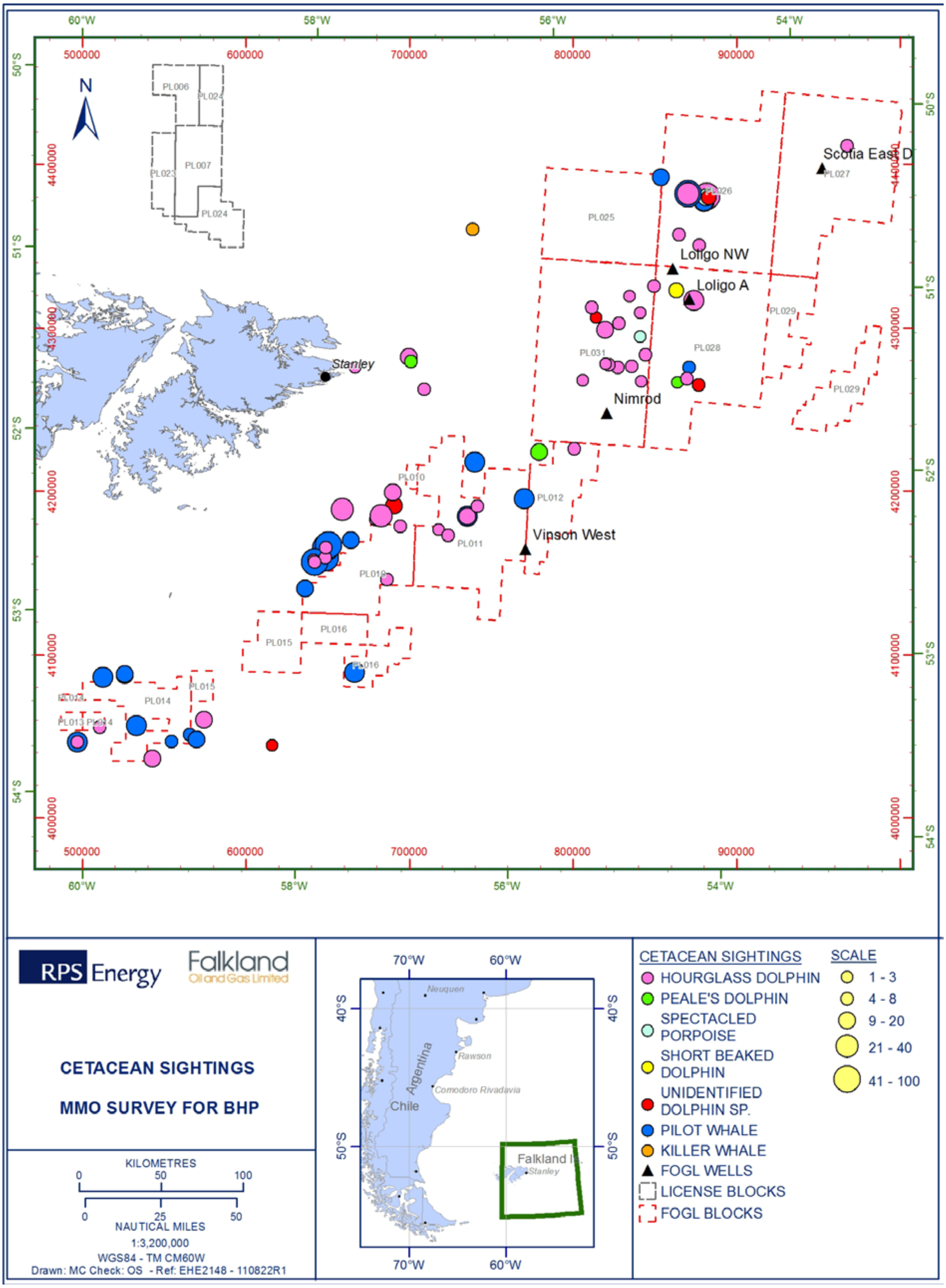
Please note the different colour coding of the species from the Figures derived from FIFD data

Figure 5.47. Whale species recorded during B&S Surveys (Oct 2007 –Feb 2008)*



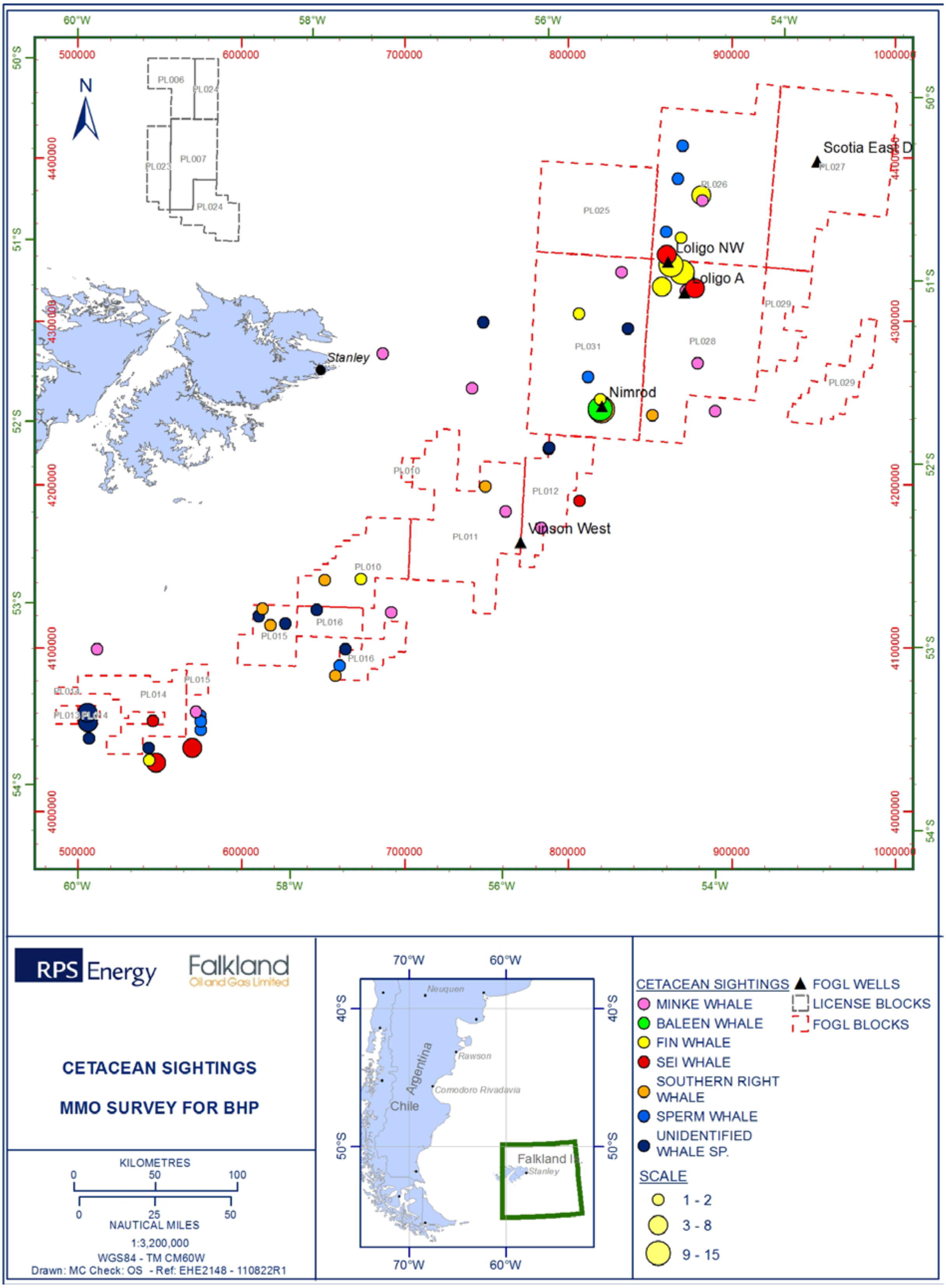
Please note the different colour coding of the species from the Figures derived from FIFD data

Figure 5.48. Delphinidae sp. recorded during FOGL; BHP Surveys (2007; Dec 2008 - Feb 2009)*



*Please note the different colour coding of the species from the Figures derived from FIFD data

Figure 5.49. Whale Species recorded during FOGL; BHP Surveys (2007; Dec 2008 - Feb 2009)*



**Please note the different colour coding of the species from the Figures derived from FIFD data*

5.3.7.3 Pinnipeds

Three species of Pinnipeds, the South American sea lion (*Otaria flavescens*), Southern elephant seal (*Mirounga leonine*), and the South American fur seal (*Arctocephalus australis australis*) breed in Falkland Island waters (*Strange, 1992*). A further two more rare species: Antarctic seals (*Arctocephalus gazella*) and sub-Antarctic fur seals (*Arctocephalus tropicalis*); have been recorded breeding (*D. Thompson pers. comm., in White et al., 2002*). The Leopard Seal (*Hydrurga leptonyx*) has been recorded annually as a non-breeding visitor to the Islands (*White et al., 2002*).

The size of breeding pinniped populations on the Falkland Islands has declined significantly over the past century (*Thompson et al., 2005; Thompson et al., 1998; Galimberti and Sanvito, 2011*). Historically, this is likely to be due to hunting for skins and oil. More recently, it is thought that the decline is due to an increase in human activity such as fisheries, oil exploration and tourism in the area (*Thompson et al., 2005*).

The results of the 'Seabirds at Sea' survey (1998-2001) represent the most recent and systematic research of pinnipeds around the Falkland Islands (Figures 5.53 and 5.54). The complementary observer data from long-line fishing vessels are presented in Figure 5.55, and exploration companies' MMO records are summarised in Figure 5.56 and 5.57.

Little is known about the at-sea distribution of Falkland Island pinnipeds. A recent study by Galimberti and Sanvito observed a swimming course of three southern elephant seals, but this data is yet to be published (*Falklands Conservation Newsletter, 2010*). Prior to this, a South American fur seal tracking programme was conducted in 2000 by *Thompson and Moss* (*2001*). Satellite tracking of southern elephant seals from Patagonia (*Campagna et al., 2007*) and Antarctic Fur Seals from South Georgia into Falkland Island waters was also carried out. In all cases the sample sizes were too small to be conclusive of pinniped distribution trends.

Despite the limited knowledge on the pinnipeds distribution offshore, the above data indicate that their foraging grounds may reach as far offshore as 150-300 kilometres, although species numbers in deep waters are likely to be insignificant.

The above data is discussed in the context of three most common Falklands area pinniped species occurring in the project area and the surrounding region:

***South American Sea Lion** (Otaria flavescens)*

***IUCN Status:** Least*

South American sea lions are found along the continental shelf around South America from the southernmost tip of Brazil to the north of Peru. Their breeding season varies by location and latitude, although at most sites both sexes will begin to arrive in mid-December, with peak numbers occurring in mid January to early February. After a gestation period of 11 months (*IUCN, 2011*), mothers will give birth to pups about 3 days after arriving at the rookery. Following this, a cycle of foraging and pup attendance commences and lasts until the pup is weaned at 8-10 months old. The diet of South American sea lions appears to be opportunistic and is characterised by a wide range of benthic and demersal fish as well as invertebrate species such as cephalopods, gastropods, crustaceans, sponges and tunicates (*IUCN, 2011*). Small cetaceans and seabirds are also part of their diet. Predators include Killer Whales, sharks, and Leopard Seals.

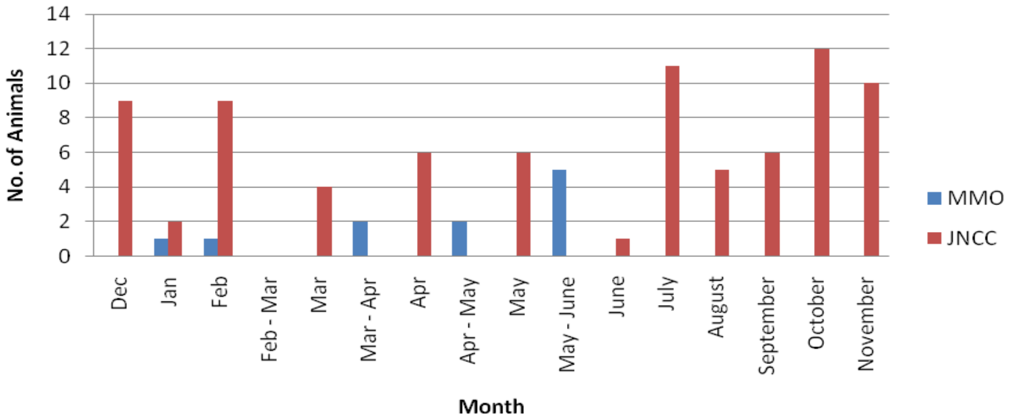
The Falkland Island population of *O. flavescens* has declined dramatically since the 1930s, with pup production falling by around 90% between then and 1965. In 1995 pup production was estimated to be just 2.5% of 1930s levels. In the past the biggest threat to South American sea lions was from hunting for oil and skins. More recently, it is thought that the expansion of fisheries in their foraging grounds has played a more significant role in their decline (*Thompson et al., 2005; Thompson et al., 1998*). Despite the overall decline in the population, *O. flavescens* is the most widely distributed pinniped species on the Falklands, with 93 documented breeding sites. Most of these sites are located on the West coast of the Falkland Islands. However, there are around 15 situated on the east coast of East Falkland.

During the JNCC survey 81 South American sea lions were observed on 77 occasions (*White et al., 2002*). They were recorded in every month, showing no clear seasonality (Figure 5.50). Their distribution was predominantly coastal although some were spotted to the far north of the FOCZ and around the Burdwood Bank (Figure 5.52). The sightings occurred in the vicinity of the Loligo, Vinson West and Nimrod sites. *Thompson et al.* (*2005*) also reported a predominantly coastal distribution of *O. flavescens* during their aerial and boat survey around the Falkland Islands.

In contrast to the JNCC findings, only a few individuals were spotted by the independent MMOs. Two sightings occurred west of the Loligo prospect and one sighting south towards the Burdwood Bank (Figures 5.56 and 5.57). The observer data from long-line fishing vessels also shows occurrence in the southern area (Figure 5.55).

Munro (2004) reports that *O. flavescens* is more active at night during feeding; hence spotting this species is difficult.

Figure 5.50. Annual sightings of South American sea lions



Southern Elephant Seals (Mirounga leonina)

IUCN Status: Least Concern

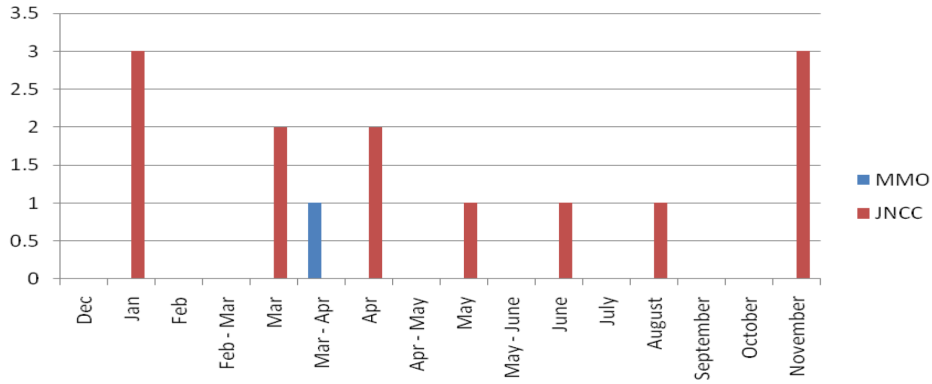
Southern elephant seals have an almost circumpolar distribution in the Southern Hemisphere. They predominantly reside around the sub-Antarctic islands near the Antarctic Polar Front (*IUCN, 2011*). Sea Lion Islands, in the southeastern waters of the Falklands, is home to the only notable breeding colony of southern elephant seals in the Falklands. Although breeding does occur elsewhere, it is extremely limited. Most of the seals' time is spent at sea with individuals only returning to shore to mate, give birth, and moult (Galimberti *and Sanvito, 2011a*). Whilst at sea, solitary *M. leonine* individuals travel thousands of miles and can dive to depths of 500 metres for between 20 and 30 minutes (*IUCN, 2011; Galimberti and Sanvito, 2011b*). All foraging is done at sea, with prey consisting mainly of cephalopods and fish. As generalist feeders, their diet changes seasonally. (*Campagna et al., 2007*). Predators of *M. leonine* include Killer Whales and, in lower latitudes, large sharks (*IUCN, 2011*).

Every year between September - November about 550 female southern elephant seals arrive on Sea Lion Island to give birth to a single pup. After giving birth, the female suckles her pup for about 23 days, mates again and leaves the island (*Galimberti and Sanvito, 2011a*).

Similar to the South American sea lion, the population of the southern elephant seals has also declined due to hunting. Numbers appear to be recovering, although due to the relative isolation of the seals on Sea Lion Island, this population is still extremely susceptible to disturbance (*Galimberti and Sanvito, 2011a*).

During JNCC survey 13 southern elephant seals were recorded to the northwest and northeast of the Falkland Islands (Figure 5.53). Only one seal was spotted by MMOs between March and April 2011 (Figure 5.51) to the northeast of the Islands at the Scotia site (Figure 5.56). Although these sightings were not near Sea Lion Island, it is likely that the animals were members of the Sea Lion Island population. Galimberti and Sanvito also observed several females making large trips to and from Sea Lion Islands as part of their normal routine (*Falklands Conservation Newsletter, 2010; Galimberti and Sanvito, 2011b*).

Figure 5.51. Annual sightings of southern elephant seals



Elephant Seals of the Sea Lion Island Research Project

Between 1995 and 2010, long term research on the population of southern elephant seals at Sea Lion Island was carried out by the Elephant Seal Research Group (ESRG) (*Galimberti and Sanvito, 2011a*). Sea Lion Island shelters the only notable breeding colony of the species in the Falkland Islands, with approximately 550 breeding females. Major analysis of the collected field data is currently ongoing, the bulk of which is laboratory based, and includes studies on genetics, hormones, pathogens, haematology and blood chemistry, and stable isotope analysis (*Galimberti and Sanvito, 2011a*).

Of particular interest is the initial analysis of the satellite tracking data. The tracking maps from the Sea Lion Island animals show that offshore foraging distances are relatively short and are focused around some concentrated feeding areas. This contrasts markedly with data from elephant seal populations from similar studies in South Georgia and the Valdez Peninsula in Argentina. Maps of tracking data from these studies show that large areas of ocean are covered by individuals, with tracks stretching far out into the Atlantic Ocean, often covering hundreds of miles (*Falklands Conservation, 2010*). However, very few individuals travelled much further. In 2009, two of the five tracked females travelled far from Sea Lion Island, foraging over long loops with tracks very similar to those travelled by the South Georgia females. In 2010, one of the four year old tracked females roamed widely, with an additional two also roaming for long distances before stopping to forage in smaller areas (*Falklands Conservation, 2010*). This data suggests that individual elephant seals could be sighted in the vicinity of FOGL wells whilst undertaking a long foraging trip, although these would likely be rare occasions due to the large areas covered by the individuals relative the probable time spent at any specific location.

The ongoing studies by the ESRG will no doubt provide highly valuable information on the population of southern elephant seals at Sea Lion Island, and will also provide useful indicators of their foraging behaviour offshore.

South American Fur Seal (Arctocephalus australis)

IUCN Status: *Least Concern*

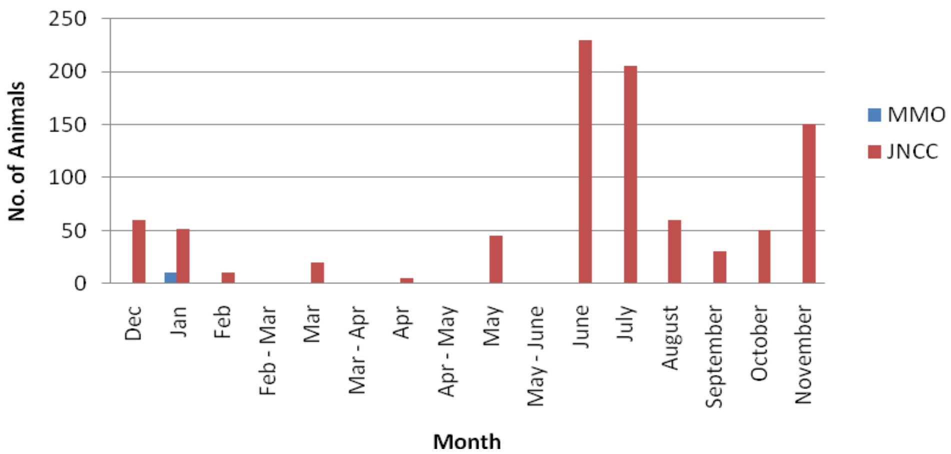
South American fur seals have an almost circumpolar distribution in the Southern Hemisphere and are most commonly found to the north of seasonally shifting pack ice. They are also found in high numbers in Argentina and there is one colony in the Falkland Islands (*IUCN, 2011*). A population of around 16,000 has been estimated around the Falklands. Pups are born between mid-October and mid-January, depending on location. When the pups are around 1 week old, the mother will mate again then begin a feeding cycle whereby she will go to sea for 3 – 5 days and return to land to nurse her pup for 1 – 2 days. Weaning begins at 8 months. When at-sea, South American fur seals have been spotted travelling at the surface in groups (*IUCN, 2011*). Their prey includes sardines, mackerel, hakes, and euphausiids.

There are few breeding sites of *A. australis* on the Falkland Islands. Most of these are located on the west coast of Falkland Islands. The closest one to the FOGL development is at Volunteer Point, on the northeastern tip of East Falkland.

During JNCC survey a total of 937 fur seals were recorded in all months, with a peak in June, July and November. *White et al.* (*2002)* suggest that the peak observed in June and July was a result of large numbers being recorded in coastal and Patagonian Shelf waters. This is confirmed by *Otley et al.* (*2008*) who report that during winter non-breeding individuals tend to remain in the Falkland Islands around breeding sites. Offshore distribution density is much lower between February and October compared to November-January months (Figure 5.54).

14 South American fur seals were recorded overall by MMOs during FOGL and BHP surveys (Figures 5.56 and 5.57). Records peaked in January at 10. One was observed every other month between December and March. These limited observations were to the south, southeast at Vinson West and to the east of the Falkland Islands, near the Loligo and Nimrod wells.

Figure 5.52. Annual sightings of South American fur seal



Leopard Seal (Hydrurga leptonyx)

The Leopard seal is a winter visitor to the Falkland Islands, with only occasional sightings reported. They are known to breed on sub-Antarctic pack ice. Their diet consists of warm blooded animals such as the crabeater seal (*Lobodon carcinophaga*) and fur seals (*IUCN, 2011*). Due to their occasional sightings they are highly unlikely to be sighted during the development project.

Figure 5.53. Pinniped Sightings During 'Seabirds at Sea' Survey, 1998-2001 (Source: White et al., 2002)

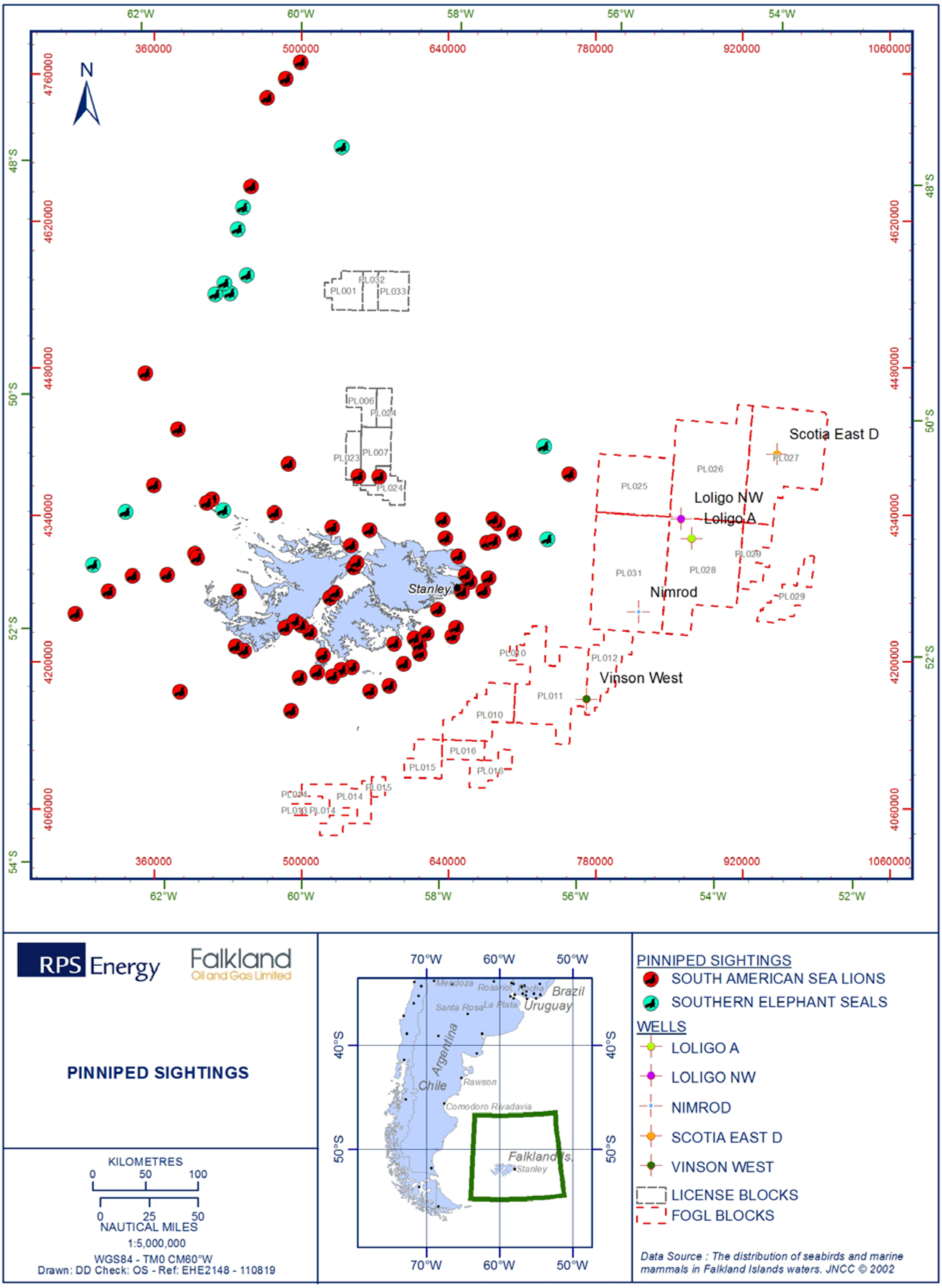


Figure 5.54. Pinniped Density Recorded During 'Seabirds at Sea' Survey, 1998-2001 (White et al., 2002)

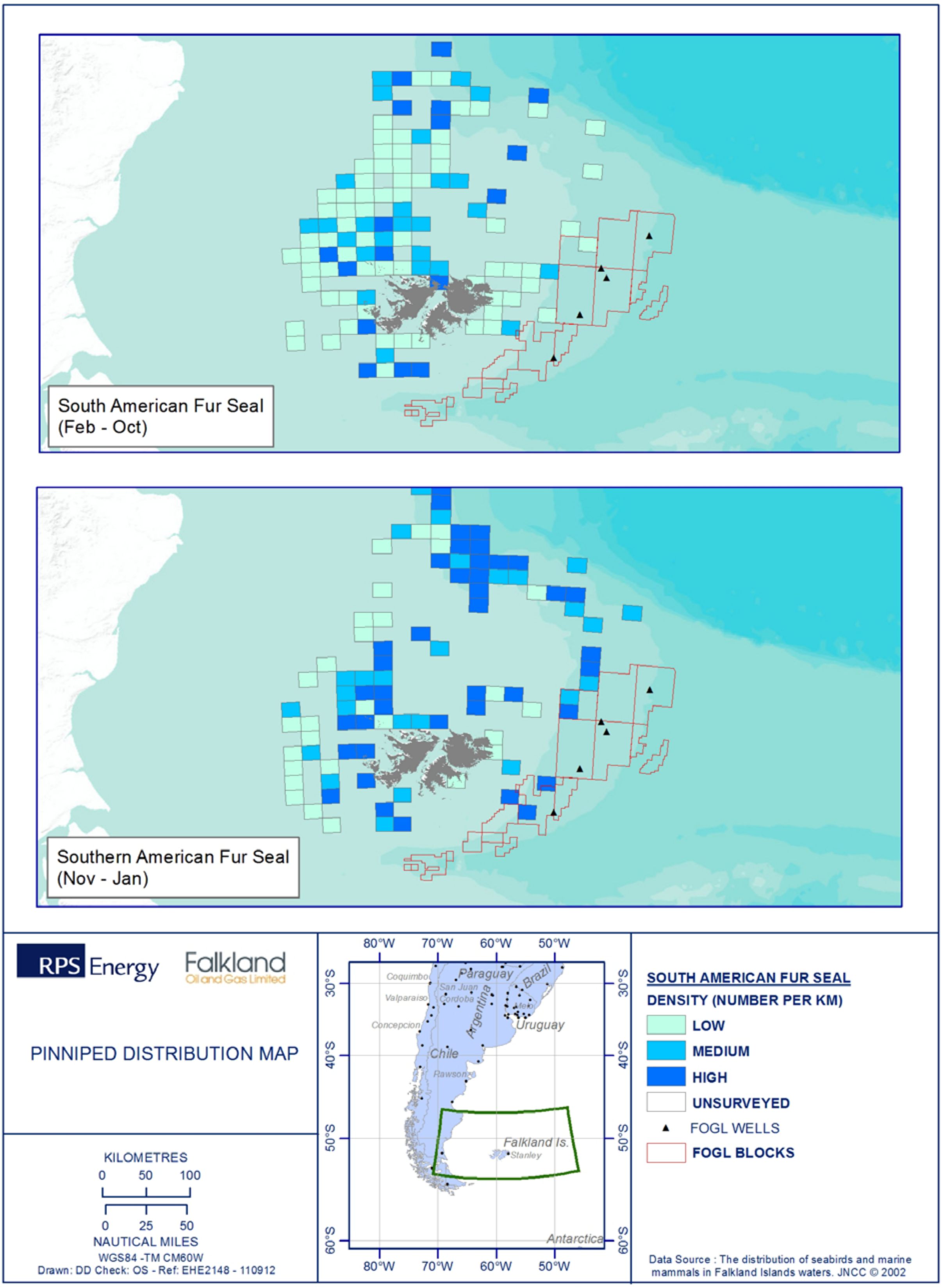


Figure 5.55. Pinniped Sightings on Long-line Fishing Vessels (FIFD database, 2000-2011)

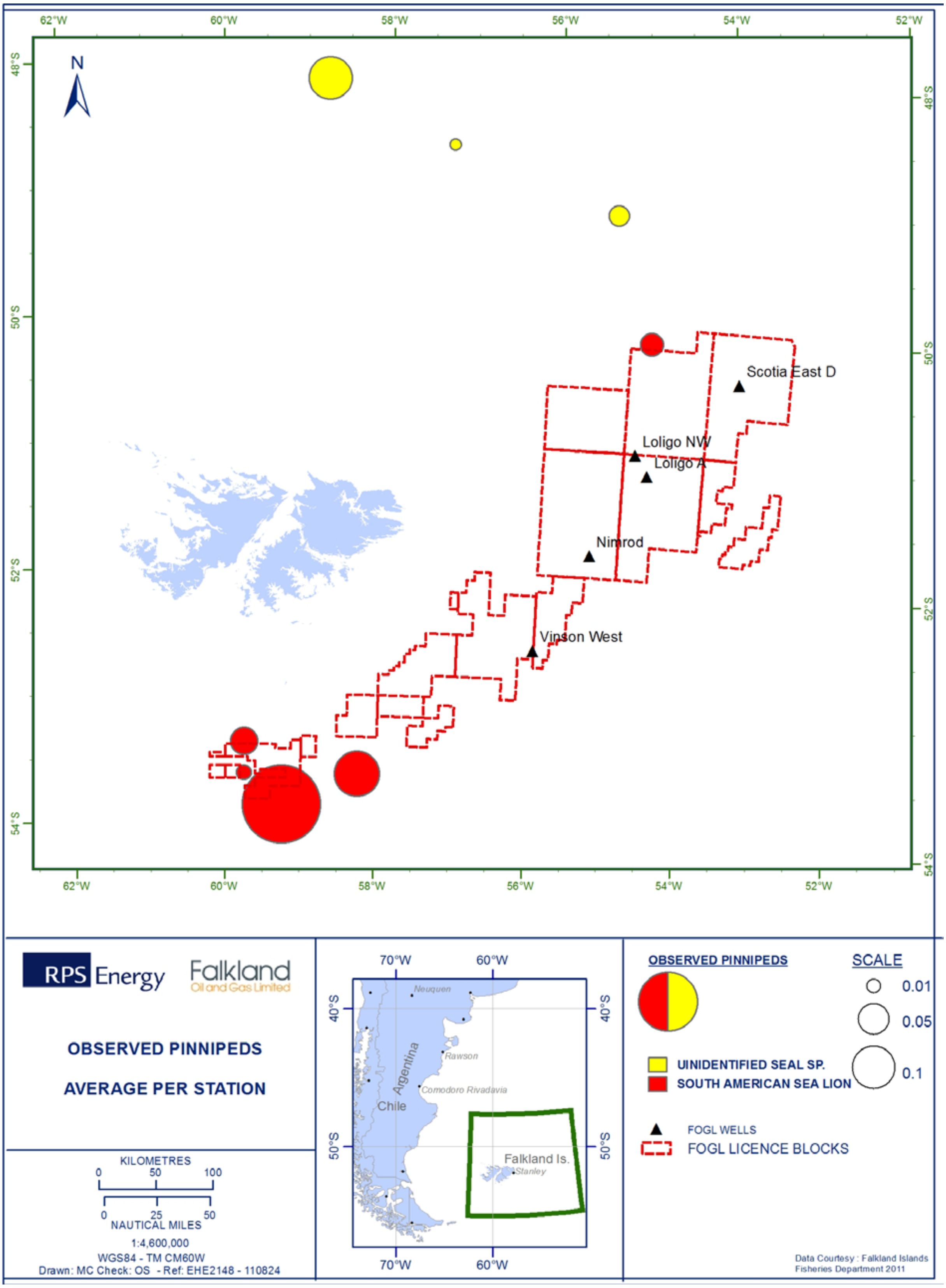


Figure 5.56. Pinniped sightings during the FOGL surveys (Feb –June 2011)

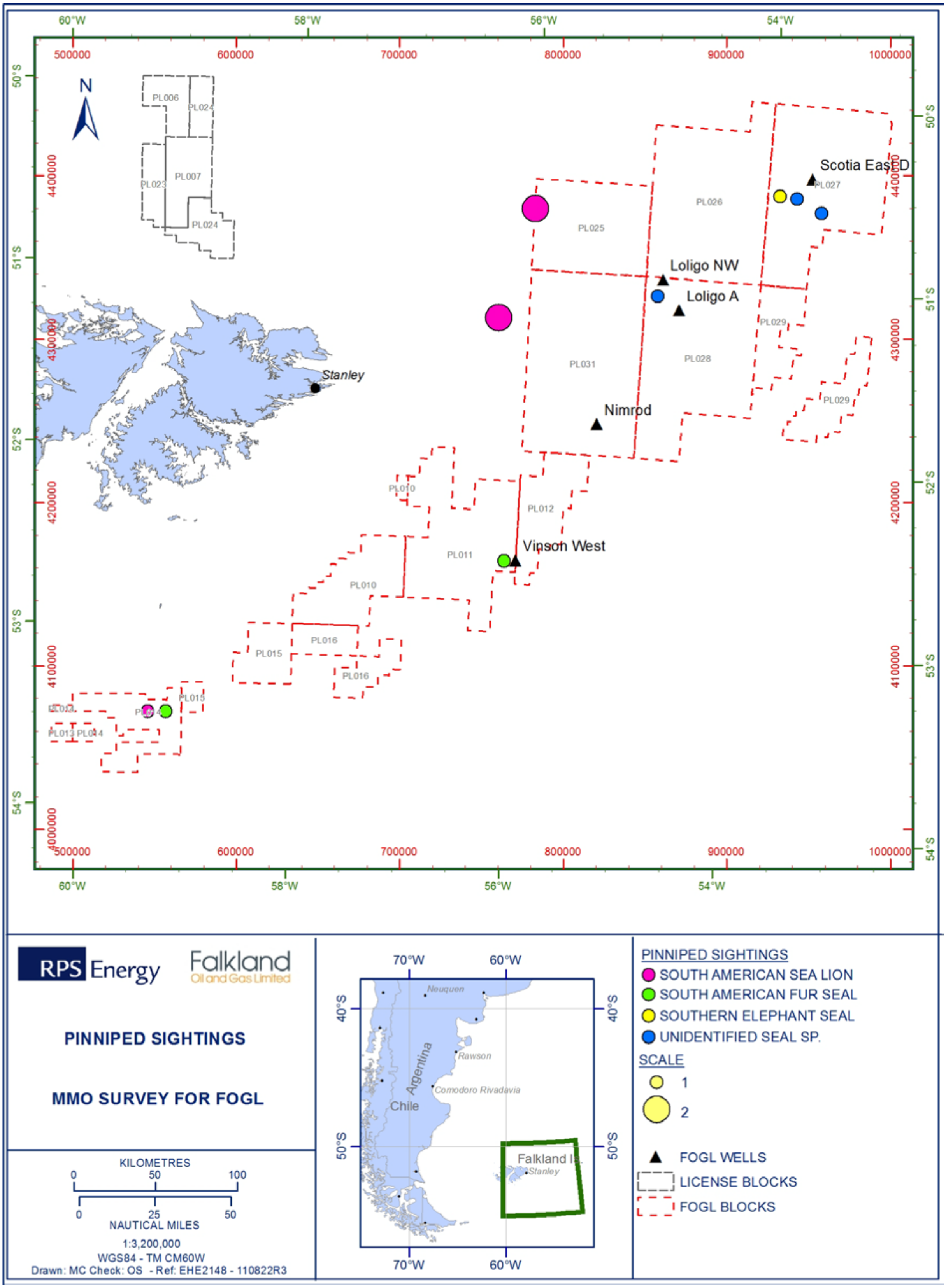
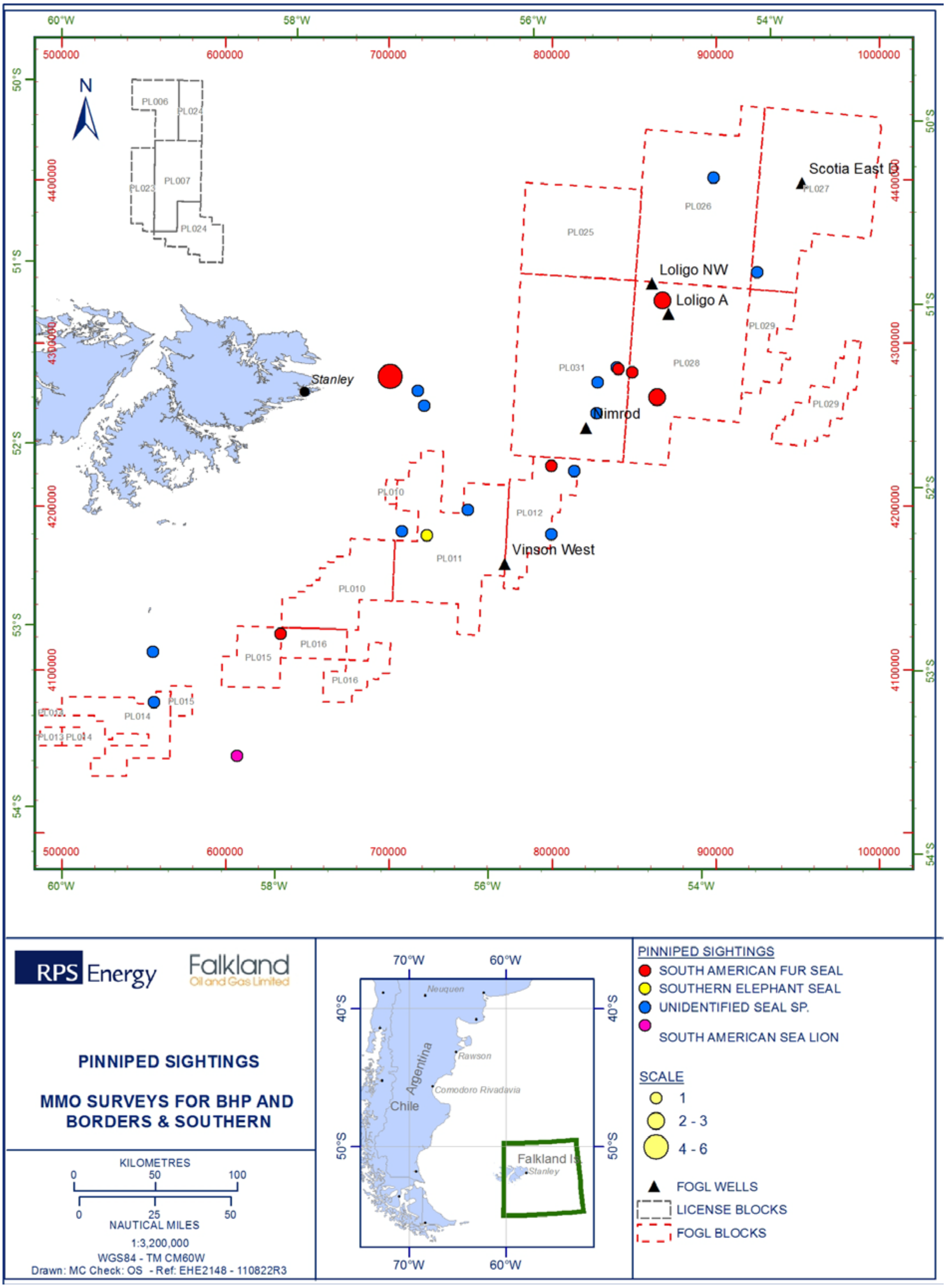


Figure 5.57. Pinniped sightings during the B&S and BHP surveys (June 2007; Oct 2007 - Feb 2009)



5.3.8 Seabirds

5.3.8.1 Overview

The Falkland Islands are an area of global importance for birdlife, particularly seabird species of international significance. The north Falklands Current upwells nutrient rich water from Antarctic waters and provides an area of high plankton activity, forming the basis of the marine ecosystem and supporting seabird activity in the region.

The avifauna of the area is well studied and documented. Although seabird distribution, breeding and foraging patterns have been extensively studied, the data is limited to the near coastal zone and is scarcer for deep offshore waters.

White *et al.*'s 'sea bird at sea' survey, undertaken between February 1998 and January 2001, has been used in this section alongside other key publications such as *Croxall et al. (1984), Woods (1998; 1997),* and *Strange (1992)* to describe seabird abundance and distribution in the region. Although the *White et al. (2002)* study is currently the most comprehensive study of seabirds around the Falkland Islands, the reliability of the study is limited by the age of the dataset as well as the sample methods used. Identifying seabirds to the species level from a distance at sea is difficult due to the short time most seabirds spend on the surface during foraging. In bad weather conditions, identification is particularly challenging. Furthermore, on land bird species may mix making accurate identification more difficult. The results of this survey are also heavily prone to human error, since they are very reliant on well trained and dedicated observers.

In addition to the key publications mentioned, the following reports and databases have been discussed in this section to provide a synopsis of seabird species numbers, locations and sensitivities.

- Origin, age, sex and breeding status of wandering albatrosses (*Diomedea exulans*), northern (*Macronectes halli*) and southern giant petrels (*Macronectes giganteus*) attending demersal long-liners in Falkland Islands and Scotia Ridge waters, between 2001 and 2005 (*Otley et al., 2007b*). The report summarises three years of survey work undertaken in Falkland Islands' waters between 2001 and 2005;
- Patterns of seabird attendance at Patagonian toothfish long-liners in the oceanic waters of the Falkland Islands, 2001–2004 (*Otley, 2007a*). The report summarises the surveys of seabirds attending Patagonian toothfish long-liners during line setting and hauling activities in deepwater to the east of the Falkland Islands made between July 2001 and June 2004. It is also noted that this dataset is potentially biased as seabirds are attracted to the prey;
- Vulnerable concentrations of seabirds (*White et al. 2002*). The report summarises two years of survey work in the form of a vulnerabilities atlas, with the aim of highlighting the locations of seabird concentrations that would be the most vulnerable to the effects of surface water pollution. This report is extremely comprehensive. However, some of the data is nearly 10 years old, meaning that the use of other sources in this review is necessary.
- Foraging patterns of male Rockhopper penguins (*Putz et al., 2003*). The report shows tracking data of foraging penguins at the beginning of austral summer 2008.
- Foraging patterns of Magellanic Penguins. This report shows the foraging movements of penguins at the beginning of the breeding season 1998/1999.
- Observer data recorded on long-line fishing vessels between 2000-2011. The data was analysed with the permission Falkland Islands Fisheries Department. This data is potentially biased as seabirds are attracted to the prey and as such cannot be considered in conjunction with or by comparison to other data collected.
- Winter migrations of magellanic penguins from the Falkland Islands (*Putz et al., 2007*). Penguins were tracked in the austral summer between 2004 and 2005.
- Satellite tracking data of birds belonging to the Procellariiforms (albatrosses and petrels) covering breeding and non-breeding seasons for an 11-year period (1996 and 2007). The data was analysed with the permission Birdlife International.

According to Woods (2004), there are 21 resident land birds, 18 water birds, 22 breeding seabirds, 18 annual non-breeding migrants and at least 139 occasional visitors in the Falkland Islands. During the

'Seabirds at Sea' survey (1998-2001) a total of 218 species along with some unconfirmed sightings were recorded (*White et al., 2002*). Between 2001 and 2005 a total of 547 sightings of 291 Banded wandering albatross *Diomedea exulans* and 21 sightings of 14 Banded giant petrels *Macronectes* spp. were made (*Otley, 2007a*). Most commonly observed seabirds on long-line fishing vessels included Giant Petrel, Kelp Petrel and Black Browed Albatross (Figure 5.58). Other less abundant Petrel and Albatross species were also recorded (Figure 5.59)

There are nine species of penguins in the Falkland Islands, five of which are breeding (rockhopper, magellanic, gentoo, king and macaroni). The Falklands are the most important world site for the endangered rockhopper penguin and are home to 80% of the world's breeding population of Black-browed albatross. Several rare and threatened species of petrel nest on offshore Islands.

According to Bird Life International and the IUCN Red List, 10 bird species found in the Falkland Islands are listed under 'Endangered' or 'Vulnerable' categories, and a further seven are 'Near Threatened' (refer to Appendix D).

Figure 5.58. Commonly Observed Birds on Long-line Fishing Vessels (FIFD database, 2000-2011)

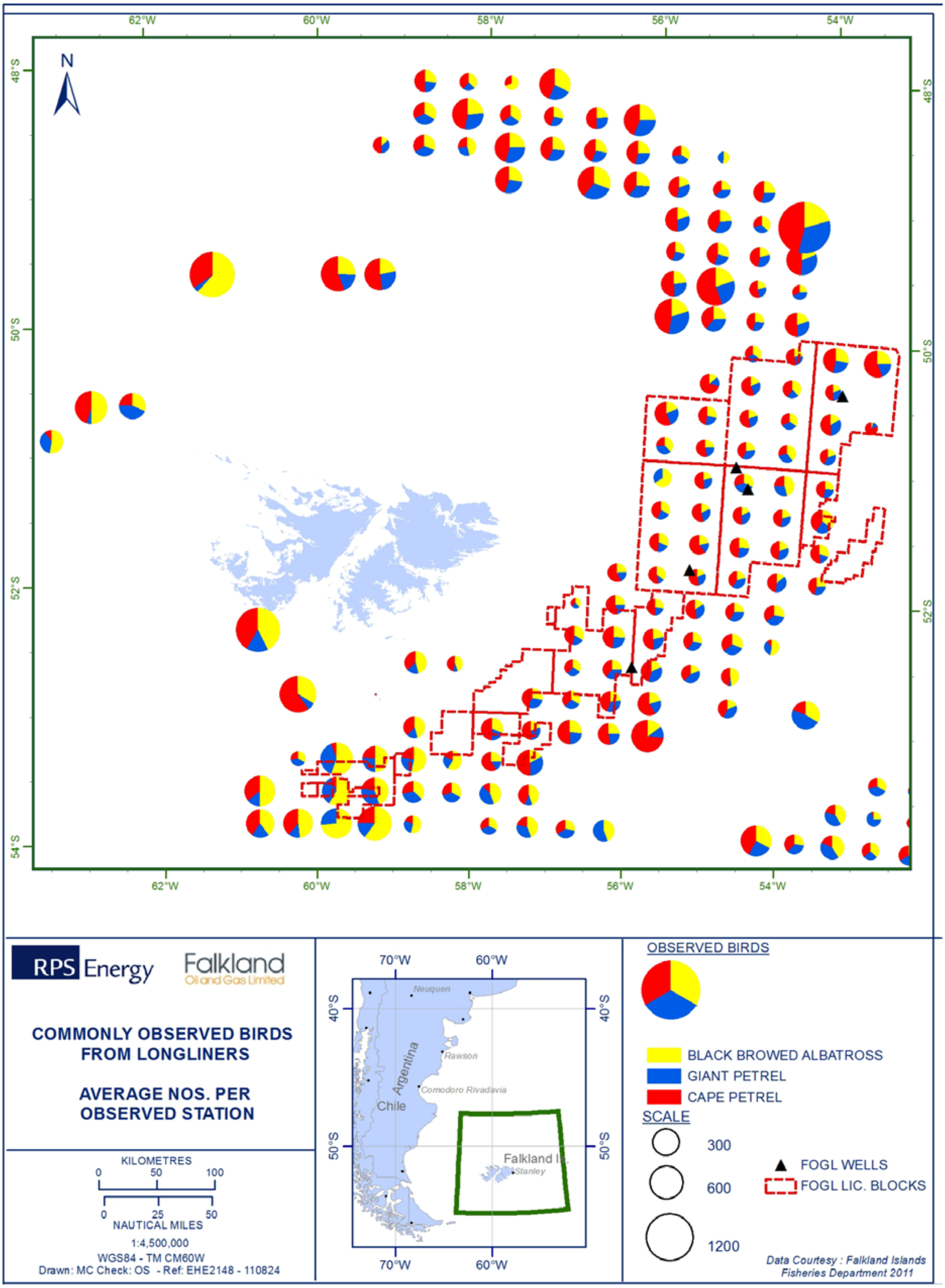
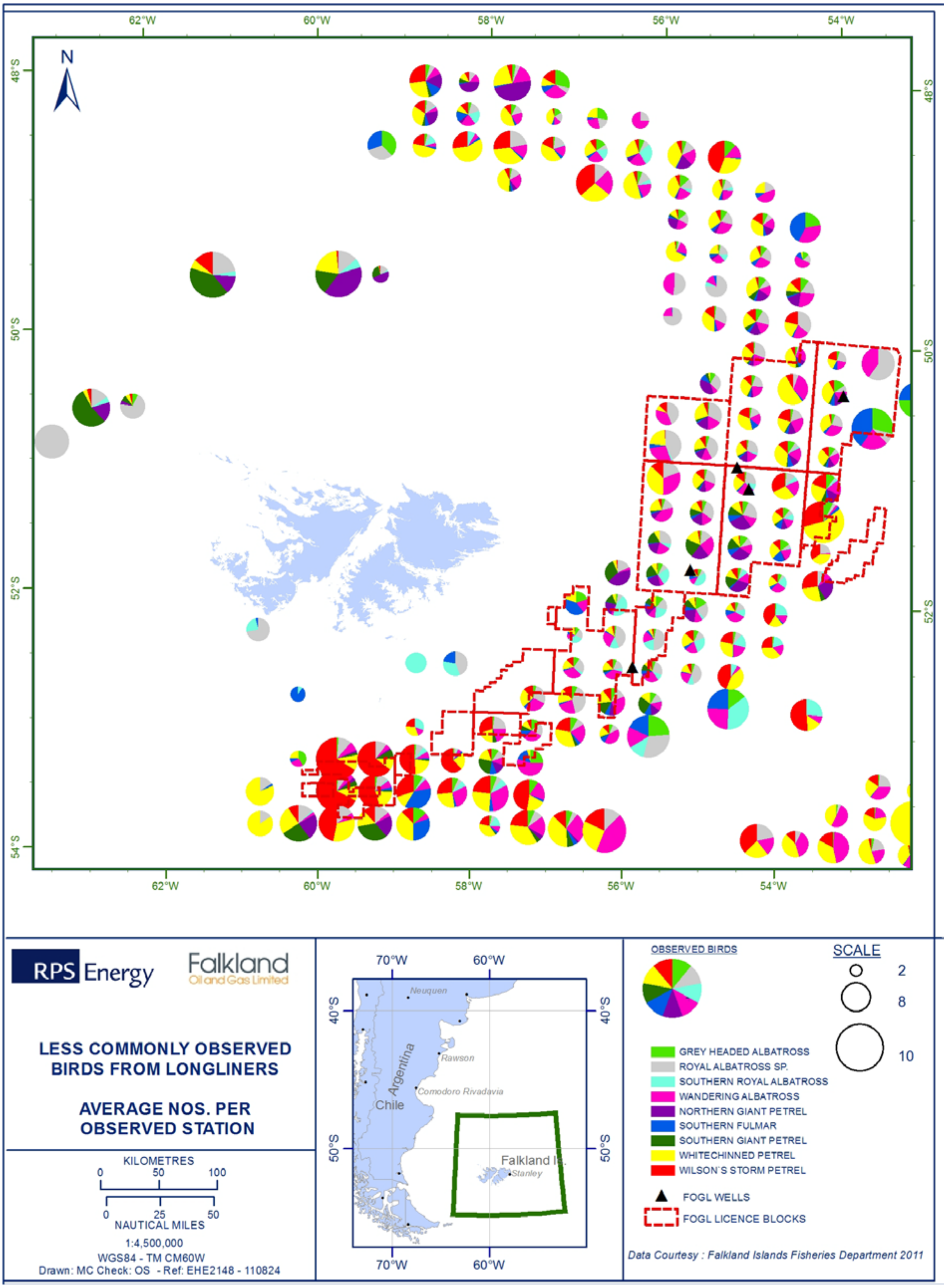


Figure 5.59. Less Commonly Observed Birds on Long-line Fishing Vessels (FIFD database, 2000-2011)

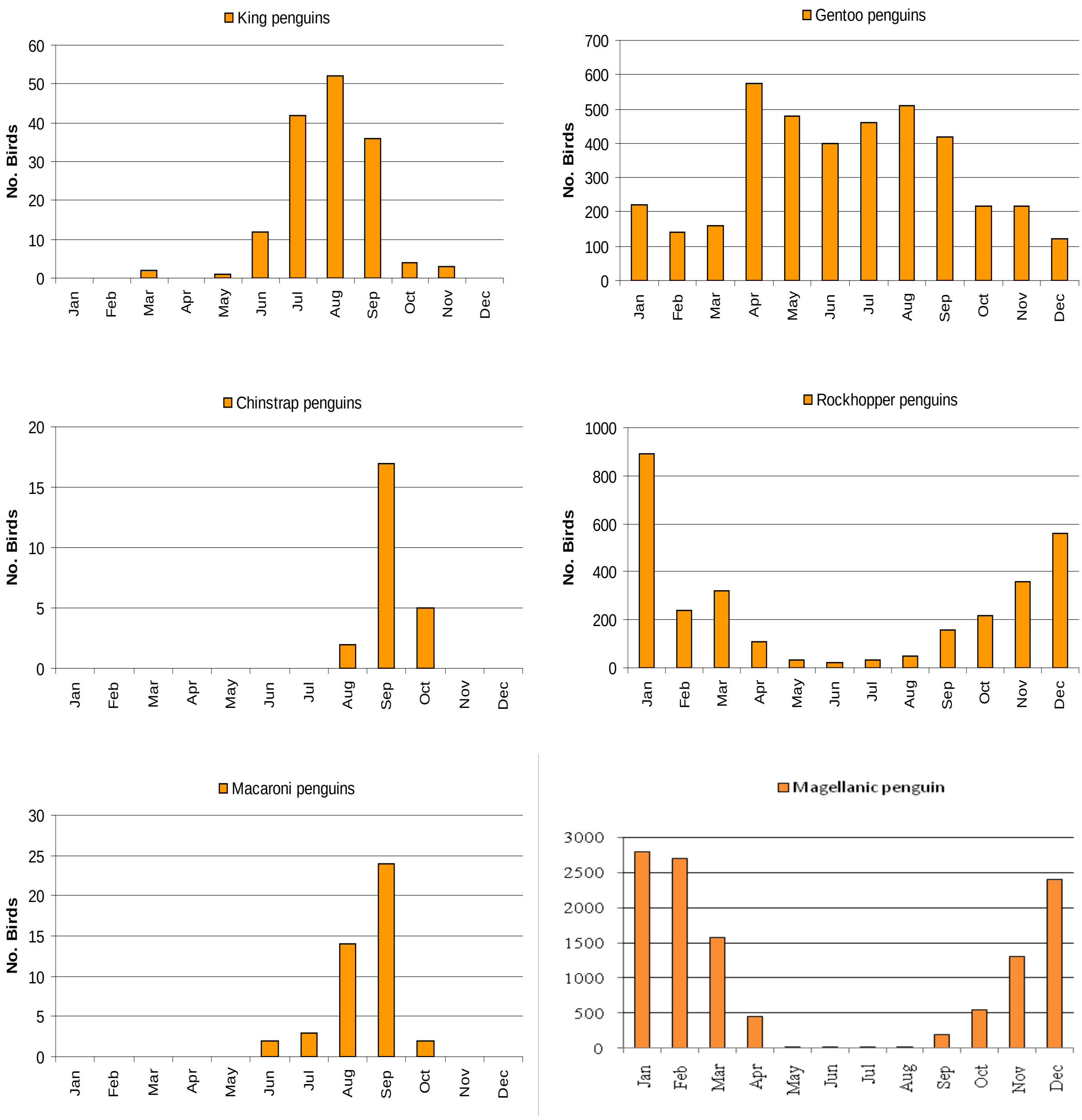


5.3.8.2 Penguins

Nine penguin species have been recorded in the Falkland Islands (Figure 5.44), of which the following six were identified during the 'Seabirds at Sea' survey between 1998 and 2001:

- King penguin (*Aptenodytes patagonicus*)
- Gentoo penguin (*Pygoscelis papua*)
- Rockhopper penguin (*Eudyptes chrysolophus*)
- Macaroni penguin (*Eudyptes chrysolophus*)
- Magellanic penguin (*Speniscus magellanicus*)
- Chinstrap penguin (*P. Antarctica*)

Figure 5.60. Penguins recorded during 'Seabirds at Sea' Survey, 1998-2001 (Source: White et al., 2002)



King penguin (Aptenodytes patagonicus)

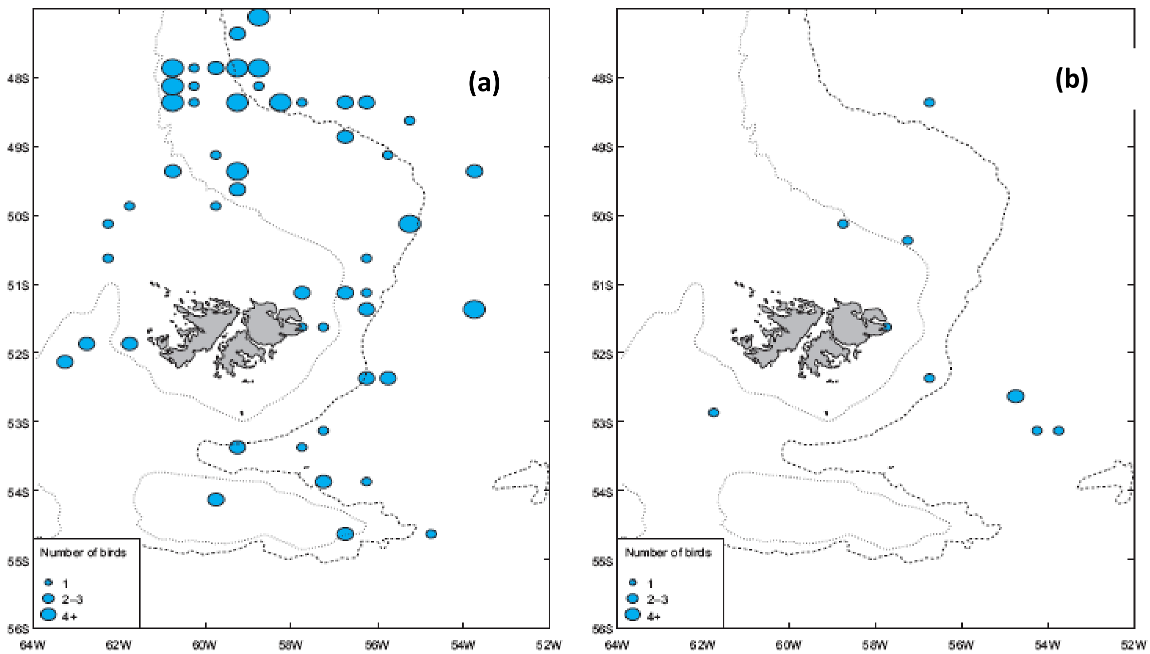
The Falkland Islands population of King Penguin is almost entirely concentrated at Volunteer Point on East Falkland Island, approximately 215 kilometres from the closest site, Loligo. A few individuals can also be found nesting amongst Gentoo penguins at four to six locations within the Falklands (*Huin, 2007*). The 2005/ 2006 Penguin Census observed 160 chicks at Volunteer Beach (*Huin, 2007*). From the 1980s to 2001, the Volunteer Beach breeding population was estimated at between 344 and 516 breeding pairs, increasing at an additional 12 to 15 chicks per year. This increase has slowed over the past three years of the study period (*Huin, 2007*).

The Falkland Islands' population makes up only 0.04% of the world population and is considered to be of local rather than global importance (*Munro, 2004*). However, since the population is mostly limited to one site its vulnerability increases with regards to disturbance events such as oil spills.

By mid winter birds begin to forage north of the Falklands around the Patagonian continental shelf and slope waters within the Antarctic Polar Frontal Zone. This area is used by many bird species as a winter feeding ground. In total, 151 king penguins were recorded during the 1998 – 2001 at-sea surveys on 81 occasions, almost entirely between May and November (Figure 5.60).

The majority of king penguin records during the 'Seabirds at Sea' survey occur to the north of the Falkland Islands between June and September (Figure 5.61; *White et al., 2002*). There were some sightings around the eastern coast of the Islands, making it likely that some king penguins will be encountered foraging within and in the vicinity of the FOGL drilling sites.

Figure 5.61. King Penguin Sightings (a) June - September and (b) October – May (Source: White et al. 2002).



***Gentoo penguin** (Pygoscelis papua)*

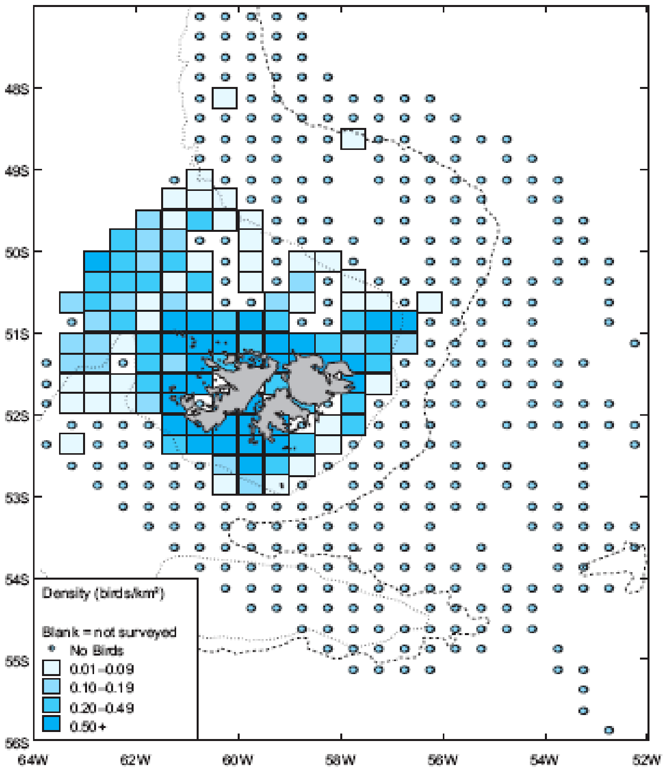
The Falkland Island's Gentoo Penguin population is the second largest in the world after South Georgia (*Huin, 2007*). Although *P. papua* is widely distributed throughout the Falkland Islands, most are found around West Falkland and the outer islands. The population was estimated at 64,426 breeding pairs in 1995/1996, 113,000 in 2001/2002 and 65,857 in 2005/2006. The reduction in Gentoo numbers between 2000 and 2005 was due to paralytic shellfish poisoning resulting from a red algal bloom in 2002.

Tracking of foraging Gentoo penguins shows that the birds predominantly remain in inshore waters, preferring either coastal plains close to sand or shingle beaches or open ocean areas free of kelp. In winter foraging trips may be undertaken up to 300 kilometres from the coast.

A total of 3,896 *P. papua* were recorded during the JNCC survey. Penguins were recorded in all months, peaking between April and September. *White et al. (2002*) noted a seasonal variation in the location of penguins during their survey. Throughout winter months (April – November), Gentoo penguins were dispersed widely over Patagonian Shelf waters surrounding the Falkland Islands (Figure 5.62). There were also high numbers present in and to the south of Falkland Sound. Gentoo penguin sightings were also recorded at East Falkland during the winter, although most were sighted off West Falkland. Although a few birds were recorded far offshore, it is unusual for these penguins to venture into deep waters (*White et al., 2002*). *Pistorius et al. (2010)* also observed a predominantly coastal distribution of *P. papua* around the Falklands during the austral summer of 2005 and 2006. The highest abundance (<10,000) of birds occurred on the western coast of West Falkland.

The predominance in near-shore areas makes it unlikely that Gentoo penguins would be encountered within the FOGL licence area.

Figure 5.62. Gentoo Penguin distribution and abundance from April to November (Source: White et al., 2002).



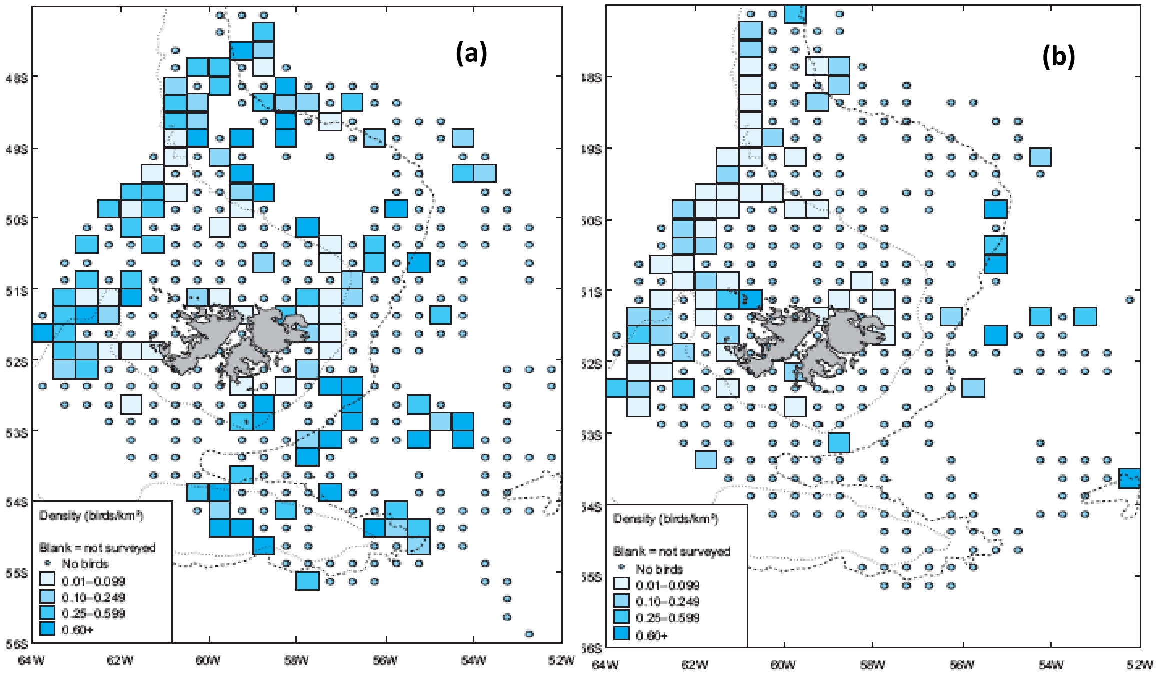
Rockhopper Penguin *(Eudyptes chrsocome)*

The Rockhopper penguin has been split into the northern rockhopper penguin (*E. moseleyi*) and southern rockhopper penguin (*E. chrysocome*). It is the southern rockhopper penguin that breeds in the Falkland Islands. The northern rockhopper penguin is occasionally spotted on the Islands, although is not thought to breed on them. Sightings have occurred on New Island (West Falkland) and to the east at MacBride Head and on Kidney Island (*Matias et al., 2009*).

29% of the world's southern rockhopper population is found on the Falkland Islands. The greatest numbers are found in the outer islands to the West. There are around 52 breeding sites in the Falklands, with a population estimates at 211,000 breeding pairs in 2005/2006 (*Huin, 2007*). Three colonies are of particular importance, including Beauchêne Island (31%), Steeple Jason (28%) and Grand Jason (5%).

There has been an 86% decline in *E. chrsocome* numbers over the past century, from 1.5 million breeding pairs in 1932 to 210,418 in 2005. This is unlikely to have been a steady decline. Initially, it is thought that the most likely cause of the decrease was the collection of eggs for food consumption. However this stopped after the 1950s. After this it is unclear exactly what caused the reduction in breeding pairs. It may be speculated that this could be partly due to increased human activity (e.g. fishing and oil exploration) in the area. However, the population appears to have been stable (see below) since the early 1990's, at the time when oil exploration started, so this activity appears unlikely to be linked. The decline of the rockhopper population has led to the IUCN classifying it as a "threatened" species (*IUCN, 2011*).

Figure 5.63. Rockhopper Penguin distribution and abundance (a) September – November and (b) April to August (White et al., 2002).



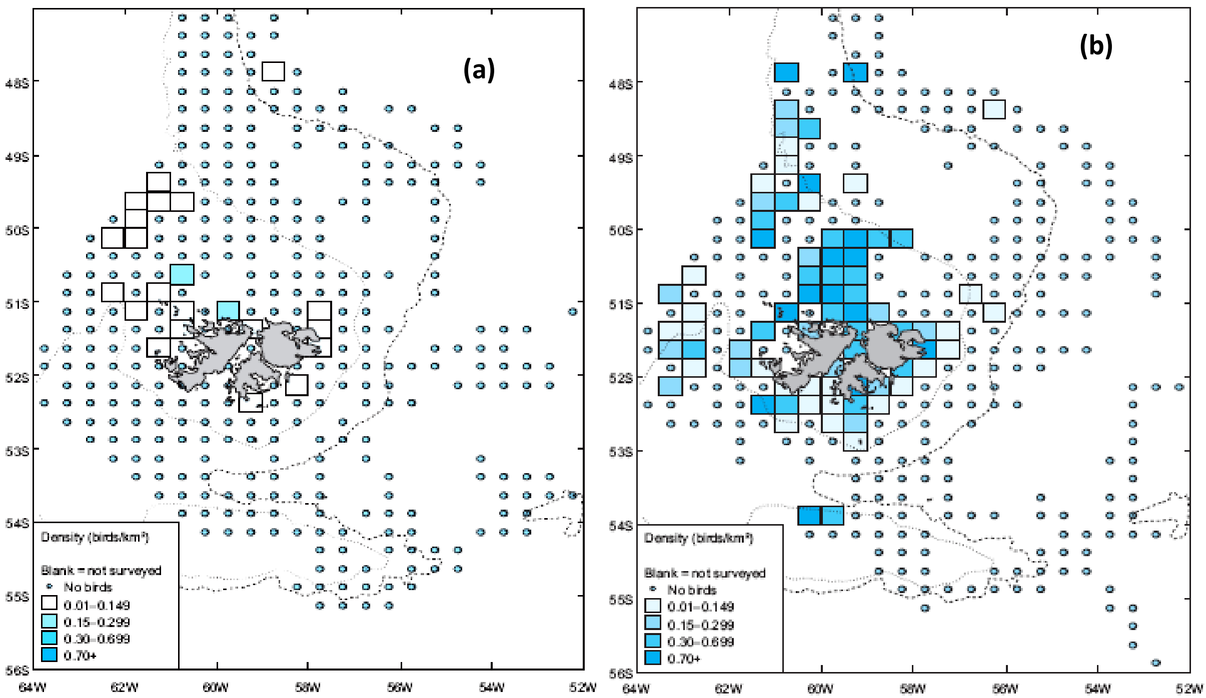
Annual surveys conducted at selected sites suggest that the rockhopper population has stabilised since the early 1990's, although there are still occasional periodic annual declines from which the populations do not fully recover. Rockhopper penguins have been observed at significant distances from the Falkland Islands. Falkland Conservation's tracking study shows Falkland rockhoppers migrating well to the north, to the latitude of northern Argentina, during the austral winter. Between December and March the majority of recorded sightings are from near shore areas. From September to November, distribution is more widely spread across Falkland Island waters (Figure 5.63; *White et al., 2002*). According to the 'Seabirds at Sea' survey results, scattered sightings are likely around all the FOGL well sites between September and November (outwith FOGL's anticipated drilling period), particularly at the Vinson West site. According to data collected by White *et al.* (2002), between April and August rockhopper penguins are only likely to be encountered around the Loligo site, if at all. Conversely, *Putz et al. (2002)* observed rockhopper penguins undertaking huge winter foraging trips to the east and west of the Falklands, indicating that these penguins are likely to occur throughout the FOGL development at all sites.

***Magellanic penguin** (Speniscus magellanicus)*

The Falkland Island magellanic penguin population is thought to account for one third of the world population, making these islands an internationally important site for this species (*Thompson, 1993*). *S. magellanicus* is less colonial than other penguin species on the Falklands. There is an estimated 20,000 breeding pairs spreading out over 90 locations across the islands. The study by *Putz et al. (2002)* indicates that Magellanic penguins can travel long distances, often extending beyond the FOCZ.

More than 12,000 Magellanic penguins were recorded during the 'Seabirds at Sea' survey, mainly between November and April, with the highest densities recorded between December and February (Figure 5.60; *White et al., 2002*). This is outside of the proposed drilling period. Few were recorded between May and August, with increasing occurrence in September and October (Figure 5.64). During winter/spring period, the foraging grounds are mostly restricted to the coast in the east and south of Falkland Islands and spread further offshore in the north. It is therefore unlikely this species will occur around all the FOGL well sites during autumn/winter season.

Figure 5.64. Magellanic Penguin Distribution and Abundance (a) May – August and (b) September – October (Source: White et al., 2002)



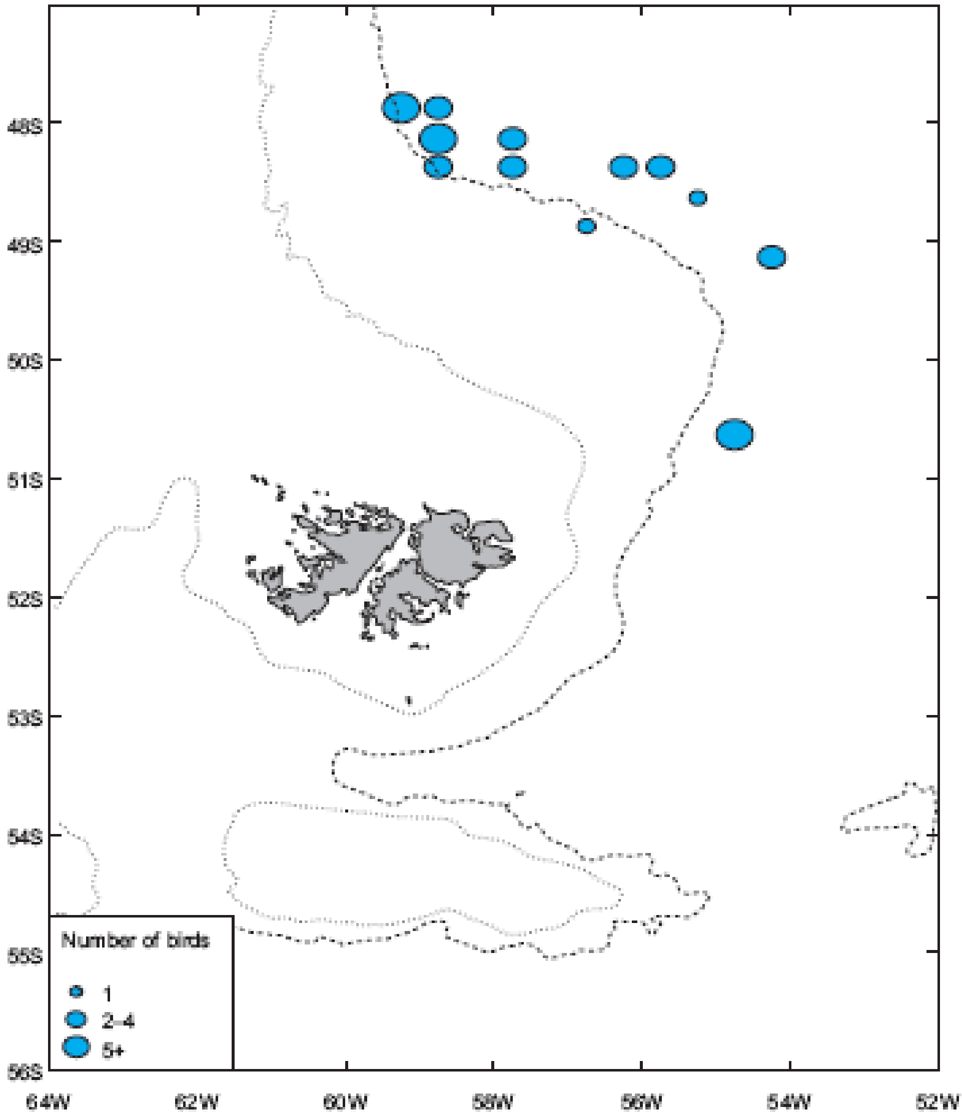
***Macaroni penguin** (Eudyptes chrysolophus)*

The Macaroni penguin is the least common breeding penguin species in the Falklands, with 24 pairs recently recorded at 19 rockhopper penguin colonies, mostly on the eastern side of the Falkland Islands (*Huin, 2007*). Mixed pairs of rockhopper and Macaroni penguins have been observed, suggesting that hybridisation may occur between the species (*White and Clausen, 2002*).

The Macaroni penguin is globally the most common species with millions of pairs present in the Southern Atlantic and Indian Oceans (*Munro, 2004*). The occurrence of vagrant individuals in the Falklands is therefore of only local interest.

The 'Seabirds at Sea' survey recorded *E. chrysolophus* mainly between June and October with significant numbers present only in August and September. The data shows offshore distribution of macaroni penguins to the northeast of the Falklands Islands during these months, which may somewhat overlap with the drilling operations (Figure 5.65; White *et al.,* 2002).

Figure 5.65. Sightings of Macaroni between June and October (Source: White et al., 2002).



Chinstrap penguin *(P. antarctica)*

Chinstrap penguins do not breed in the Falkland Islands. However, a total of 24 individuals were recorded on 10 occasions during the 'Seabirds at Sea' survey. All records occurred between August and October to the southeast of the Falkland Islands. This is outside of the proposed drilling period.

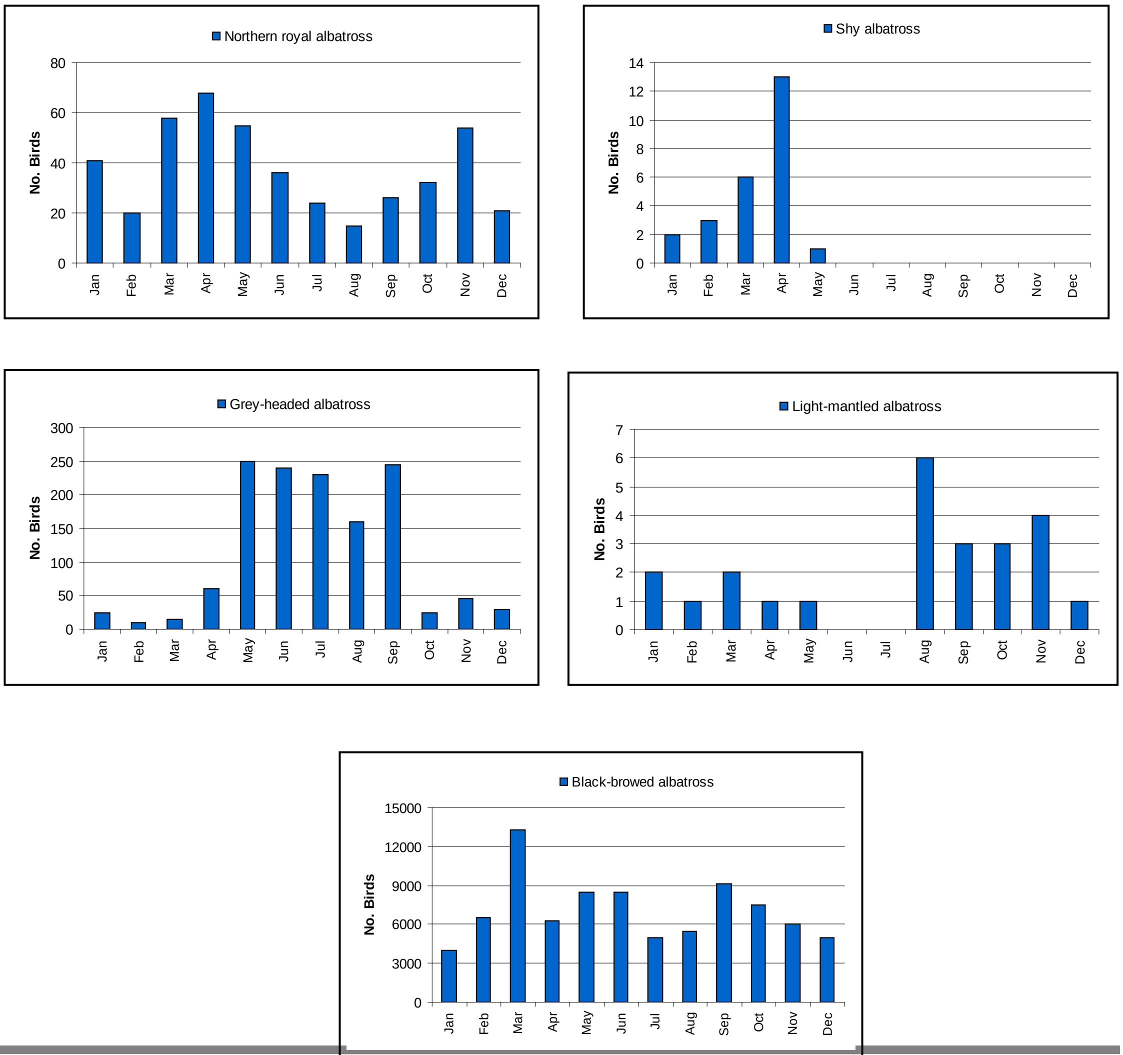
5.3.8.3 Albatross

Albatross species are globally declining, with population numbers falling by 28% between the 1960s and 1980s (*Woods, 1988*). Eleven species of albatross have been recorded in the Falkland Islands, although only the black-browed albatross is a resident breeding species.

Ten of the 11 species of albatross recorded in the Falkland Islands are afforded conservation status. These are listed below and 'Seabirds at Sea' survey records are summarised in Figure 5.66.

- Black-browed albatross (*Thalassarche melanophris*) – Endangered;
- Buller's albatross (*Thalassarche bulleri*) – Vulnerable;
- Grey-headed albatross (*Thalassarche chrysostoma*) – Vulnerable;
- Light-mantled sooty albatross (*Phoebetricia palpebrata*) – Near Threatened;
- Northern royal albatross (*Diomedea sanfordi*) – Vulnerable;
- Shy albatross (*Thalassarche cauta*) – Near Threatened;
- Sooty albatross (*Phoebetria fusca*) – Endangered;
- Southern royal albatross (*Diomedea epomophora*) – Endangered;
- Wandering albatross (*Diomedea exulans*) – Vulnerable;
- Yellow-nosed albatross *(Thalassarche chlororhynchos)* – Endangered.

Figure 5.66. Albatross recorded during 'Seabirds at Sea' Survey, 1998-2001 (White et al., 2002)



***Black-browed albatross** (Thalassarche melanophris)*

The population of the black-browed albatross in the Falkland Islands is genetically distinct from all other populations and is the only species that breeds on the Islands. The estimated 400,000 breeding pairs represent 74% of the world population. This makes the islands critically important with regards to the conservation of this species (*White et al., 2002*). Furthermore, the Falkland Islands is one the most important breeding sites for this species (*Granadeiro et al., 2011*). The black-browed albatross is classified as 'Endangered' by Birdlife International and the IUCN Red List. It should be noted that human activities that overlap the habitat of *T. melanophris* (e.g. via fishing vessels or oil exploration) are still considered to be a significant threat to this population (*Granadeiro et al., 2011*).

T. melanophris were recorded throughout the year with a total of 84, 614 birds being recorded (Figure 5.66; *White et al., 2002*). The highest densities were observed every month around the west of the Falkland Islands. However, there were sightings in the area around all the FOGL well sites. Similarly, observer data from long-line fishing vessels indicate particularly high numbers to the south and north of FOGL licence area.

***Grey-headed albatross** (Thalassarche chrysostoma)*

Grey-headed albatross visit the Falkland Islands from breeding grounds in South Georgia and Diego Ramirez. This species is classified as 'Vulnerable' by the IUCN.

A total of 1,321 grey-headed albatross were recorded, covering all months with a peak between May and September (Figure 5.66; *White et al., 2002*). Distribution between July and January was concentrated in waters to the east of the Falklands. During this time, the birds are likely to be present around all of the FOGL sites. Between February and June *T. chrysostoma* were mainly spotted to the west of the Islands. However they were also spotted near the locations of the Vinson West well site at this time.

Long-line observations show comparatively few Grey-headed albatrosses around the project area with the numbers not considered to be significant.

***Light-mantled sooty albatross** (Phoebetricia palpebrata)*

The light-mantled albatross is a non-breeding visitor from the South Georgia region where there are an estimated 5,000 –7,000 breeding pairs.

Overall, 24 individuals were recorded during the 'Seabird at sea' survey (Figure 5.66; *White et al., 2002*). Most observations were in August to November in waters deeper than 200 m. One or two were observed each month between December and May, with none being recorded in June or July. Sightings were made predominantly to the northeast, east and southeast of the Islands. This means that that *P. palpebrata* occurrence is possible at all the FOGL well sites.

Northern** (Diomedea sanfordi) **and Southern** (Diomedea epomophora) **royal albatross

The royal albatrosses are also visiting species, breeding in New Zealand and using the South Pacific and Patagonian Shelf as feeding grounds. The southern royal albatross is classified as 'Vulnerable' whereas the northern royal albatross is 'Endangered', according to the IUCN red list (*2011*).

Of the 4,114 Royal albatrosses recorded (1998–2001), 3,252 were identified as southern and 447 as northern (with 415 not determined) albatrosses (Figure 5.66; *White et al., 2002*). Highest numbers of southern royal albatross were seen between March and June, particularly to the northwest of the Falklands. Highest numbers of northern royal albatross were seen between March and July, mostly to the northwest of the Islands. Some birds were also observed around the Vinson West well area at this time.

Shy albatross *(Thalassarche cauta)*

Although the Shy albatross is found in Patagonian waters, their dispersal from breeding grounds in Australia and New Zealand is not well known. The Shy albatross is classified as 'Near Threatened' according to the IUCN red list (*IUCN, 2011*).

Only a few Shy albatrosses have been recorded in the Falkland Islands previously. During 'Seabird at sea' survey a total of 25 birds were observed, all between January and May (Figure 5.66; (*White et al., 2002*). One bird was recorded in the vicinity of the Vinson West site. There were no other recordings near FOGL sites.

Wandering albatross *(Diomedea exulans)*

The Wandering albatross originates in South Georgia and is a non-breeding visitor to the Falkland Islands. The Wandering albatross is classified as 'Vulnerable' by the IUCN red list. The population continues to decline with only 1,553 breeding pairs recorded in 2003–2004.

Wandering albatrosses were recorded during the 'Seabirds at Sea' survey in all months, with a peak in November and highs between January and April (*White et al., 2002*). Between July and September this species was only observed around the Loligo prospect. Similarly, observer data from long-line fishing vessels indicate a relatively ubiquitous distribution of *D. exulans* around the Falklands, with sightings throughout FOGL's licence area (Figure 5.59).

5.3.8.4 Petrels and Shearwaters

Petrels and shearwaters form the largest group of oceanic birds, remaining at sea throughout their lives, except for a few months each year when they return to land to breed. The most common breeding species is the southern giant petrel (*Macronectes giganteus*) (*Otley et al., 2008*). As many as 26 species have previously been recorded in the Falkland Islands, including:

Northern giant petrel (*Macronectes halli*)

Antarctic petrel (*Thalassoica Antarctica*)

Antarctic fulmar (*Fulmarus glacialoides)*

Kerguelen petrel (*Pterodroma brevirostris*)

Atlantic petrel (*Pterodroma incerta*)

Grey petrel (*Procellaria cinerea*)

Great shearwater (*Puffins gravis*)

Little shearwater (*Puffins assimilis*)

Grey backed storm-petrel (*Garrodia nereis*)

White-bellied storm-petrel (*Fregetta grallaria*)

Northern giant petrel (*Macronectes halli*)

Southern giant petrel (*Macronectes giganteus*)

Cape petrel (*Daption capense*)

Blue petrel (*Halobaena caerulea*)

Soft-plumaged petrel (*Pterodroma mollis*)

Prion spp (*Pachyptila spp*)

White-chinned petrel (*Procellaria aequinoctialis*)

Sooty shearwater (*Puffins griseus*)

Wilson's storm-petrel (*Oceanites oceanicus*)

Black-bellied storm-petrel (*Fregetta tropica*)

White-bellied storm-petrel (*Fregetta grallaria*)

Southern giant petrel (*Macronectes giganteus*)

The Falkland Islands hold a significant percentage of the world population of the southern giant petrel and surveys have shown offshore distributions to be concentrated mainly over Patagonian Shelf waters. Fishing related mortality is estimated to be around 100 birds per annum in these waters and world populations are declining. The species is classified as 'Vulnerable' by the IUCN (*IUCN, 2011*).

Giant petrels are divided between the northern and the southern, with only the southern giant petrel breeding regularly in the Falklands. The population is estimated at between 5,000 and 10,000 pairs (*Woods and Woods, 1997*).

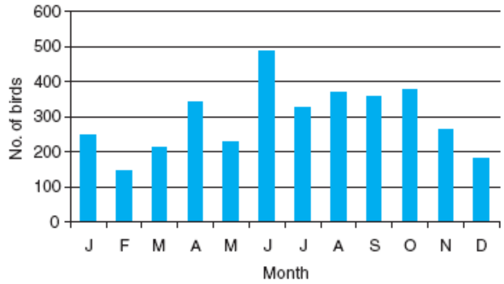
In total, 6,672 Giant petrels were recorded during 'Seabird at sea' survey (*White et al., 2002*), if which 3,535 were southern giant petrels, and 751 were northern giant petrels. 2,386 were recorded as unidentified giant petrel.

Figure **5.**67 presents the total monthly sightings for 20 of the observed species. The distribution data from the JNCC report were also reviewed for these species in relation to the location of the FOGL sites and are described below.

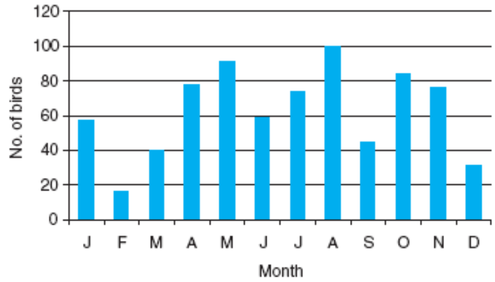
Observers on long-line fishing vessels recorded a wide distribution of Giant Petrel species (Figures 5.58 and 5.59). Their distribution appears to be relatively uniform, although smaller numbers were observed around the proposed FOGL well sites.

Figure 5.67. Petrels and Shearwaters Recorded During 'Seabirds at Sea' Survey, 1998-2001 (Source: White et al., 2002).

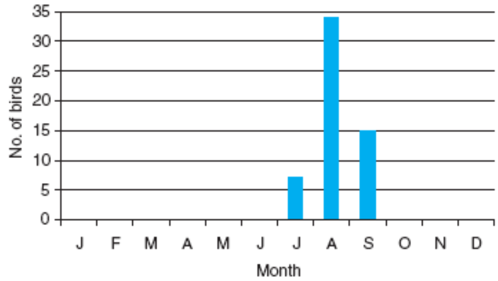
Southern giant petrel



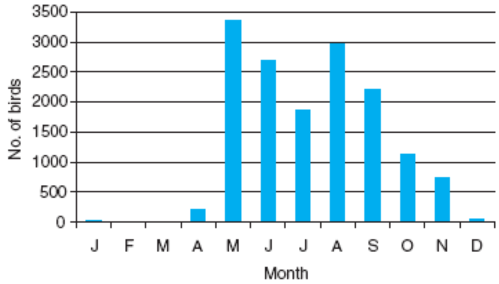
Northern giant petrel



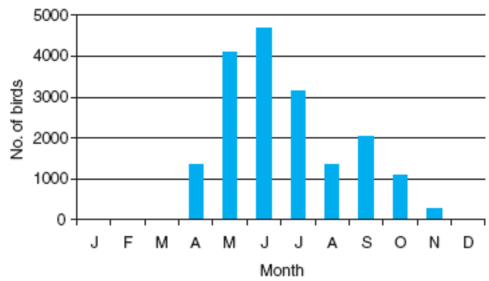
Antarctic petrel



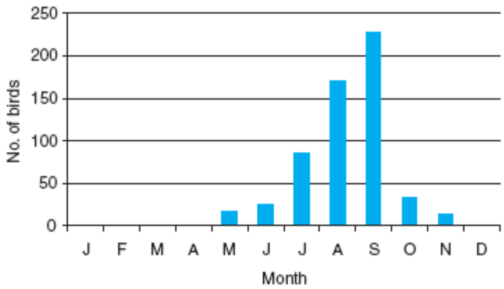
Cape petrel



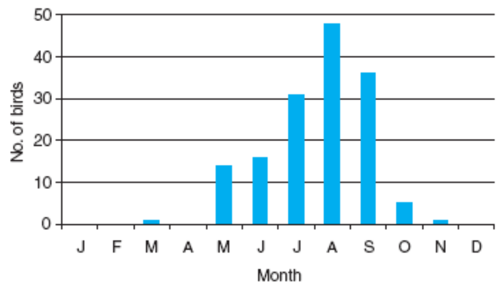
Antarctic fulmar



Blue petrel



Kerguelen petrel



Soft plumaged petrel

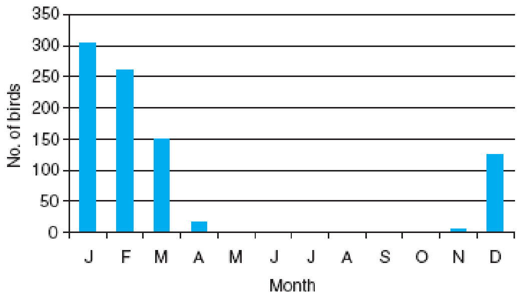
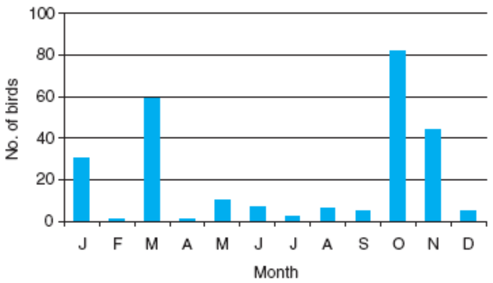
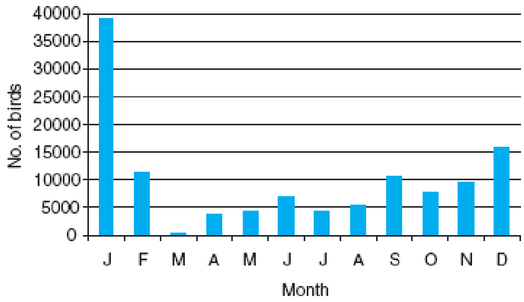


Figure 5.67. (cont.) Petrels and Shearwaters Recorded During 'Seabirds at Sea' survey, 1998-2001 (Source: White et al., 2002).

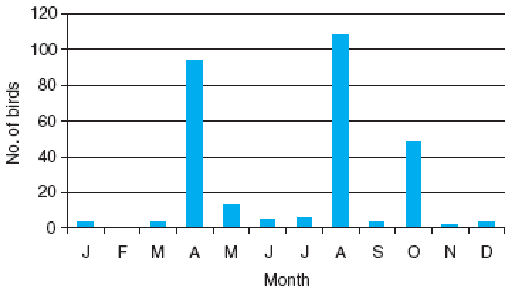
Atlantic petrel



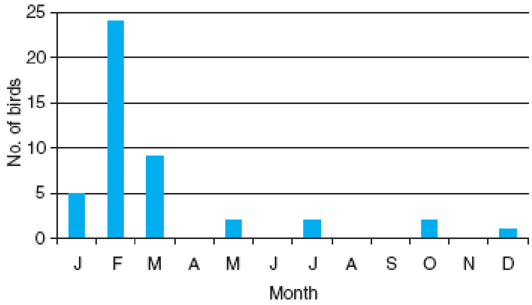
Prions



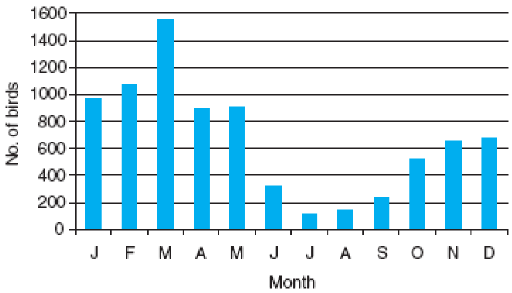
Fairy prion



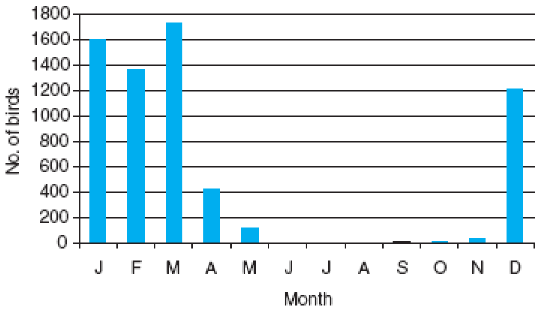
Grey petrel



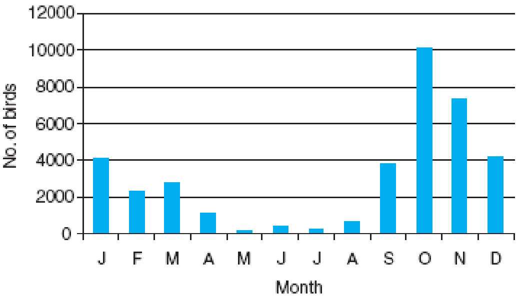
White chinned petrel



Great shearwater



Sooty shearwater



Little shearwater

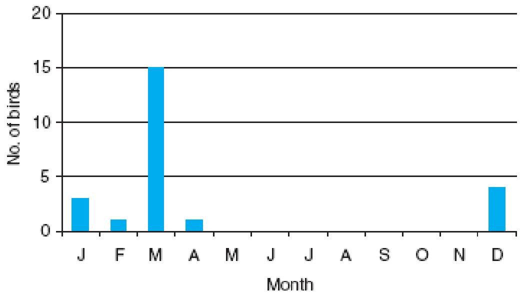
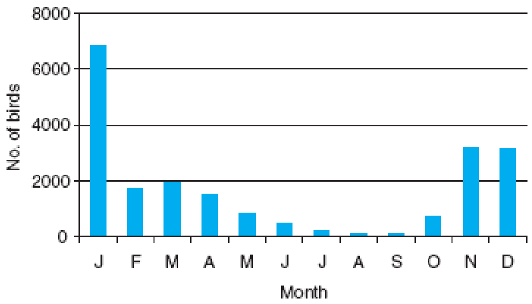
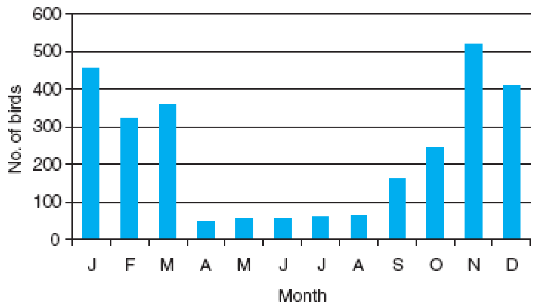


Figure 5.67. (cont.) Petrels and Shearwaters Recorded During 'Seabirds at Sea' Survey, 1998-2001 (White et al., 2002).

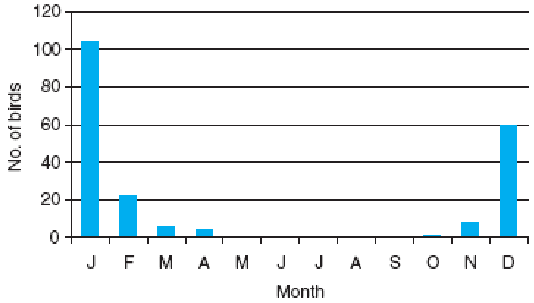
Wilson's Storm petrel



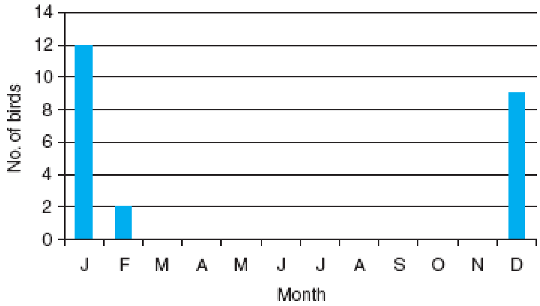
Grey backed storm petrel



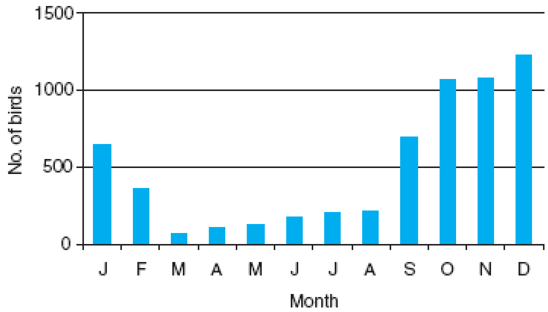
Black bellied storm petrel



White bellied storm petrel



Diving petrel



***Southern Giant Petrel** (Macronectes giganteus)*

Southern giant petrels were recorded in all months during the JNCC survey (Figure 5.67), peaking in June. The highest densities were recorded between March and June over the Patagonian Shelf waters to the south of the Falklands. The southern giant petrel breeds at 38 locations around the Falklands, in colony sizes ranging between one and 110, 000 breeding pairs (*Reid and Huin, 2005*).

Most colonies concentrate around the south of the Falkland Islands and in the Western Falkland waters. Nearly 20,000 breeding pairs were counted in 2004/2005, which account for 40% of the global population (*Reid and Huin, 2005*). Southern giant petrels were recorded in the vicinity of the Vinson West well throughout the year. They were observed around the Loligo sites between November and February, and July and October. They were not present between March and June in this area.

***Northern Giant Petrel** (Macronectes halli)*

Northern giant petrels were recorded throughout the year by *White et al. (2002),* with densities peaking between March and August to the northwest of the Islands. From September to February sightings were less concentrated and more widely scattered. *M. halli* were less likely to be recorded in coastal or inshore waters. They were sighted in the vicinity of all the FOGL sites throughout the year. In contrast, MRAG recorded low numbers of *M. halli* to the east of the islands around the Loligo sites. Northern giant petrels were also observed in low numbers to the south of the Islands.

***Antarctic Petrel** (Thalassoica antarctica)*

Antarctic Petrels are winter visitors to the Falkland Islands. A total of 56 individuals were recorded between July and September (*White et al., 2002*) in waters to the southeast of the Falklands. Only one sighting was made outside of this area. Therefore, *T. antarctica* is likely to only be sighted around the Vinson West well during exploration.

***Cape Petrel** (Daption capense)*

Cape petrels were recorded every month, with a total of 15,199 records made throughout the JNCC survey. Highest numbers were recorded between May and September with very few records occurring between December and April. Between May and September observations of *D. capense* were made at all the FOGL sites. Similarly, observer data from long-line fishing vessels revealed a wide distribution of *D. capense* around the southern and eastern waters of the Falklands. They were observed around each of the FOGL sites, with the highest distribution occurring to the east of the Islands, specifically at the northeastern sites.

***Blue Petrel** (Halobaena caerulea)*

Blue petrels are another non-breeding visitor to the Falkland Islands. A total of 573 were recorded between May and October (*White et al., 2002*). Most of these observations were made in eastern Falkland Island waters around all of the FOGL sites.

***Kerguelen Petrel** (Lugensa brevirostris)*

A total of 152 Kerguelen petrels were recorded (*White et al., 2002*), almost solely between May and November in deep waters to the north, east and south of the Falklands. Distribution of *L. brevirostris* was widespread with peak numbers being recorded in August. Numerous sightings were made by *White et al. (2002)* at all the FOGL sites*. L. brevirostris* are categorised as "Vulnerable" by the IUCN.

***Soft-plumaged Petrel** (Pterodroma mollis)*

Soft-plumaged petrels are non-breeding late summer visitors to the Falklands. Observations by *White et al. (2002)* occurred between November and April, peaking in January. In total, 861 Soft-plumaged petrels were recorded during the JNCC survey, mainly in deep waters to the northeast of the Falklands. It is unlikely this species will occur in FOGL licence area during the proposed drilling period in significant numbers.

***Atlantic Petrel** (Pterodroma incerta)*

P. incerta is categorised as "Vulnerable" by the IUCN. A total of 252 Atlantic Petrels were recorded year round (*White et al., 2002*), primarily between October and March., therefore it is unlikely this species will occur in FOGL's licence area during the proposed drilling period in significant numbers.

***Grey Petrel** (Procellaria cinerea)*

P. cinerea is listed as "Near Threatened" by the IUCN. A total of 45 grey petrels were recorded, mainly between December and March, with peak numbers occurring in February (*White et al., 2002*). All observations were made in deep waters to the north and east of the Falklands. It is unlikely this species will occur in FOGL licence areas during the proposed drilling period in significant numbers.

White-chinned Petrel *(Procellaria aequinoctialis)*

P. aequinoctialis is categorised as "Vulnerable" by the IUCN. A total of 8,044 white-chinned petrels were recorded throughout the JNCC survey (*White et al., 2002*). Observations occurred in all months, peaking between January and May. None were observed around any of the FOGL sites. The furthest east sightings occurred was at 58°W. In contrast, observer data from long-line fishing vessels indicate a relatively ubiquitous distribution of *P. aequinoctialis* with the highest numbers occurring to the southeast (Figure 5.59). There were also high numbers observed in deeper waters outside the FOCZ.

Great Shearwater *(Puffinus gravis)*

Great shearwaters were recorded primarily between December and April during the JNCC survey, with very few being observed between June and October (*White et al., 2002*). A total of 6,468 were recorded, mainly over shelf slope and oceanic waters to the north and east of the Falkland Islands. *P. gravis* were recorded at each of the FOGL well sites. Although of importance at a local level, the population is not globally significant.

Sooty Shearwater *(Puffinus griseus)*

Sooty shearwaters breed on the Falkland Islands, with a population estimated at 10,000 to 20,000 pairs (*Woods and Woods, 1997*). This species is listed as "Near Threatened" by the IUCN. A total of 37,109 Sooty shearwaters were recorded, mainly between September and March, peaking in October (*White et al., 2002*). Most records occurred throughout inshore waters and over the shelf to the east and south. It is unlikely this species will occur in FOGL's licence area during the proposed drilling period.

Little shearwater *(Puffinus assimilis)*

A total of 24 Little shearwaters were recorded during the JNCC survey, all between December and April with a peak in March. All sightings occurred in waters to the north and east of the Falklands. Two point sightings occurred in the area around the FOGL sites in the northeast. Therefore, the abundance of the species within the area of interest is not considered to be significant at the beginning of the drilling period.

Wilson's Storm Petrel *(Oceanites oceanicus)*

Wilson's storm petrel breeds on the Falklands with an estimated population in excess of 5,000 pairs (*Woods and Woods, 1997*). A total of 21,019 Wilson's storm petrels were recorded by *White et al. (2002),* mainly between October and June. Most records were to the west and northwest of the Falklands, although high densities also occurred to the northeast between November and February. No *O. oceanicus* were recorded at the FOGL sites. The northeastern FOGL sites were not surveyed, however, meaning that a lack of sightings in this area does not necessarily equate to low bird abundance. Observer data from long-line fishing vessels indicate significant numbers of *O. oceanicus* to the south of the Falkland Islands near the Burdwood Bank. Several were also spotted around the Vinson West site and to the east near the Nimrod site, but not in significant numbers. Several were also spotted in deeper waters outside the FOCZ.

Grey Backed Storm Petrel *(Garrodia nereis)*

The Falkland Islands support between 1,000 and 5,000 breeding pairs of Grey backed storm petrels (*Woods and Woods, 1997*). A total of 2,758 Grey backed storm petrels were recorded, mainly between September and March (*White et al., 2002*). Records occurred around Falkland Islands, with high densities recorded to the north from November to March. It is unlikely this species will occur in FOGL's licence area during the proposed drilling period in significant numbers.

Black *(Fregetta tropica)* ***& White Bellied*** *(Fregetta grallaria)* ***Storm Petrel***

Black bellied and White bellied storm petrels were both recorded, primarily between December and February in deep waters to the northeast of the Falklands (*White et al., 2002*). There were 205 records of Black bellied storm petrels and 23 of White bellied storm petrels. Numbers of both species peaked in January. Black bellied storm petrels were observed in the vicinity of the north eastern sites between October and April. It is unlikely this species will occur in FOGL's licence area during the proposed drilling period in significant numbers.

Diving petrel

A total of 6,078 Diving petrels were recorded during JNCC survey, incorporating both the Magellan (133 confirmed) and common (753 confirmed) Diving petrel. The remainder were not specifically identified, but were combined with common Diving petrel numbers for the purposes of the report (*White et al., 2002*). Most Diving petrels were recorded between September and February, with greatest densities to the west and south of the Falklands. Diving petrels were observed in all months around the southeast areas. They were only observed around the north eastern sites between March and August.

5.3.8.5 Prions

Due to the difficulty in identifying Prions (small petrels) to a species level at sea, most records from the JNCC survey were recorded as just "Prion species". A total of 119,610 observations were made, making Prions the most numerous seabirds encountered during the JNCC survey. The highest numbers were recorded between September and January, with the highest densities being recorded to the west, north and south of the Falklands. Observations were made in the vicinity of all the FOGL sites. In contrast, MRAG observers only recorded prion species to the south of the Falkland Islands.

Fairy Prions *(Pachyptila turtur)*

The Fairy Prion was identifiable at sea and was recorded separately by *White et al. (2002*). Overall, 228 Fairy Prions were recorded in all months except for February. Numbers peaked in April, August and October with birds primarily being observed in continental shelf slope and oceanic waters. *P. turtur* distribution was widely scattered in areas around the FOGL sites. None were spotted at the exact location of any of the sites. Therefore, numbers around the FOGL sites are not expected to be significant.

5.3.8.6 Shags

Three species of shag have been recorded in Falkland Islands waters (*Woods, 1988*), of which only two are resident breeding species; Rock shag (*Phalacrocorax magellanicus*) and Imperial shag (*Phalacrocorax atriceps*). The other (Red-legged shag) is a vagrant and was not recorded during the JNCC survey.

The population of Rock shags is estimated at between 32,000 and 59,000 pairs (*Woods and Woods, 1997*). They are only found in the Falkland Islands and South America. A total of 796 Rock shags were recorded by *White et al. (2002)* peaking in July and mainly within enclosed or partially enclosed waters. All Rock shags were recorded within 27 km of the coast, with evidence of birds remaining closest to the coast during summer. Occurrence of Rock shags around the FOGL sites therefore is not expected.

The population of Imperial shag in the Falkland Islands is estimated at 45,000 to 84,000 breeding pairs (*Woods and Woods, 1997*). A total of 39,264 Imperial shags were recorded during the JNCC survey, peaking between June and September. The average sighting is within 12 kilometres of the shore during the summer, and 37 kilometres during June to October (*White et al., 2002*). Occurrence around the FOGL sites is therefore not expected.

5.3.8.7 Swans, Geese and Ducks

According to *Woods and Woods (1997)* twenty-one species of Swans, Geese and Ducks have been recorded in the Falkland Islands, including fourteen native and one introduced species. Most species are likely to be found in coastal areas, and are migratory.

The Falklands Streamer duck (*Tachyeres brachydactyla*) was the only species of duck recorded during the JNCC survey. This species is endemic to the Falklands, with an estimated population of between 9,000 and 16,000 pairs (*Woods and Woods, 1997*). A total of 699 were recorded by *White et al. (2002).* However, all records were made in coastal waters so it is unlikely that this species will be encountered during FOGL activities.

5.3.8.8 Skuas

Five species of Skua have been recorded in the waters of the Falkland Islands;

- Falklands skua (*Catharacta Antarctica*);
- Arctic skua (*Stercorarius parasiticus*);
- Long-tailed skua (*Stercorarius longicaudus*);
- South polar skua (*Catharacta maccormicki*);
- Chilean skua (*Catharacta chilensis*).

***Catharacta Skua** (Stercorarius skua)*

Of the 737 Catharacta skuas recorded by *White et al. (2002),* 573 were recorded as Falklands skuas, four as Chilean skuas and the remainder that could not be accurately identified were counted as Antarctic skuas for the purposes of the distribution atlas. Most records occurred between November and April in inshore waters and the wider area of the north Falklands Basin. Skuas were observed at all the FOGL sites, except for at Vinson West, between November and April by *White et al. (1992)*.

***Arctic skua** (Stercorarius parasiticus)*

Only 35 Arctic Skuas were recorded during the *White et al. (2002)* survey between January and April. *S. parasiticus* are summer visitors to the Falklands and were recorded in inshore waters and deeper waters to the north of the Islands. None were recorded in the vicinity of any FOGL sites.

***Long Tailed Skua** (Stercorarius longicaudus)*

Long-tailed skuas were recorded in the waters off the Falkland Islands between November and April by *White et al. (2002).* A total of 239 were observed, mainly in deep waters to the north and north east of the Falklands. Sightings of *S. longicaudus* were made in the vicinity of the north eastern FOGL well sites.

5.3.8.9 Gulls

Seven species of gull have been recorded in the Falkland Islands, of which the following three species are known to breed in the Falklands;

- Dolphin gull (*Larus scoresbii*);
- Kelp gull (*Larus dominicanus*);
- Brown-hooded gull (*Larus maculipennis*).

***Dolphin Gull** (Leucophaeus scoresbii)*

The Falkland Islands population of Dolphin gulls is of global significance, accounting for 85% of the world population. 3,000 – 6,000 pairs are estimated to inhabit the Islands. *White et al. (2002)* observed a total of 114 Dolphin gulls on 60 occasions in all months except March. Peaking in July, distribution was concentrated in coastal waters – no gulls were recorded more than 20 km from the coast. Therefore, this species is not expected in the vicinity of any FOGL sites.

***Kelp Gull** (Larus dominicanus)*

The Falkland Islands Kelp gull population is estimated at between 24,000 and 44,000 pairs (*Woods and Woods, 1997*). A total of 2,288 were recorded by *White et al. (2002),* covering all months and peaking from June to September. Records between November and April were primarily close to shore. This is in contrast to records from May to October which were more widespread over the Patagonian Shelf and continental shelf slope waters. Observations of *L. dominicanus* were very rare in deep waters. None were spotted at any of the FOGL sites. However, this may be due to a low survey effort in these areas, as opposed to low bird numbers.

Brown hooded gull *(Chroicocephalus maculipennis)*

The Falkland Islands Brown hooded gull population is estimated at between 1,400 and 2,600 pairs (*Woods and Woods, 1997*), compared to a global population of approximately 50,000 pairs. A total of 134 Brown hooded gulls were recorded in each month during the JNCC survey. Numbers peaked in January, with the majority of records being made within 10 km of the coast. No sightings were made in the vicinity of the FOGL sites.

5.3.8.10 Terns

Three species of Tern were recorded during the JNCC survey;

- South American tern (*Sterna hirundinacea*);
- Arctic tern (*Sterna paradisea*);
- Unidentified sterna tern (*Sterna spp.)*

A further five species have been previously recorded in Falkland Island waters (*Otely et al., 2008*). Of these, only one is known to breed in the Falklands.

South American Tern *(Sterna hirundinacea)*

A total of 1,894 South American terns were recorded by *White et al. (2002)* in all months, peaking from March - April. The South American tern is the only species known to breed in the Falkland Islands. Distribution was mainly in coastal waters with no sightings made in the vicinity of the FOGL sites.

Arctic tern *(Sterna paradisaea)*

Arctic terns are a summer visitor to the Falklands. A total of 21 Arctic terns were recorded during the JNCC surveys, all between October and March. They were widely distributed throughout the survey area, mostly in offshore waters. A number of unidentified sterna terns were also recorded. Of the 160 unidentified terns recorded in offshore waters, the majority were recorded between April and November. Distribution was widely scattered. No sightings occurred around any of the FOGL sites.

5.3.8.11 Rare Seabirds

Less than ten sightings of the below listed seabird species were recorded during the JNCC survey (*White et al., 2002*).

Broad-billed prion (*Pachyptila vittata*)	Ceyenne tern sterna (*Sterna (sandvicensis) eurygnatha*).
Chilean skua (*Catharacta chilensis*)	Cory's shearwater (*Calonectris diomedea*)
Great-winged petrel (*Pterodroma macroptera*)	Grey phalarope (*Phalaropus fulicarius*)
Manx shearwater (*Puffinus puffinus*)	Sooty Albatross (*Phoebetria fusca*)
Spectacled petrel (*Procellaria conspicillata*)	White-headed petrel (*Pterodroma lessonii*)

5.3.8.12 Satellite Tracking Data

Satellite-tracking data available for a number of pelagic seabirds belonging to the Procellariiformes (albatrosses and petrels) were requested for analysis from the Birdlife International Global Procellariiform Tracking Database (*Birdlife International, 2004*). This includes tracking data for several species during breeding and non breeding seasons (see Figure 5.68).

It is important to note that the proposed drilling period (March-July) does not coincide with the breeding period of some Procellariiformes. A summary of the tracking data timeframes is given in Table 5.6.

Due to the global coverage of Procellariiformes, it is likely that part of their population distribution may coincide with the FOGL licensed area at some stage in their life-history. To better understand the potential risk of interaction, a series of spatial maps were developed to identify their actual tracks in addition to more general spatial density distributions. The latter use Utilisation Distribution (UD) maps to provide probability contours based on the relative time those birds spend in particular areas (see Figure 5.68; *Birdlife International, 2004*).

Table 5.6. Seabird Tracking Data (Source: Birdlife International Database, 2004).

Species	Site	Start Date	End Date	Status	Contributor(s)
WCP	South Georgia	30/11/1996	27/02/1998	Breeding	BAS
WCP	South Georgia	06/02/2003	26/10/2003	Non breeding	BAS
WWA	South Georgia	16/02/2004	05/10/2004	Breeding	BAS
NRA	Chatham Island	04/11/1994	21/05/1996	Breeding	C. Robertson, D. Nicholls
NRA	New Zealand	06/11/1993	04/02/1998	Breeding	C. Robertson, D. Nicholls
NRA	New Zealand	11/02/1998	27/11/1998	Non-Breeding	C. Robertson, D. Nicholls
BBA	Falkland Islands	13/02/2000	04/12/2000	Breeding	Nic Huin
BBA	Falkland Islands	04/11/1998	08/03/1999	Breeding	Nic Huin
BBA	Falkland Islands	03/11/2006	27/11/2006	Breeding	Nic Huin
BBA	Falkland Islands	19/04/2007	16/08/2007	Non breeding	Nic Huin
BBA	Falkland Islands	04/01/1999	01/10/2000	Breeding	Nic Huin, BAS
BBA	Falkland Islands	28/02/1999	01/10/2000	Non -breeding	Nic Huin, BAS
NGP	South Georgia	29/10/1998	01/12/1998	Breeding	BAS
SGP	South Georgia	08/11/1998	05/01/1999	Breeding	BAS

Table 5.7. Breeding and non -breeding seasons of seabirds (Source: Birdlife International Database, 2004).

Species	Breed Status	Months Covered by Data											
		1	2	3	4	5	6	7	8	9	10	11	12
White-chinned Petrel	non-breeding		■	■	■	■	■	■	■	■	■		
White-chinned Petrel	breeding	■	■									■	■
Wandering Albatross	breeding		■	■	■	■	■	■	■	■	■		
Northern Royal Albatross	non - breeding	■	■	■	■	■	■	■	■	■	■	■	
Black-browed Albatross	breeding	■	■	■	■					■	■	■	■
Black-browed Albatross	non-breeding		■	■	■	■	■	■	■	■	■		
Northern Giant Petrel	breeding										■	■	■
South Giant Petrel	breeding	■										■	■
Key ■ Breeding	□ Non - breeding												

Figure 5.68. An example of UD maps produced from the tracking data

Black browed albatross non-breeding

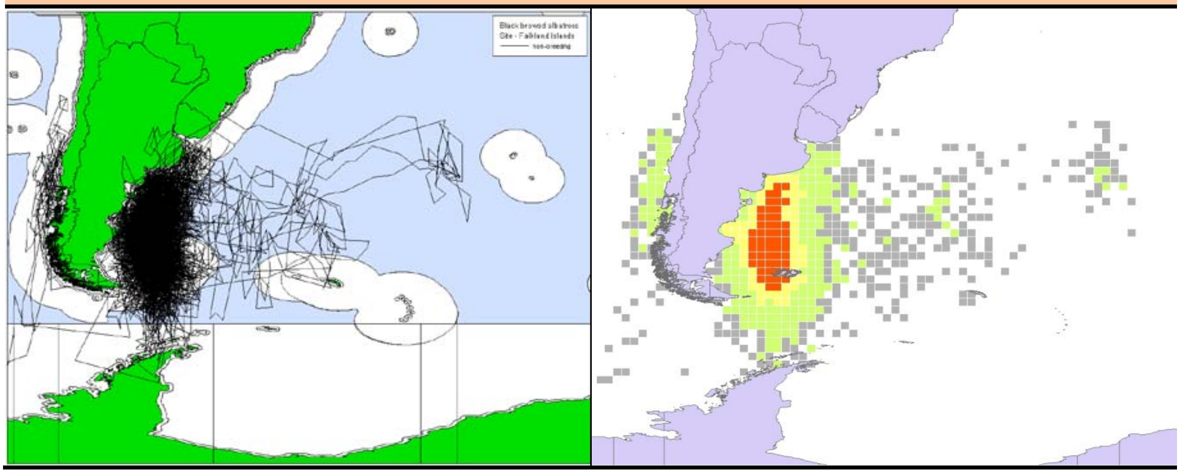


Figure 5.69. Estimation of UD contours based on high (50%), medium (75%) and low (95%) activity against spatial coverage (total number of grid squares).

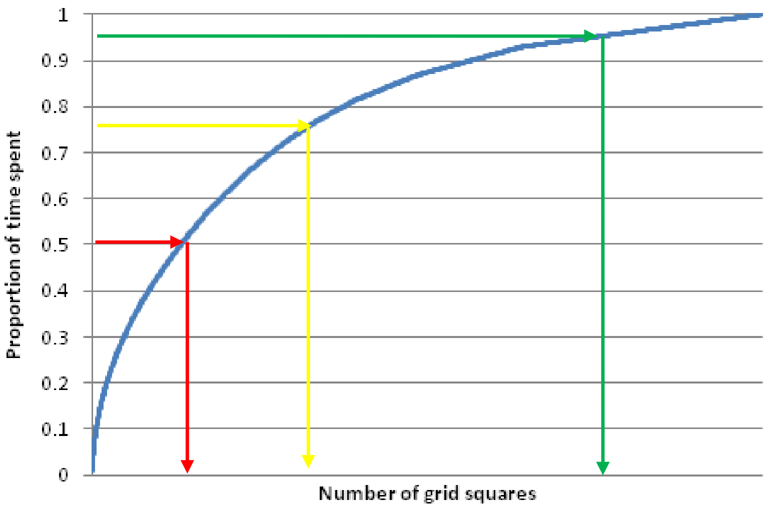


Figure 5.70. Satellite Tracking Utilisation Distribution of Black Browed Albatross, non - breeding season (Source: Birdlife International Database, 2004).

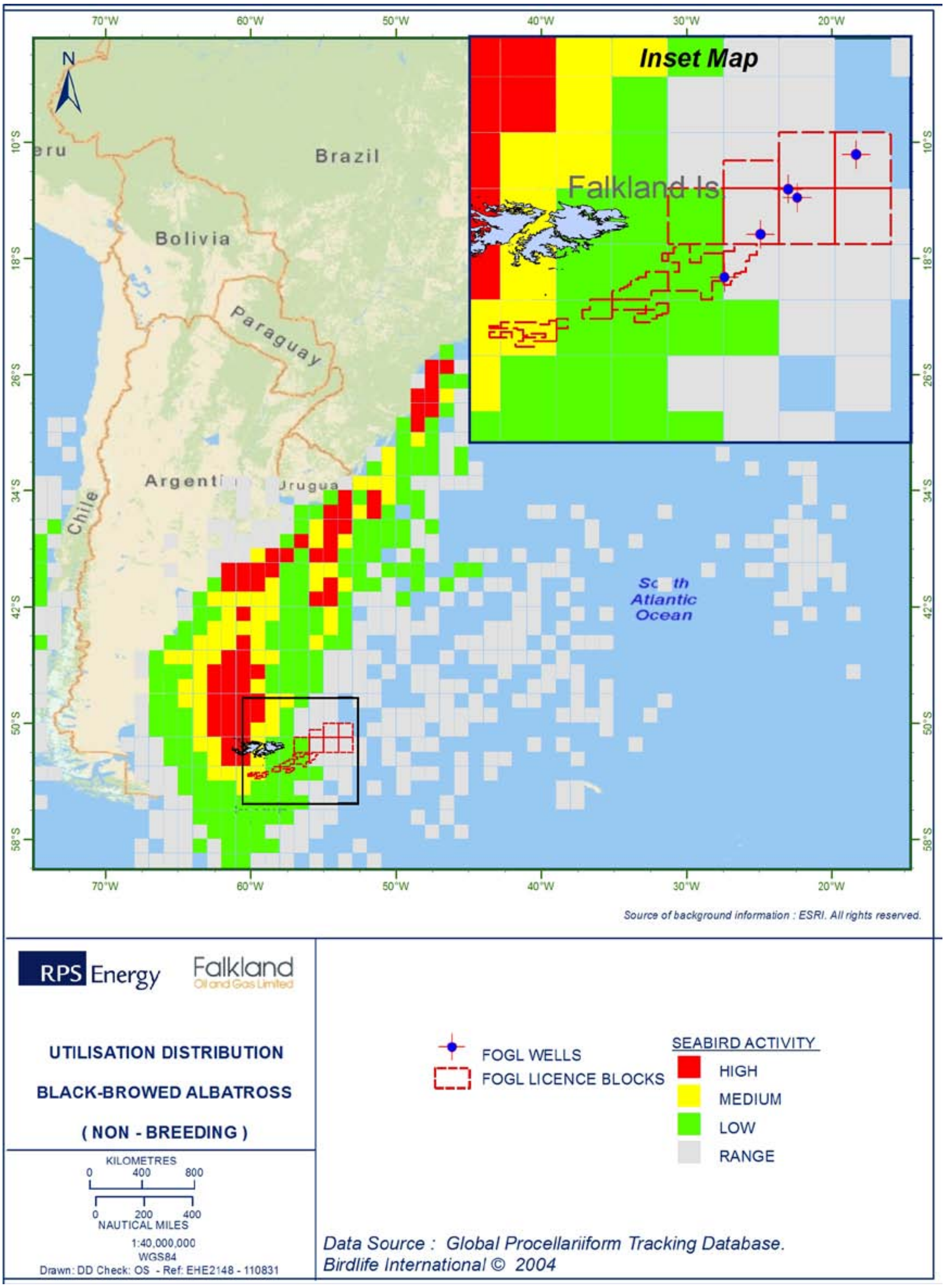


Figure 5.71. Satellite Tracking Utilisation Distribution of Black Browed Albatross, breeding season (Source: Birdlife International Database, 2004).

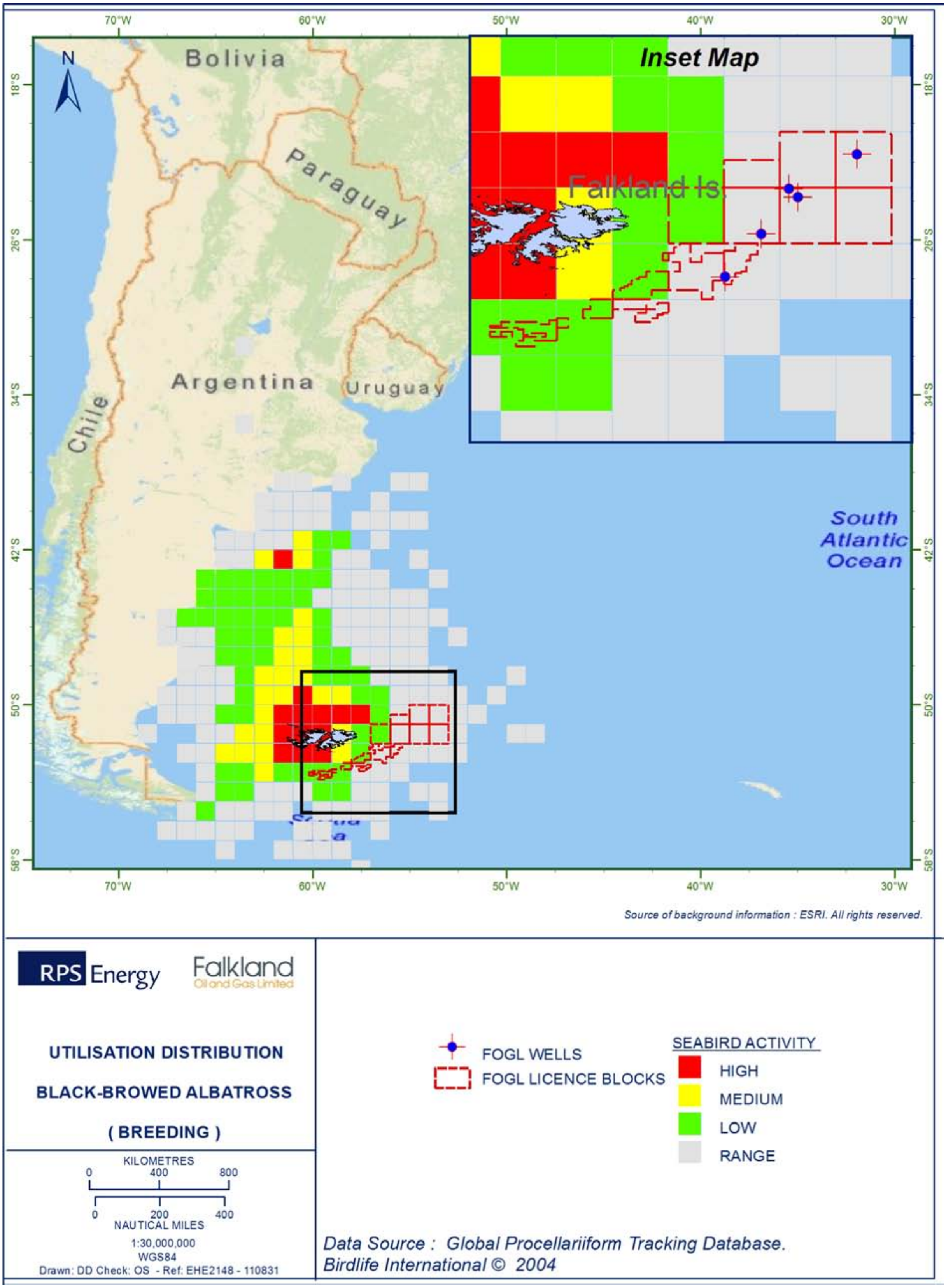


Figure 5.72. Satellite Tracking Utilisation Distribution of White Chinned Petrel, non - breeding season. (Source: Birdlife International Database, 2004).

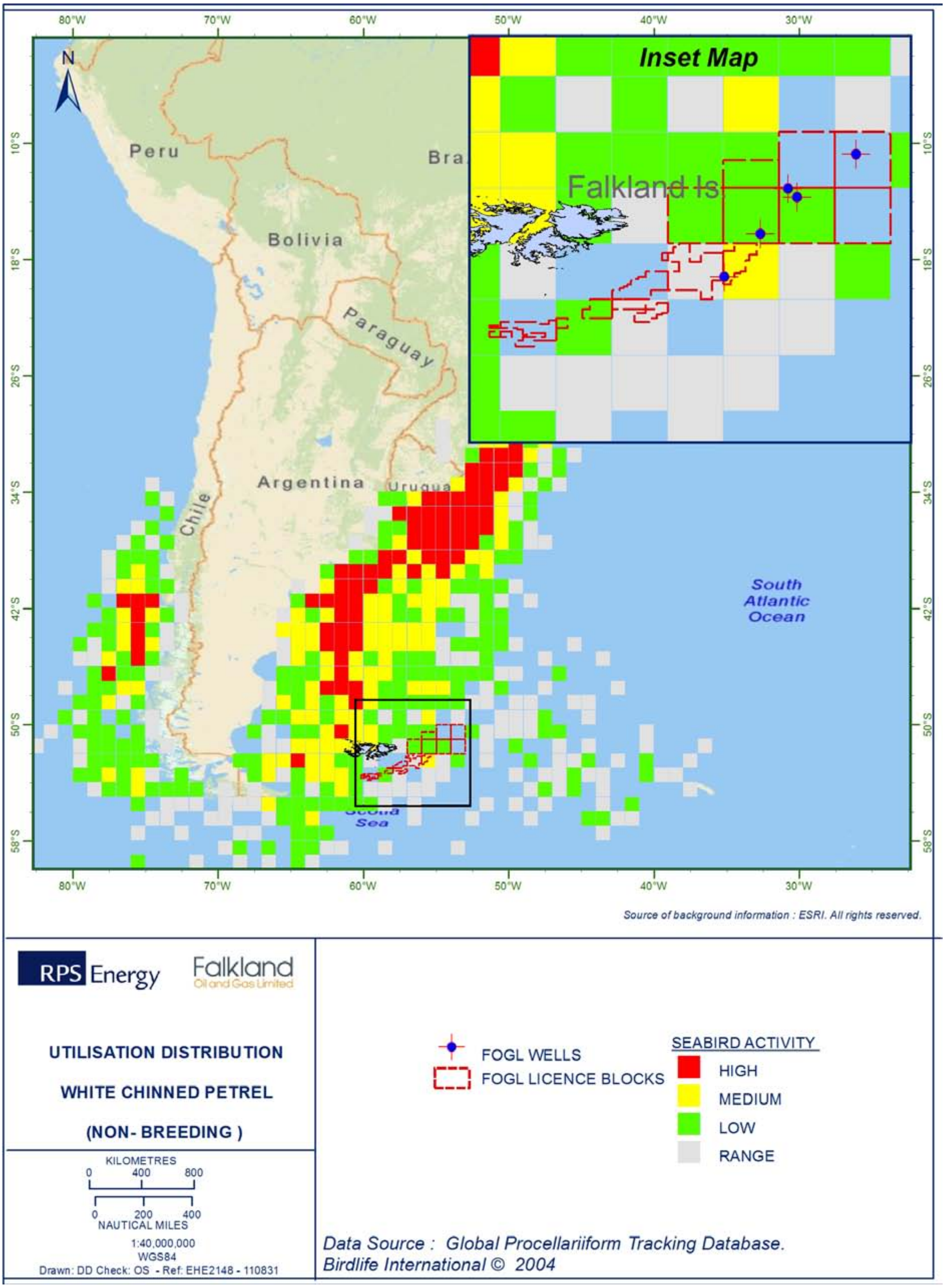
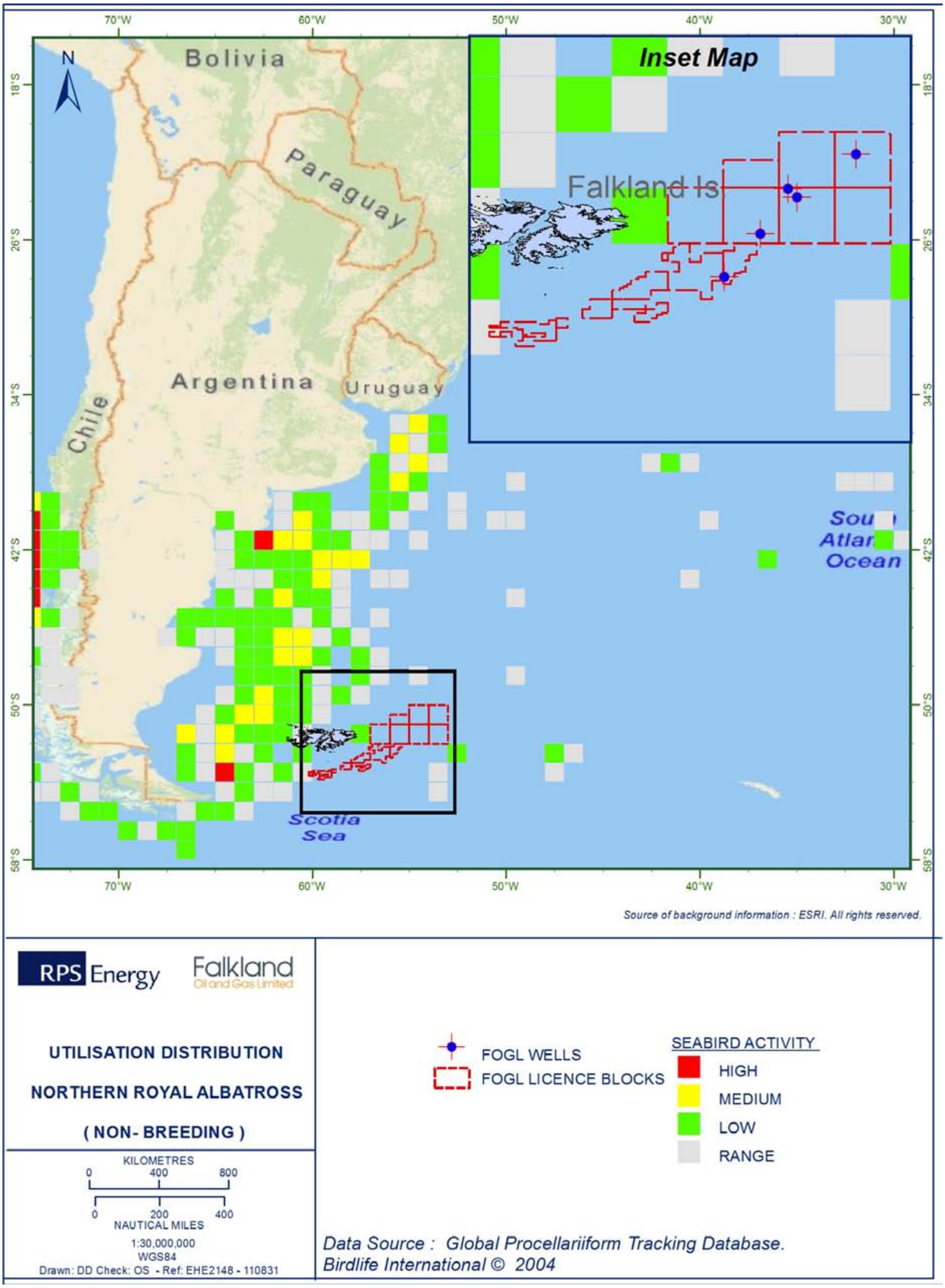
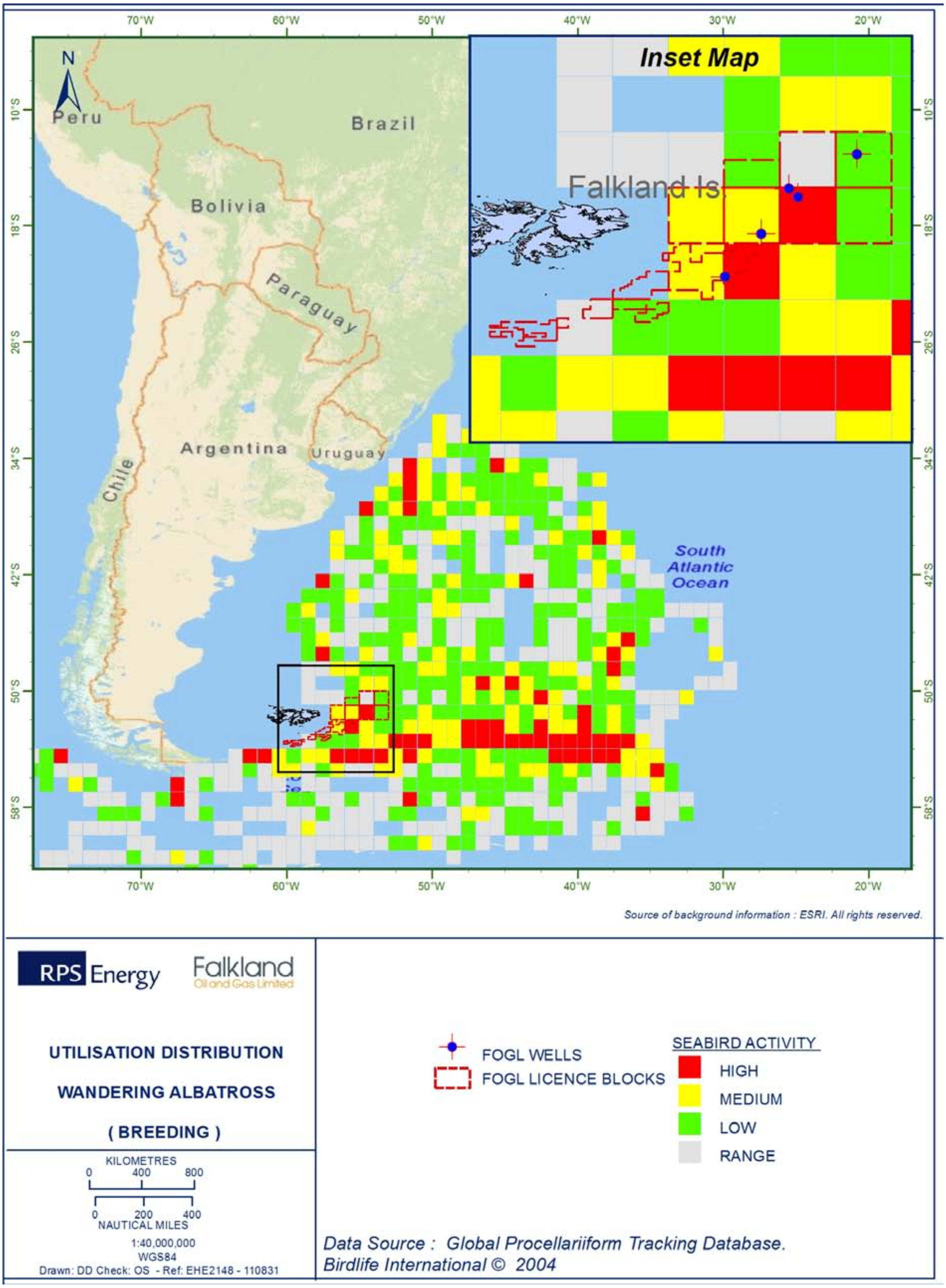


Figure 5.73. Satellite Tracking Utilisation Distribution of Northern Royal Albatross, non -breeding season. (Source: Birdlife International Database, 2004).



5.74. Satellite Tracking Utilisation Distribution of Wandering Albatross, breeding season. (Source: Birdlife International Database, 2004).



5.3.8.13 Seabirds Vulnerability

Seabirds are affected by a number of anthropogenic factors including, competition with commercial fisheries, mortality through longline fishing and contamination from various forms of pollution. Within the Falkland Islands' waters, negative impacts on seabird productivity through competition for food with commercial fisheries have not yet been identified (*White et al., 2001*).

To date, reports of adverse effects to seabirds from surface pollution, such as oil, are low in the Falkland Islands. This presumably reflects the absence of oil pollution in activities to date. It is possible that the increasing oil and gas exploration activities in the area could be a potential threat to seabird populations. Further research and comparison with other activities i.e. fishing is likely to be required in areas of exploration success and potential development.

The following information has been sourced from '*Vulnerable Concentrations of Seabirds in Falkland Islands Waters*' (1998–2000), a report produced by *White et al.* and JNCC (*White et al., 2002*) under contract to Falklands Conservation, with funding support from the Falkland Islands Government (FIG). Although the most comprehensive data to date, these have limited coverage, particularly to the east and south of Falkland Islands, hence the interpretation of results has been carried out using a conservative approach and approximation of data to the areas with limited coverage.

Seabird vulnerability was assessed with regard to species-specific aspects of their feeding, breeding and population ecology. Maps produced in the report can be used to identify areas supporting seabird concentrations at greatest risk to the threat of surface pollution. Methods used for development of the vulnerability atlas are complex, well documented and widely accepted for the assessment of vulnerability in offshore areas (*White et al., 2002*) and are not expanded upon further here.

A summary of the seabird vulnerability survey results for each month of the year, focusing on the FOGL licence area and the proposed drilling period (March-July plus few months of contingency for potential delays or an ongoing spill) is provided in Figures 5.75 and 5.76, and Table 5.8.

It can be seen that most of the project specific area is not adequately covered by JNCC survey results; hence it would be inappropriate to use these data for the interpretation of seabird vulnerability in vicinity of the proposed wells. The JNCC survey effort was mostly concentrated towards the north and west of Falkland Islands as well as coastal zone, therefore the findings are relevant for the assessment of oil spills drifting towards the shore.

Table 5.8. Seabird vulnerability to oiling around the FOGL sites

March	April	May	Jun	Jul	Aug	Sep	Oct
Unsurveyed	Unsurveyed	Unsurveyed	Low	Low	High	Low	Low

Key:	*Unsurveyed*	*Low*	*High*

For areas with no data, vulnerability has been interpolated with ratings from closest areas with data

Figure 5.75. Seabird vulnerability to oiling in the vicinity of the FOGL well sites from March to June (White et al., 2002)

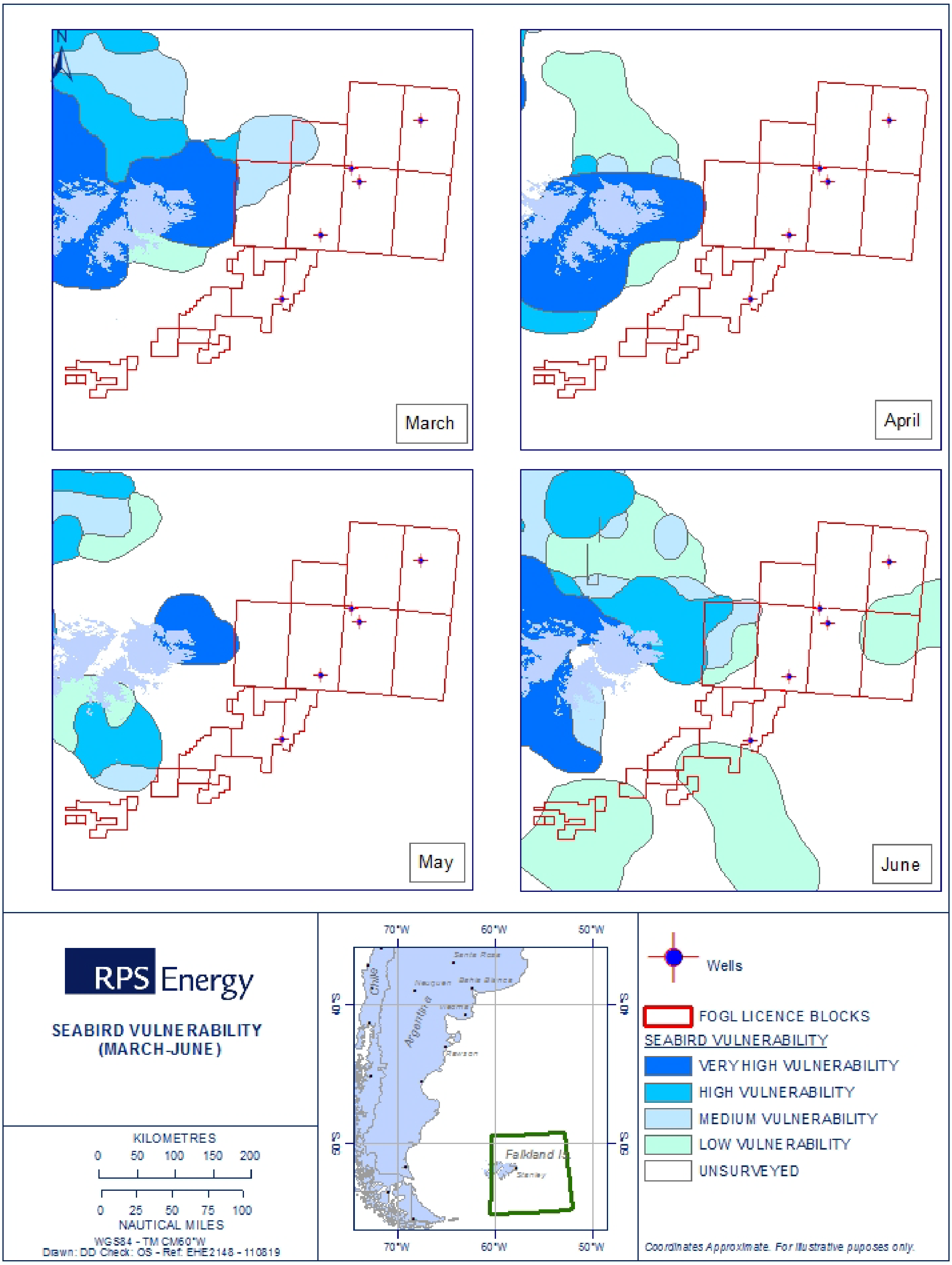
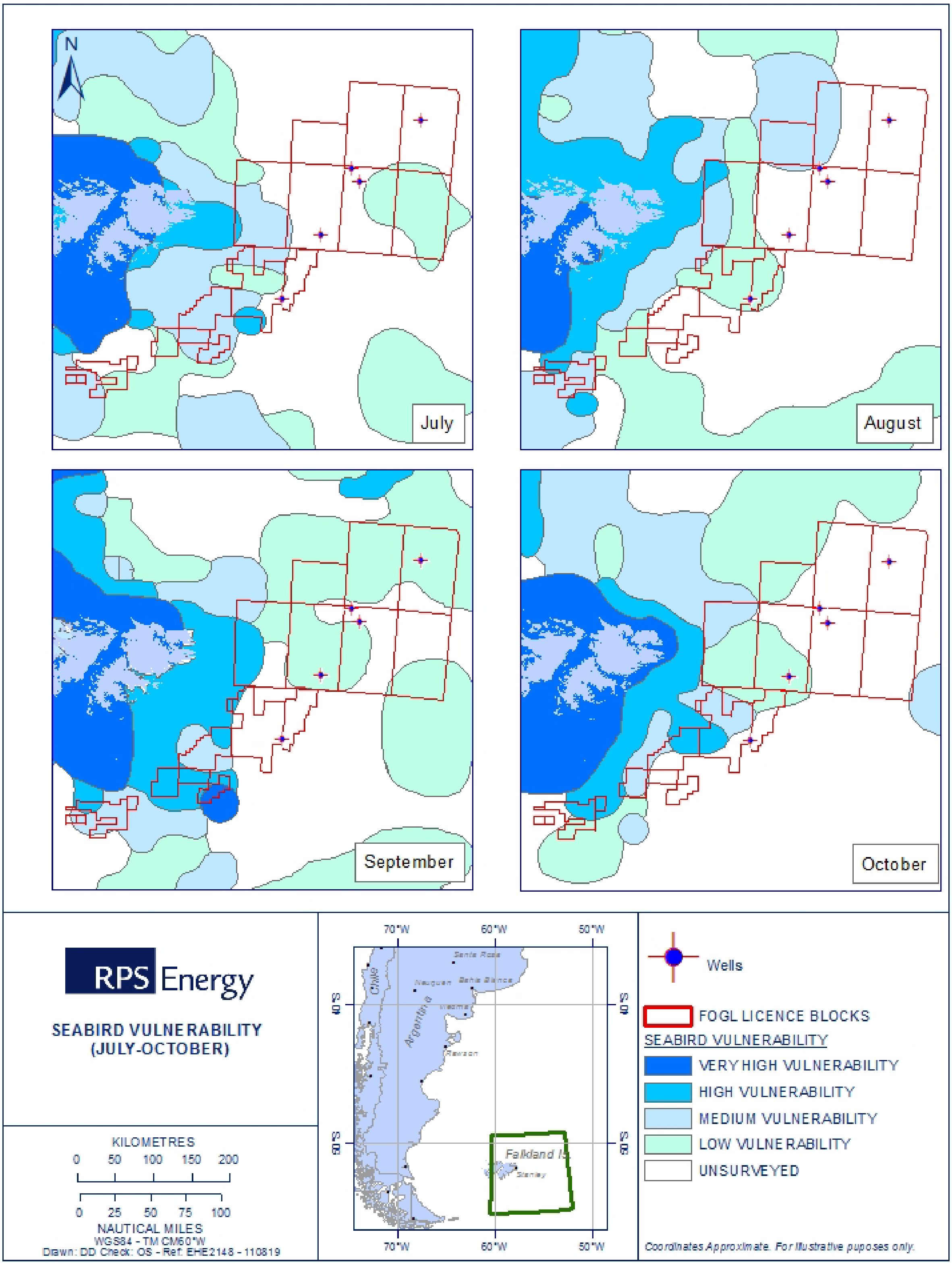


Figure 5.76. Seabird vulnerability to oiling in the vicinity of the FOGL well sites from July to October (White et al., 2002)



5.3.8.14. Summary

Taking into account the seasonality and distribution of seabirds, the following species are likely to be present around the Falkland Islands and potentially the project area in high numbers throughout the FOGL drilling programme (about 100 days):

- Gentoo Penguin – *Near Threatened*
- King Penguin – *Least Concern*
- Imperial Shag – *Least Concern*
- Grey Headed Albatross – *Vulnerable*
- Northern Royal Albatross - *Endangered*
- Southern Royal Albatross - *Vulnerable*
- Black browed Albatross - *Endangered*
- Light Mantled Sooty Albatross – *Near Threatened*
- Wandering Albatross - *Vulnerable*
- Shy Albatross - *Near Threatened*
- Cape Petrel - *Least Concern*
- Antarctic Fulmar – *Least Concern*
- White Chinned Petrel – *Vulnerable*
- Kerguelen Petrel - *Vulnerable*
- Cape Petrel – *Least Concern*
- Blue Petrel – *Least Concern*

Other species are also likely to be present but either in insignificant numbers or mostly outside the proposed drilling window (March-July).

5.4 Protected Sites and Sensitive Habitats

The following three types of formally protected areas are located in the Falkland Islands:

- National Nature Reserves (NNRs) (designated under the Conservation of Wildlife & Nature Ordinance (1999));
- National Parks (designated under the National Parks Ordinance); and
- Ramsar sites.

Existing national Nature Reserves designated under the Nature Reserves Ordinance 1964 and Sanctuaries designated under the Wild Animals and Birds Protection Ordinance 1964 are now designated as NNRs. (Table 5.9; Figure 5.62). The closest of these to a FOGL well site is the Stanley Common & Cape Pembroke Sanctuary Protected Area, located approximately 153 km to the northwest of Vinson West.

Table 5.9. National Protected Areas in the Falkland Islands

Date		Order	Designated Area
Nature Reserve Orders (now National Nature Reserves)	1964	Nature Reserves (Kidney & Cochon Islands) Order 1964 (1/64)	Cochon Island Kidney Island
	1966	Nature Reserves (Flat Jason Island) Order 1966 (2/66)	Flat Jason
	1969	Nature Reserves (Bird Island) Order 1969 (4/69)	Bird Island
	1973	Nature Reserves (Crown Jason Islands) Order 1973 (10/73)	Elephant Jason South Jason North Fur Is. South Fur Is. Jason East Cay Jason West Cay The Fridays White Rock Seal Rocks
	1978	Nature Reserves (Sea Dog & Arch Islands) Order 1978 (2/78)	Sea Dog Island Arch Islands (Inc. Arch Island East, Natural Arch, Clump Island, Tussac Island, Pyramid Rock, Last Rock & Albemarle Rock)
Sanctuary Orders (now Nature Reserves)	1964	Wild Animals & Birds Protection (Sanctuaries)(The Twins) Order 1964 (2/64)	The Twins, Adjacent to Carcass Island, West Falklands
	1964	Wild Animals & Birds Protection (Sanctuaries) (Low Island) Order 1964 (3/64)	Low Island, Adjacent to Carcass Island, West Falklands
	1964	Wild Animals & Birds Protection (Sanctuaries) (Beauchene Island) Order 1964 (4/64)	Beauchene Island,
	1966	Wild Animals and Birds Protection (Sanctuaries) (Middle Island) Order 1966 (4/66)	Middle Island, King George Bay, West Falklands
	1968	Wild Animals and Birds Protection (Volunteer & Cow Bay Sanctuary) Order 1968 (11/68)	Volunteer Point and Inside Volunteer, Cow Bay area of Carysford Camp.
	1968	Wild Animals and Birds Protection (Cape Dolphin Sanctuary) Order 1968 (12/68)	Extreme end of Cape Dolphin.

Date		Order	Designated Area
	1970	Wild Animals & Birds Protection (Bleaker Island Sanctuary) Order 1970 (3/70)	Bleaker Island north of Long Gulch.
	1973	Wild Animals & Birds Protection (Stanley Common and Cape Pembroke Peninsula Sanctuary) Order 1973 (1/73)	Stanley Common & Cape Pembroke.
	1993	New Island South Sanctuary Order 1993 (14/93)	New Island South
	1996	Moss Side Sanctuary Order 1996 (26/96)	Pond and sand-grass flats behind Elephant Beach (Top Sandgrass Camp & Sorrel Pond Camp).
	1998	Narrows Sanctuary Order 1998 (53/98)	Narrows Farm, West Falklands.
	1998	East Bay Sanctuary Order 1998 (54/98)	East Bay Farm, West Falklands
	N/A	Wild Animals and Birds Protection (East Bay, Lake Sulivan and River Doyle)	Proposed
	N/A	Wild Animals and Birds Protection (Pebble Island East)	Proposed
	N/A	Wild Animals and Birds Protection (Port Harriet Point and Seal Point)	Seal Point
National Parks	N/A	Hill Cove Mountains	Proposed
Ramsar Sites	1999	Bertha's Beach	51°55'S 058°25'W
	1999	Sea Lion Island	52°25'S 059°05'W
	N/A	Lake Sulivan, River Doyle and East Bay	Proposed
	N/A	Pebble Island East	Proposed

Falkland Islands Implementation Plan for the Agreement on the Conservation of Albatrosses and Petrels (ACAP)

The Falkland Islands Implementation Plan for the Agreement on the Conservation of Albatrosses and Petrels (ACAP) (*Wolfaardt et al., 2010*) aims to maintain a favourable conservation status for albatrosses and petrels. The plan describes a number of conservation measures that contracting parties need to implement to improve the conservation status of the threatened albatross and petrel species. ACAP has listed in its annex a number of species for protection. These are presented in Table D.4 in Appendix D. In addition, the breeding sites for the ACAP species are also highlighted in the plan (Table D.5 in Appendix D), which lists a total of 42 sites, of which 9 are National Nature Reserves (NNRs).

Important Bird Areas (IBAs) have been defined and are an initiative of Birdlife International, a global partnership of conservation organisations. IBA identification is based on a standard set of criteria applied consistently worldwide, with Falklands Conservation responsible for the cataloguing and description of IBAs within the Falklands. IBAs are not part of any international agreement or convention, and were created to address the increasing global threat to birds from habitat loss and fragmentation.

Currently, 22 sites of international conservation importance for birds (IBA) have been identified in the Falkland Islands (Table 5.10., Figure 5.78. *Important Bird Areas around the Falkland Islands*. The closest of these to a FOGL well site is the Kidney Island Bird group area, located approximately 164 km to the northwest of Vinson West, and a number of other sites. Sea Lion Island and Beauchêne Island are also considered significant habitats with regards to the FOGL project since they are home to significant numbers of birds and marine mammals.

Figure 5.77. Protected Areas around the Falkland Islands

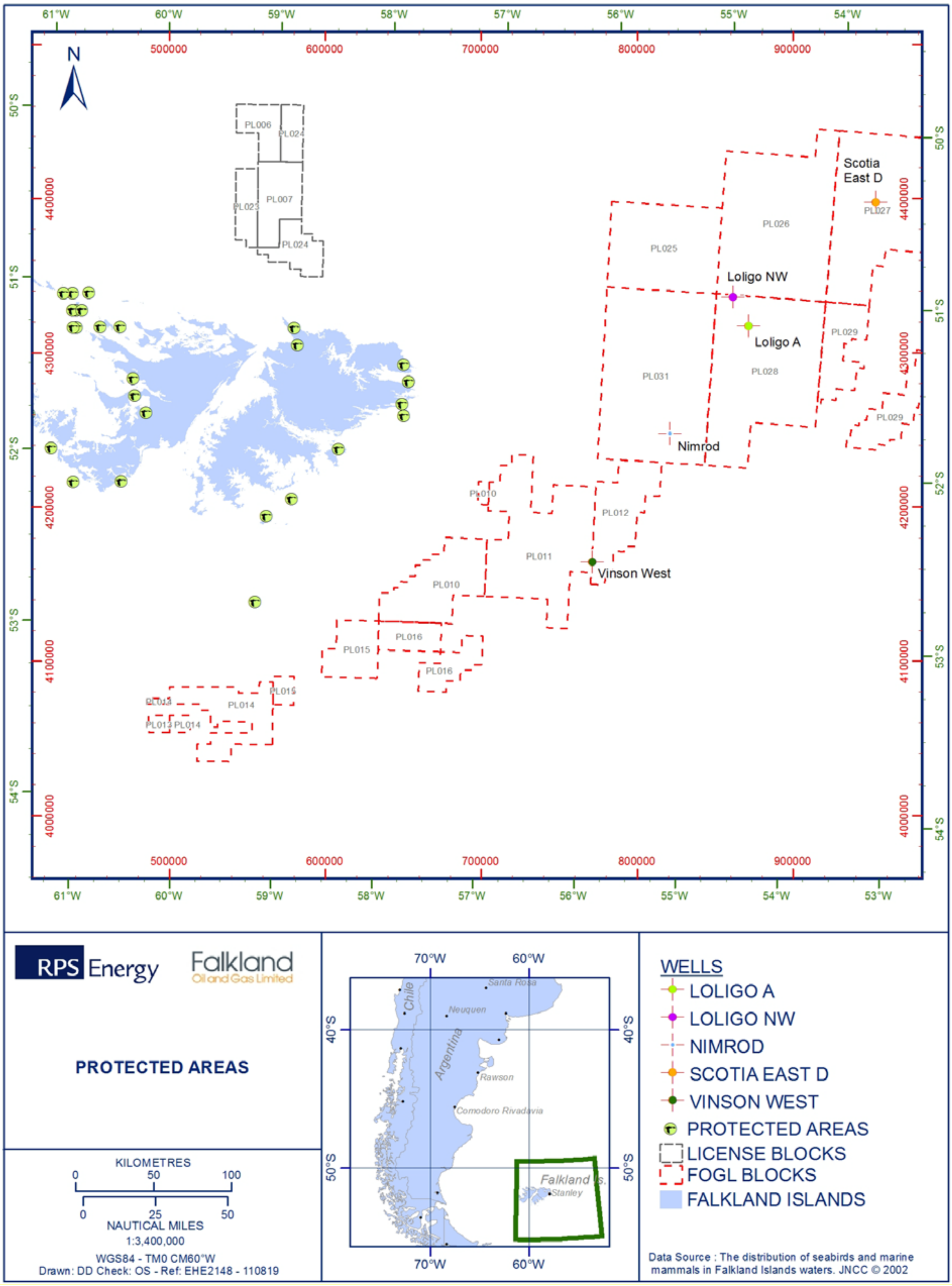


Figure 5.78. Important Bird Areas around the Falkland Islands

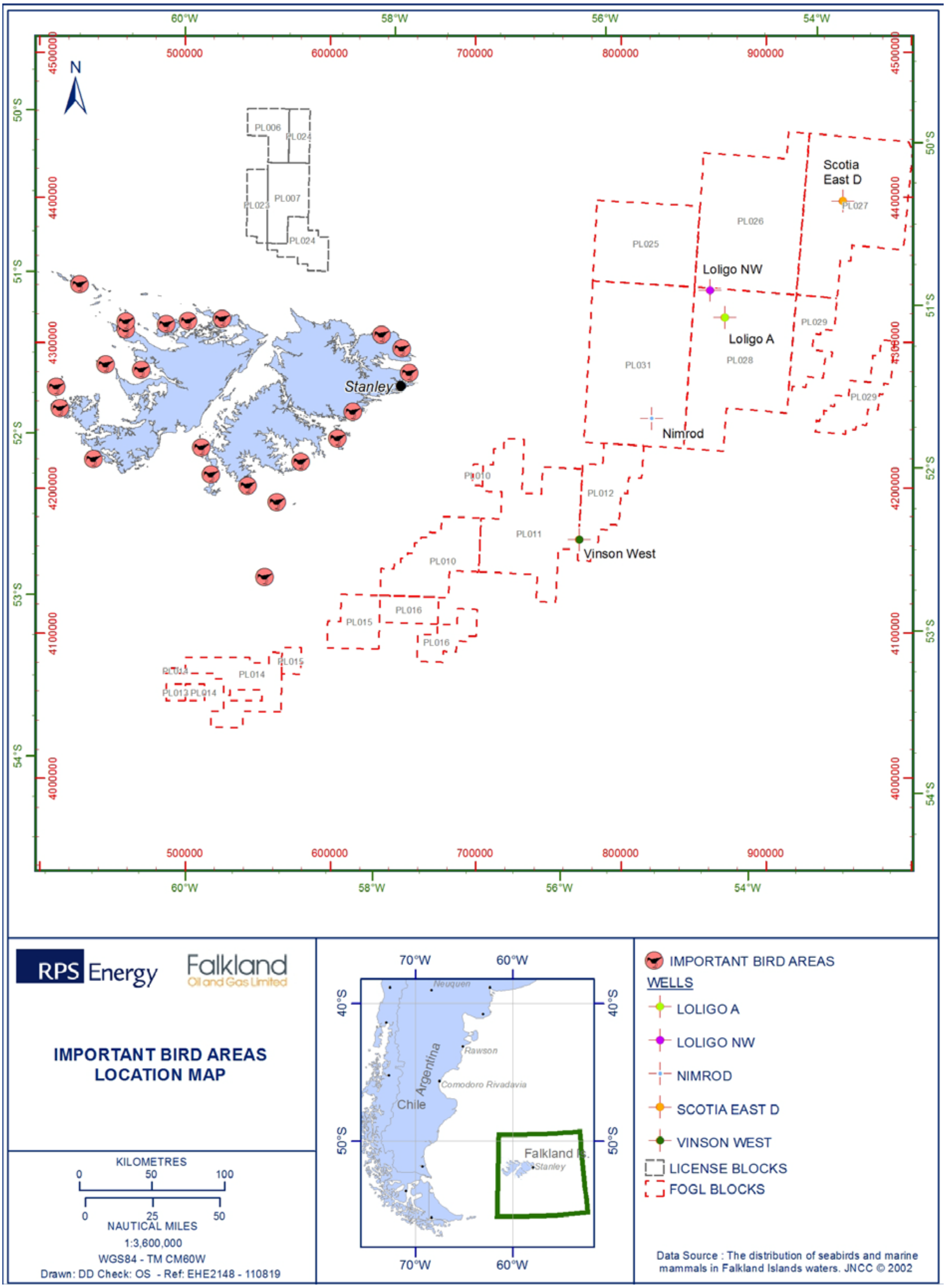


Table 5.10. Internationally Important Bird Areas (IBAs) in Falkland Islands

Important Bird Areas in the Falkland Islands	
Beauchêne Island	Beaver Island group
Bertha's Beach (East Falklands)	Bird Island
Bleaker Island group	Bull Point (East Falklands)
Elephant Cays group	Hope Harbour (West Falklands)
Hummock Island group	Jason Islands group
Keppel Island	Kidney Island group
Lively Island group	New Island group
Passage Islands group	Pebble Island group
Saunders Island	Sea Lion Island group
Seal Bay (East Falklands)	Speedwell Island group
Volunteer Point (East Falklands)	West Point Island group

Kidney Island group

Kidney Island lies approximately 0.5 km off the coast of East Falkland, at the southern entrance to Berkeley Sound. It is largely low lying, with the highest point at just 18 m above sea level. It is almost entirely covered with mature Tussac, although its coasts are characterised by boulder braches on east and west coasts, a large sand bay facing southwest and near vertical cliffs along much of the northern coastline. Kidney Island is located approximately 164 km from the Vinson West well site.

The Kidney Island group comprises of Kidney Island and Cochon Island – a small island lying adjacent to Kidney Island. Cochon's vegetation is limited to Tussac, Wild Celery and Stonecrop.

Kidney Island is an Important Bird Area, with at least 34 species breeding on the islands. The most abundant is the Sooty shearwater, which burrows around the coast and inland. Kidney Island is also home to one of only three breeding colonies of White-chinned petrels. Furthermore, it is the only known breeding site for the Great Shearwater outside the Tristan da Cunha and Dough Island group in the South Atlantic. Other species present on the Island group include;

- Macaroni Penguins (*Eudyptes chrysolophus*)
- Rockhopper Penguins (*Eudyptes chrysocome*)
- Rock Shag (*Phalacrocorax magellanicus*)
- Imperial Shag (*Phalacrocorax atriceps*)
- Ruddy headed Goose (*Chloephaga rubidiceps*)
- Black crowned night Heron (*Nycticorax nycticorax*)
- Upland Goose (*Chloephaga picta*)
- Short eared Owl (*Asio flammeus*)
- Dark-faced Ground-tyrant (*Muscisaxicola maclovianus*)
- Falkland Pipit (*Anthus correndera)*
- Falkland Grass Wren (*Cistothorus platensis*)
- Falkland Thrush (*Turdus falcklandii falcklandii)*
- Long-tailed Meadowlark (*Sturnella loyca*)

Sea Lion Island

Sea Lion Island lies 17 km to the south of mainland East Falkland. The island is approximately 2.2 acres and for many years was a sheep farm. It is now a premier wildlife site, attracting visitors year round. Birdlife International lists the island as an "Important Bird Area". The following bird species have been observed on Sea Lion Island;

- King penguin (*Aptenodytes patagonicus*)
- Gentoo penguin (*Pygoscelis papua*)
- Rockhopper penguin (*Eudyptes chrysocome*)
- Magellanic penguin (*Spheniscus magellanicus*)
- Macaroni penguin (*Eudyptes chrysolophus*)
- Silvery grebe (*Podiceps occipitalis*)
- Black-crowned night-heron (*Nycticorax nycticorax)*
- Sooty shearwater (*Puffinus griseus*)
- Ruddy-headed goose *(Chloephaga rubidiceps)*
- Kelp goose (*Chloephaga hybrid)*
- Chiloë wigeon *(Anas sibilatrix)*
- Flightless steamer duck (*Tachyeres brachypterus,*)
- Crested caracara (*Polyborus plancus*)
- Speckled teal (*Anas flavirostris*)
- Magellanic oystercatcher (*Haematopus leucopodus*)
- Striated caracara (*Phalcoboenus australis*)
- White rumped sandpiper (*Calidris fuscicollis*)
- Two-banded plover (*Charadrius falklandicus*)
- Brown hooded gull (*Chroicocephalus maculipennis*)
- Kelp gull (*Larus dominicanus*)
- Dark faced ground- tyrant (*Muscisaxicola maclovianus*)
- South American tern (*Sterna hirundinacea*)
- Greass wren (*Cistothorus platensis*)
- Falkland pipit (*Anthus correndera*)
- Black throated finch (*Poephila cincta*)
- Cobb's wren (*Troglodytes cobbi*)
- White tufted grebe (*Rollandia rolland*)
- Silver teal (*Anas versicolor*)
- Rock shag (*Phalacrocorax magellanicus*)
- Peregrine falcon (*Falco peregrines*)
- Upland goose (*Chloephaga picta*)
- Rufous – chested dotterel (*Charadrius modestus*)
- Patagonian crested duck *Lophonetta specularioides* specularioides
- Dolphin gull (*Leucophaeus scoresbii*),
- Short eared owl (*Asio flammeus*)
- Long tailed meadowlark (*Sturnella loyca*)
- Falkland thrush (*Turdus falcklandii*)

The islands are also home to a rich assemblage of marine mammal species. 95% of the Falkland population of southern elephant seals reside on Sea Lion Island. This area is also regarded as an important breeding site for southern sea lions, although numbers being born here have declined over the past century. Killer Whales are also common around Sea Lion Island, particularly during pinniped breeding times. Peale's and Commerson's dolphins are also observed year round near the islands.

Beauchêne Island

Beauchêne Island compromises the southernmost land in the Falklands archipelago, lying approximately 54 km south of Porpoise Point on the mainland. It has not been cultivated or settled on and is free of introduced predators. Two thirds of the island is covered with Tussac.

More than 30 bird species have been recorded on the island. Most of these are migratory seabirds that are present in high numbers during the breeding season. The islands are home to the second largest populations in the world of Black-browed albatrosses and rockhopper penguins. The second densest breeding population of Striated Caracaras in the Falklands also reside here. Beauchêne Island is also an important site for the following species:

- Wilson's Storm petrel (*Oceanites oceanicus)*
- Common Diving Petrel (*Pelecanoides urinatrix*)
- Cobb's Wren (*Troglodytes cobbi*)
- White-chinned petrel (*Procellaria aequinoctialis*)
- Southern Giant Petrel (*Macronectes giganteus*)
- Grey-backed Storm-petrel (*Garrodia nereis*)
- Fairy Prion (*Pachyptila turtur*)
- Imperial Shag (*Phalacrocorax atriceps)*
- Magellanic Penguin (*Magellanic Penguin*)

Southern Sea Lions also use the islands as a breeding site while a large number of other pinniped individuals use it as a haul-out station during foraging trips.

Offshore Protected Sites

Legislation on the protection of certain marine habitats has developed significantly in recent years and now constitutes a very central aspect to any environmental assessment for offshore developments. There do not appear to be protected or designated marine areas in the vicinity of the FOGL sites, although there are several in shallow waters around the East Falkland coast which should be considered with regards to shipping activity during the development.

5.5 Socio-Economic Environment

5.5.1 Economy

The economy of the Falkland Islands has traditionally been restricted due to its small population and isolation from external markets. Since 1982 the economy has grown rapidly, initially as a result of UK aid but more recently from the development of the fishing industry. The Falklands have received no aid from Britain since 1992 and are now self-sufficient in all areas with the exception of defence (*FCO, 2010*).

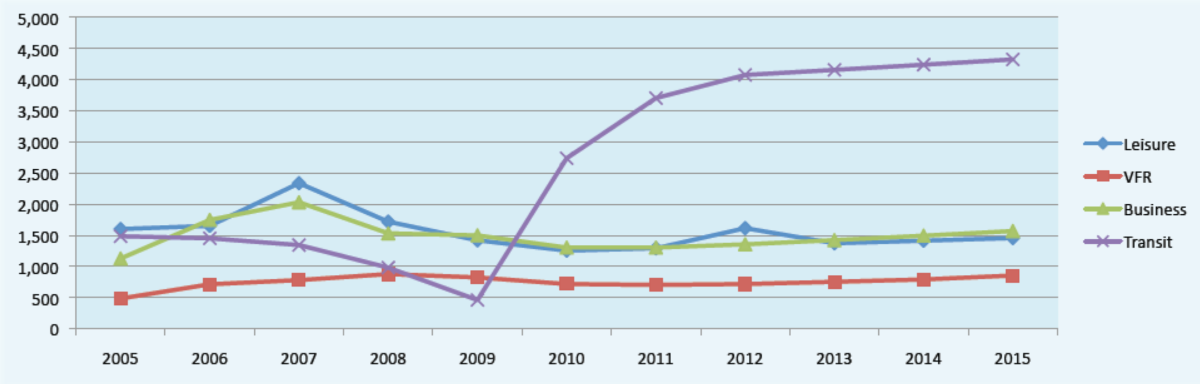
A workforce of over 2000 exists in the Falklands, with the FIG the largest employer, employing around 600 people. The three largest industries are agriculture, commercial fisheries (refer to Section 5.5.3) and tourism (refer to Section 5.5.2). The fisheries, tourism, infrastructure development and retail industries are steadily growing and employing an increasing number of people. In addition, the recent renewed interest in oil and gas exploration of the area has brought with it further opportunities for the expansion of services in this sector.

5.5.2 Tourism

The tourism industry is growing rapidly, with large numbers of passengers arriving in Stanley each year from cruise ships. The main attractions are the Islands' unique environment and wildlife. According to the Falkland Islands Environmental Planning Department, there are plans to further utilise the Islands' cultural, natural and built heritage sites so as to attract more tourists. It is suggested that this could be achieved via the promotion of niche tourism packages such as eco-tourism, cultural tourism and battlefield tours. In general, services on the Falkland Islands will be improved in the coming years to make the islands a more desirable place for eco-tourists to visit.

According to Acorn Tourism Consulting (ATC), tourist arrivals to the Falkland Islands are expected to increase by 16% in 2011. Included in these figures are leisure and business tourists as well as those visiting friends and relatives (VFR) and those passing through the islands during transit. These groups are presented separately in Figure 5.79.

Figure 5.79. Tourism Trend in the Falkland Islands (Acorn Tourism Consulting, 2011).



Between 2010 and 2011 leisure tourism grew by over 17%, although there were decreases in VFR and business tourists. Most tourists arrived from the UK, with numbers increasing by around 73% between 2010 and 2011.

Passenger numbers in recent years on cruises to the Falklands peaked in the 2008 – 2009 season with 62, 488. This fell to 48, 359 in 2009 – 2010 and again to 40, 542 in the 2010 – 2011 season. ATC predict that numbers will increase again year on year from the 2011/2012 season onwards. Numbers are expected to be particularly high in 2012, since this marks 30 years since the Falkland Islands conflict. The Falkland Islands Tourism Board aims to increase the number of cruise ship day visitors and longer staying tourists in a manner that is sustainable.

The Falkland Islands main tourist lodges are located at Port Howard, Darwin, Pebble Island, Sea Lion Island and Weddell Island. Self-catering accommodation can be found at a selection of holiday cottages on island farms, and several locations in East and West Falkland. In Stanley, there is only one hotel (the Malvina House Hotel) and a choice of guest house and bed and breakfast accommodation.

Cruise ships from various points of origin travel to the Falkland Islands, although the movement of vessels through the waters to the south and east of the islands is likely to be limited. The recent growth in cruise ship movements increases the significance of this aspect and emphasis the need for early notification, ongoing communication and the use of standby vessels to support drilling operations.

Due to the significant distance of the FOGL wells, from the mainland (minimum 155 kilometres), interactions and impacts on the tourist industry from routine operations are expected to be low from the aesthetic perspective. There could be potentially an overlap in demand for accommodation, which is extremely scarce in Falkland Islands. However, it should be noted that the majority of tourists stay on cruise ships.

5.5.3 Commercial Fishing

5.5.3.1 Overview

Commercial fisheries are the largest source of income for the Falkland Islands. All fishing within 200 nautical miles of the Falklands is subject to licensing by the Falkland Islands Government (FIG). The fisheries generate £10 to £20 million per annum in licence fees, roughly half the government revenue. Approximately £0.6 million of fisheries income is spent each year on catch and conservation monitoring, research and administration. Target species for the commercial fisheries operating in Falkland Islands waters are:

- Argentine shortfin squid (*Illex argentinus*);
- Patagonian squid (*Loligo gahi*);
- Southern blue whiting (*Micromesistius australis australis*);
- Hoki (*Macruronus magellanicus*);
- Patagonian toothfish (*Dissostichus eleginoides*);
- Patagonian hake (*Merluccius australis*);
- Common hake (*Merluccius hubsii*);

- Common rock cod (*Patagonotothen ramsayi*)
- Red cod (*Salilota australis*);
- Skates & rays *(Rajidae).*

Table 5. 19111 shows the total revenue generated from the fisheries industry from 2004 to 2010. Revenue in 2010 was up slightly on the previous year at £11.5 million compared to £10.8 million (*FIG, 2011*).

Table 5. 11. Falkland Islands fisheries annual revenue 2004-2010 (Falkland Islands Government Fisheries Department, 2011)

2004	2005	2006	2007	2008	2009	2010
11,912,319	10,552,357	14,401,541	15,393,593	15,308,645	10,850,229	11,484,738

Table 5.12. Falkland Islands Fisheries catches (tonnes) of all species by year 2003 – 2009 (Falkland Islands Government Fisheries Department, 2011)

Species	Common name	2004	2005	2006	2007	2008	2009	2010
Patagonotothen spp	Rock cod	0	0	20,211	30,157	60,589	58,149	76,411
Loligo gahi	Patagonian Squid	26,835	58,811	43,067	42,003	52,260	31,475	66,541
Macruronus magellanicus	Hoki	25,905	16,721	19,761	16,669	15,902	23,170	19,219
Merluccius hubbsi	Common hake	0	0	8,414 **	11,908**	8,805 **	13,051**	13,612**
Micromesistius australis	Southern blue whiting	28,554	17,047	20,533	22,204	13,208	10,395	6,412
Rajidae	Skates and Rays	5,151	5,698	4,679	5,663	3,853	5,865	5,922
Salilota australis	Red Cod	2,781	2,467	3,469	5,195	4,076	5,079	3,131
Genypterus blacodes	Kingclip	1,841	1,936	2,821	3,592	2,226	3,395	3,643
Dissostichus eleginoides	Patagonian toothfish	2,002	1,677	1,572	1,519	1,429	1,419	1,403
Macrouridae	Grenadiers	0	0	797	622	943	958	450
Osteichthyes/ Chondrichthyes	Others	5,080	10,717	1,133	1,099	502	246	221
Illex argentinus	Illex squid	1,720	7,937	85,614	161,402	106,608	44	12,109
Zygochlamys patagonica	Scallop	1,279	1,358	1,161	14	6	13	3
Martialia hyadesi	Martialia squid	24	0	0	0	0	0	0
Merluccius spp/ australis†	Austral hake	1,926	2,735*	23***	0***	0***	0***	0
	Totals:	103,098	127,104	213,255	302,047	270,407	153,259	195,465

† *Merluccius spp.* until 2005; M. australis since 2006

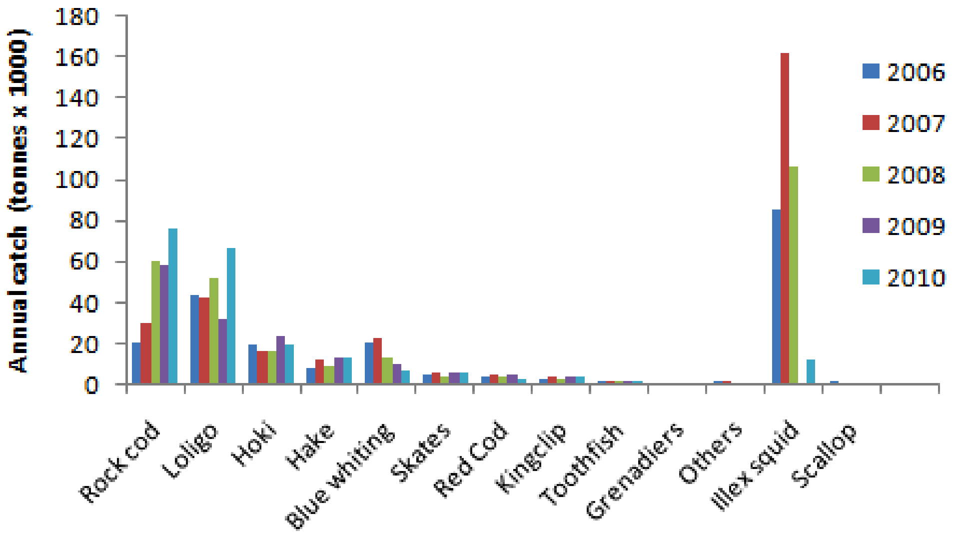
* *Merluccius spp.*, ** *M. hubbsi*, *** *M. australis*

Shaded rows – key species for the Falkland Islands fisheries.

The key catches for the years 2004-2010 are shown in Table 5.710122. Figure 5.80 shows commercial catches taken over the last 5 years and shows the total catch during 2010 was at an average level, although the composition of the catch has changed with the emphasis away from squid and onto finfish, in particular rock cod (*Patagonotothen ramsayi*) which has changed from being a discarded species to having the highest commercial catch.

Conversely, catches of *Illex* have remained low after crashing to just 44 tonnes in 2009 from very high prior catches. Despite subsequent high fishing effort catches remained relative low at 12,103 tonnes. Catches of southern blue whiting also continue to drop although this is also due to the fishing ban imposed on the southern blue whiting spawning grounds for the duration of the spawning period. As such, catches were at an historic low of only 6,414 tonnes in 2010 (*FIG, 2011*).

Figure 5.80. Commercial catches taken from Falkland Island waters, 2006 – 2010 (FIG, 2011)



Research shows that the commercial squid species are short-lived and fast growing, living for about a year and spawning once within that time (*Rodhouse, 1988*). Typically, species with this sort of lifecycle are susceptible to changes in environmental conditions. This can create a high level of variability in stocks on a year-to-year basis. *Illex* stocks are traditionally prone to high variability in abundance, bringing instability to its fishery and marketing.

To protect against poachers, the waters are patrolled by FIG aircraft and fishery patrol vessels (FPVs) which monitor the exclusive economic zone (EEZ) borders for infringement by unregistered vessels. The Falklands has one dedicated FPV (*Protegat*) with the FPV *Pharos* occasionally patrolling Falklands waters in between deployments in South Georgia.

Fisheries catch statistics (2008-2010) in relation to the FOGL licensed areas are displayed in Section 5.3.6.2. The majority of fishing vessels operate in 100-kilometres zone around Islands and extend further north and west. In the western and northern part of the FOGL licence blocks, Loligo and Rock cod are caught in significant quantities (Figure 5.64). Long-lining vessels are most common within the licence area, with a predominant catch of Patagonian toothfish as well as experimental grenadier fisheries (Figure 5.66). Most long-line catches are made to the north and south of the Falkland Islands.

5.5.3.2 Finfish fisheries

***Patagonian toothfish** (Dissostichus eleginoides)*

The long-line fishery for *D. Eleginoides* in the Falklands began in 1992 with an exploratory period and the commercial exploitation began in 1994 with two vessels licensed that year. Currently there are both bottom trawl and long-line vessels operating in the fishery, with bottom trawlers targeting younger individuals mainly at depths between 120 to 350 metres. The long-line fishery became the first Falkland fishery to be managed by Total Allowable Catch (TAC) rather than effort and operates all year round or until the quota is caught (*FIG, 2011*). Unlike the trawl fishery, it targets larger, older individuals normally between depths of 650 to 2000 metres (*Laptikhovsky and Brickle, 2005*).

During 2010 the cumulative catch by bottom trawlers was 460 tonnes with predominately 3+ and 4+ year aged fish caught giving a good indication of recruitment in the shelf population and of future long-line catches. The long-line fishery had a total catch of 943 tonnes for 2010 year with some 155 tonnes of the Total Allowable Catch (TAC) not taken; this was subsequently carried over to 2011 giving a total TAC of 1,355 tonnes. This has been the lowest total catch since 2001, with total catches fluctuating during this period from 1,403 tonnes in 2010 to 2,002 tonnes in 2004. Stock assessments during 2010 produced similar estimates to that of the previous year which estimated the spawning stock biomass (SSB) to be 12,930 – 24-156 tonnes (*FIG, 2011*).

Currently only one long-line vessel is licensed, so catches can be highly variable throughout the year, due to only one vessel being in the fishery. During 2010, catches appeared to tail off from July through to November, although this was due mainly to the vessel leaving the fishery for a number of weeks in the middle of September (Figure 5.81).

Figure 5.81. Catches of toothfish by long-line vessel during 2010 (from FIFD fisheries data).

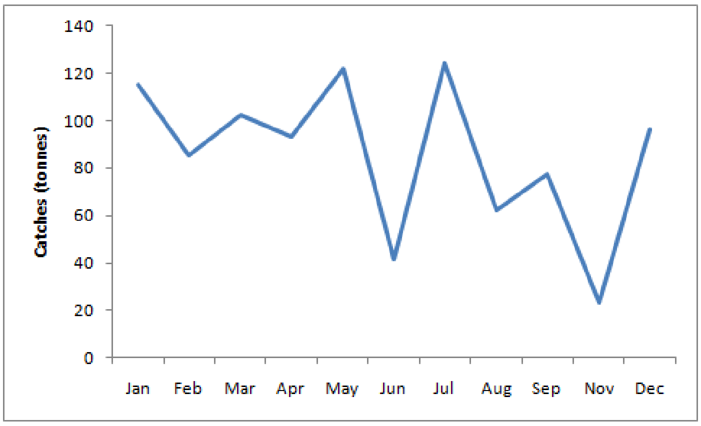
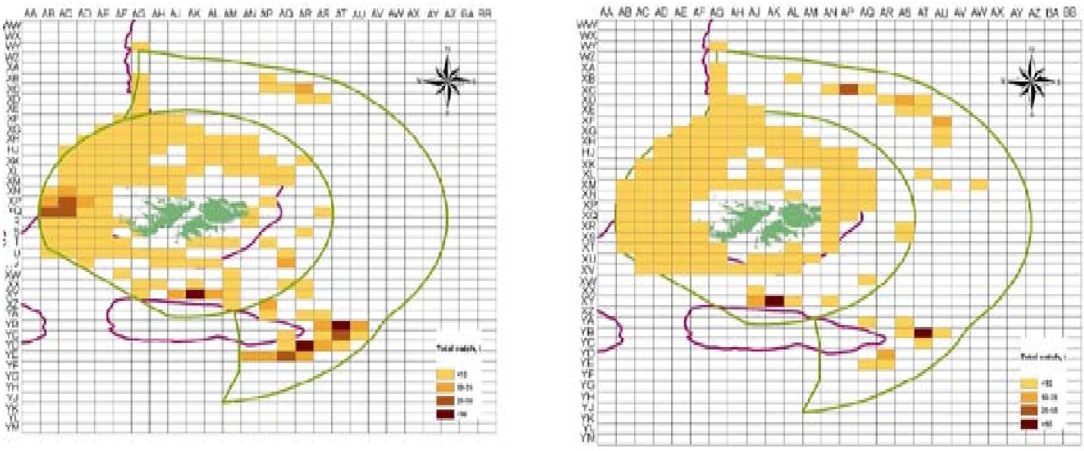


Figure 5.82 shows the catch distribution within the FOCZ during 2010, catches to the north and west are taken by trawlers and although they are over a larger area they represent a smaller catch by weight (460 tonnes) than that taken by the long-liners. Long-liners operate in the deeper waters to the south of the FOGL area around the Burdwood Bank, which has also been shown to be one of the main spawning areas (Section 5.3.6.2). There may also be some crossover with the fishing grounds to the north of the FOGL box particularly during the 2nd season from July to December.

Figure 5.82. Spatial distribution of catches (tonnes) of Dissostichus eleginoides during (a) first fishing season and (b) second fishing season in 2010 (source: FIG, 2011).

(a) **(b)**



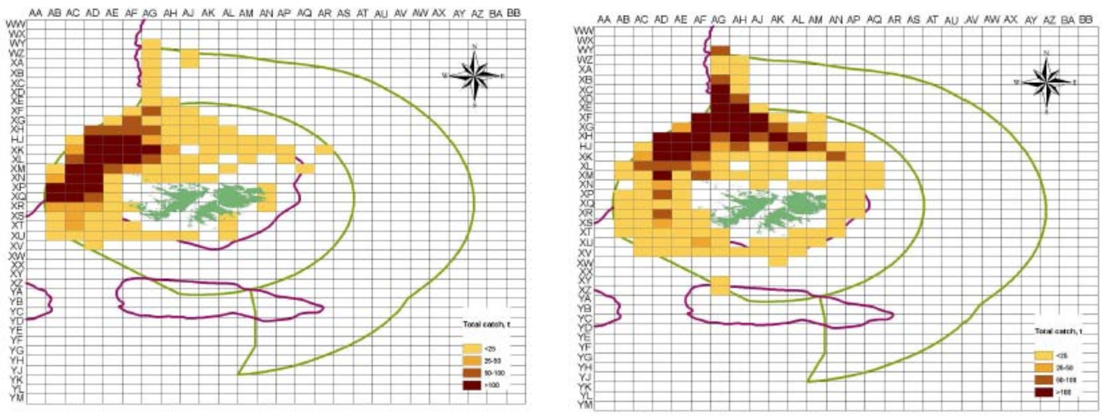
Hake *(Merluccius spp.)*

Both hake species are abundant to the west of the FICZ and are targeted by Spanish and Falkland registered trawlers licensed for unrestricted finfish (*FIG, 2011*). Both hake stocks are shared with Argentina and *M.australis* are also shared with Chile, but only a small proportion of the total stock migrates into Falkland waters (*FIG, 2011*). The principal fishing method is demersal trawling (*Tingley et al., 1995*). In commercial catch data, no distinction is made between the two species (*Tingley et al., 1995*). The total catch of hake decreased from 12,000 tonnes in 1990 to 1500 tonnes in 1994-1997 and then remained between 1,678-3,069 tonnes, from 2000 to 2005 (*FIG, 2011*). In the period from 2005 to present the annual catches of hake increased substantially, with the greatest catches occurring in 2010 (13,610 tonnes) (*FIG, 2011*).

In 2010, hake were caught predominantly to the northwest of the Falkland Islands, at depths between 170-200m, and catch was highest between April and September (Figure 5.83b) (with exception of June when there was low effort) (*FIG, 2011*). The observed distribution of both *Merluccius* species shows that they are unlikely to occur in significant abundance within the FOGL licensed areas and that the impact on these species will be minimal.

Figure 5.83. Spatial distribution of catches (tonnes) of Merluccius hubbsi during (a) first fishing season (January - June) and (b) second fishing season (July - December) in 2010 (source: FIG, 2011).

(a) **(b)**



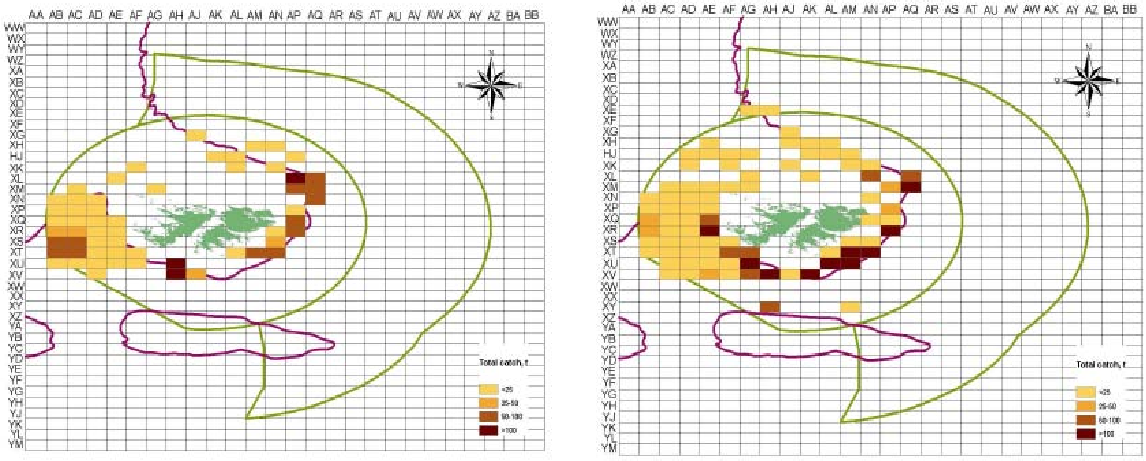
***Southern Blue Whiting** (Micromesistius australis)*

Southern blue whiting have historically been one of the main fish species targeted in Falkland Island waters (*FIG, 2011*). Annual catches of around 25,000 tonnes were taken by pelagic and bottom-trawl vessels from 1992 until 2007, when a downward trend was seen (*FIG, 2011*). Southern blue whiting was fished mainly in austral spring and autumn (Sept-Nov and Mar-May) (Figure 5.84). However, due to the results of an assessment carried out in 2009 that showed the stock was in critical condition, a ban on fishing for southern blue whiting was imposed in 2010 on the spawning grounds (11 grid squares in FICZ) for the period from September to the first half of October (*FIG, 2011*). As lowest catches ever were observed in 2010 (6,414 tonnes), FIFD advised that the ban be continued into 2011 from 1 August to 15 October for pelagic trawlers and 1 Sept to 15 October for demersal trawlers. This is to allow undisturbed spawning so that the fishery can be rebuilt to acceptable commercial levels (*FIG, 2011*).

Southern blue whiting is a straddling stock, with the resource shared between the Falkland Islands and Argentina, where catch limits remain at higher levels (*FIG, 2011*). Since 2007, pelagic trawlers have instead been fishing from October to December for aggregations of post-spawning fish feeding in Falkland Islands waters before heading south (*FIG, 2011*). This amounted to more than half of the catch taken in 2009 (*FIG, 2010*). The observed distribution and catches of *M. australis* shows that it is unlikely to occur in significant abundance within the FOGL licensed areas and that the impact on this species will be minimal.

Figure 5.84. Spatial distribution of catches (tonnes) of Micromesistius australis during (a) first fishing season (January - June) and (b) second fishing season (July - December) in 2010 (source: FIG, 2011).

(a) **(b)**



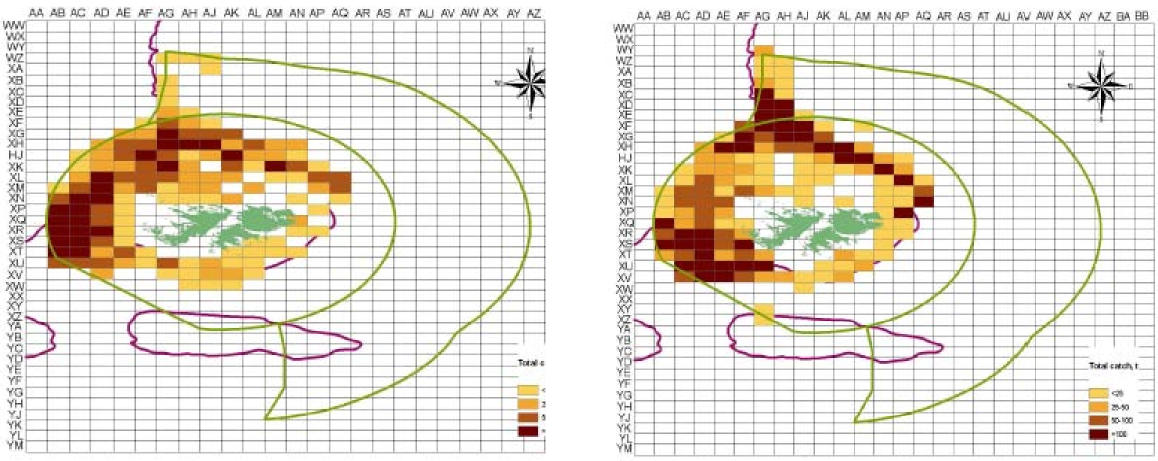
Whiptail hake / hoki (*Macruronus magellanicus*)

Because of the seasonal migration, populations within the FICZ are targeted commercially beforehand in February – May and post-spawning during November (Figure 5.85). Initially *M. magellanicus* was targeted as bycatch until direct fisheries were established and catch rose from 10,000 tonnes in the early 1990s to 16,670-26,970 tonnes by 1998. They are targeted by licensed finfish trawlers but are also considered important as bycatch in the *Loligo*, mixed species rajid and surimi fisheries (*FIFD, 2011*). Current stock levels are considered to be in good condition however the future sustainability of the *M. magellanicus* stock is questionable given the historical variance in catch. For instance, catch fell considerably in 2005 before rising again in 2006 and in 2010 total catch fell to 19,214 tonnes; 4,000 tonnes lower than the previous year (*FIFD, 2011*). Stock assessment is difficult due to the migratory nature of the species and the small representation within the commercial trade, however catches have remained relatively consistent with constant effort over the last few years implying the risk of over exploitation is low (*FIFD, 2011*). Catches throughout the year are shown in Figure 5.85.

The observed distribution of the fishery for *M. magellanicus* shows that it is unlikely to conflict with operations within the FOGL licensed areas and that the impact on these species would be expected to be minimal.

Figure 5.85. Spatial distribution of catches (tonnes) of Macruronus magellanicus (a) first fishing season (January - June) and (b) second fishing season (July - December) in 2010 (source: FIG, 2011).

(a) **(b)**

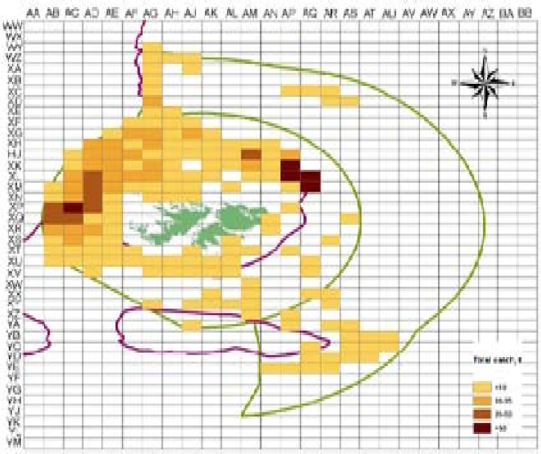


Skates and rays *(Rajidae spp.)*

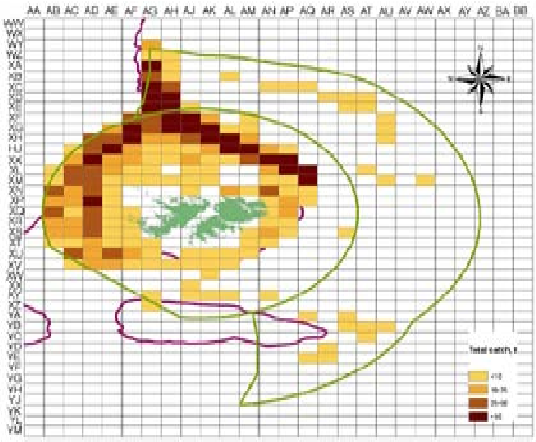
Skate catches have been increasing since 1998 with 5,886 tonnes being taken in 2010. The majority of the catch (56%) is taken as bycatch under finfish licences with the remainder harvested as targeted catch. In both cases the majority of the catch is taken during the second half of the year. Commercial catches do not differentiate between different species. However observer data from commercial catches shows the three most prevalent species as *B. griseocauda* (21.8%), *B. brachyurops* (21.7%), and *B. albomaculata* (13%). Data are also available from a survey cruise dedicated to assessing population abundance and species composition within a defined 'Skate Box' to the north of the islands between October and September 2010. 12 different species were caught with biomass estimates (throughout the survey area) calculated as 7,232 tonnes for *B griseocauda*, 7,312 tonnes for *B. brachyurops*, 4,016 tonnes of *B. albomaculata* with the remaining species estimated at 7,312 tonnes. These rankings and estimates, combined with the commercial CPUE data show that the skate biomass has remained stable with respect to the major species (*FIG, 2011*). The spatial distribution of catches for 2010 is shown in Figure 5.86. While the majority of the catches are to the north of the islands there are some areas of overlap with the FOGL area to the south throughout the year and to the north during the second fishing season (July – December).

Figure 5.86. Spatial distribution of catches (tonnes) of Rajidae during (a) first fishing season (January - June) and (b) second fishing season (July - December) in 2010 (source: FIG, 2011).

(a)



(b)



Rock Cod *(Patagonotothen ramsayi)*

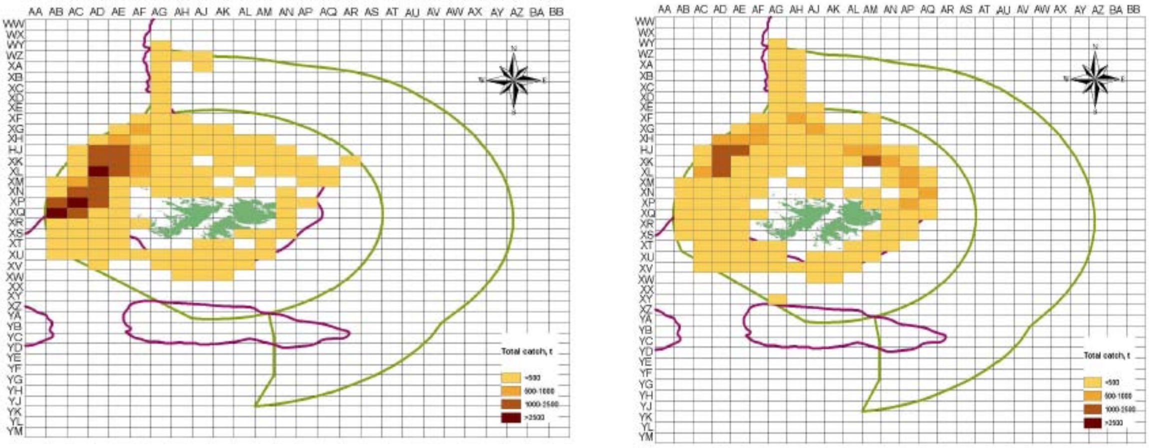
Prior to 2006 rock cod were classed as a discard species. Since then, have they been the subject of targeted fishery by licensed finfish trawlers. 2010 saw record catches, above those of other finfish species. It is also caught as bycatch in other fisheries, particularly the *Loligo gahi* trawl fishery where 5,058 tonnes of the total catch of 76,411 tonnes was taken in 2010 (*FIG, 2011*). Dense fish aggregations occur in the warmer season from January - February (Figure 5.87) (*Winter et al., 2010; FIG, 2011*). Catch has been increasing since 2006 from 30,635 tonnes to 76,411 tonnes in 2010 but it is unknown whether the increase in recent years is a result of increased efforts to target the species or increased abundance in the area (*Winter et al., 2010; FIG, 2011*). A 15% increase in the bycatch on the *Loligo* trawlers between 2009 and 2010 suggests an increase in abundance. If this is the case, it may explain the increase in catch of hake (*Merluccius* spp.) in the FICZ / FOCZ region, a common predator to *P. ramsayi* (*FIG, 2011*).

Because of recent interest, the stock is still considered to be in the initial 'fishing down' period (*Winter et al., 2010*). Stock biomass estimates calculated maximum sustainable yield at 72,547 tonnes with a higher catch of 76,411 tonnes caught in 2010 not including unreported discards (*FIGF, 2011*). A catch limit for 2011 was set to 60,000 tonnes (*FIG, 2011*) reducing the estimated overfishing risk from 50% to 35%.

It is unlikely that there will be any overlap between the fishing grounds or spawning areas and the FOGL area.

Figure 5.87. Spatial distribution of catches (tonnes) of Patagonotothen ramsayi (a) first fishing season (January - June) and (b) second fishing season (July - December) in 2010 (source: FIG, 2011).

(a) **(b)**



Red Cod *(Salilota australis)*

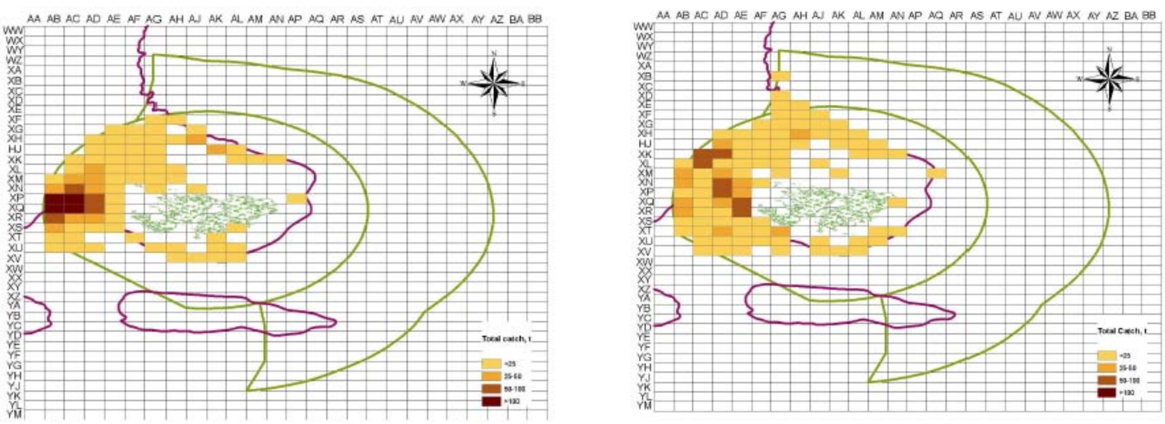
S. australis are retained within the Falkland Island finfish fishery, which caught 3,133 tonnes in 2010, the lowest in 5 years (*FIG, 2011*). This decline however, was attributed to the closure of part of the fishing ground during October to protect the spawning and post-spawning stock, which is historically the period of highest catches. These precautionary measures were put in place due to the results of a recent stock assessment that suggested a regional decline in abundance (*FIG, 2011*).

Catches occur throughout most of the population's spatial distribution around the Falkland Islands, but with concentrations in the first season of 2010 (Jan – Jun) in western borders of the FICZ parallel with the Falkland Island landmass. In the second season of 2010 (Jul – Dec), the concentration of catch was more scattered but generally within same western region of the FICZ (Figure 5.88).

Neither the fishery nor the spawning grounds overlap with the FOGL area.

Figure 5.88. Spatial distribution of catches (tonnes) of S. australis during (a) first fishing season (January - June) and (b) second fishing season (July - December) in 2010 (source: FIG, 2011).

(a) **(b)**



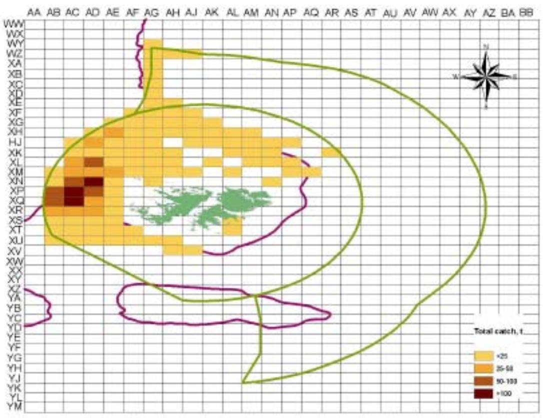
Kingclip *(Genypterus spp)*

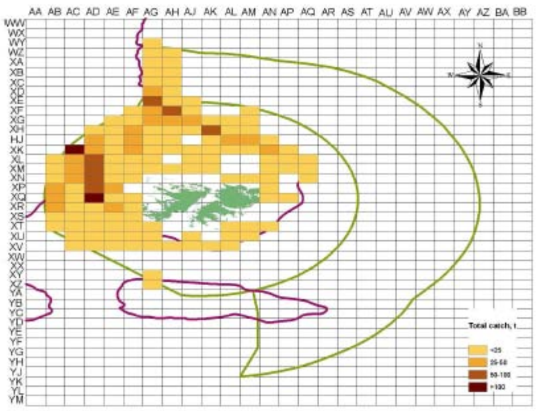
There is not currently a directed fishery for Kingclip in Falkland Island waters, but demersal trawls targeting finfish and squid take Kingclip as bycatch (*Brickle et al., 2003; FIG, 2011*). Kingclip is retained as it has a favourable price in European markets (*Brickle et al., 2003*). An experimental fishery for kingclip was undertaken by a single demersal long-liner between September and November 2006 in the western and southern parts of the Falkland Shelf and on northern slopes of Burdwood Bank. It set a total of about 1.1 million hooks and caught a total of 210 tonnes of fish, of which 55% were rays and 30% were kingclip (*FIG, 2007*). Rays were more common in catches on the south part of the shelf, and kingclip catches were greatest on the western shelf (*FIG, 2007*). The experimental fishery was stopped because of a high level of skate bycatch (*FIG, 2007*).

The 2010 catch of Kingclip by demersal trawlers was 3,645 tonnes, the best ever recorded in FI waters (*FIG, 2011*). As finfish effort has been steady since 2003, it is likely that the increase in Kingclip catch reflects an increase in its abundance in FI waters (*FIG, 2011*). The highest catches of Kingclip over the past 10 years have been in austral autumn (Mar-May) and spring (Sept-Nov) (*FIG, 2011*). This corresponds with the observed departure of Kingclip from the western part of the FICZ to spawn in June and July (Figure 5.89). The observed distribution and catches of *G. blacodes* shows that it is unlikely to occur in significant abundance within the FOGL licensed areas and that the impact on this species will be minimal.

Figure 5.89. Spatial distribution of catches (tonnes) of Genypterus blacodes during (a) first fishing season (January - June) and (b) second fishing season (July - December) in 2010 (source: FIG, 2011).

(a) **(b)**





Grenadier *(Macrourus spp.)*

While not yet a commercial fishery, in 2010 a total of 450 tonnes were taken as bycatch in trawl and long-line fisheries. All bycatch by the long-liner (75 tonnes) was discarded, whereas 60% of trawl bycatch was processed (*FIG 2011*). Most commercial catch (224 tonnes) was taken between August and September at depths of 200-350 metres, during immigration of large female *M. carinatus* to the southwestern part of the Falkland shelf.

An experimental fishery has been operational south of 51^0W to the east of the islands, operating at depths of between 500m and 100m, with the aim of testing the commercial viability of licensed fishery.

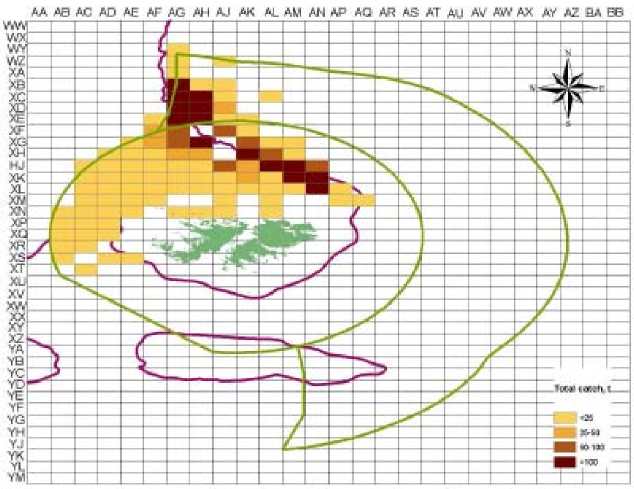
While macrourids are likely to occur within the FOGL licensed areas, their wide distribution suggests any impact on these species will be minimal.

5.5.3.3 Cephalopods

Argentine shortfin squid (Illex argentines)

Illex is fished throughout the Patagonian shelf (*Haimovici et al., 1998*), and the shelf-break region to the south of the Falkland Islands represents the most southerly extent of the species' distribution (*Csirke, 1987; Basson et al. 1996*). In Falkland Islands waters, the fishery operates between February and June (*Rodhouse et al., 1995*) and the fished population consists almost exclusively of winter spawners (*Csirke, 1987; Beddington et al. 1990; Basson et al. 1996*) migrating south from the spawning and hatching grounds of the northern Patagonian shelf (*Haimovici et al. 1998*). Inter-annual catches within the Falkland Islands have fluctuated widely (44–224,000 tonnes), which is influenced by oceanographic variability on recruitment (*Waluda et al. 1999, 2001; Nigmatullin et al. 2004*). In 2010 the total annual catch was 12,109 tonnes, the fourth lowest catch of *Illex* since the start of the fishery in 1987 (*FIG, 2011*). The spatial distribution of catches show that the commercial fishery for *Illex* does not operate within the proposed FOGL licensed areas (Figure 5.90).

Figure 5.90. Spatial distribution of catches (tonnes) of Illex argentines during 2010 (Source: FIG, 2011)



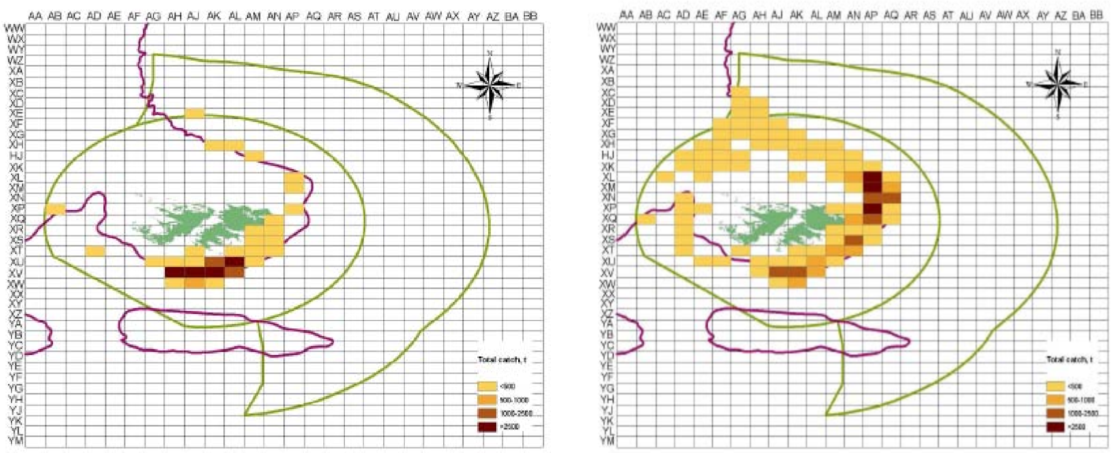
Patagonian Squid *(Loligo gahi)*

Patagonian squid forms an important commercial species within the region, although annual catches are highly variable dependent on annual recruitment patterns (23,700 tonnes – 66,500 tonnes; (*FIG, 2011*). The fishery operates within the Loligo Box: A fisheries statistical area positioned about 100 nm to the south and east of the Islands and permits licensed vessels to fish during two fishing seasons. During 2010, sixteen demersal trawlers were licensed to target *Loligo*. The FOGL licensed areas are situated to the south and east of the Loligo box and are therefore not thought to impact the main fishing operations for Patagonian squid situated in shallower waters.

Each year, Falkland Islands Fisheries Department (FIFD) carries out scientific surveys of the *Loligo* box to estimate the level of biomass before the start of each fishing season. During 2010, a pre-season biomass survey for the first *Loligo* season was conducted in February, and indicated above average abundance of squid. In the same year, *Loligo* catches reached their highest level of the last 15 years at 66,539 tonnes annual catch (*FIG, 2011*).

Figure 5.91. Spatial distribution of catches (tonnes) of Loligo gahi during (a) first fishing season and (b) second fishing season in 2010 (source: FIG, 2011).

(a) **(b)**



5.5.3.4 Summary

The main commercial species potentially found in the vicinity of the FOGL licensed area include toothfish (*Dissostichus eleginoides*) and *Loligo gahi*.

Of these species, adult toothfish undertake seasonal migration from the foraging grounds around the Falkland and Patagonian Shelf to the Burdwood Bank to breed; and an ontogenic migration from the shelf waters into bathyal waters upon maturity (*Laptikhovsky et al. 2006*). It is therefore likely that part of the southern FOGL licensed areas may coincide with toothfish spawning and seasonal migration patterns; although this conclusion is reached based on the assumption that commercial catch distributions represent the actual distribution of the species concerned. With respect to *Loligo gahi*, spawning generally occurs in shallow water, less than 50 metres and is therefore unlikely to coincide with the FOGL licensed areas.

Other species that may be affected are the rock cod, which has been found to spawn on Burdwood Bank in the austral spring, and hake where the adult fish have been predicted to migrate to the south and east of the Falklands in the austral winter, down to around 500m.

Some species of skate have also been found in the FOGL area; they appear in catches all year around in the southern area, over the Burdwood Bank and are caught during the second season (June to December) in the northern section. Observer data shows these to be mainly Antarctic skate, dark belly skate and butterfly skate.

The observed distribution and catches of other species shows that they are unlikely to occur in significant abundance within the FOGL licensed areas and that direct impact on these species will be minimal, although it should be noted that this conclusion is again based on the assumption that commercial catch distributions represent the actual distribution of the species concerned.

Table 5. 13. Summary of commercial species most significant to the FOGL zone

Species	Fishery on / near FOGL	Spawning on / near FOGL
Patagonian toothfish	Yes - with the longline fishery to the south all year and to the north during the 2nd fishing season July – December.	Yes, mainly to the south but also some to the east and north. Two peaks in May and July through to August.
Hake	Possibly, fish are predicted to migrate to just outside the FOGL area down to around 500m during austral winter from June to August	No
Southern blue whiting	No	No
Whiptail hake / hoki	No	No
Skates and rays	Yes, to the south year round and to the north July – December.	Not known, will vary by species. Grey tail skate endangered but widely distributed along with other skate species throughout the FOCZ so unlikely to be affected by the FOGL area.
Rock cod	No	Yes, on the Burdwood Bank during austral spring (September to November)
Red cod	Unlikely	No
Kingclip	No	No
Grenadier	Yes, around Burdwood Bank area to the south*.	Possibly, spawning north of 51^{0}S during austral autumn in March – April
Illex	No	No
Loligo	Some possible overlap although the 'Loligo box' lies to the northwest of the area	No

5.5.4 Submarine Cables & Communications

There are currently no submarine cables or pipelines within the vicinity of the FOGL wells (*Hydrographer of the Navy, 2009*).

Mobile phone reception is available within the Falkland Islands and is provided by Cable & Wireless. However, the network is currently limited to Stanley and Mount Pleasant (*Falkland Islands Information Portal, 2010*).

5.5.5 Military Activity

The Falklands are defended by a British military garrison comprising air, sea and land assets, backed by reinforcement capability if required. The Strategic Defence Review concluded that the composition of the land force in the Falklands was appropriate to ensure the security of the Falklands. Since 1982 the Falklands have had a relatively large British military presence, with up to 2000 personnel living at the Mount Pleasant air base complex which was constructed in the mid 1980s. As well as military personnel, civilian employees of the MoD and contractors responsible for the provision and maintenance of services, live at the base.

A Royal Navy River Class offshore patrol vessel (currently HMS Clyde) is permanently stationed in the Falklands at the East Cove military port located at Mare Harbour, and there are regular visits from the Atlantic Patrol Task (south) warship (either a destroyer or frigate), accompanied by an RFAS support vessel, throughout the year. Air defence is provided by Royal Air Force interceptors, which are supported by VC-10 tankers, Lockheed/Hercules C-130s and Sea King search and rescue helicopters. Logistical support for the garrison is also provided by various civilian contractors operating Sikorsky S-61 helicopters based at Mount Pleasant, and a tug and small cargo vessel based at East Cove.

Fishery patrol vessels (FPVs) are also present which monitor the exclusive economic zone (EEZ) borders for infringement by unregistered vessels. The Falklands has one dedicated FPV (Protegat) with the FPV Pharos occasionally patrolling Falklands waters in between deployments in South Georgia.

There are a number of wildlife avoidance areas around the Falklands. These are demonstrated in Figure 5.92, below. This map is adapted from information provided by the Defence Geographic Centre (part of the UK MoD) and is used primarily for the identification of avoidance areas for the use of military personnel. This map is under review and should not be taken as definitive for operational purposes. Any updates to the avoidance areas will be incorporated into operational management plans as they become available.

Wildlife avoidance areas currently apply primarily to military flights and use of helicopters, although they will be equally applicable to helicopter movements to and from any vessels or drill units operating offshore the Falkland Islands. These areas are shown in full on map GSGS 5563: *'Falkland Islands range and avoidance areas'* (Edition 4) as produced by the UK Ministry of Defence (classified document). The map has three categories of wildlife sensitive wildlife sites, which have specific regulations.

Falklands Conservation and the Environmental Planning Department have made a number of recommended changes to the range and avoidance areas map, including formalising regulations concerning landing distances, updating the sensitive areas and revising the comments on sensitive species associated with the map shown in Figure 5.77.

Known sensitive breeding sites of penguins and seals

Sensitive breeding sites of penguins and seals are not to be over-flown by helicopters below 500 feet (150 metres). There are numerous sites identified across the Falkland Islands as shown in Figures 5.61 and 5.62 above.

Very sensitive areas with high risk of bird strike

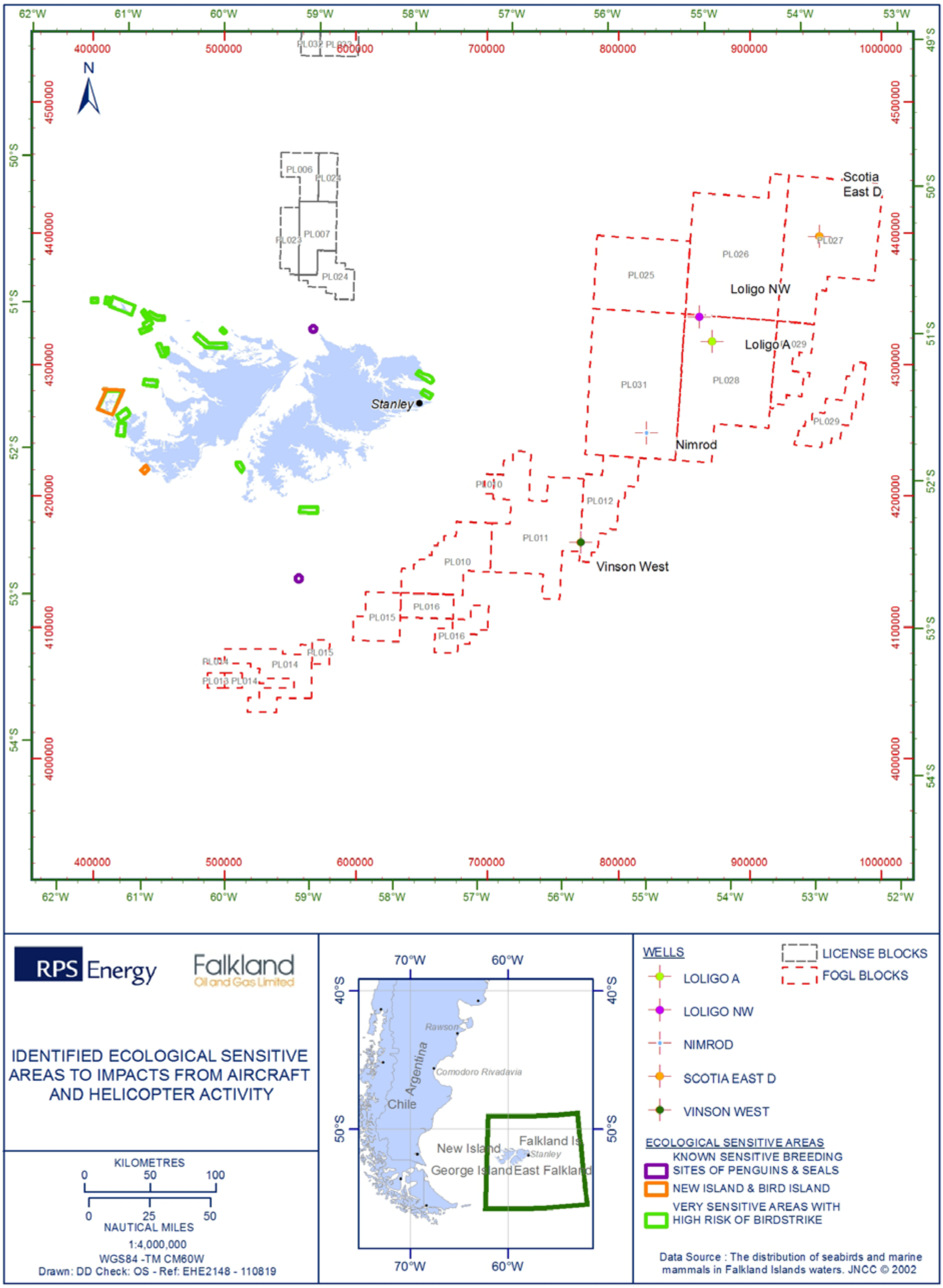
Very sensitive areas with high risk of bird strike are not to be over-flown by any aircraft below 1,500 feet (460 metres) except where operationally necessary. These sites include:

- Volunteer Point;
- The Kidney/Cochon/Mt. Low area;
- Sea Lion Island;
- Elephant Cays group;
- Eddystone Rock;
- Port Egmont Cays group;
- Keppel Island/Saunders Island;
- West Point/Grave Cove area;
- 2nd, 3rd and 4th Passage Islands;
- The Jason Islands group;
- The Governor/Staats/Tea Island group;
- The Channel/Barclay/Fox New Island group;
- Bird Island.

New Island and Bird Island

New Island and Bird Island should be avoided by helicopter below 500 feet at night due to the presence of prions and petrels which are nocturnal.

Figure 5.92. Ecologically sensitive areas to impacts from aircraft and helicopter activity (adapted from the "Falkland Islands Range and Avoidance Areas" map provided by the Defence Geographic Centre, part of the UK Ministry of Defence, Crown copyright)



5.5.6 Shipping and Ports

There is a low density of shipping activity around the FOGL licence areas.

Freight is transported to the Falkland Islands from the UK by sea. The primary port is located in Stanley Harbour and known as Falklands Interim Port and Storage System (FIPASS). FIPASS, a floating system installed by the military after 1982 and purchased by the Falkland Islands Government (FIG) in 1988, is currently operated by Byron McKay Port Services Ltd.

A commercial wharf is also located in Stanley harbour in close proximity to most retail and commercial operations, and provides a 4 metre draft with limited warehousing, storage areas, water and fuel supplies.

The FIG is reviewing options for port development. A feasibility study has been undertaken in order to identify a suitable site to construct a new port.

Freight is transported locally by road or sea. Workboat Services Ltd. provides a coastal shipping service, although this is not running at the time of writing. The UK Ministry of Defence provides a 35 day sailing from the UK, which offers a freight facility to the Falkland Islands Company Ltd. (FIC) and through the FIC to the local civilian community.

5.5.7 Existing Oil and Gas Infrastructure

To date, no permanent offshore oil industry infrastructure is currently in place. Shore based resources and infrastructure such as FIPASS and helicopter links, are currently being utilised for the current ongoing exploration and appraisal drilling programmes.

In the previous drilling campaign in the 1990s, a total of 6 wells were drilled in the north Falklands Basin, but all failed to find significant hydrocarbons. For this drilling campaign, the Falklands Offshore Sharing Agreement (FOSA) was in operation before the drilling programmes in the north Falklands Basin. FOSA comprised Shell, Amerada Hess, Lasmo, IPC Falklands Limited and their respective partners. FOSA undertook all of the logistics and support work to facilitate a multi-well drilling campaign in the north Falklands Basin. FOSA managed the sharing of a single rig, supply base, aviation link, site survey facility and operations/logging staff and resulted in savings of over £24 million per company.

In the current exploration drilling effort in the north Falklands Basin, a total of twelve wells have been drilled so far. Rockhopper Exploration initially drilled the Sea Lion (14/10-1) and Ernest (26/6-1) exploration wells. Sea Lion was a significant oil discovery; however the Ernest exploration effort was unsuccessful. Rockhopper continue to drill exploration and appraisal wells in the area of the Sea Lion discovery well i.e. wells 14/10-2 to 14/10-9 recently finished. Desire Petroleum has to date drilled five wells: Liz, Rachel, Rachel Sidetrack, Rachel North, Dawn and Ninky, however, these wells have failed to find commercial hydrocarbons. Rockhopper are currently drilling a farm-in well in Desire's area. Argos Resources has carried out seismic surveys and is planning exploration drilling.

BHP Billiton and FOGL have drilled the Toroa well in the Southern Falklands Basin. This well failed to find commercial hydrocarbons. Borders & Southern will be drilling two wells in the South Falklands area in February to May 2012.

5.5.8 Wrecks and Marine Archaeology

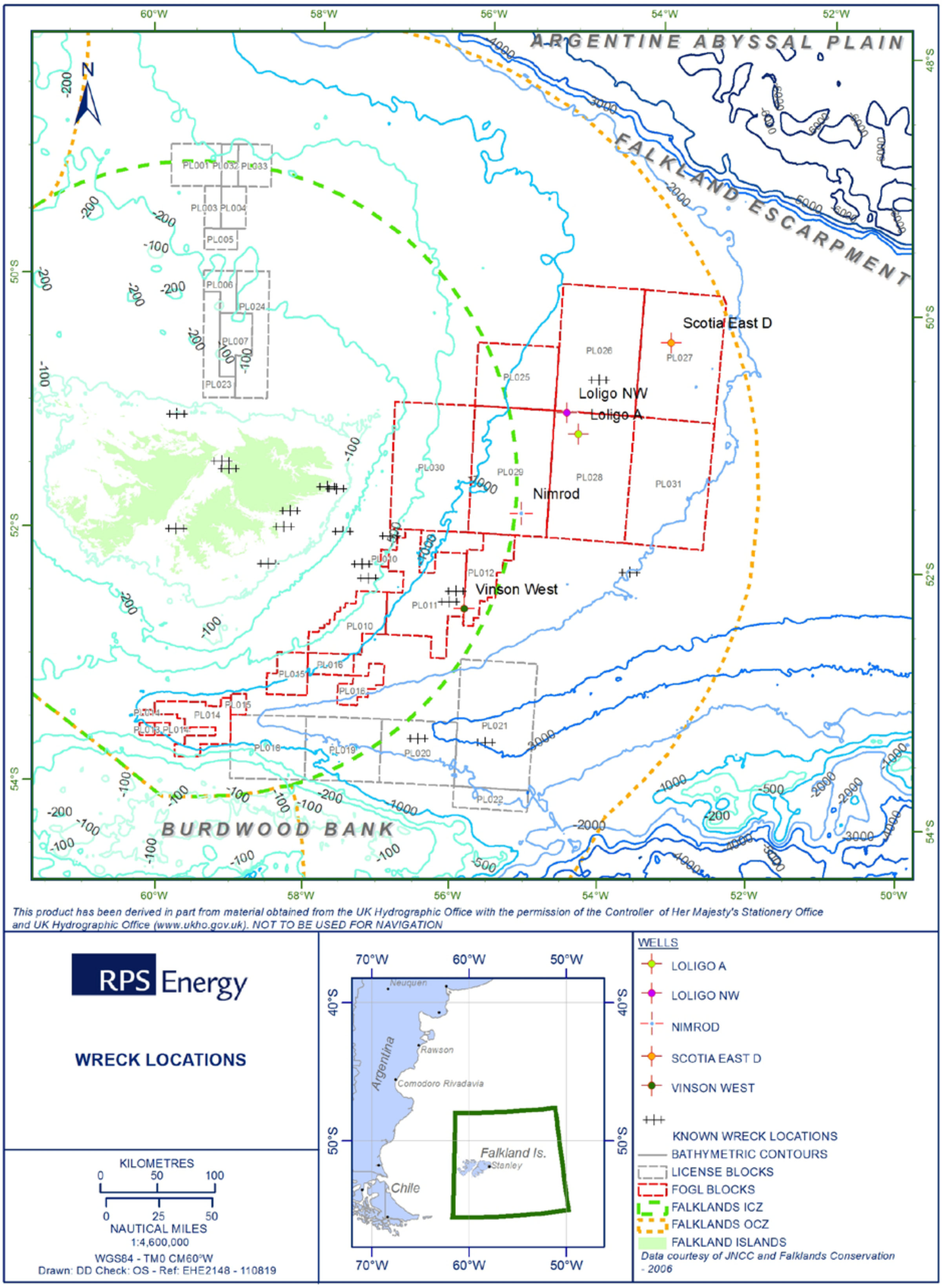
Numerous ship wrecks lay in Falkland Islands waters including 19 registered shipwrecks. The Hydrographic Office identification number/name and co-ordinates of the known wrecks are presented in Table 5.14. Six of these are from the World War One battle of the Falkland Islands (Figure 5.93). Other designated war graves exist which cannot be disturbed.

Stanley harbour contains wrecks of wooden ships constructed in the 19th century, including the vessels *'Lady Elizabeth'* and the *'Jhelum'*, which are considered important examples of ship construction of this period. There is one wreck located close to the Loligo NW site and two in the vicinity of the Vinson West well.

Table 5.14. Known wreck locations in Falkland Islands waters (UKHO, 2008)

Wreck	Location	
	Latitude	Longitude
SMS Leipzig	-53 38 34.3781	-56 31 2.6080
SMS Nurenburg	-53 14 47.4865	-55 37 11.6317
Baden	-52 17 15.7440	-57 20 14.8323
Gneisenau	-52 33 9.9049	-56 11 32.2810
HMS Antelope	-52 02 3.6451	-59 43 41.2890
HMS Ardent	-51 33 33.5224	-59 04 9.1386
HMS Coventry	-51 07 55.6134	-59 43 11.1419
Santa Isabel	-52 23 46.2691	-57 14 55.7152
Scharnhorst	-52 27 53.6516	-56 07 3.4636
2	-52 00 38.2382	-58 21 12.4858
3	-51 53 4.6758	-58 16 43.7152
4	-51 41 14.8595	-57 48 54.1981
5	-51 42 3.4288	-57 42 5.2655
6	-51 29 59.9435	-59 09 34.4775
9	-50 44 7.6692	-54 28 49.5420
10	-52 13 31.4690	-53 54 14.1888
11	-52 03 30.1614	-56 59 33.1460
12	-52 02 13.5400	-57 35 48.2348
13	-52 18 13.2903	-58 32 27.3286

Figure 5.93. Known shipwrecks within the Falkland Islands (UKHO, 2008)



5.6. Key Environmental Sensitivities

Table 5.13 below demonstrates the range of environmental sensitivities present in the vicinity of FOGL exploration wells and surrounding waters. Seasonal vulnerabilities likely to be present in the vicinity of the FOGL wells and for the surrounding area are discussed in this section, and are summarised below:

5.6.1 Physical sensitivities:

- Falkland Islands are characterised by weather conditions with strong winds and average wave height of 2-3 meters.
- Icebergs occur throughout the licensed area.

5.6.2 Biological sensitivities:

- Medium density of kelp species can be found throughout the project areas, which provides food and habitat for a wide range of marine invertebrates and fish.
- Insufficient data exist to classify the coral colonies as an Annex I habitat protected under the EU Habitats Directive. There is no evidence for, or against, potential reef development elsewhere within the general survey area.
- Fish species known to spawn in the vicinity of the FOGL exploration wells include Patagonian Toothfish (peaks in May and July through to August), Grenadier during March-April.
- The following species of cetacean were recorded during the austral winter by the JNCC survey (*White et al., 2002*) around the proposed FOGL well sites: fin whale, long-finned pilot whale, hourglass dolphin, Peale's Dolphin, Sei Whale, Antarctic Minke Whale, Sperm Whale, Killer Whale, Blue Whale and Spectacled Porpoise. It is important to note that surveying during these months is particularly challenging due to adverse weather conditions so some species may have been missed. However, according to available literature, this is a reasonably accurate assessment of cetacean diversity in Falkland Island waters at this time.
- Pinnipeds present in the vicinity of the FOGL sites include; South American sea lion, southern elephant seal, South American fur seal and the rare leopard seal. All of these species except the Leopard Seal spend the summer months ashore on the Falkland Islands breeding. During winter, however, they have been observed undertaking long foraging trips which overlap with the FOGL blocks.
- Petrels known to be present in the vicinity of the FOGL site, with particularly high numbers occurring during the drilling period, include; Antarctic fulmar, kerguelen petrel, cape petrel, and blue petrel. Other seabird species likely to be present include: Soft plumaged petrel, white chinned petrel, grey-backed storm petrel, great shearwater, sooty shearwater, great shearwaters, little shearwater, prion and skua *sp,* kelp gull, South American tern and the Arctic tern.
- Of the penguin species recorded offshore the Falkland Islands, only king penguins and gentoo penguins are likely to be present in significant quantities during the proposed drilling period; they can forage far offshore but predominantly stay closer to the shore.
- It is possible that the following species of albatross will be present in the vicinity of FOGL blocks throughout the year: Southern and northern royal albatross, black-browed albatross and grey-headed albatross, light -mantled sooty albatross, wandering albatross and shy albatross.
- Seabird vulnerability is assumed to be high throughout the drilling period due to variability in seasonality and occurrence of various birds with protected status. Based on the JNCC study, seabird vulnerability to oil spills in the proximity to project area is highest in August, rated as high on the vulnerability scale. During winter and spring months seabird vulnerability was rated as low, and there was no data for March and May. The JNCC data coverage is not sufficient for impact assessment purposes and would be used as indicator of vulnerability for more coastal sites.

- Numerous sensitive areas exist on the Falkland Islands coast related to seabirds and seal colonies, the closest of which to the proposed FOGL well sites is the Stanley Common & Cape Pembroke Sanctuary Protected Area, located approximately 153.58 km northwest of the Vinson West well site.

5.6.3 Socio-economic sensitivities:

- The Patagonian Toothfish and Grenadier is the main catch throughout the FOGL licensed area, with some Rock Cod fishing in the vicinity of the northern well sites. Other species caught in this region include Skates, Hake and Loligo.
- Low density of shipping in general offshore, and FOGL licence areas.
- Tourism in the Falklands is growing rapidly. However, tourist levels peak in austral summer, outside the FOGL drilling timetable.
- There is an increasing exploration interest in the Falklands basin with a focus to the northern licences. In the south and eastern prospects only one well (Toroa -2010) has been drilled.

5.75. Overview of the key seasonal environmental sensitivities for the FOGL blocks and surrounding waters. The drilling period is highlighted in red.

Species	J	F	M	A	M	J	J	A	S	O	N	D
Plankton												
Key:	Peak Bloom Period		Summer Bloom Period									

Species	J	F	M	A	M	J	J	A	S	O	N	D
Patagonian toothfish *(Dissostichus eleginoides)*												
Grenadier *(Macrourus spp.)*												
Key:	Known Spawning Period											

Species	J	F	M	A	M	J	J	A	S	O	N	D
Penguins *(Indicating vulnerability only in coastal areas)*												
King Penguin (*Aptenodytes patagonicus*)												
Gentoo penguin (*Pygoscelis papua)*												
Rockhopper penguin *(Eudyptes chrysolophus)*												
Macaroni Penguin (*Eudyptes chrysolophys*)												
Magellanic penguin (*Speniscus magellanicus*)												
Chinstrap penguin *(P. Antarctica)*												
Key	Peak Occurrence		Known Occurrence			Unlikely Occurrence						

Species	J	F	M	A	M	J	J	A	S	O	N	D
Albatrosses *(Indicating vulnerability only in coastal areas)*												
Black – browed albatross (*Thalassarche melanophris*)												
Grey-headed albatross (*Thalassarche chrysostoma*)												
Light – mantled sooty albatross (*Phoebetricia palpebrata*)												
Northern Royal Albatross (*Diomedea sanfordi*)												
Southern royal albatross (*Diomedea exulans*)												
Wandering Albatross (*Diomedea exulans*)												
Shy Albatross (*Thalassarche cauta*)												

Key *Peak Occurrence* *Known Occurrence* *Unlikely Occurrence*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Petrels and Shearwaters *(Indicating vulnerability only in coastal areas)*												
Southern Giant Petrel (*Macronectes giganteus*)												
Northern Giant Petrel (*Macronectes halli*)												
Antarctic Petrel (*Thalassoica antarctica*)												
Cape Petrel (*Daption capense*)												
Antarctic Fulmar (*Fulmarus glacialoides*)												
Blue Petrel (*Haloboena caerulea*)												
Kerguelen Petrel *(Lugensa brevirostris*)												
Soft plumaged Petrel (*Pterodroma mollis*)												
Atlantic Petrel (*Pterodroma incerta*)												
Grey Petrel (*Procellaria cinerea*)												
White-chinned Petrel (*Procellariaaequinoctialis*)												
Wilson's Storm – Petrel (*Oceanites oceanicus*)												
Grey Backed Storm Petrel (*Garrodia nereis*)												

Key *Peak Occurrence* *Known Occurrence* *Unlikely Occurrence*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Diving Petrels												
Black Bellied Storm Petrel (*Fragetta tropica*)												
White Bellied Storm Petrel (*Fragetta grallaria*)												
Great Shearwater (*Puffinus gravis*)												
Sooty Shearwater (*Puffinus griseus*)												
Little Shearwater (*Puffinus assimilis*)												

Key *Peak Occurrence* *Known Occurrence* *Occurrence Unlikely*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Prions *(Indicating vulnerability only in coastal areas)*												
Fairy Prion (*Pachyptila turtur*)												
Rock Shag (*Phalacrocorax magellanicus*)												
Imperial Shag (*Phalacrocorax atriceps*)												
Swans, Geese and Ducks												

Key — *Peak Occurrence* — *Known Occurrence*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Skuas Stercorariidae *(Indicating vulnerability only in coastal areas)*												
Catharacta Skua (*Stercorarius skua*)												
Arctic Skua (*Stercorarius paasiticus*)												
Long Tailed Skua (*Stercorarius lonicaudus*)												

Key — *Peak Occurrence* — *Known Occurrence* — *Occurrence Unlikely*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Gulls Laridae *(Indicating vulnerability only in coastal areas)*												
Dolphin Gull (*Larus scoresbii*)												
Kelp Gull (*Larus dominacanus*)												
Brown-hooded gull *(Larus maculipennis*)												
South American Tern *(Sterna hirundinacea)*												
Arctic Tern *(Sterna paradisaea)*												

Key — *Peak Occurrence* — *Known Occurrence* — *Occurrence Unlikely*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Cetaceans												
Fin Whales (*Balaenoptera physalus*)												
Sei Whale (*Balaenoptera borealis*)												
Antarctic Minke Whale (*Balaenoptera acutorostrata*)												
Sperm Whale (*Physeter macrocephalus*)												
Southern Bottlenose Whale (*Hyperoodon planifrons*)												
Southern Right Whale (*Eubalaena australis*)												

Long – Finned Pilot Whale (*Globicephala melas*)												
Hourglass Dolphin (*Lagenorhynchus cruciger*)												
Peale's Dolphin (*Lagenorhynchus australis*)												
Commerson's Dolphin (*Cephalorhynchus commersonii*)												
Killer Whale (*Orcinus orca*)												
Blue Whale (*Balaenoptera brydei*)												
Spectacled Porpoise (*Phocoena dioptrica*)												

Key		*Peak Occurrence*		*Known Occurrence*	
	Known Coastal Occurrence		*Occurrence Unlikely*		*Peak Coastal Occurrence*

Species	J	F	M	A	M	J	J	A	S	O	N	D
Pinnipeds												
South American Sea Lion (*Otaria flavescens)*												
Southern Elephant Seal (*Mirounga leonine*)												
South American Fur Seal (*Arctocephalus australis*)												
Leopard Seal (*Hydrurga leptonyx*)												

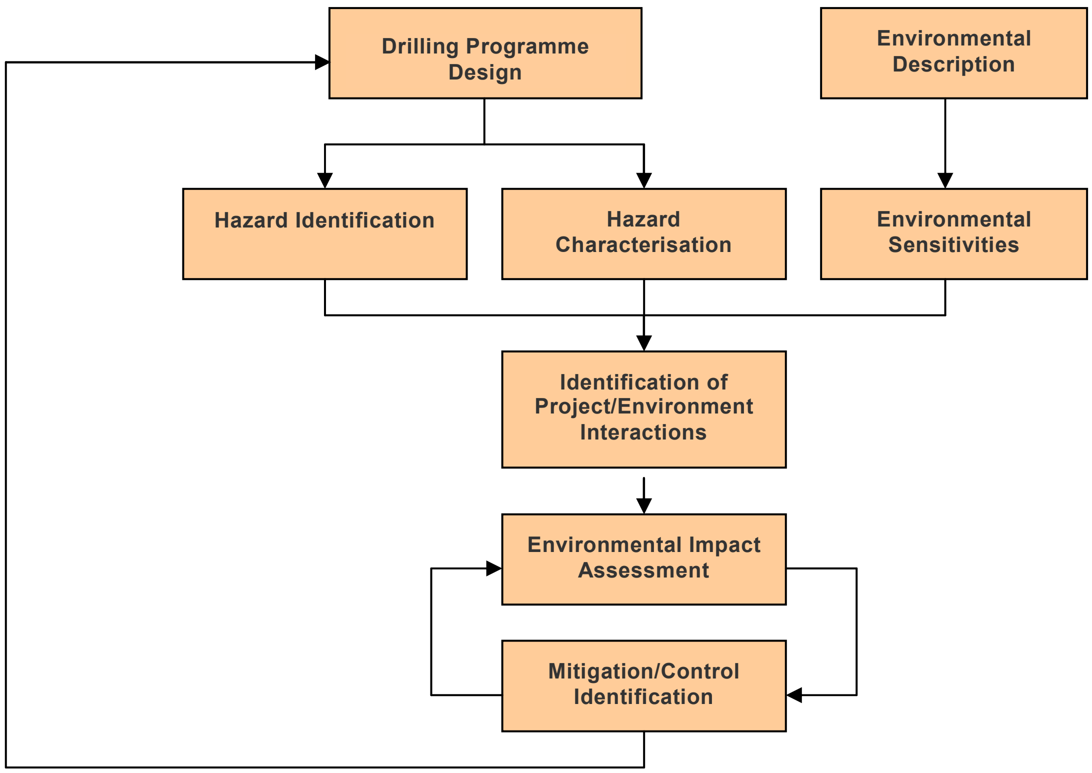
Note - meteorological, oceanographic and ecological variables during surveys have not been incorporated into table outputs, and therefore the table gives only a basic guide to the presence/absence of species throughout the year.

6 Environmental Hazards, Effects and Mitigation Measures

6.1 Introduction

The methodology used for environmental impact assessment follows the sequence summarised in Figure 6.1, with consultations incorporated into every phase.

Figure 6.1. Methodology for Environmental Impact Assessment



The main supporting information required for an assessment includes a description of both the project (Section 4) and the environment in which it will take place (Section 5). In this section, the interactions between the project and the environment are identified and an environmental impact assessment is undertaken by establishing a matrix of hazards against environmental sensitivities.

The results of this qualitative risk assessment exercise are presented in the form of a matrix that highlights areas where some interaction is expected and provides a measure of the expected significance based on the criteria provided in Table 6.1. This qualitative scale helps to rank issues on a relative basis and identify areas where additional control measures may be required.

Table 6.1. Assessment of Significance of Effect or Hazard (from UKOOA, 1998)

SIGNIFICANT IMPACTS	1	**Severe** Change in ecosystem leading to long term (>10 years) damage and poor potential for recovery to a normal state. Likely to affect human health. Long term loss or change to users or public finance.
	2	**Major** Change in ecosystem or activity over a wide area leading to medium term (>2 years) damage but with a likelihood of recovery within 10 years. Possible effect on human health. Financial loss to users or public.
	3	**Moderate** Change in ecosystem or activity in a localised area for a short time, with good recovery potential. Similar scale of effect to existing variability but may have cumulative implications. Potential effect on health but unlikely, may cause nuisance to some users.
INSIGNIFICANT IMPACT	4	**Minor** Change which is within scope of existing variability but can be monitored and/or noticed. May affect behaviour but not a nuisance to users or public.
	5	**Negligible** Changes which are unlikely to be noticed or measurable against background activities. Negligible effects in terms of health or standard of living.
		None No interaction and hence no change expected.

6.2 Impact Assessment Matrix

Table 6.2 summarises the interactions between the proposed exploration activities and the sensitivities of the local and regional environment during the proposed drilling period. A measure of the expected significance for each of the interactions has been derived based on the criteria provided in Table 6.1, above. The significance level assumes that the mitigation measures, identified for each of the hazards in the following sections, have been implemented in a timely and effective manner.

Table 6.2. Potential Hazards and Associated Impacts from the Proposed Drilling Operations following Implementation of Pollution Prevention and Mitigation Measures

Hazard	Water & Air		Flora & Fauna							Socio-economic						Other		
	Water Quality	Air Quality	Plankton	Seabed Fauna	Fish Spawning	Offshore Sea Birds	Coastal Birds	Marine Mammals	Sensitive Coastal Sites	Fishing	Shipping	Military Activity	Pipelines, Wells & Cables	Archaeology	Tourism / Leisure	Land Use	Sediments	Resource Use
Physical Presence						4				4	4	5	5		5			4
Seabed Disturbance				3									5	5			4	
Noise & Vibration					5	5	5	4										
Atmospheric Emissions		4																
Marine Discharges	5		5	4	5													
Solid Waste									5							3		
Minor Loss of Containment	4		4		5	4		5		4	5	5			5			
Major Loss of Containment	3		3	4	3	2	3	2	3	3	3	4			3		4	3

Key to Significance of Effect (see Table 6.1 for definitions)

1	Severe	2	Major	3	Moderate	4	Minor	5	Negligible		None

6.3 Design Control Measures

Environmental performance has been a key consideration in option selection and through the design process. Environmental studies and controls, implemented during the design stage of the project, ensure that additional control and mitigation measures required during the operational phases of the project are limited.

The environmental impact assessment undertaken for each phase of the project uses the design basis - with its integral design controls - as the benchmark for assessing potential impacts and identifying any additional control or mitigation methods required.

6.4 Physical Presence

6.4.1 Drilling Rig

There is no subsea infrastructure, such as cables or pipelines, in the area of the proposed wells; hence no interference is expected from the drilling operations. A number of wrecks have been identified near Loligo NW and Vinson West. The site survey of Loligo A confirmed no archaeological findings in a close proximity to the Loligo A well (see below). The results from Vinson West site survey are pending and will be provided in the Operational Addendum.

Drilling the proposed exploration wells will not result in any significant obstruction to other marine activities (e.g. fishing and/or shipping operations) since the proposed drilling locations are outside most key fishing areas and there are no known shipping lanes passing through the proposed well sites. However, some longline fishing and grenadier experimental fishing takes place throughout the FOGL licence area. At the end of the drilling programme, the proposed wells will be plugged and abandoned. The seabed structures will be dealt with according to FIG guidelines, taking account of the likelihood of this equipment posing a threat to ship anchors or over-trawling by fishing vessels.

Vessel collision risk is considered to be low and the following mitigation measures will be implemented in order to achieve this:

- A safety exclusion zone (500 meters) will be established during the drilling operations and warnings from the operational support vessels will minimise the risk of vessel collision.
- The planned activities will be promulgated in advance through Notice to Mariners and VHF broadcast for the duration of the operations.
- The British Military will also be continually informed of the operational activities.
- The Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) will be complied with.
- The rig will conform to the appropriate marine lighting standards.

6.4.2 Support Vessels

Although the licence area is situated outside the key fishing areas, the impact of competing port use by rig support/supply vessels and other customers must be considered. The majority of fish (by weight) caught in the Falklands Interim Conservation and Management Zone (FICZ) are not landed. Transhipping operations take place at sea or in sheltered waters (either Port William or Berkeley Sound) from the fishing vessel on to a 'reefer' (freezer) vessel. These vessels transport the catch directly to market without having to berth in the Falkland Islands. A small proportion of the total fish catch is landed onshore at FIPASS in Stanley but most is back loaded into freezer containers for shipment to Uruguay. The only fish species where the complete catch is landed in the Falkland Islands is the small Toothfish catch from the Falkland and South Georgia fisheries. The interference with port users is assessed to be of minor significance.

Two Dynamically Positioned Support Vessels (PSVs) and one Emergency Response and Rescue Vessel (ERRV) will be used to support the operation. The ERRV will remain in close proximity to the rig and provide standby and emergency response cover. The PSVs will shuttle between the FIPASS Port Facility and the rig carrying essential drilling equipment and bulk fuel, water, mud chemicals and cement. Movement of the vessels between the rig and the FIPASS port Facility will be scheduled to ensure the essential materials and equipment required to undertake the drilling of the wells are loaded and unloaded in a timely and effective manner. This activity will be driven by the timing of each section of the well and how it is drilled.

Given the likelihood of simultaneous drilling campaigns in both the offshore north and south Falklands, detailed planning and cooperation between operators and the port authorities will be requested to maximise port utilisation. A plan of the proposed schedule of movements for each vessel will be provided to the FIPASS Management to allow them to plan for the timely and effective management of the port facility, taking cognisance of the needs of all port users be they oilfield related or none oilfield related. Given the nature of the drilling business, the FIPASS management will be made aware of the need to allow for changes in schedules at short notice to ensure uninterrupted drilling operations can effectively be maintained at all times, subject to all other port operational requirements being effectively managed to satisfy other customer demands.

Given the above, it is envisaged that the increased vessel traffic around the port will not impact the majority of the fishing vessels operating around the Falklands. The effect on the remainder of vessels will be equally low.

6.4.3 Resource Use

Resource consumption from acquisition of drilling consumables and equipment (casing, cement, mud, and chemicals) is assessed to be of low importance as they will not be sourced from the Falkland Islands. The remote drilling location will require sufficient materials, equipment, spares and contingency supplies to be ordered in advance and shipped prior to rig mobilisation. Reordering and transporting replacement parts or additional materials during drilling will be financially and logistically impractical.

Fuel consumption throughout the drilling campaign is considered to be of medium importance as it is likely that the fuel will be sourced via the Islands. The consumption of heli-fuel, aviation fuel for flights, diesel and marine fuel oil is an operational necessity, although fuel consumption can be minimised by a regular programme of maintenance and servicing. Advanced planning will be undertaken and should help to ensure flights and transfers are kept to a minimum. However regular crew changes are a necessity both for operational and health and safety reasons.

Water for drilling and domestic use is assessed to be of low importance. The exploration wells will require between 1500 cubic metres to 2,000 cubic metres of fresh water per well to drill top hole sections (bottom hole sections will be drilled with seawater). Drilling operations will take place during the wet season when sufficient quantities of fresh water are available. Availability of water has been confirmed with the Falkland Islands Government Public Works Dept. Approximately 900 cubic metres of water per day (maximum 1400 cubic metres) can be supplied by local water treatment facilities. Fresh water supply at FIPASS can be delivered at a rate of 25-35 tonnes per hour, therefore planning in advance and loading outside peak times should minimise any impacts on the local community. Water for drinking and domestic use will be sourced from the desalination plant onboard the rig.

6.4.4 Light Emissions

Seabirds and other bird species, including migrants, are known to congregate around large offshore structures such as drilling rigs. They can be present in above-average numbers due to artificially increased food concentrations, the use of bright lighting, and attraction to the structure itself for roosting (Wiese *et al*, 2001). Several studies have demonstrated that bird densities surrounding platforms were increased compared to those in surrounding waters (*Tasker et al, 1986* cited in *Wiese et al, 2001; Baird, 1990*).

Particularly sensitive to artificial offshore lights are nocturnal breeding seabirds, such as petrels and shearwaters (*Corre et al., 2002*). Seabird mortality has been widely reported around islands with large breeding populations (*Miles et al., 2010*). This has been associated with the prevalence of artificial lights since inexperienced fledglings foraging for bioluminescent squid may accidentally collide with a lit up structure after mistaking it for food. Many subsequently die either due to starvation or predation (Corre *et al.,* 2002). In Hawaii, urban lights have been shown to induce extensive seasonal mortalities of petrels (Corre *et al.,* 2002). In their study of the impacts of artificial lights on the behaviour of petrels at St Kilda, Miles *et al.* (2010) report that although the numbers of petrels attracted to the artificial lights during their study were low, reducing light emissions is still recommended in order to reduce numbers of disorientated fledglings.

Light induced mortality in Procellariiformes appears to be seasonal and linked to the breeding schedule of each species (*Corre et al., 2002*). The Falkland Islands breeding season for seabirds is variable between species but tends to occur during austral summer (November – February). Some Procellariiformes (e.g. the wandering albatross and black browed albatross) do breed during the austral winter and have been observed around the proposed FOGL well sites (section 5.3.8.3.). Due to their nocturnal habits during the breeding season, they may be affected by light on the rig. However, recent evidence from the study of seabird observations during drilling operations offshore north of Falklands indicates no negative interaction or mortalities throughout the observation period (*Grant Munro, 2011*). The data collected did suggest a positive association of seabirds with the drilling rig. Seabird species were present in 235 (73%) of the 320 radial point counts conducted. At least 12 different seabird species were identified and 1,085 seabirds recorded. Observed seabird densities were said to be relatively low.

In summary, whilst a level of seabirds around the drilling rig may be considerable, given the short duration of the proposed drilling operations, and non-breeding period of petrel species, the impact of light on the overall seabird population offshore Falklands is likely to be minor. It is recommended to use shielding of eternal light where possible.

6.5 Seabed Disturbance

6.5.1 Physical Presence

For the proposed drilling programme, FOGL plan to use the Ocean Rig semi-submersible rig *Leiv Eiriksson* which is designed to dynamically position itself using powerful thrusters, precluding the use of anchors.

At the wellhead a BOP will be in place that will occupy an area of 9.5 square metres. The only other physical presence on the seabed will be 4 hydro-acoustic positioning transponders that are deployed to aid the dynamic positioning of the vessel. The transponders are suspended above cement clump weights. The clump weights are approximately 1 ft x 1ft in size. At the end of the drilling operation the transponders are released from the clump weight, leaving the clump weight on the seabed.

The impact on the seabed from the above equipment will be minor given the relatively small footprint.

6.5.2 Deposition on seabed

The main potential source of seabed disturbance from the proposed drilling will be caused by the deposition of drill cuttings and cement on the seabed. The major physical waste product of a drilling operation is the generation of rock cuttings together with fine solids from the centrifuges. Other waste products include the discharge of drilling muds with the cuttings and cement during cementing of well casings.

Cuttings dispersal modelling has been carried out for Loligo A, the worst case scenario well (maximum cuttings and chemical discharges) of the Loligo wells, likely to be drilled first. When the location of a second well is confirmed, modelling will be carried out for inclusion into an Operational Addendum.

6.5.2.1 Cuttings Modelling for Loligo A

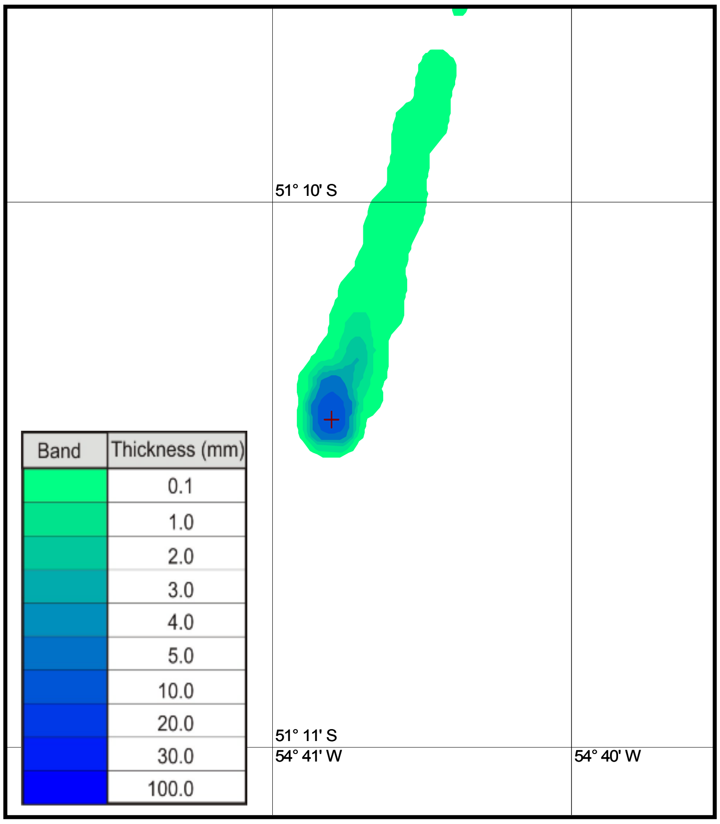
It is estimated that drilling of the Loligo A well will generate a maximum total of 1312 tonnes of cuttings associated with WBM. These cuttings together with muds will be discharged to the sea, sinking to the seabed and depositing in a pattern that reflects the nature of the cuttings' particle size distribution, the water depth and the water movements at the time of discharge.

The deposition of the cuttings and mud on the seabed has been modelled to gauge the potential pattern of deposition and to allow an estimation of the effect this could have on the benthic fauna. The Pollution Risk Offshore Technical Evaluation System (PROTEUS) model (version 1.5), developed by BMT Cordah (a UK based environmental consultancy and information systems company) was used to carry out the modelling. Details on the model set up and the way in which the model works are provided in Appendix F.

To simulate residual water movements in the area, a detailed hydrodynamic current dataset was integrated into the modelling programme (*BMT, 2011*). In model set up, this applies surface current speed and direction throughout the duration of the model run. The model assumes the input current to be true at the surface, and interpolates the currents as slowly diminishing down through the water column in accordance with the current shear effect (the effect of friction between the moving water mass and the seabed slowing the moving water down).

The results from the model are illustrated in Figures 6.2-6.3, which show that discharged material settles in an ellipse pattern, with a 'tail' of deposition along the axis of the water current at 19 degrees, approximately to the north, northeast direction. Figure 6.2 displays cuttings pile thickness contour plots with a thickness range in millimetres (mm). The maximum cuttings pile thickness found was 20 mm, which occurred at the drilling location itself. This is likely to be the result of the top-hole well sections (the 42" and 26" sections) being discharged directly to the seabed. When cuttings are deposited directly at the seabed, they have a limited chance to disperse through the water column and be transported away from the point of release, resulting in a thicker deposition.

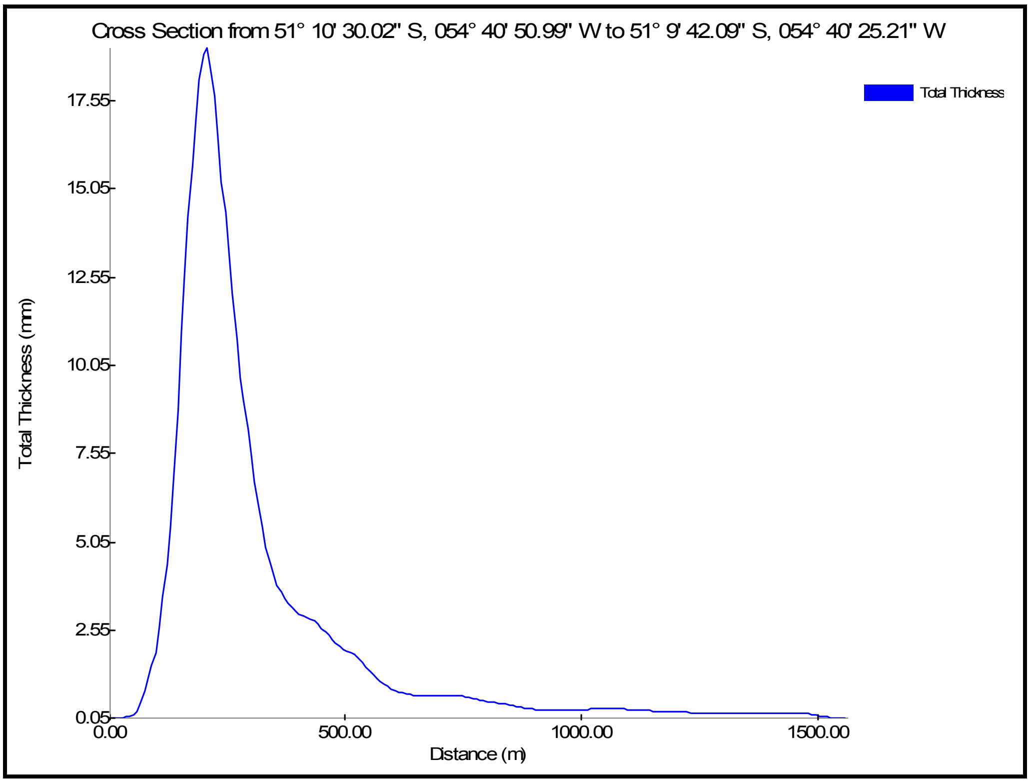
Figure 6.2. Predicted cuttings deposition on the seabed around the proposed Loligo A well (refer to Figure 6.3 for horizontal scale).



The area of cuttings footprint with more than one millimetre thickness is confined to an elliptical region of 220 metres by 370 metres. The cuttings are deposited along a north, northeast oriented axis, drifting away from the drilling location towards the north. This is the result of the current characteristics input into the model and shows the effect of residual current direction in the area on the discharged cuttings. The widespread and thin deposition observed is likely to be the result of the mid and bottom-hole well sections (17½" and 12¼" sections) being discharged overboard from the rig. This is because when cuttings are discharged close to the water surface, particularly in deep waters, they can remain suspended in the water column for a significant period of time under the influence of the surface and bottom currents, before settling through the water column and finally being deposited on the seabed. This often results in more widespread deposition of the cuttings and a much less thick deposition of cuttings around the well.

In the case of the Loligo A well, the water depths in the area are significant (1,381 metres at the drilling location), meaning the time over which the particles would settle to the seabed would probably be considerable. As such, it is likely that the majority of cuttings, particularly smaller particles that require less energy to be entrained, would be dispersed over a very great distance. After settling on the seabed, their thickness would be so small that it would be undetectable against the normal sediment regimes of the area.

Figure 6.3. Cross section along the long axis of the cuttings pile around the Loligo A well.



6.5.2.2 Potential Impacts

The deposition of cuttings and fine solids described above has the potential to directly affect the seabed fauna via smothering effect and changes in the sediment grain size and chemistry. Studies have shown that impacts from smothering can occur where the depth of cuttings is one millimetre or more (*Bakke et al., 1986*).

At the Loligo A well location, the cuttings pile thickness exceeds 1 mm in a relatively small area (220 by 370 metres) surrounding the drilling location and reaches 20 mm at the actual well head. However this thickness does not account for the discharged cement which will contribute to the height of the pile around the well.

Alteration of sediment structure

The discharge of cuttings, muds and cement will initially alter the seabed topography and sediment structure of a small area close to the wellheads. The material deposited will be a mixture mostly of cuttings (rock fragments and sediment removed from the well) of various sizes, and drilling mud including particles of barite (barium sulphate: $BaSO_4$) and bentonite, a mineral clay. Cement discharge for this programme is 25% in a worst case scenario (estimated 520 tonnes for Loligo A). The natural sediments in the project area range from fine to coarse sand or gravel throughout the area (see Section 5.2.3 and Appendix C).

A study of the development drilling in the Pompano field in deep water in the Gulf of Mexico (*Fechelm et al., 1999*) has assessed the dispersion of Synthetic-based Drilling Muds (SBM) cuttings from two platforms in water depths of 393 metres and 565 metres. The cuttings from these multi-well developments totalled 7,659 bbl (approximately 980 tonnes) of the SBM *Petrofree LE* (90% LAO, 10% Ester), although the mud weight discharged was not estimated. The dispersion of these cuttings was surveyed, and results indicated that no cuttings pile was observed at either location. Instead there was a thin 'veneer' of cuttings dispersed over a large area in a patchy fashion, the thickest patches were observed to be 20-25 centimetres deep. Chemical analyses indicated that most of the fluid was observed along transects in the direction of the surface and mid-level currents rather than in the direction of bottom currents. Maximum measured SBM concentrations were recorded close to the platform (100 metres) and were in the order of 30-50,000 µg/g in the top 2 centimetres of sediment. Benthic abundance was highest in sediment along the same transect that had high SBM concentrations. ROV video was used to count demersal megafauna (primarily fish). Neither benthic fauna nor demersal fish abundance appeared to have been adversely affected by the SBM cuttings discharge (*Fechelm et al., 1998*).

Other evidence of cuttings dispersion exists from the UKCS. In 1987 a benthic environmental survey was undertaken at a single well site in the Central North Sea (*AUMS, 1987*). The well had been drilled five years prior to the survey using a WBM and a total of approximately 800 tonnes of cuttings had been deposited on the seabed. The results of the survey indicated that, with the exception of a slightly elevated barium concentration, levels of sediment metals and hydrocarbons were similar to background. The analysis of the benthic fauna indicated that, even at sites closest to the wellhead, full recovery of the impacted sediments had taken place. This well site was revisited by Oil and Gas UK (formerly UKOOA) in 2005 and results now show that the area is completely consistent with background conditions (*Hartley Anderson Ltd., 2005*). In addition, field studies in the United States of America have shown that recovery of benthic communities impacted with water based drilling discharges is likely to be very rapid (i.e. within a few months) (*Neff, 1982*).

Contamination of sediments

From post-drilling environmental surveys on cuttings piles contaminated purely by WBM in the North Sea, impacts to the seabed sediments in the immediate vicinity of the well can be summarised as follows:

- elevated levels of barium;
- elevated levels of some trace metals associated with the barium;
- mild organic enrichment of the sediment at some locations.

Barium inputs arise from the use of barium sulphate (or barite) as a weighting agent in drilling mud. Barium sulphate is an insoluble, chemically inert mineral powder that normally also contains measurable concentrations of several trace metals. In this form, the barium is 'biologically unavailable' and will have no measurable effect, in chemical terms, on the benthic fauna (*Jenkins et al, 1989; Hartley, 1996*). The environmental impact of other trace metals will depend on their concentration in the WBM-contaminated cuttings, which depends to some extent on the geological source of the barite. However, studies have shown consistently that metals associated with WBM are virtually unavailable to marine organisms that might come into contact with discharged drilling fluids (*Neff et al, 1989; McKelvie, 1996*).

WBMs contain very small amounts of organic material. Slightly elevated concentrations of barium or hydrocarbons have been recorded at some sites in the North Sea drilled with WBMs. Although the origins of hydrocarbon inputs have not always been clear, diesel has often been implicated in the past. Its presence could arise from the now outdated practice of using diesel to free stuck drill strings or when formation problems were encountered. Payzone cuttings could also have been the cause in some cases.

Impacts on benthic organisms

Considerable data has been gathered from the North Sea and other production areas, indicating that physical disturbance is the dominant mechanism of ecological disturbance where WBMs and cuttings are discharged (*DTI, 2001*). Biological effects on seabed faunal communities from the discharge of WBM and associated cuttings are usually subtle or undetectable, although the presence of drilling material at the sea bed is often chemically detectable (see above). Monitoring studies around well sites drilled with WBMs have rarely shown any effects to benthic infauna (at a community level) detectable beyond 50 metres. Subtle impacts to the benthos were identified at up to 750 m from a production site developed using WBMs, but these were associated with hydrocarbon contamination (*Hartley & Bishop, 1986*).

The sedentary fauna in the immediate vicinity of the well heads may well be buried by the accumulation on the sea bed of cuttings and WBM particles from the tophole sections. In addition, enhancement and altered particle size distribution of suspended particles in the water near the sea bed may impair respiratory and feeding processes, inducing metabolic stress and reducing growth and survival rates in individuals of some species outwith this area. Laboratory studies have shown that elevated concentrations of bentonite and barite, the two major constituents of WBMs, can affect the growth of suspension feeding organisms (*Cranford & Gordon, 1992; Cranford et al, 1999; Barlow & Kingston, 2001*), and some species are more sensitive than others. It is also feasible that changes in sediment particle size characteristics could affect the suitability of the sea bed for re-colonisation by species normally characteristic of the area, although in a dynamic area it is probable that the sediments will rapidly return to their original composition under the influence of seabed currents and natural sedimentation. The studies from UKCS and the United States of America have shown that recovery of benthic communities impacted with water based drilling discharges is likely to be very rapid (i.e. within a few months) (*Neff, 1982*).

The net result can be expected to be a short-term reduction in productivity just after drilling, and medium-term change in the composition of the benthic community over a small area centred on the wellheads. Long-term effects can be expected to be minimal due to both the overall low toxicity of the WBM, and the currents close to the sea bed that will enable (most of) the cuttings to disperse over a wide area so that any impacts are indistinguishable from natural background variation. No detectable effects on the benthic community are expected outside the area affected by materials discharged at the well heads.

The most prominent colonial epifauna encountered across the Loligo site constitutes cnidarians. These included at least two species of gorgonian (soft corals) and at least one species of scleractinian (hard or stony coral). The recovered coral samples, although superficially similar to the cold water coral *Lophelia pertusa*, are believed to be analogous Antarctic species, capable of withstanding colder waters. It is known that cold corals provide suitable substrata for other animals, thereby greatly enhancing local diversity. There is insufficient evidence to conclude that recorded coral species are the part of cold coral colonies/reefs classified as Annex I habitat under the EU Habitats Directive. However a precautionary approach has been adopted and it is assumed (until more evidence is gathered) that potentially sensitive benthic fauna may be present within a wider project area.

Various studies have shown that exposure of warm water corals to drilling fluids may result in reduced viability, morphological changes, altered feeding behaviour or disruption to the pattern of polyp expansion, and that the effects may vary between species. There is some evidence that *L. pertusa* may tolerate some exposure to drilling discharges, but further information is needed on the effects of exposure to drilling muds on growth and reproduction of *L. pertusa* and other habitat-forming cold-water corals (*Freiwald et al, 2004*). In California, an adverse impact on

Caryophyllia species on the outer continental shelf and slope depended on the doses of cuttings received and the time of exposure, and was attributed to the physical effects of increased sediment loading rather than to toxic effects (*Hyland et al, 1994 cited in Freiwald et al, 2004*). Considerable evidence of impacts on deep coral communities from fishing activities shows that such coral communities are particularly susceptible to physical damage and are slow to recover (*Freiwald et al, 2004*).

Potential Impacts on archaeology

The only archaeological features that could possibly be damaged by subsea equipment (or drilling discharges) are historic shipwrecks, if these lie in the immediate vicinity of a well. Wrecks have been recorded within the FOGL license area, with two wrecks located north of Loligo NW and one north of Vinson West. The site survey confirmed that no shipwrecks or any other archeological features are present within the proximity of Loligo A well. Therefore, the direct disturbance by subsea facilities to archaeological features has been assessed to be negligible for the Loligo A well.

6.5.2.3 Mitigation measures

Impacts from drilling discharges are unlikely to be significant, but various mitigation measures should be in place to further reduce impacts, as summarised below;

- All chemicals used are of low toxicity and regulated under the OSPAR HOCNF scheme.
- Best practice to be followed to minimise the amount of excess cement deposited on the sea bed.
- Mud recovery systems to be used, thus minimising the amount of drill fluids to be discharged.
- Any shipwrecks or objects of potential archaeological interest should be reported to FIG;
- Additional ROV footage should be reviewed by a specialist biologist to validate the density and distribution of coral species and associated habitats.
- Consideration was given to designing slimhole wells (i.e. thinner than usual well bore) where possible. These generate fewer cuttings, require less drilling fluid and chemicals, and are generally faster than a conventional drilling programme. However, due to the unknown drilling characteristics of this area, it was considered prudent to maintain larger hole sizes for contingency against problems in reaching the target formations.

6.5.2.4 Conclusions

A very localised area of sea bed will be physically disturbed during installation of the well equipment. Impacts on the benthic communities from drilling discharges may occur in the immediate vicinity of each well from the smothering effect, with likely recovery within months to years depending on the local hydrographic regime. Given the strong bottom currents offshore Falklands, it is likely that any cuttings will become mixed with the natural sediments and disperse within months.

The significance of impacts resulting from direct physical disturbance of the sea bed depends on the occurrence of key features of ecological or archaeological conservation importance in the immediate vicinity of operations. As outlined above, the overall nature of the benthic environment in the project area is homogenous with some presence of hard coral species with uncertain coverage and conservation status. Therefore, the impacts of discharges on benthic communities have been deemed to be moderate. The impact on marine archaeology is assessed to be of minor significance.

6.6 Noise and Vibration

6.6.1 Introduction

Sound is readily transmitted underwater and there is potential for sound produced from the exploration drilling to cause detrimental effects to marine animals. Because of the low loss characteristic of underwater sound transmission compared with underwater light transmission, the use of sound has evolutionarily developed as the predominant long-range sensory modality for marine mammals (*Weilgart, 2007; Ansmann, 2005; Potter and Delory, 1998*). The use of underwater sound is therefore very important for marine mammals (e.g. seals, whales, porpoises and dolphins) in order to navigate, communicate and forage effectively.

Cetaceans use echolocation as their principle means of navigation, communication, prey detection and predator avoidance. This is where the individual monitors its surroundings by emitting sound waves and waiting for them to reflect off different objects (*Weilgart, 2007; Ansmann, 2005; Potter and Delroy, 1998*). Light propagates poorly in the viscous and opaque marine environment and is absorbed at a few tens of meters (*Potter and Delroy, 1998; Nowacek et al., 2007*). In contrast, low frequency underwater sound may travel for hundreds of kilometres without losing intensity (Nowacek et al., 2007). In murky waters, the use of echolocation means that objects are often “heard” before they are seen (*Ansmann, 2005*). This ability is extremely effective; bottlenose dolphins (*Tursiops truncates*), for example, can differentiate between two aluminium plates varying by just 0.23mm and can detect objects up to 113m away (*Au, 2002; 354*). This level of precision is indicative of the importance of echolocation for foraging and navigation by cetaceans.

Pinnipeds are not thought to possess specialised echolocation abilities (*Schusterman et al., 2000*). This is likely to be due to their amphibious lifestyle which requires social communication in both the atmosphere and hydrosphere. They are thought to predominantly use vocalisations for intra-species communication - e.g. mating calls and group cohesion. This is particularly helpful during breeding season when thousands of individuals may congregate in relatively small areas to mate (Schusterman, 2000). Underwater, pinnipeds use low – frequency, broadband acoustic signals for intra-species communication as well as prey and predator detection (*Southall et al., 2000*).

The introduction of anthropogenic noise into the marine environment could potentially interfere with the ability of marine mammals to determine the presence of other individuals, predators, prey and underwater features or obstructions. Recent studies into the reactions of marine mammals to anthropogenic noise produced during activities associated with offshore drilling have shown a tendency for avoidance, which may lead to habitat displacement and ultimately stress (*Wright et al., 2007; Lusseau, 2005; Southall et al., 2000*).

The impact of noise generated during the drilling of exploration wells is dependent on the strength of the sound source as well as the sound transmission conditions of the receiving environment. In the marine environment, sound propagation is principally impacted by the physical parameters of both the sound source and the surrounding environment (*Nowacek, et al., 2007; Richardson et al., 1995*). Low frequency sounds are not absorbed as much as high frequency sounds and in general will attenuate less (*Richardson et al., 1995*). Moreover, seasonal variations in temperature also influence the attenuation of sound waves; absorption declines with declining temperature, resulting in an increased “sound footprint” during winter months (*Munk et al., 1991*).

Falkland Island waters are home to several species of toothed whales, baleen whales and pinnipeds. The most abundant are the toothed whales and pinnipeds, although baleen whales are present throughout the year (refer to Section 5.3.7). The most frequently recorded species are Commerson’s Dolphins (*Cephalorhynchus commersonii*), Peale’s Dolphins (*Lagenorhynchus australis*) alongside the following pinnipeds; South American Sea Lion (*Otaria flavescens*), Southern Elephant Seal (Mirounga *leonine*), and the South American Fur Seal (*Arctocephalus australis*), all of which will be present during the FOGL exploration period.

6.6.1.1 Background noise in the marine environment

Anthropogenic noise is only audible to marine mammals when it is at intensities greater than ambient noise levels (*Richardson et al., 1995; 226*). Natural sounds in the sea are produced by wind, waves, currents, rain, ice-breaking, echo-location and communication noises generated by marine mammals and other natural sources such as tectonic activity. Naturally occurring noise levels in the ocean as a result of wind and wave action may range from around 90 dB re 1µPa under very calm, low wind conditions to 110 dB re 1µPa under windy conditions.

In addition to the natural occurring sounds there are anthropogenic sounds generated by air traffic and shipping (including military, merchant and fishing). Shipping is the dominant source of sound in the world’s oceans in the range from 5 to a few hundred Hertz (*NRC, 2005*). Certain aspects of the drilling campaign could also generate noise in excess of ambient conditions.

6.6.1.2 Noise produced during drilling activities

Sources of noise related to activities of the semi-submersible rig/drill ship include pumps, non-propulsion engines, generators, ventilators and other onboard machinery (*Richardson et al., 1995*). Sound and vibration paths on semi-submersible ships are mainly through air or through the risers, in contrast to the direct paths through the hull of a drill ship (*Richardson et al., 1995*). In addition to the emissions from machinery onboard vessels, noise from the Leiv Eiriksson Rig will also be produced by the thrusters to maintain its position (DP). McCauley (1998) reports sound generated by DP semi-submersible rigs is greater than anchored MODUs. Lawson *et al.* (2001) report source levels used for dynamic positioning thrusters to be 162 to 180 dB re 1µPa @ 1 m.

Noise will also be produced by supply vessels which will visit the rig on rotation. Noise from these sources originates from ship engines and gears, propellers, and thruster noise if the vessel is operating on dynamic positioning (DP). Emissions from ships are a major contributor to noise in the world's oceans, especially at low frequencies between 5 and 500 Hz (NRC, 2003). Sound levels and frequency characteristics are roughly related to ship size and speed but there is a significant individual variation among vessels of similar classes. Ships moving to site will generally produce more noise than stationary vessels because of propeller cavitation noise. Typical source levels associated with shipping range between 160 and 190 dB re 1µPa @1m (*Richardson et al., 1995*). Ships moving to site will generally produce more noise than stationary vessels because of propeller cavitation noise. However, the supply vessels will maintain position alongside the drilling rig using DP during supply and refuelling operations.

Initially, underwater sound will spread spherically from the sound source to a range approximately equal to water depth. This is followed by the cylindrical spreading of sound waves (www.fas.org, *2010*).

The most widely used formula for underwater sound propagation is the following, derived from Richardson *et al.* (1995);

$$L_r = L_s - 20 \, Log \, R$$

Where: L_r = Received level (dB re 1µPa)

L_s = Source level at 1 metre in (dB re 1µPa)

R = Range (metres)

Typical subsea noise levels from offshore operations are shown in Table 6.4. The sound levels at a range of distances from various drilling facilities are also provided and have been estimated using the equation for spherical underwater noise spreading given above.

Table 6.4. Sound sources from various offshore activities (adapted from: Evans & Nice, 1996; Richardson et al, 1995 and Simmonds et al, 2003)

Activity	Frequency range (kHz)	Average source level (dB re 1µPa-m)	Estimated received level at different ranges (km) by spherical spreading			
			0.1 km	1 km	10 km	100 km
High resolution geophysical survey; pingers, side-scan	10 to 200	<230	190	169	144	69
Low resolution geophysical seismic survey; seismic air gun	0.008 to 0.2	248	210	144	118	102
			208	187	162	87
Vertical Seismic Profiling	0.005 to 0.1	190	150	129	104	29
Production drilling	0.25	163	123	102	77	2
Jack-up drilling rig	0.005 to 1.2	85 to 127	45 to 87	24 to 66	<41	0
Semi-submersible rig	0.016 to 0.2	167 to 171	127 to 131	106 to 110	81 to 85	6 to 10
Drill ship	0.01 to 10	179 to 191	139 to 151	118 to 130	93 to 105	18 to 30
Large merchant vessel	0.005 to 0.9	160 to 190	120 to 150	99 to 129	74 to 104	<29
Super tanker	0.02 to 0.1	187 to 232	147 to 192	126 to 171	101 to 146	26 to 71

** (dB) The magnitude of the sound manifests itself as pressure, i.e. a force acting over a given area. It is expressed in terms of 'sound levels', which use a logarithmic scale of the ratio of the measured pressure to a reference pressure (Decibels (dB)). Level of underwater noise is reported in dB re 1µPa @ 1 metre in water.*

As sound spreads underwater it decreases in strength with distance from source: this sound transmission loss is the sum of spreading loss and attenuation loss. Attenuation losses are the physical processes in the oceans that distort the mathematical spreading laws. Factors include sound absorption or scattering by organisms in the water column, reflection or scattering at the seabed and sea surface, and the effects of temperature, pressure, stratification and salinity. Taking the average noise levels generated from drilling operations using a semi-submersible drilling rig and assuming a spherical propagation of noise from the source, it can be seen from Table 6.4 that background noise levels of 100 dB will be reached within approximately 5 to 10 kilometres of the source. It is important to note that high resolution equipment (such as sonar / echo sounders) propagate for considerably further into the marine environment: the background noise level is shown to be 144 dB at a range of 10 kilometres from the source. However, this equipment will not be in continual use throughout the campaign and the output is highly directional, helping to mitigate any impact from use.

During the proposed drilling, a crew changeover will occur every two weeks using CHC helicopters. Low-flying helicopters may increase localised underwater noise levels. Helicopter noise generation at the source ranges from 149–151 dB re 1µPa at 1 metre, but the penetration of the noise into the ocean is dependent on the angle of the aircraft and its distance from the sea surface. At angles greater than 13º from the vertical, most of the sound does not penetrate into the water but is reflected. Only marine wildlife immediately below the aircraft will therefore be affected (*Richardson et al., 1995*).

During wireline velocity surveys, an airgun suspended from the rig into the sea will be used as a sound source at intervals over several hours.

6.6.1.3 Marine Mammal Hearing Range

The frequency at which marine mammals can detect noise is species specific. Table 6.5 shows functional hearing group ranges, derived from Southall et al. (2007).

Table 6.5. Functional marine mammal hearing groups and their estimated auditory bandwidths, adapted from Southall et al. (2007).

Functional Hearing group	Estimated auditory bandwidth	Species represented in the vicinity of the FOGL license blocks
Low Frequency Cetaceans	7 Hz – 22 kHz	Fin Whale (*Balaenoptera physalus*) Sei Whale (*Balaenoptera borealis*) Antarctic Minke Whale (*Balaenoptera acutorostrata*) Blue Whale (*Balaenoptera brydei*) Southern Right Whale (*Eubalaena australis*)
Mid – Frequency Cetaceans	150 Hz – 160 kHz	Southern Bottlenose Whale (*Hyperoodon planifrons*) Long – Finned Pilot Whale (*Globicephala melas*) Hourglass Dolphin (*Lagenorhynchus cruciger*) Peale's Dolphin (*Lagenorhynchus australis*) Commerson's Dolphin (*Cephalorhynchus commersonii*) Killer Whale (*Orcinus orca*) Sperm Whale (*Physeter macrocephalus*)
High – Frequency Cetaceans	200 Hz – 180 kHz	Spectacled Porpoise (*Phocoena dioptrica*)
Pinnipeds in water	75 Hz – 75 kHz	Southern Elephant Seal (*Mirounga leonine*), South American Fur Seal (*Arctocephalus australis*), Leopard Seal (*Hydrurga leptonyx*)
Pinnipeds in air	75 Hz – 30 kHz	Same species as pinnipeds in water (above)

6.6.2 Potential Impacts

6.6.2.1 Noise Impact on Marine Mammals

Cetacean auditory systems may be directly compromised if exposed to high intensity noise by the onset of temporary threshold shifts (TTS) or, in severe circumstances, permanent threshold shifts (PTS) (*Gordon et al., 2004*). TTS involves a temporary shift in the hearing threshold (Richardson et al., 1995; 367) and may be associated with metabolic exhaustion of sensory cells as well as anatomical damage and change at the cellular level (*Gordon et al., 2004*). Where TTS is prolonged PTS may result. This is where inner ear sensory cells are lost completely. The point at which TTS becomes PTS is unclear, but it is thought that PTS can occur without an initial TTS (*Weilgart, 2007*).

Southall et al. (2007) define the minimum exposure criterion for injury as the level at which a single exposure is estimated to cause onset of PTS. Generally, sound levels above 230 dB re 1 µPa (peak) (flat) would be expected to cause injury to cetaceans, and those above 218 dB re 1 µPa (peak) (flat) would be expected to cause injury to pinnipeds. During the proposed drilling operations the background noise is not expected to reach these intensities. However, there is the potential for very short term, isolated events to reach levels in excess of these intensities..

With regards to TTS, at frequencies of 3 kHz, 10 kHz, and 20 kHz, TTS occurred in five bottlenose dolphins at intensities between 192 – 201 dB re 1µ Pa (*Schlundt et al., 2000 cited by Southall et al., 2007*). There are no figures available for mysticetes, although Southall et al. (2007) notes that, based on their auditory anatomy and ambient noise levels in the frequency ranges they use, mysticetes almost certainly have a higher threshold for the onset of TTS. Similarly, for high-frequency species, data from mid-frequency cetaceans is currently used as a substitute in the absence of available data for this group. TTS has been induced in a Northern elephant seal underwater at 172 dB re 1 µPa by

Kastak et al. (*2005 cited by Southall et al., 2007*). Based on these figures, TTS is unlikely to occur in any of the marine mammals present more than few meters away from the rig or support vessel.

It is suggested by Davis et al. (1990) that seals are particularly susceptible to hearing damage from industrial noise since their hearing sensitivity is good at low frequencies. This is an important consideration since pinnipeds are likely to be in the vicinity of the FOGL licence area during the austral winter when the development is scheduled to take place. Davis et al. (1990) also notes that auditory damage may occur if marine mammals were exposed to sounds greater than 120 dB for prolonged periods of time. To be exposed to such sound levels, the animal would have to be within 220 to 345 m of a semi-submersible drilling rig during drilling activities. Given the short duration of the drilling campaign (90 to 100 days) and a very low probability of marine mammals staying close to the rig for extended periods of time, such impacts are unlikely.

If the frequency of anthropogenic noise overlaps with the frequencies used by marine mammals, this may reduce the animal's ability to detect important sounds for navigation, communication and prey detection (*Weilgart, 2007*). This "masking" effect occurs if two frequencies overlap in the "critical band" of each other. In this respect, masking may occur anywhere within a cetacean's auditory range (*Wright et al., 2007; Richardson et al., 1995; 234*). Masking of important cetacean vocalisations will result in increasing information ambiguity and may culminate in cetaceans being unable to orientate in the environment (*Wright et al., 2007*). As shown in

Figure 6.4 and Table 6.5, the noise frequencies produced by a semi- submersible rig (similar or lower noise levels expected from the support vessels) may mask vocalisations for the following species within 100 meters of the noise source;

- Sperm Whale (*Physeter macrocephalus*)
- Southern Right Whale (*Eubalaena australis*)
- Hourglass Dolphin (*Lagenorhynchus cruciger*)
- Commerson's Dolphin (*Cephalorhynchus commersonii*)
- Long – Finned Pilot Whale (*Globicephala melas*)
- Peale's Dolphin (*Lagenorhynchus australis*)
- Southern Elephant Seal (*Mirounga leonine*)
- South American Sea Lion (*Otaria flavescens)*
- South American Fur Seal (*Arctocephalus australis*)
- Spectacled Porpoise (*Phocoena dioptrica*)

Figure 6.4. Sound levels expected from drilling operations and frequency bands used by cetaceans.

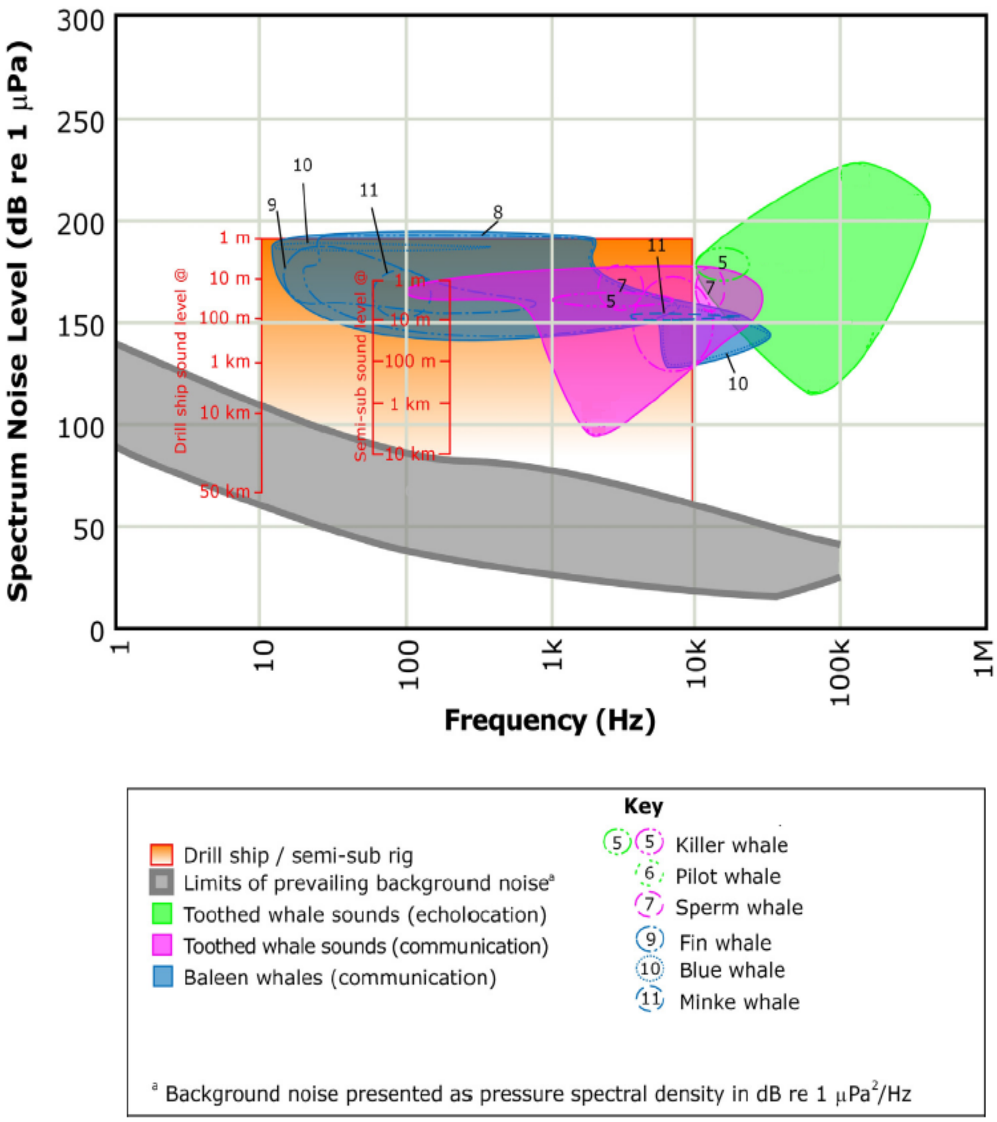


Figure 6.4. also shows that the noise from a semi-submersible rig will interfere mainly with baleen and toothed whales communication, at the levels above 140 dB and 160 dB re 1µPa-m, which equates few hundred meters around the drilling rig or support vessel (refer to Table 6.4).

However, it should be noted that cetaceans exhibit directional hearing abilities, meaning that sound detection can be localised (*Richardson et al., 1995; 234*). This means that masking will only occur if the noise directly overlaps with the direction of the cetacean signal (*Richardson et al., 1995; 234*). Generally, masking is reduced if the noise comes from a different direction than that targeted by the cetacean, or if the noise is omnidirectional (*Richardson et al., 1995; 234*). In case of disturbance cetaceans typically move away from the area of impact (e.g. *Bedjer et al., 2006; Herr et al., 2005*).

During the proposed drilling period, sperm whale disturbance is of particular concern since this species is categorised as "Vulnerable" by the IUCN (2011) and is highly protected. Studies have shown that the reaction of sperm whales to boat traffic varies between individuals, with some being tolerant and others exhibiting avoidance behaviour (*Richter et al., 2003; Richardson et al., 1995; 261*). At elevated sound intensities, such as those produced by a semi-submersible drilling rig, it is likely that sperm whales will avoid the limited in size area of increased noise levels.

There is limited literature regarding the reaction of pinnipeds to anthropogenic noise. It is reported in Richardson et al. (1995) that Northern fur seals and sea lions exhibited a varied response to boat traffic, with some being tolerant of the noise and others leaving the area.

Helicopters

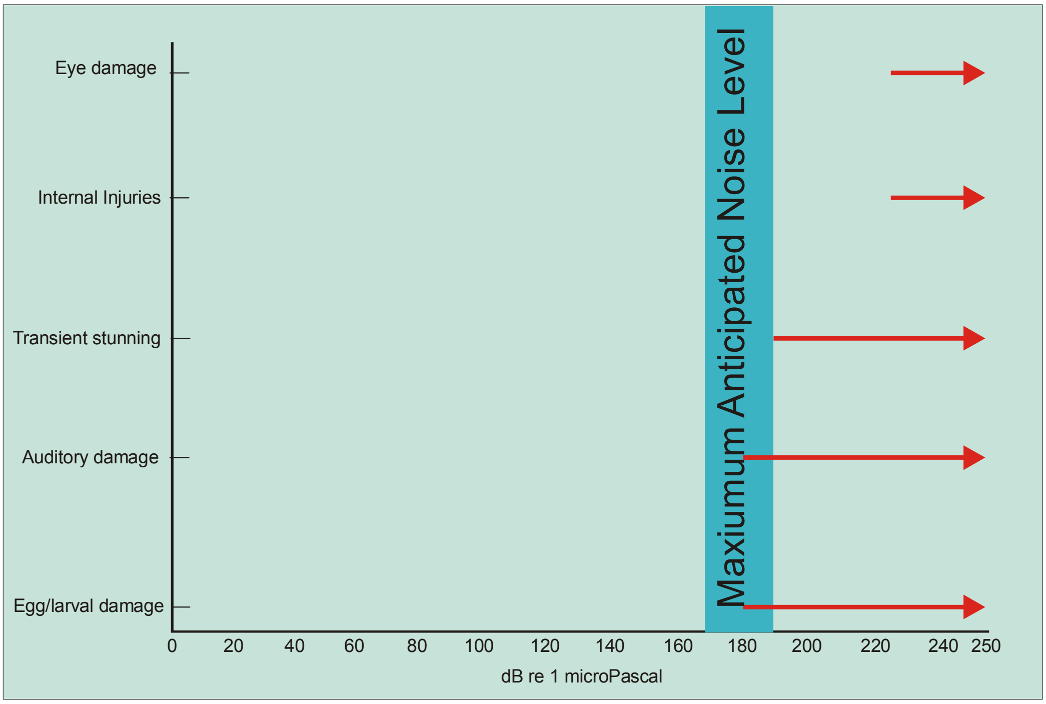
Noise from helicopters is likely to disturb pinnipeds more than cetaceans, since they spend more of their life cycle on land. In general, pinnipeds which are hauled out may return to the water in response to overhead aircraft. Northern elephant seals at San Miguel Island, California, were generally unresponsive to overhead aircraft unless they were particularly intrusive (e.g. at altitudes lower than 180 metres). Similarly, Northern sea lions exhibit variable reactions to overhead aircraft. Immatures and pregnant females were more likely to move into the water when compared to males or small pups. In contrast to this, Northern fur seals have been observed stampeding into the water in response to low – level overhead flights (*Richardson et al., 1995; 244*). It is expected that helicopter flights will fly from Stanley Airport, which may cause disruption to pinnipeds hauled out at the four protected areas in this region (Figures 5.61. and 5.76, Section 5). At the time of the FOGL development, harems of pinnipeds are likely to be hauled out at these sites. However, since pinnipeds have been recorded undertaking extensive foraging trips during this time, numbers are likely to be reduced in comparison to breeding times. Cetaceans tend to be less impacted by aircraft since sounds from aircraft are less relevant to them in their environment. Where reactions have been recorded, these include changes to dive times, water slapping or a change in direction away from the aircraft (Richardson et al., 1995; 245 – 247).

6.6.3 Potential Impacts on Fish

Sound is perceived by fish through the ears and the lateral line (the acoustico-lateralis system) which is sensitive to vibration. In addition, some species of teleost or bony fish have a gas filled sack called a swimbladder that can also be used for sound detection. The swimbladder is sensitive to the pressure component of a sound wave, which it resonates as a signal that stimulates the ears (Hawkins, 1983). Additionally, benthopelagic deep sea fish, such as grenadiers, possess sound-producing muscles on their swim bladders which they use to facilitate communication during courtship and spawning (*Mann and Jarvis, 2004*). Some groups of fish, e.g. flatfish and elasmobranches or cartilaginous fish such as sharks and rays, do not possess a swimbladder and so have a reduced hearing ability. Those species that are particularly sensitive to noise include the clupeids and gadoids (herring and cod families).

The impacts of anthropogenic sound on fish can either be behavioural or physiological (*Potter and Delory, 1998*). Fish are generally sensitive to sound within the frequency range of <1Hz to 3kHz, however, it has been reported that they will respond consistently to very low, or very high frequency sound (*Knudsen et al. 1992, 1994*). Sounds in the range of 50 Hz to 2 kHz, such as the peak sound levels produced by many anthropogenic activities, only produce short-term startle response at the outset of sound production, with subsequent habituation to noise (*Knudsen et al. 1992, 1994; Westerberg, 1999*). Avoidance by fish is species specific (*DNV, 2007*), but generally occurs at 160 – 180 dB re 1µPa (*McCauley et al., 2000*) (Figure 6.5.). With this in mind, only fish in the immediate vicinity (less than 0.1 kilometres either side) will be displaced by activities during the FOGL development. This may be of particular concern to spawning or mating fish in the area, particularly grenadiers, who use sound in order to communicate during courtship and mating (*Mann and Jarvis, 2004*). As shown in section 5.3.6., two grenadier species have been recorded in Falkland Island waters in the vicinity of the proposed FOGL development. However, it is felt that due to the highly localised (relative to the perceived spawning grounds), temporary nature of the drilling of each well and the small period of overlap between the spawning period and project window (March and April), the potential impact to spawning will be minimal.

Figure 6.5. Sound Pressure Level Thresholds for the Onset of Fish Injuries (after Turnpenny & Nedwell, 1994)



Physical damage will occur however to fish eggs and larvae, which have limited mobility and are the most sensitive to the noise. The project area lies within or close to spawning and nursery grounds for Patagonian toothfish and grenadier (section 5.3.6.). A few meters away from the source, these impacts will be negligible. During spawning, the impact will be minor due to localised area of impact.

6.6.3.1 Noise Impact on Seabirds

The majority of seabird species in the Falkland Islands are observed in coastal and near shore areas. Offshore seabirds are more likely to be found in higher numbers and hence more susceptible to noise during winter and spring seasons (June-November). According to White et al. (2002) it is possible that several species of petrel, penguin and albatross will be present in the vicinity of the proposed FOGL wells throughout the development (see section 5.6).

Anticipated airborne noise from drilling activities is likely to be rapidly attenuated and, as a result, any impact to seabirds (i.e. displacement from the area) is likely to be much localized within the immediate vicinity of the drilling, and will be temporary in nature. There are two IBAs in the vicinity of Stanley (Cape Pembroke and Volunteer Point) meaning that aircraft noise may be an important consideration at this location.

Other than in the vicinity of Stanley, the proposed well locations are not considered to be in areas of particularly high sensitivity for sea birds. Therefore the impact of proposed drilling activity on seabirds in the area is considered to be negligible. With regards to the IBAs near Stanley, mitigation measures may be required in order to minimize any potential impacts.

6.6.4 Mitigation Measures

The combined impact of noise generated by drilling activities is assessed to be of low significance to marine mammals within the project area. It is not expected that any physiological impacts will result from exposure to drill rigs or supply vessels. Short term behavioural impacts may result, although these are not expected to have a significant effect on the wider ecosystem.

Most seabird species in the Falklands are observed in coastal and nearshore areas, meaning that noise produced during the FOGL operations will not have a significant impact on these species. As noted above, there are two IBAs in the vicinity of Stanley airport, meaning that aircraft noise is an important consideration at this location.

To reduce these impacts further, the following mitigation measures are proposed;

- Helicopter operations lower than 460 meters will be prohibited above marine mammal and seabird colonies identified as sensitive sites (refer to Figure 5.78) unless essential for safety purposes.
- Helicopter flights will adopt flight paths taking into account environmentally sensitive areas (refer to Figure 5.78).
- Small boat movements will be prohibited in the vicinity of marine mammals (cetacean and pinnipeds) unless absolutely necessary for personnel safety, and will avoid rafts of seabirds.
- Rapid movement of vessels towards and in the vicinity of marine mammals will be avoided.

6.6.5 Conclusions

Underwater noise emissions from drilling and vessel activities are estimated to be in the range of 160 – 190 dB re 1 µPa and are not considered to be of sufficient amplitude to cause direct harm to marine mammals. Sonar and echo sounders have the potential to reach levels sufficient to cause TTS or PTS, but due to the relative short duration of their use and the short periods of location the effects are likely to be minimal. Vocalisations may be masked for several odontocete and pinniped species within few hundred meters of the noise source. This may induce localised behavioural changes in some marine species. However, there is no evidence of significant behavioural changes due to drilling that may impact on the wider ecosystem.

With reference to impacts on other marine wildlife, there is not expected to be any significant impact. Seabirds are generally not expected to be impacted negatively by noise from the development, except at the IBAs around Stanley which may be affected by overhead aircraft. Fish are not likely to be significantly displaced within the project area.

Overall, any impacts caused as a result of anthropogenic noise during FOGL development will be temporary in nature and short term (up to 100 days). In addition, the potential second well locations will be separated by 20 to 150 km from the first well.

6.7 Atmospheric Emissions

The main sources of atmospheric emissions during drilling operations will result from diesel burnt for power generation for the drill rig and associated standby vessels. A small scale low emission International Maritime Organisation (IMO) certified incineration unit will be used onboard the rig to minimise combustible waste. The emissions will be the EU air quality standards relevant for incineration equipment.

Diesel burnt for power generation will give rise to minor emissions of carbon dioxide (CO_2), oxides of nitrogen (NOx), nitrogen dioxide (NO_2), sulphur dioxide (SOx) and unburned hydrocarbons. The estimated atmospheric emissions from both wells are presented in Table 6.6. These emissions are anticipated to disperse rapidly under most conditions to levels approaching background within a few tens of metres of their source.

Table 6.6. Predicted Atmospheric Emissions (tonnes) from two-well drilling campaign [1]

Emissions[1]	Drill Rig	Support Vessels [3]	Helicopters [4]	Total
Carbon dioxide	8,640	10,656	323	**19,619**
Carbon monoxide	42.4	52.3	0.52	**95.2**
Oxides of nitrogen	160.38	197.80	1.26	**359.4**
Nitrous oxide	0.59	0.73	0.02	**1.35**
Sulphur dioxide	10.80	13.32	0.40	**24.5**
Methane	0.49	0.60	0.01	**1.09**
Volatile organic chemicals	5.40	6.66	0.08	**12.14**

Note 1: Pollutant emission figures have been based on estimated tonnes of fuel usage and emission factors – based on API Compendium 2009 for GHG and EEMS factors for the other air emissions.

Note 2: Rig is estimated to consume @ 30 tonnes fuel/day for 90 days duration.

Note 3: 2 Support vessels (PSVs) and one Emergency Response and Rescue Vessel (ERRV) are estimated to consume 15 and 7 tonnes fuel/day, respectively for 90 days duration.

Note 4: Atmospheric emissions for helicopter trips assumes flights for crew changes will occur 60 times (round trip) throughout the drilling programme. Fuel consumption is estimated at 3 tonnes per 1,000 kilometres, with a return trip from Mt. Pleasant Airport to the rig estimated at 460 and 660 kilometres for Loligo A and Scotia East D, respectively.

6.7.1 Mitigation measures

Practical steps to limit atmospheric emissions that will be adopted during the drilling programme include advanced planning to ensure efficient operations, well maintained and operated power generation equipment and regular monitoring of fuel consumption. Use of low sulphur fuel should be also adopted throughout the drilling programme. The EU Directive 2005/33/EC has limited the maximum level of sulphur in marine diesel sold within the EU to 1.5% from 2010.

6.7.2 Conclusions

Atmospheric impacts offshore are generally mitigated circumstantially by the open and dispersive environment. Drilling rigs and support vessels are built and operated to standards that preclude significant impacts to the health of their crews, whilst other environmental receptors (e.g. flora and fauna) tend to be sparsely distributed and/or transient in the local area. Impacts at this level are therefore likely to be negligible. The emissions from the proposed project will contribute to the overall pool of greenhouse and acidic gases, but given the short-term duration of drilling and no planned flaring, cumulative impact on a global scale is estimated as minor.

6.8 Marine Discharges

Sources of marine discharges for the proposed wells are:

- Water based mud (WBM) and drill cuttings;
- Cement;
- Grey (e.g. showers, sinks) and Black (Sewage) waters;
- Drainage water; bilge and ballast water.

These discharges are discussed in the following sections.

6.8.1 Water Based Mud (WBM) and Drill Cuttings

WBM will be discharged as mud on cuttings and fine solids and, upon the completion of drilling each section of each well. The drilling mud composition is essentially a brine solution, with small amounts of chemicals added to maintain the properties of the mud and to prevent damage to the well bore and the reservoir.

The main components of WBM will comprise natural products (for example, brine, bentonite and barite), which are biologically inert. The muds typically have a very low toxicity, with an LC_{50} of more than 50,000 parts per million (*Jones et al., 1986; Leuterman et al., 1989*). In fact, the WBM comprises approximately 90 percent water. The vast majority of WBM components discharged for the well (approximately 96 percent) are classified under Annex 6 of the OSPAR convention (*OSPAR, 1999*) as substances, which are considered to Pose Little Or No Risk to the environment (PLONOR chemicals) (refer to Section 4.4.7).

Of the limited quantity of chemicals not classified as PLONOR and anticipated to be discharged along with the WBM, all are categorised as Category E or Gold (the lowest environmental risk category) under the UK Harmonised Offshore Chemical Notification Scheme (see Appendix B for a description of the UK Harmonised Offshore Chemical Notification Scheme, CHARM and Hazard Quotients).

Discharge of water based muds and cuttings at the sea bed will cause local increases in turbidity near to the seabed, while discharges at the sea surface will be suspended in sea water creating a discharge 'plume' of finer material released from the coarser cuttings that drift with prevailing currents. Rapid dilution and dispersion of the discharge 'plume' is expected due to tidal currents and the water depths in the project area (>1,300 metres). Dilution of the 'plume' in well-mixed ocean waters, is estimated to be 100-fold within 10 metres of the discharge and 1,000-fold after 10 minutes approximately 100 metres from the discharge point. Studies of the discharge of WBM into the water column in areas where currents are weak have found dilutions of 500 to 1,000 times within one to three metres of discharge *(Ray and Meek, 1980)*. Dilution will therefore be rapid in the Falklands offshore and this, together with the low toxicity, indicates that any impacts within the water column will be undetectable shortly after discharge. The magnitude of increased turbidity in the water column due to discharged drilling muds is considered low and will not significantly impact plankton communities.

Discharge of the WBM will not contribute to any impacts on the local marine environment through toxicity, bioaccumulation, low biodegradability or other aspects such as the endocrine disruption. In some cases drilling muds may be associated with elevated levels of heavy metals. However, a wide range of studies have shown that these are not bio-available and do not therefore result in any direct affects on marine fauna and flora (*Neff et al., 1989*).

Any impacts from mud and cuttings discharge on water quality are assessed to be minor.

6.8.2 Cement Chemicals

During drilling of the wells, some surface returns of cement and associated chemicals will be lost to the seabed in the immediate vicinity of the well. The worst case scenario discharge is around 25% of the cement use, and will be minimised wherever possible.

The cement is comprised mostly of PLONOR chemicals (refer to Section 4.4.7). All chemicals to be discharged which are non-PLONOR have a HQ band of GOLD or E (lowest environmental risk category). Any impacts from cement discharges on water quality are assessed to be minor.

6.8.3 Grey Water, Black Water and Kitchen Waste

An estimated 0.22 m^3/day of grey water and 0.10 m^3/day of black water will be generated by each person on board the drilling rig and support vessels (based on previous modelling and assumptions for offshore drilling operations (*BP, 2002*). Table 6.7 show the estimated volumes of grey and black water produced per drilling period (90 days) from the drilling of the exploration wells (assuming 120 persons onboard the rig and vessels).

Table 6.7. Estimated quantities of grey and black water discharge during drilling period (90 days)

Type of water	Volume (m^3)
Grey water produced (m^3)	2376
Black water produced (m^3)	1080

Black water can contain harmful microorganisms, nutrients, suspended solids, organic material with a chemical and biological oxygen demand and residual chlorine from the sewage treatment disinfection. Onboard treatment in a certificated IMO compliant sewage treatment facility will treat sewage to IMO standards as set out in Annex IV of MARPOL. The treatment standard is 250 faecal coliforms per 100ml, the total suspended solids must be less than 50 mg/l and the BOD less than 50 mg/l. Increased BOD directly impacts water quality by increasing the uptake of dissolved oxygen concentration by microorganisms that decompose organic material in the sewage, which in turn reduces the dissolved oxygen content of the water. During a relatively short-term drilling period the treated black water discharge will be spread over a large offshore area, which is expected to disperse and dilute quickly due to tidal currents. The magnitude of impact of the water quality due to sewage discharge is low.

Grey water discharge includes drainage from baths, showers, laundry, wash basins and dishwater. Grey water is not required to be treated before discharge by the regulations in MARPOL 73/78 as it is not considered garbage or sewage (provided it does not contain a pollutant prescribed in the Regulations or MARPOL). Therefore it may be discharged to the sea without treatment. Grey water discharge is not predicted to cause deterioration to water quality except locally to the discharge. The magnitude of this discharge is considered low.

Organic waste discharge from galleys will introduce nutrients and organic material to the water column, which may cause a local increase in BOD. The ground (macerated) discharge will disperse and dilute quickly due to currents. It will be released from several vessels over a large offshore area over approximately 90 days. The magnitude of impact to water quality from organic waste discharge is rated as negligible.

The overall impact of grey and black water discharges and organic kitchen waste discharge is assessed as negligible.

6.8.4 Drainage, Bilge and Ballast water

Good housekeeping standards will be maintained onboard the rig to minimise the amount of hydrocarbons and other contaminants entering the drainage systems. Liquid storage areas and areas that might otherwise be contaminated with oil are generally segregated from other deck areas to ensure that any contaminated drainage water can be treated or accidental spills contained. All the drains from the rig floor will be directed to a containment tank and the fluids processed/filtered to remove hydrocarbons (<15 parts per million hydrocarbons in water) as required under the MARPOL Convention and discharged to sea. Residual hydrocarbons will be routed to transit tanks for processing onshore.

Similarly, drainage and bilge water may potentially be contaminated with oil/hydrocarbons, which would reduce water quality if discharged to the marine environment. Drainage and bilge water will be directed to the holding tank (bilges) then routed through an oil/water separator and monitored for oil concentration before discharge. The content of oil contaminated drainage and bilge water is controlled under MARPOL Annex 1 and discharge of water with greater than 15 ppm is prohibited. As the oil in water content will be below 15 ppm, there will be no visible sheen and dispersion will be rapid. Due to inherent mitigation of all drainage and bilge water passing through an oil/water separator and meeting set standards before discharge, the overall impact of drainage and bilge water discharge is assessed as negligible.

Depending on where it was taken onboard, ballast water may contain harmful micro-organisms, marine organisms from other locations and contaminated sediments in suspension. Ballast water is taken onboard as appropriate to maintain safe operation and manoeuvring of the vessels. The MODU may need discharge ballast water during rig movement to the project area. However, as it will be mobilised from within Falklands waters to the proposed drilling locations. any potential impacts are predicted to be negligible to minimal.

6.8.5 Mitigation Measures

FOGL are to employ several measures to reduce impacts to the marine environment from these discharges as detailed below:

- Planned use of water based mud (WBM) for all sections of the well with the selection of most environmentally benign mud and cement chemicals.
- All drilling chemicals to be assessed using the HOCNS methodology where appropriate, in accordance with the UK's Offshore Chemicals Regulations (OCR) 2002. Any chemicals with substitution warnings will be substituted where practicable.
- Appropriate drainage and sewage treatment systems will be on all rig/vessels. Use of MARPOL approved sewage treatment plant.
- All discharges from the rig/supporting vessels will be treated and discharged according to the MARPOL Convention.
- Good housekeeping standards to be maintained on the rig to control the amount of hydrocarbons and other contaminants entering the drainage system. Hydrocarbons and chemicals will be bunded with no residues/spills permitted to enter the overboard drainage system.
- Provide the maximum practicable ability to avoid and control spills, and allow recovery of any spilled material. Spill kits will be readily available with staff trained in their use.
- Bilge water will be passed through an alarmed oil-in-water separator to ensure oil levels are below 15 ppm before discharged.

6.8.6 Conclusions

Due to the low toxicity of the majority of the discharges and the anticipated dilution and dispersion, all impacts on water quality are predicted to be short-term and localised and assessed to be either negligible or minor.

6.9 Waste

Careful consideration is given to minimising the amount of waste generated and controlling its eventual disposal. It is acknowledged that waste disposal and treatment options in the Falklands are limited. The waste options will be assessed with the drilling contractor, and in consultation with FIG. A tailored project waste management plan will be developed and implemented.

It is estimated that approximately 6 tonnes of hazardous and 22 tonnes of general waste (7 tonnes of which can be incinerated onboard the rig using IMO certified low emissions incineration unit) will be generated per month from a single well drilling programme. All waste streams will be segregated by type, and stored in designated containers and skips. Non-hazardous waste will be periodically transported to shore for recycling and disposal in a controlled manner through authorised Falklands waste contractors. All hazardous waste will be transferred to the UK for treatment and disposal.

FOGL will ensure that a waste management programme is implemented to minimise waste generation and to ensure material such as scrap metal, waste oil and surplus chemicals are sent for re-cycle or re-use as much as practicable.

All discharges from the supporting vessels will be treated and discharged according to the MARPOL Convention (as relevant to the Atlantic Ocean). The MARPOL Convention prohibits discharge of any garbage or solid wastes (with the exception of macerated food waste) offshore.

All vessels, including the rig, will implement appropriate waste management plans and store and dispose of all solid wastes onshore accordingly. Procedures for dealing with hazardous waste will be implemented in accordance with regulatory guidelines.

Given the limited capacity of landfill sites in Falklands (where non-hazardous waste from the drilling operations is to be directed) and a long haul transfer of hazardous wastes to UK, the overall impact from waste generated throughout the drilling campaign is assessed to be of moderate significance.

6.10 Accidental Events

The risk of accidental hydrocarbon and/or chemical spillage to the sea is one of the main environmental concerns associated with oil industry developments. Spilled oil and chemicals at sea can have a number of environmental and economic impacts, the most conspicuous of which are on seabirds and marine mammals. The actual impacts depend on many factors, including the volume and type of oil spilled, and sea and weather conditions. During exploration and appraisal drilling, there is a risk of spillage of oil (fuel/crude), and spillage or leakage of chemicals. Both gas and oil prospects are anticipated within the licensing area, however only oil scenarios are considered as they have larger environmental implications.

6.10.1 Potential Oil Spill Scenarios

The wells will target oil reservoirs, and therefore the main spill risks associated with drilling operations are accidental loss of hydrocarbons from the reservoir or an accidental loss from the drilling rig fuel oil inventory, the worst case being a total loss of well control (i.e. blow out), or a total loss of the fuel inventory from the rig. The likelihood of such events occurring is in the range identified as low risk.

The total hydrocarbon inventory of the *Leiv Eiriksson* rig during drilling is shown in Table 6.8. The fuel capacity for support vessels will be much lower than for the rig and is not discussed in the context of this assessment.

In the rare event of a loss of well control from an exploration well, the amount lost per unit time would depend on the unrestricted open hole flow rate. Oil spill response procedures would be put into action in a timely and effective manner to reduce the impact of any spill, which is discussed in the sections below.

For the purposes of oil spill modelling, the maximum theoretical open hole flow rates and worst case hydrocarbon characteristics for the wells have been estimated (Table 6.9). These rates are indicative, as they are based on assumptions on the characteristics of potential oil reservoirs, which have not been penetrated to date. The wells are the first in the region.

Table 6.8. Inventory of Hydrocarbons for the Proposed Falkland Islands Exploration Wells

Type of Oil	Maximum Quantity (tonnes)	Comments
Diesel	4,631m^3 (3,853 tonnes)	Used as fuel oil on rig.
Lube and Hydraulic Oil	15 tonnes (assumed)	Hydraulic oil volumes vary depending on work in progress. Hydraulic oil drums are stored in secure bunded areas on deck.
Aviation Fuel	2 tonnes (assumed)	Used for occasional re-fuelling of helicopters. Stored in IBCs on deck.
Crude, (18-25° API for Loligo A and Vinson West, 30° API for Scotia East).	Dependent on estimated open hole flow rates (representing the worst case scenario). Refer to Table 6.9 for estimated flow rates.	The worst case scenario would be the uncontrolled flow of reservoir hydrocarbons from the wells.

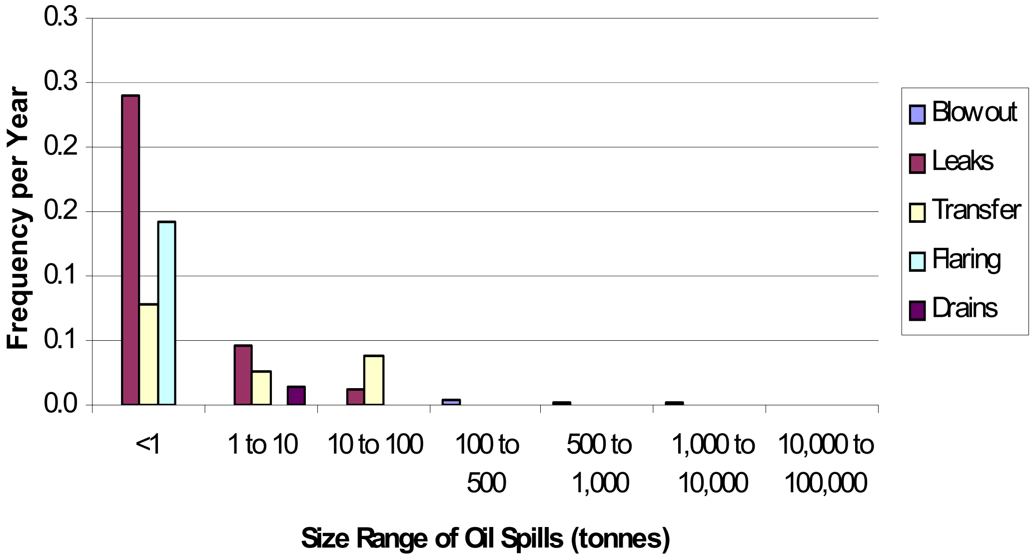
Table 6.9. Indicative Maximum Open Hole Flow Rates and Worst Case Expected Hydrocarbon Characteristics for the Proposed Exploration Wells

Well	Estimated type of reservoir hydrocarbons	Estimated Maximum Open Hole Flow Rates		
		bopd	m^3 day^{-1}	tonnes day^{-1}
Loligo A/NW, Vinson West and Nimrod	Av. 18-25^o API crude expected	47,000	7,473 (311 hr^{-1})	7,099
Scotia East D	Av. 30^o API crude expected	47,000	7,473 (311 hr^{-1})	6,277

6.10.2 Likelihood of Hydrocarbon Spill Occurrence

Using the UK Continental Shelf (UKCS) as an example, it should be noted that spills of diesel are the most frequent type of spill on the UKCS (Figure 6.6), comprising 14.5 percent of UKCS spills by number and 3.5 percent of the total amount of oil spilt. Gas condensate spills are the least frequent, comprising 1.9 percent of the number of spills on the UKCS and 0.3 percent of the total amount of oil spilt.

Figure 6.6. Frequency and Size of Oil Spills during Offshore Drilling Operations per Rig per Year (data from UKCS and SINTEF Database)



An incident, such as a collision, could potentially cause the entire inventory of hydrocarbons stored on the mobile offshore drilling unit (MODU) to be released to the sea. To serve as an example from the UKCS data, for MODUs in the North Sea between 1980 and 1997, a total loss accident frequency of 3.75 occurrences per 1000 unit years was recorded (*Worldwide Offshore Accident Databook – Statistical Report 1998, DET NORSKE VERITAS*). In practice, it is most likely that any release of oil would occur over a period of time. An immediate release could, however, occur in the unlikely event that all compartments/tanks on the MODU containing oil were instantaneously fractured in some way.

Accidental diesel spills during bunkering are identified as a moderate risk but the expected volumes of hydrocarbon released would be generally small (0.6 tonnes) (*HSE, 1995*). Such a volume would disperse rapidly and will not impact along the coast.

The worst-case scenario is considered to be from a major oil spill occurring as a result of a loss of well control or blow out. Historically, the worldwide frequency of blow outs is approximately 0.0063 per well, or 1 in every 159 wells (*Holand, 1997*). Statistics from the World Offshore Accident Data Bank (WOAD) indicate that worldwide the frequency of occurrence of blowouts from mobile drilling units is in the order of 10 per 1000 unit years (*WOAD, 1998*); This is supported by data from the UK, where over 3500 exploration, appraisal and development wells have been drilled from 1997 to 2008 (includes mechanical sidetracks) with no major blow outs. The probability of a blow out during drilling in the exploration wells is therefore very low. However, the recent large scale Macondo blowout in the Gulf of Mexico indicates that they do occur.

Rig Spill History

The Ocean Rig *Leiv Eiriksson* has no hydrocarbon spill history in the last 5 years, apart from minor chemical spillages (Table 6.10).

Table 6.10. Leiv Eiriksson Spill History (compiled from undesirable events reports, available to date)

Incident Date	Description	Cause	Remedial Action
02.02.2008	Unintentional discharge to sea of brine.	Leaking pit and master dump valves.	Pit dump valve o-ring seal replaced, Master dumpline valve replaced.
29.03.2008	Discharge to sea of 2 m^3 of Glydril mud whilst testing BOP function.	Lower Annular inner seal failure.	Inspection / overhaul of Lower Annular on BOP pull.
29.03.2008	Well control incident: Well was observed to overflow over top of wellhead at rate of $20lmin^{-1}$.Total $20m^3$ mud lost to sea.	Formation ballooning through cement job (negative pressure test).	Reconnection to wellhead. Well intervention operations.
14.11.2008	Loss of $3m^3$ of active drilling mud from trip tank.	Trip tank dump valve left open. Trip tank dump valve gear position indicator misaligned.	Trip tank dump valve gear position indicator re-aligned.
15.03.2009	Loss of $18m^3$ of mud to deck.	Rig floor standpipe valves not closed after shut down of cement unit.	Cement pump procedures modified. Cascaded to all crews. Fabrication of overflow tank in cement room.

FOGL have reviewed the above undesirable incidents attached to the *Leiv Eiriksson*. FOGL will be checking the contractor's management systems on board the rig, in order to minimise the risk of a spill incident occurring.

6.10.3 The Fate of Hydrocarbons at Sea

When oil is released into the marine environment it undergoes a number of physico-chemical changes, some of which assist in the degradation of the spill, while others may cause it to persist. These changes are dependent upon the type and volume of oil spilled, and the prevailing weather and sea conditions.

Evaporation and dispersion are the two main mechanisms that act to remove oil from the sea surface. Following a hydrocarbon spill, evaporation is the initial predominant mechanism of reducing the mass of oil, as the light fractions (including aromatic compounds such benzene and toluene) evaporate quickly. If the spilled oil contains a high percentage of light hydrocarbon fractions, such as diesel, a large part of the spilled oil will evaporate relatively quickly in comparison to heavier (crude) oil. The evaporation process will be enhanced by warm air temperatures and moderate winds and can produce considerable changes in the density, viscosity and volume of the spill.

After the light fractions have evaporated from the slick, the degradation process slows down and natural dispersion becomes the dominant mechanism in reducing slick volume. This process is dependent upon sea surface turbulence which in turn is affected by wind speed. Water soluble components of the oil mass will dissolve in the seawater, while the immiscible components will either emulsify and disperse as small droplets in the water column (an oil-in-water emulsion) or, under certain sea conditions, aggregate into tight water-in-oil emulsions, often referred to as 'chocolate mousse'. In practice, usually only one of the two processes will take place (dominate), as they will hardly ever will take place at the same time.

The rate of this emulsification is dependent upon the oil type, sea state and the thickness of the oil slick. Thick (large) oil slicks tend to form water-in-oil emulsions, where thin (smaller) slicks tend to form oil-in-water emulsions that usually disappear by natural dispersion.

When a water-in-oil emulsion (chocolate mousse) is formed, the overall volume of such a water-in-oil emulsion increases significantly, as it may contain up to 70 or 80% water. This chocolate mousse will form a thick layer on the sea surface reducing slick spreading and inhibiting natural dispersion. By diminishing the surface area available for weathering and degradation, these chocolate mousses will be difficult to break up using dispersants. In their emulsified form, with drastically increased volume, they can cause difficulties for mechanical recovery devices as well.

Wind and surface current speed and direction are the main parameters involved in affecting where a slick travels. The slick will roughly travel at the same speed and direction as the surface water current. Additionally, the prevailing wind drives a slick downwind at 3 to 4% of the wind speed.

Spill modelling in is a pre-requisite for understanding the fate of a particular oil under given meteorological conditions.

6.10.4 Oil Spill Modelling

Spill modelling of both diesel fuel oil and crude oil has been undertaken to estimate and illustrate the fate and movement of the oil for contingency planning purposes, using the BMT Oil Spill Information System (OSIS) 4.2.2 model. Further model specifications are provided in Appendix G.

Input Current Data

A hydrodynamic hindcast database for the Falkland Islands has been obtained and built into OSIS modelling programme. The system is configured for the global ocean with HYCOM as the dynamical model. It comprises of the following;

- Daily surface current velocity fields derived from the ocean circulation model hindcast data (at 1/12 degree resolution).
- Bathymetry, derived from a quality controlled NRL DBDB2 dataset.
- Surface forcing, derived from Navy Operational Global Atmospheric Prediction System (NOGAPS). This includes wind stress, wind speed, heat flux (using bulk formula), and precipitation.

The HYCOM system is a hybrid isopycnal model, which has fixed layer thicknesses in the upper mixed layer, and constant density layers through most of the water column. Archived analysis field data have been extracted for the Falkland region of interest for the model surface layer, which is representative of the upper 1 metre of the water column. Further details of the modelling system can be found at www.hycom.org.

Tidal currents are derived from BMT ARGOSS' in-house tidal database. This has been generated from global analysis of satellite altimeter observations, combined with tidal elevation measurements from around 5000 coastal stations. The model computes depth averaged barotropic tidal current velocities; these have then been extended through the water column using an empirical logarithmic velocity profile, to estimate equivalent tidal current velocities in the top 1 metre.

Input Wind Data

Winds in the area around the proposed development predominantly range between 11 and 21 knots (see section 5.2.7). For the purposes of oil spill modelling, a 30 knot onshore wind towards the nearest landmass is used as a worst case wind scenario, as outlined in the UK's guidance notes relating to The Merchant Shipping (Oil Pollution Preparedness, Response Co-operation Convention) Regulations 1998, produced by the Department of Energy and Climate Change. Therefore, for the trajectory modelling, a 30 knot onshore wind was chosen to represent a worst case scenario.

For the purposes of the stochastic (typical wind conditions) oil spill modelling, wind roses were obtained for the most likely drilling window (April, May and June) from the wind database for 1992-2002, presented in the metocean report compiled by Fugro GEOS (2005), which summarises the metocean conditions observed in the southern licence areas (refer to Sections 5.2.6 and 5.2.7). From these monthly wind rose data for April, May and June, an average wind rose was compiled. Note that a 30 knot onshore wind is very unlikely.

Modelling Results for Diesel Spills

Diesel oil spill modelling was undertaken at the proposed Vinson West location, this being the closest of the three wells to the shoreline. The following scenarios were determined:

- The weathering of a 10 tonne operational spill of diesel with a 30 knot onshore wind;
- The weathering of a full rig inventory (3,853 tonnes) instantaneous diesel spill with a 30 knot onshore wind;
- The weathering of a full rig inventory (3,853 tonnes) diesel spill released instantaneously under typical wind conditions.

All above scenarios were modelled until no diesel remained at sea. The spill modelling scenarios and results are summarised in Table 6.11.

Trajectory modelling of a 10 tonne operational spill of diesel fuel from the Vinson West well location with a worst case 30 knot onshore wind towards the nearest landfall (Cape Pembroke) indicated that the oil would disperse offshore within 1 hour and would not reach the coastline. The model showed that the diesel travelled approximately 2.5 kilometres to the northwest before the oil dispersed completely.

Similarly, trajectory modelling of the full diesel inventory of the rig (3,853 tonnes) released instantaneously (representing a total catastrophic loss of the drilling rig) from the Vinson West well location with a worst case 30 knot onshore wind towards the nearest landfall (Cape Pembroke) showed that the diesel dispersed offshore within 10 hours without reaching the shore. The model showed that the diesel travelled approximately 25 kilometres to the northwest before the oil dispersed completely.

Stochastic modelling, for 3,853 tonnes release using typical wind conditions for the area for the Vinson West well location indicated that the diesel would weather offshore with the oil drifting and dispersing in a north easterly direction, in line with the prevailing wind and currents. The modelling indicated a zero percent chance of the diesel beaching. This indicates that the predominant effect of the prevailing winds is to keep any spilt diesel offshore.

No further oil spill modelling regarding diesel fuel oil was considered necessary, with the remainder of the spill modelling focusing on reservoir hydrocarbons.

Table 6.11. Modelling Results for the Vinson West Well

From Location	Oil Type	Spill Size (tonnes)	Scenario	Wind Conditions	Fate of Spill
Vinson West	Diesel	10	Operational transfer	Trajectory: 30 knot onshore wind (bearing 129°) towards nearest landfall (Cape Pembroke, 156 km, bearing 309°)	Oil travels approx. 2.5 kilometres to the northwest. Disperses offshore within 1 hour.
Vinson West	Diesel	3,853	Rig inventory loss (trajectory)	Trajectory: 30 knot onshore wind towards nearest landfall (Cape Pembroke, 156 km 309°)	Oil travels approx. 25 kilometres to the northwest. Disperses offshore within 10 hours.
Vinson West	Diesel	3,853	Rig inventory loss (stochastic)	Typical wind conditions (stochastic)	Oil remains offshore with a drift mainly towards the northeast. 0% probability of oil beaching.

Modelling Results for Crude Oil

Crude oil spill modelling was carried out for three proposed exploration well locations. This was done to cover the closest to the shore well (Vinson West), the most likely drilling location Loligo A, as well as Scotia East D well for which lighter API oil is expected. The following scenarios were determined for each well location:

- The weathering of a blow-out of the expected reservoir crude oil released over 10 days (240 hours) with a 30 knot onshore wind towards the nearest landfall for the Loligo A, Vinson West wells (Heavy oil of 18^{o} API) and Scotia East (Medium oil of 30^{o} API);
- The weathering of a blow-out of the expected reservoir crude oil released over 10 days (240 hours) under typical wind conditions for all three wells.

The above modelling scenarios were based upon the indicative maximum open hole flow rates (refer to Table 6.9). Modelling was run until no oil remained at sea.

The spill modelling scenarios and results are summarised in Table 6.12 and presented in the corresponding Figures 6.7-6.12. It must be noted that these results are based on no mitigation actions (i.e. dispersant spraying) being in place. In Figures 6.7 – 6.9, the red lines represent the expected spill trajectory, which is calculated for every 20 minutes following the spill. The black dots indicate the fate of residual particles from the oil spill.

Trajectory modelling is undertaken to establish minimum oil spill response times. An arbitrary worst case onshore wind is modelled, driving an oil spill to shore. In the UK, and so here too, this is taken as a 30 knot wind (15.6metres/second). However, onshore winds lasting for 10 days in areas east of the Falklands are considered very unlikely (refer to Section 5.2.6).

The properties of the oil as it weathers can also be used to identify the window of opportunity for the use of chemical dispersant to accelerate the dispersion of the oil. The modelling shows that the oil from the Scotia East well would remain amenable to chemical dispersion throughout the weathering process (less than 2,000 mPa). The oil from the Loligo A and Vinson West wells would be amenable to chemical dispersion only soon after (<1 hour), and close to the location of, a continuing spill.

18°API oil is a heavy crude, which is persistent and will tend to form a stable, water in oil emulsion, following spillage onto the sea. The cold temperatures of the south Atlantic will increase the time taken for it to weather. Conversely the high winds and high 'energy' at the sea surface will tend to assist the natural weathering process. Under these conditions the heavy oil from the Loligo A location beached in 177 hours (Figure 6.7) and the Vinson West location beached in 105 hours (Figure 6.9).

Table 6.12. Modelling Results for the Uncontrolled Well Blowout Scenario (release rate of 311 m3/ hour for 240 hours)

From Location	Wind Conditions	Fate of Spill	Figure
Worst case 30 knots onshore wind			
Loligo A	Trajectory: 30 knot onshore wind towards nearest landfall (60°)	The oil quickly forms water-in-oil emulsion which then weathers very slowly. Oil beaches in 177 hours. 74,640 m^3 spilt, 59,385m^3 of emulsified oil reaches the shore.	6.7
Scotia East	Trajectory: 30 knot onshore wind towards main Falkland Islands (45°)	Oil disperses offshore within 157 hours. During this time the slick is driven some 180 km to the SW. However it is completely dispersed 150 km offshore. 74,640 m^3 spilt, 0 m^3 reach the shore.	6.8
Vinson West	Trajectory: 30 knot onshore wind towards main Falkland Islands (90°)	The oil quickly forms water-in-oil emulsion which then weathers very slowly. Oil beaches in 105 hours. 74,640 m^3 spilt, 72,684 m^3 of emulsified oil reaches the shore.	6.9
Typical wind conditions blowout scenarios			
Loligo A	Typical wind conditions (stochastic)	Oil driven by prevailing winds and currents to the NE. There is a low probability of the oil beaching on the Falkland Islands and central Argentine. The total probability of oil beaching is1.22%	6.10
Scotia East	Typical wind conditions (stochastic)	Oil driven by prevailing winds and currents to the NE. The position of the well and the light oil would result in it all dispersing offshore. There is a zero probability of oil beaching.	6.11
Vinson West	Typical wind conditions (stochastic)	Oil mostly driven by prevailing winds and currents to the NE. There is a low probability of the oil beaching on the coast of central Argentina and South Georgia. The total probability of oil beaching in these places is 5.61 %. There is a zero probability of the oil beaching on the Falkland Islands.	6.12

30°API oil is medium crude, which is relatively volatile, and will tend to form a water-in-oil emulsion, but this degrades relatively quickly. The greatest rate of spillage envisaged from the Scotia East location, 240 hour blow-out at 311 m^3 per hour, completely weathered before reaching the shore and so did not beach (Figure 6.8). Smaller spills would therefore not beach either.

Stochastic modelling is used to apply the range of wind and current conditions recorded at a location to oil spill scenarios. The model output illustrates the typical fate of the oil and gives a chart with the probability of a particular area being affected by the oil as a 'contour map'. It also indicates the locations (blue dots in Figures 6.10-6.12), and probability of beaching where applicable. This can then be used to identify particularly sensitive areas that could be affected together with a probability of it occurring.

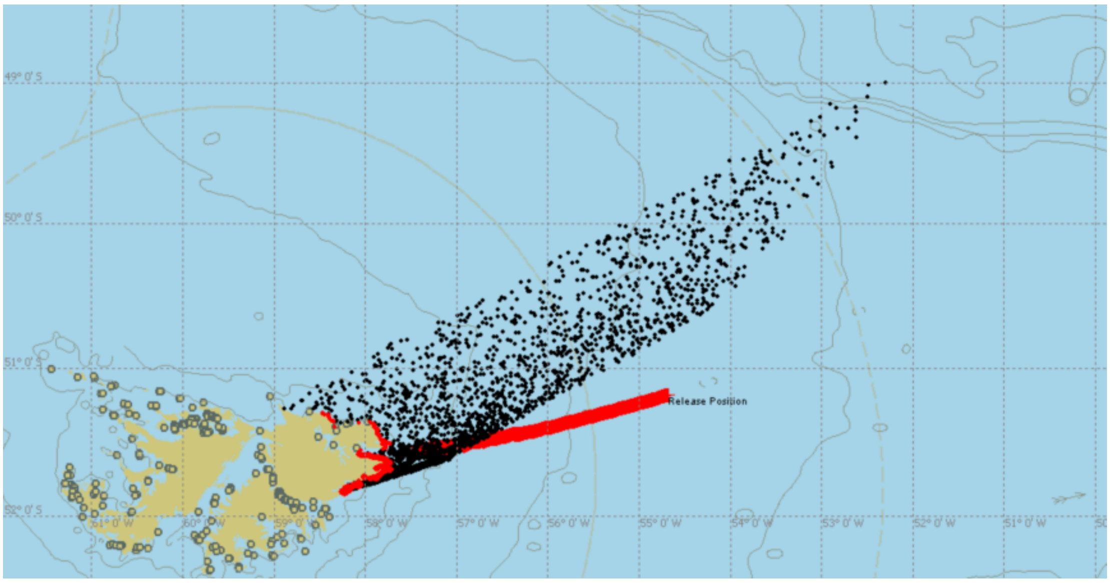
Scotia East is located furthest to the northeast, and is the most distant from the Falkland Islands, of the three well locations. It also has the lighter oil. The modelling illustrates that from this well location the worst case oil spill would not be expected to beach and would weather completely at sea (Figure 6.11).

The oil from the Loligo A well is persistent and would be expected to endure for longer at sea, giving it a greater opportunity to reach land. The modelling shows that the oil would not be expected to beach on the Falkland Islands, but there is a low probability that it could beach on either the Argentine coast or on South Georgia. The combined probability of this happening is

1.22% (Figure 6.10). There is obviously a far greater probability that the oil would weather completely at sea and not go ashore.

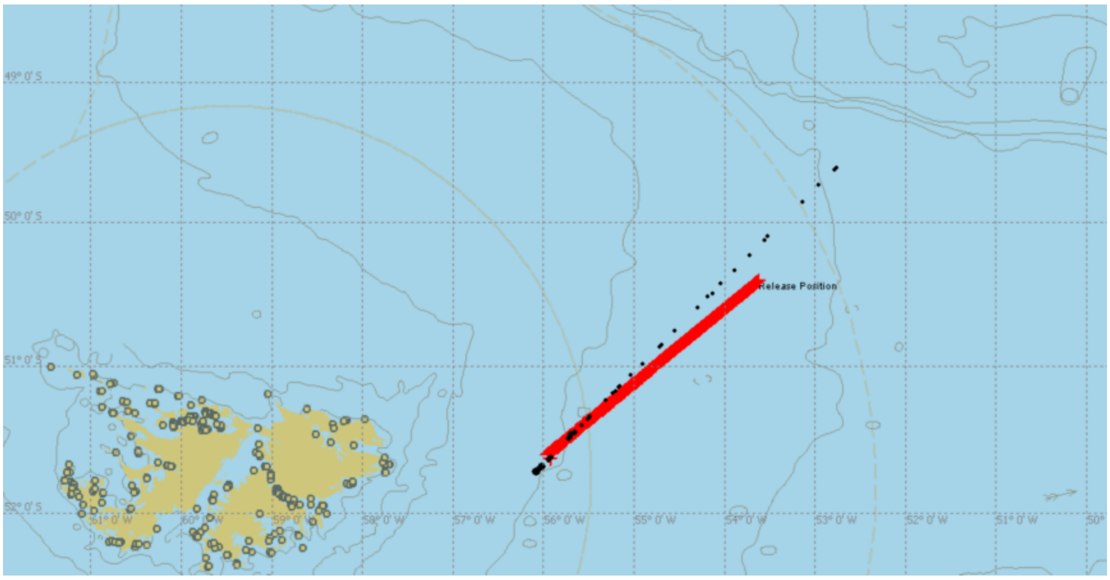
The oil from the Vinson West Well is a persistent oil and would also be expected to endure for longer at sea also with a greater opportunity to reach land. The modelling shows that there is a low probability that it could beaching on either the Argentine coast or on the Falkland Islands. The combined probability of this happening is 5.61% (Figure 6.12). Again there is a far greater probability that the oil would weather completely at sea and not go ashore.

Figure 6.7. Trajectory model run* for a blowout scenario (311m^3 per hour, for 240 hours) of 18^{o}API crude oil with a 30 knot onshore wind from the Loligo A well location



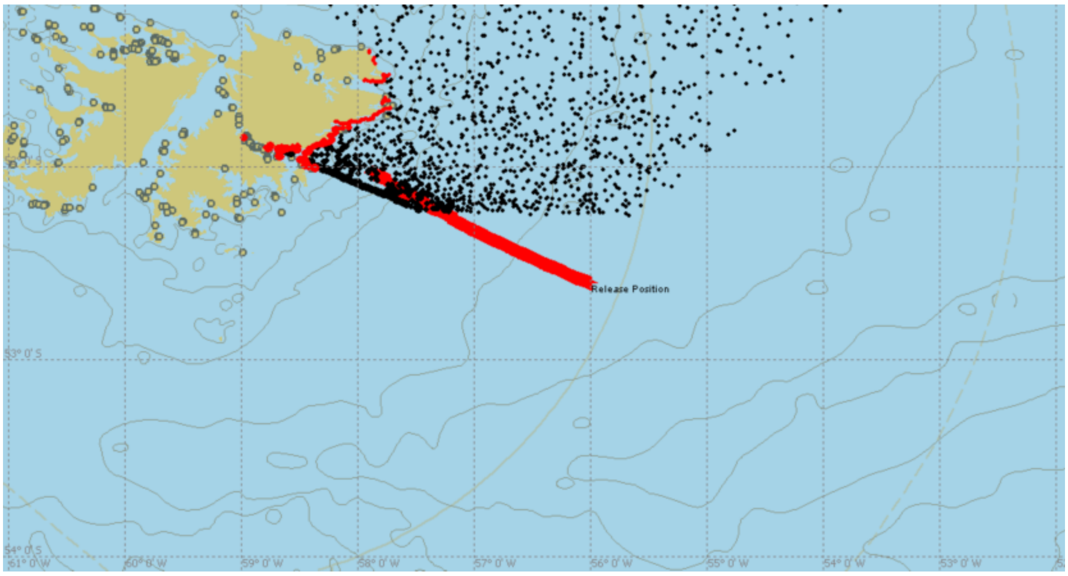
** the red lines represent the expected spill trajectory, which is calculated for every 20 minutes following the spill. The black dots indicate the fate of residual particles from the oil spill*

Figure 6.8. . Trajectory model run* of uncontrolled flow (blowout) spill of 30^{o}API crude oil over 10 days (240 hours) with a 30 knot onshore wind from the from the Scotia East well location



** the red lines represent the expected spill trajectory, which is calculated for every 20 minutes following the spill. The black dots indicate the fate of residual particles from the oil spill*

Figure 6.9. Trajectory model run of uncontrolled flow (blowout) spill of 18°API crude oil over 10 days (240 hours) with a 30 knot onshore wind from the Vinson West well location*



** the red lines represent the expected spill trajectory, which is calculated for every 20 minutes following the spill. The black dots indicate the fate of residual particles from the oil spill*

Figure 6.10. Stochastic model run of uncontrolled flow (blowout) spill of 18°API crude oil over 10 days (240 hours) under typical wind conditions at the Loligo A well location (blue points indicate oil beaching locations)

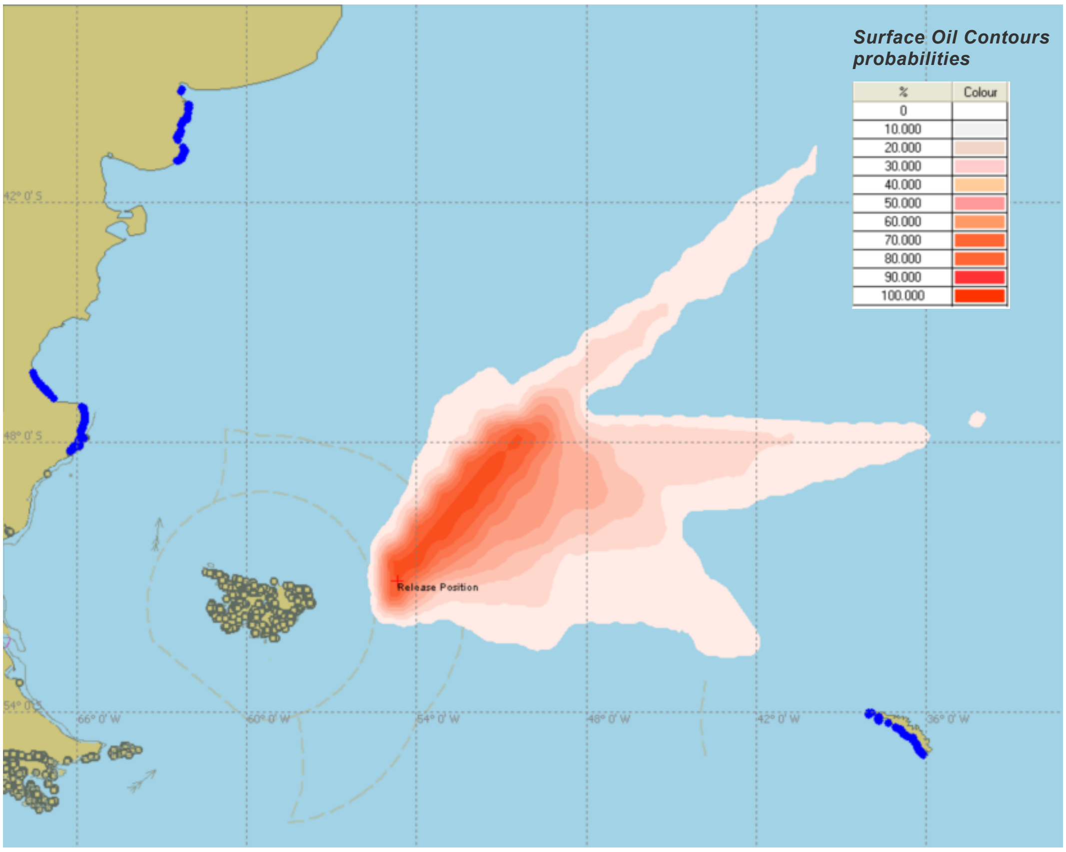


Figure 6.11. Stochastic model run of uncontrolled flow (blowout) spill of 30°API crude oil over 10 days (240 hours) under typical wind conditions at the Scotia East well location (blue points indicate oil beaching locations)

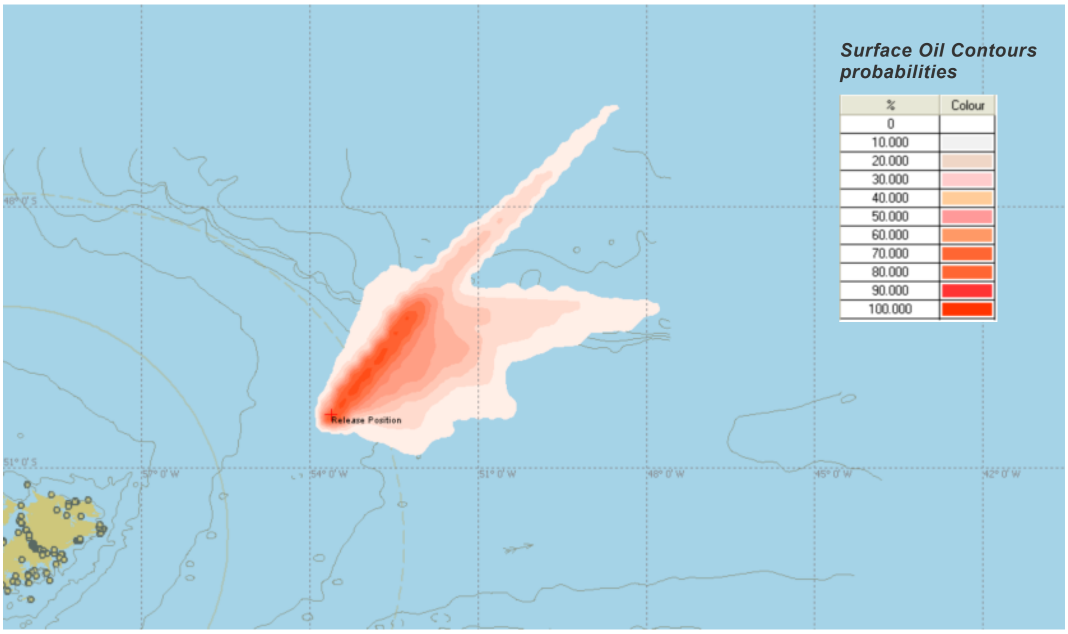
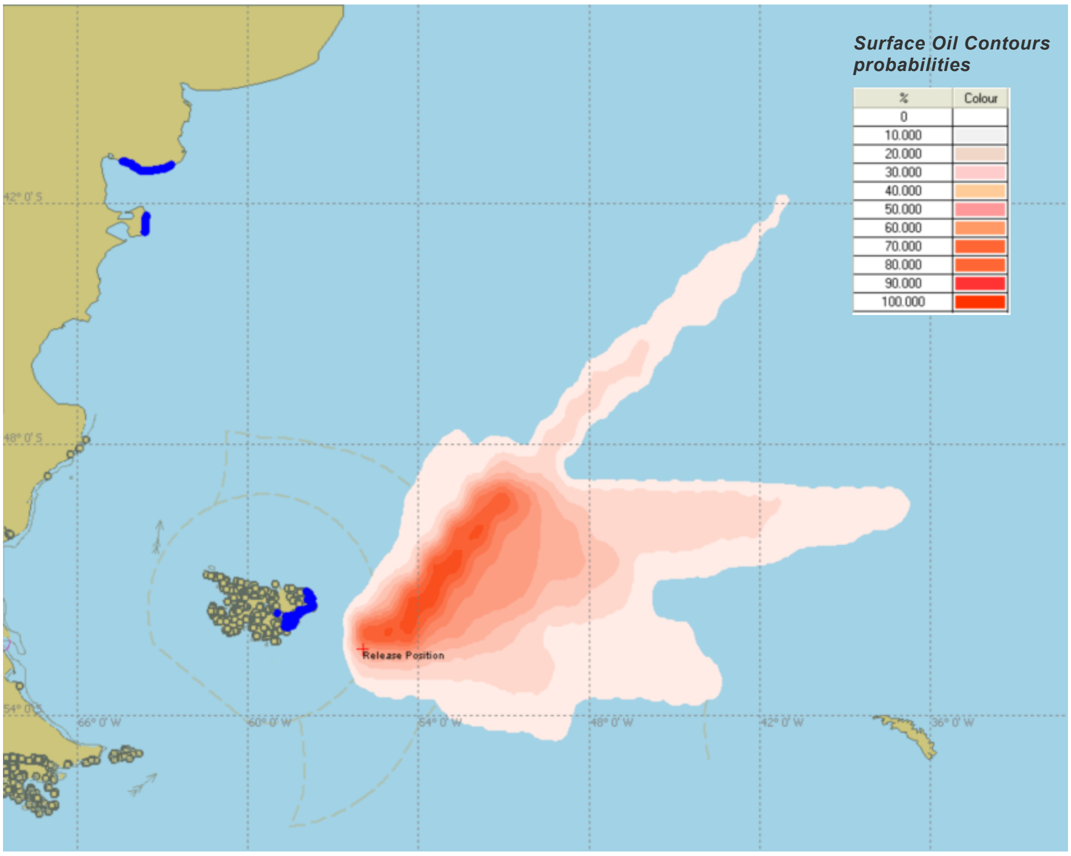


Figure 6.12. Stochastic model run of uncontrolled flow (blowout) spill of 18°API crude oil over 10 days (240 hours) under typical wind conditions at the Vinson West well location (blue points indicate oil beaching locations)



6.10.5 Potential Impacts –Oil spills

Factors important in determining the significance of oil spill impacts and recovery rates include the type of oil, the thickness of shore deposits, climate and season, the biological and physical characteristics of the area, the relative sensitivity of species and communities and the type of clean-up response. The above modelling results indicate the scale of impact without oils spill response being in place and oil being released at high rates continuously for 10 days.

The potential hydrocarbon spills during the proposed drilling programme may impact a wide range of sensitive receptors offshore and onshore, including:

- Offshore seabirds and Internationally Important seabird colonies of the western coast of Falklands (refer to Section 5.3.8 and 5.4). It should be noted that existing data (*White et al., 2002*) relating to seabird vulnerability is only applicable if oil were to enter coastal zones. In the areas surrounding the proposed well locations the lack of data means that FOGL will be assuming high seabird vulnerability to oil spillage on a precautionary basis.
- Southern Falklands coast sites designated as National Nature Reserves (refer to Section 5.4) and potentially South Georgia and Argentinean coast (combined beaching probabilities for oil from various locations:-_below 6% - Vinson West, 1.22% -Loligo A, 0% - Scotia East D).
- Marine mammals, particularly pinniped colonies along the coastal zone (refer to Section 5.3.7).
- Fishing resources (refer to Section 5.5.3).
- Tourism (refer to Section 5.5.2)

The impacts arising from oil spills are well documented, and a summary of these impacts on sensitive resources present within the project area of influence is provided Table 6.13.

As identified by the oil spill modelling, there is a low probability of hydrocarbons beaching (less than 1.22% to 5.61% for a 10-day oil release with no spill response) in the event of worst case well blowout under typical weather conditions, however the oil slick would impact the wildlife offshore (Table 6.13). Although diesel spills will not impact the coastline, their toxic effect on the wildlife in a close proximity to a spill will be significant (Table 6.13).

Table 6.13. Summary of potential impacts from hydrocarbon spills

Community or Species	Vulnerability to Oil	*References*
Plankton	Abundance of phytoplankton may increase after an oil spill due to increased nutrient availability, while zooplankton, fish larvae and eggs may suffer increased mortality due to toxicity in the water column. The effect of an oil spill on plankton is dependent on the structure of the plankton community; the natural environmental conditions e.g. sea temperature; relationships between plankton types that may conceal contaminant effects. Conclusive effects of oil spills are difficult due to the natural variability and high turnover of plankton communities. Many studies of oil spills have not demonstrated any major effects on phytoplankton. Oil spills may however lead to lethal and sub-lethal effects on fish larvae and juveniles, and therefore can affect the food chain of other fish species.	*Varela et al. (1996, 2006); Thomas et al. (1981);Lee et al. (1978);*
Benthic Invertebrates	Sub-tidal regions generally have lower hydrocarbon concentrations after a spill than inter-tidal regions as often the oil is carried and spread at the sea surface. Effects can include rapid mortality of oil sensitive species such as crustaceans and amphipods; a period of reduced species and abundance; a period of altered community structure with increased abundance of opportunistic species; then a decline as sensitive species start to re-colonise the habitat.	*Kingston (1995); Lee & Page (1997);* *Hawkins et a (2002);* *de la Huz et al. (2005);*
Fish	Oil exposure in fish can lead to mortality or sub-lethal impacts on growth, physiology, behaviour and lowered disease resistance. Fish are often considered more resistant to oil spills than other groups due to their ability to avoid spill areas, but larvae and juveniles may suffer higher mortality. Certain species, such as demersal rock fish, that are more territorial, may suffer most from habitat pollution. Longer term impacts of an oil spill have shown genetic damage, physical deformities, reduced abundance and growth, and compromised survival of some life stages. Oil induced mortality and longer term recruitment studies do not demonstrate a clear link.	*Edgar et al. (2003); Edgar & Barrett (2000); Collier et al. (1996); Hose & Brown (1998); Richardson et al. (1995).*
Pelagic and coastal birds	Toxic effects of oil on intertidal areas would most directly affect water birds through smothering and toxicity to invertebrates on which they feed. Oiling of birds can increase mortality through smothering of feathers leading to loss of insulation, and disrupting feeding, and causing starvation. Ingestion of oil from preening or from eating smothered invertebrates, or inhibited inhalation, can cause sub-lethal toxicity and mortality. Diving of pelagic birds can cause oiling of feathers and damage to eyes, and ingestion of prey items that are oiled. High mortality is often associated with oil spills, and in the case of the Exxon Valdez spill In an enclosed waterway, an estimated 30,000 plus birds of 90 species were collected from polluted area five months later, and total mortality was estimated at 100,000 to 300,000 birds. Recovery of seabird habitat was evident five years later and populations can often recover over time due to their high mobility.	*Heubeck et al. (2003), Kingston (2002);*

Community or Species	Vulnerability to Oil	*References*
Marine Mammals	Elevated poly aromatic hydrocarbon (PAH) levels can occur in cetaceans, which reflect the higher trophic position of these animals, where PAH are concentrated through the food chain. Some oil components can irritate skin and mucous membranes of the respiratory and digestive tract due to solubility of cutaneous lipids (fats). Continued contact can cause epidermal necrosis. Other studies suggest cetacean skin is effective against the toxic effects of petroleum and no contact dermatitis has been observed in other studies. Eyes can be sensitive to oil, from irritation to corneal ulcers to loss of vision with intense long term exposure. Inhalation of the light volatile fraction of oil can lead to absorption into the circulatory system; mild irritation and even permanent damage to tissues such as membranes of eyes, mouth and respiratory tract. Release of volatile PAHs such as benzene, toluene, may pose more risk than a thick oil residue as cetaceans inhale the air immediately above the polluted surface, and would be at biggest risk immediately after release. Pinnipeds are susceptible to oiling and the contamination of food sources, particularly in the coastal areas around their colonies, where their density is highest.	*Marsili et al. (2001);* *Walsh et al. 1974 in Bratton et al. (1990);* *Geraci et al. (1980, 1983, 1986, 1988,* *1990;* *Owen (1984);* *Sorensen et al. (1984) – all in Bratton et al.(1990]*
Tourism	Coastal tourism is vulnerable to the effects of major oil spills e.g. reduced amenity value. The impact would be influenced by a number of factors including media coverage and public perception.	

The greatest environmental sensitivity to oil spills would be the presence of vulnerable and protected seabird populations (i.e. penguins, petrels, albatrosses) and marine mammals (cetaceans and pinnipeds in particular). The impact on these species from a large scale blowout will have severe consequences affecting regional population count and dynamics, long term (>10 years) damage and poor potential for recovery rates (refer to Table 6.1). Provided effective and timely spill response measures are put in place the overall impact is likely to reduced to a low (major) significance where medium term (>2 years) damage to ecosystem occurs with a likelihood of recovery within 10 years (refer to Table 6.1).

The proposed exploration wells are located away from the coastal areas with the highest seabird vulnerability (minimal distance of 155 kilometres from Vinson West well).However a large oil spill could spread quickly to affect nearer shore sensitive areas (Figures 6.13).

Figure 6.13. Seasonal Seabird Vulnerability to Oiling Overlain with Stochastic model run of well blowout (311m³ per hour, for 240 hours) of 18° API crude oil released at the Vinson West under typical wind conditions

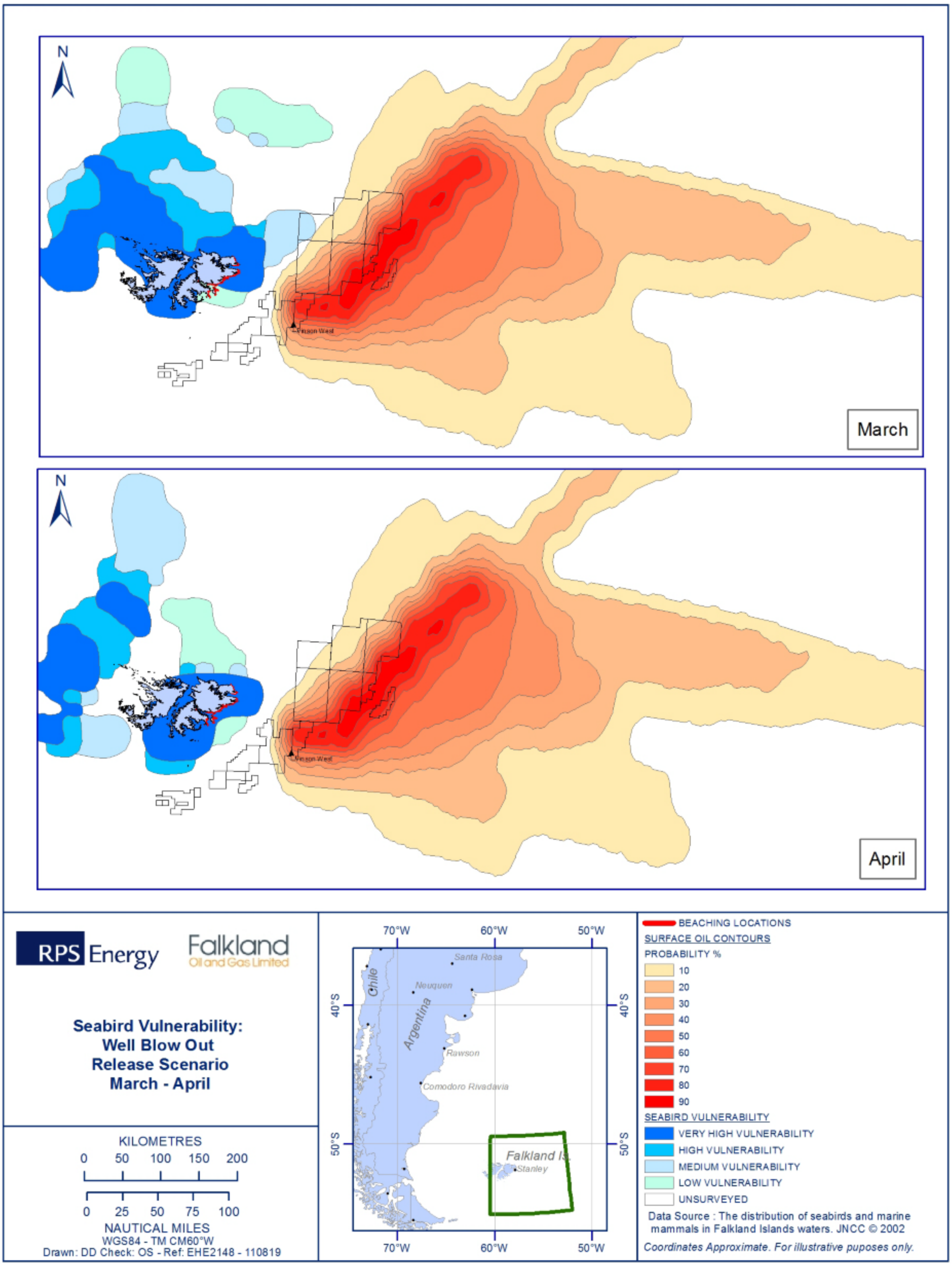


Figure 6.13 (cont.). Seasonal Seabird Vulnerability to Oiling Overlain with Stochastic model run of well blowout (311m³ per hour, for 240 hours)) of 18° API crude oil released at the Vinson West under typical wind conditions

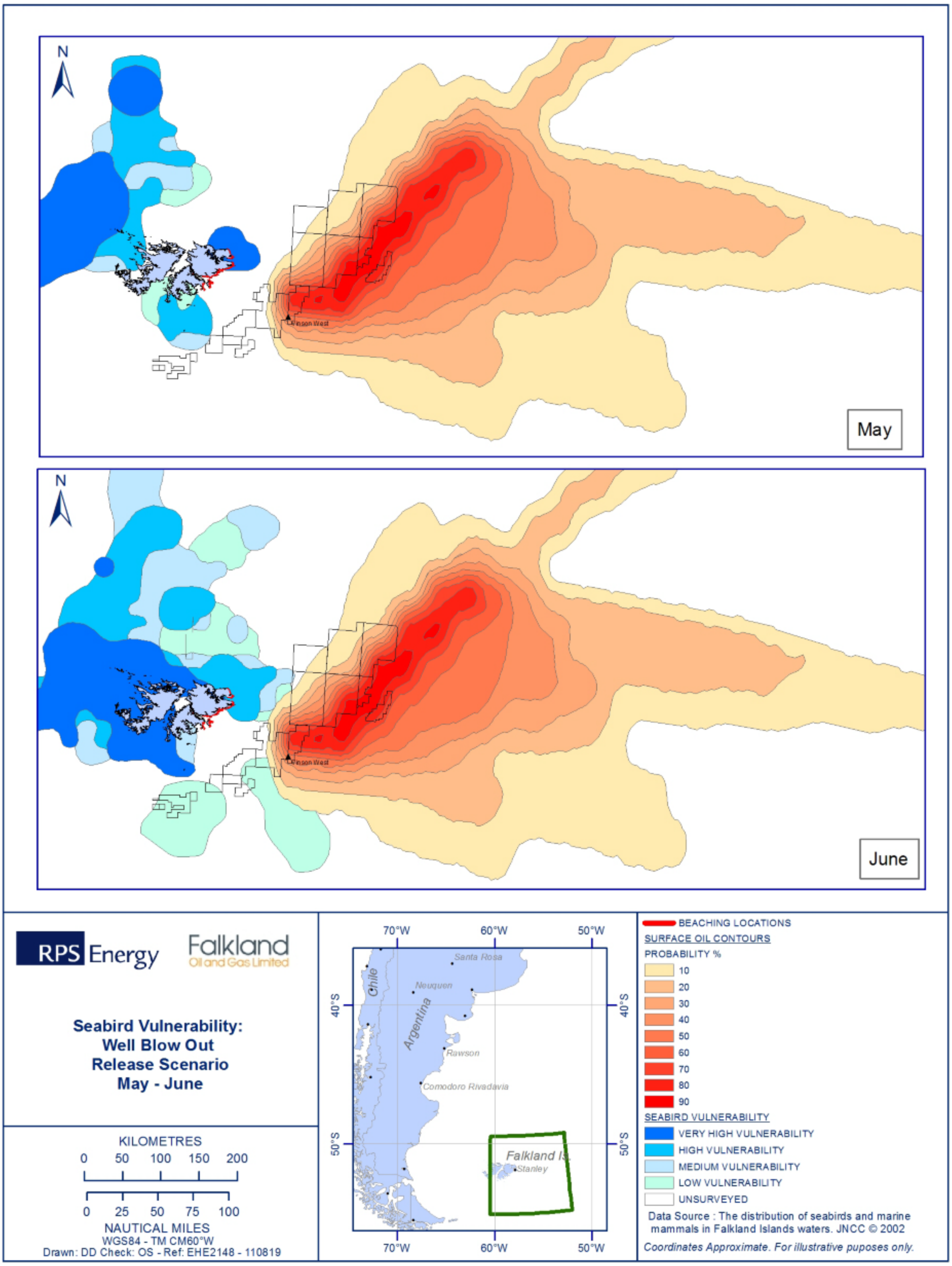
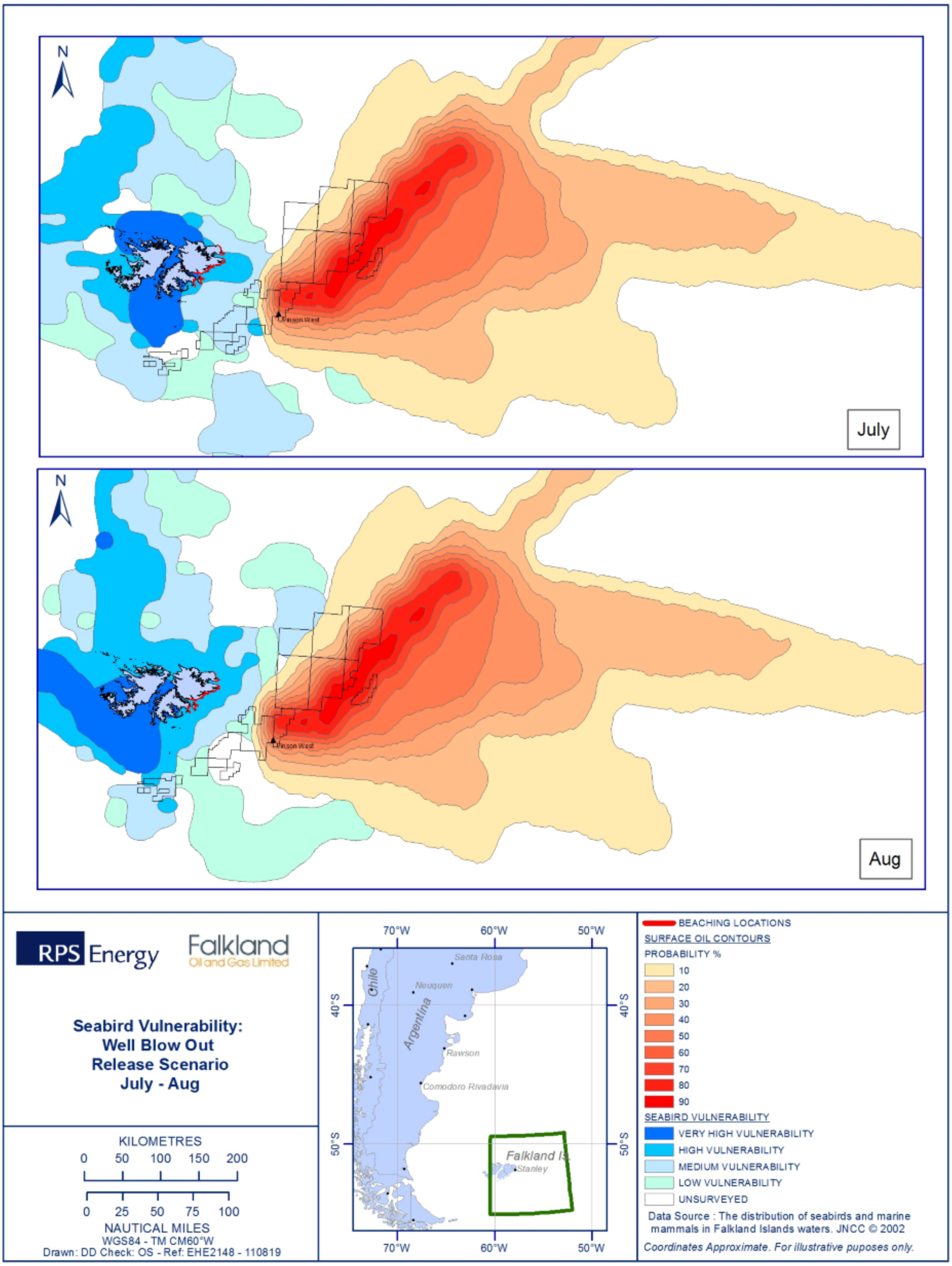


Figure 6.13 (cont.). Seasonal Seabird Vulnerability to Oiling Overlain with Stochastic model run of well blowout (311m³ per hour, for 240 hours)) of 18° API crude oil released at the Vinson West under typical wind conditions



Further offshore, the magnitude of any impact will be dependent on the percentage of bird population present at the time of any oil spill event. The Patagonian Shelf waters, to the north (the direction of the oil slick migration) and west of the Falklands, support low to moderate densities of protected and endangered albatross and petrel species year-round (refer to Section 5.3.8). Due to data deficiency on seabird vulnerability in remote offshore areas, particularly east and south of the Falkland Islands where FOGL blocks are located, an accurate risk assessment for a large oil spill cannot be carried out. Therefore, the risk it is assumed to be high based on limited information available and the adopted pre-cautionary approach.

As mentioned above, highest vulnerability tends to be associated with the inshore waters around the Falkland Islands, largely due to the presence of resident species with a predominantly coastal distribution. This does include highly vulnerable to spill pinnipeds present in high densities along the southern, eastern and northern coasts of Falkland Islands (the area of potential beaching). Pinnipeds will also forage offshore and likely to be impacted by oil spills.

Given the high sensitivity of seabirds and marine mammals (pinnipeds in particular) to oil spill, further discussion of the possible effects is provided below.

6.10.5.1 Potential Impacts on Marine Mammals

Marine mammals are vulnerable to oil spills because of their amphibious habits and their dependence on air. Some marine mammals live and migrate in small groupings while others exist in large localised colonies. These feeding and behavioural differences mean that oil spills will have varying impacts, may be very seasonal and will affect a few individuals or large colonies (*AMSA, 2002*). Potential impacts to cetaceans and seals differ significantly from seabirds as these two groups spend a larger proportion of their time under the sea surface and do not use the surface to rest or preen as seabirds do (*Ridoux et al., 2004*).

Marine mammals surfacing in an oil spill may suffer lethal and/or sub-lethal effects due to inhalation or ingestion of hydrocarbons. Effects of oil on marine mammals are dependent upon species but may include the following (*AMSA, 2002*):

- hypothermia due to conductance changes in skin, resulting in metabolic shock;
- toxic effects and secondary organ dysfunction due to ingestion of oil;
- congested lungs;
- damaged airways;
- interstitial emphysema due to inhalation of oil droplets and vapour;
- gastrointestinal ulceration and haemorrhaging due to ingestion of oil during grooming and feeding;
- eye and skin lesions from continuous exposure to oil;
- decreased body mass due to restricted diet; and
- stress due to oil exposure and behavioural changes.

Cetaceans

Documentary evidence of cetaceans being affected by oil spills is less common than for other marine fauna, e.g. seabirds, probably due to their migratory behaviour and their movement away from an impacted area, causing problems in cause/effect studies on oiled cetaceans (*AMSA, 2002*). Further, some reports indicate a tendency for dead cetaceans to sink in the ocean, further reducing the opportunity for study (*AMSA, 2002*).

Baleen whales feeding habitats increase the likelihood of these animals ingesting oil, as these whales tend to skim the surface when feeding, and are thereby more likely to ingest oil than toothed whales (*AMSA, 2002*). Vulnerability of baleen whales to effects of oil spills further increases while feeding as oil may stick to the baleen while the whales filter feed near oil slicks.

Although some studies indicate cetaceans avoid the presence of oil spills, strong attraction to specific areas for breeding or feeding may override this tendency (*AMSA, 2002*). Therefore, sticky, tar-like residues are particularly likely to interfere with feeding and 'foul' the whale's baleen plates (*AMSA, 2002*).

Dolphins are smooth-skinned, hairless mammals, so oil tends not to stick to their skin, but oil and its vapours may instead be inhaled, most likely occurring when they surface to breathe. This leads to damage to the airways, lung ailments, mucous membrane damage, or even death. Their eyesight may also be affected by oil, potentially consuming oil-affected food or even starving due to the lack of available food or an inability to find food (*AMSA, 2002*).

Chronic ingestion of subtoxic quantities of oil may have subtle effects on dolphins which would only become apparent through long-term monitoring. Adverse effects to their young may occur through the transfer of petroleum hydrocarbons through the mother's milk to sucking young (*AMSA, 2002*).

In a study that monitored two killer whale populations (resident and transient populations), five years prior to and for 16 years after the Exxon Valdez oil spill in the Prince William Sound (Alaska) in 1989, links between mortality relating to the oil spill and recoverability were proposed (*Matkin et al., 2008*). One resident pod and one transient population were observed to have suffered losses of 33 and 41%, respectively, in the year following the spill. Following 16 years after oil spill, the resident pod had not recovered to pre-spill numbers and the transient population continued to decline (*Matkin et al., 2008*).

Indirect impacts to cetaceans may occur through decreased prey availability, whereby fish and invertebrates have been shown to absorb and accumulate hydrocarbons of the dissolved fraction of oil and oil-specific (PAHs) and metallic trace elements in their tissues. The tanker Erika oil spill in the Bay of Biscay in 1999 introduced a massive amount of vanadium in the ecosystem that was detected in organisms of lower tropic levels (Ridoux et al., 2004). A study conducted by Ridoux et al., (2004) investigated the effects of the Erika oil spill on top predators (grey seals (*Halichoerus grypus*) and common dolphins (*Delphinus delphis*), by measuring (a) possible shifts in food availability from stomach content analysis in dolphins; (b) vanadium concentrations in liver and kidney of dolphins and in seal blood; and (c) porphyrins (considered as a biomarker of toxicity) in seal blood (*Ridoux et al., 2004*). No change in diet composition particular to the year following the spill was observed in common dolphins. In addition, there was no acute change in vanadium concentration in common dolphins, though background concentrations measured in these dolphins were noted as higher than in most other areas and similar to regions affected by chronic exposure to oil (*Ridoux et al., 2004*). Porphyrin measurements in grey seals did not show any effect, which may have been due this animal being a transient visitor to the Bay of Biscay and therefore potentially short amounts of time spent in the impacted area.

Pinnipeds

Seals are very vulnerable to oil pollution because they have to spend much of their time on or near the surface of the water. They need to surface every few minutes to breathe, and regularly haul out on to beaches. During the course of an oil pollution incident they are at risk both when surfacing and when hauling out (*AMSA, 2002*). Fur seals are more vulnerable due to the likelihood of oil adhering to fur. Heavy oil coating and tar deposits on fur seals may result in reduced swimming ability and lack of mobility out of the water (*AMSA, 2002*).

Seals, sea lions and fur seals have been reported swimming in oil slicks during a number of documented spills (*Geraci and St.Aubin, 1990*). However, this may be attributed to pinnipeds staying near established colonies and haul out sites, and that oil also tends to collect in natural inlets on foreshores used by seals as haul outs (*AMSA, 2002*).

In 1989 the Exxon Valdez oil spill affected harbour seal habitat, including key haul out areas and adjacent waters, in Prince William Sound and as far away as Tugidak Island, near Kodiak. Estimated mortality as a direct result of the oil spill was approximately 300 seals. Some of the haul out sites were oiled through the pupping season, and many pups became oiled shortly after birth. Based on aerial surveys conducted at previously monitored haul out sites in central Prince

William Sound before (1988) and after (1989) the oil spill, seals in oiled areas declined by 43%, compared to 11% in un-oiled areas (http://www.evostc.state.ak.us/recovery/status_harborseal.cfm).

Seal pups are more vulnerable to the effects of oil spills due to the greater risk of oiling, as pups spend much of their time in rocky shore areas and tidal pools, in comparison to adults who swim in open water (*AMSA, 2002*). This therefore increases the chance of exposure of pups to oil slicks that have a tendency to collect in such areas. Some seal pups have been recorded as being so encased in oil that their flippers have been stuck to their bodies, thereby increasing body weight and density, leading to buoyancy problems, drowning or increased predation (*AMSA, 2002*).

In addition, recent evidence suggests that pinniped pups are further vulnerable during oil spills as the mother/pup bond is affected by the odour. Pinnipeds use smell to identify their young and so if the mother cannot identify its pup by smell in a large colony, it may not feed it, or it might even reject attempts by the pup to suckle, leading to starvation and abandonment (*AMSA, 2002*).

6.10.5.2 Potential Impacts on Seabirds

Seabirds are highly vulnerable to the effects of oiling through coming into contact with the sea surface, and therefore potentially oil from a spill. The effects of oil on seabirds have been reported by AMSA (2002) as follows:

- Contact with crude oil or refined fuel oils. This causes feathers to collapse and matt and change the insulation properties of feathers and down.
- Matting of feathers. This can severely hamper the ability of birds to fly.
- A breakdown in the water proofing and thermal insulation provided by the feathers. This often causes hypothermia.
- Oiled feathers. This can cause the seabirds to lose buoyancy, sink and drown because of increased weight or lack of air trapped in the feathers.
- Body weight decreases quickly as the metabolism attempts to counteract low body temperature.
- Severe irritation of the skin.
- They ingest the oil in an attempt to preen themselves.
- Irritation or ulceration of the eyes, skin, mouth, or nasal cavities
- The food searching instincts such as diving and swimming are inhibited.
- Ingestion of oil via their prey if their food chain becomes contaminated.
- Poisoning or intoxication.

Ingestion of oil can be sub-lethal or acute and will depend to a large extent on the type of oil, its weathering stage and inherent toxicity. Such internal effects can include (AMSA, 2002):

- destruction of red blood cells, important for the immune response;
- alterations of liver metabolism;
- adrenal tissue damage;
- pneumonia;
- intestinal damage;
- reduced reproduction ability;
- reduction in the number of eggs laid;
- decreased fertility of eggs;
- decreased shell thickness; and
- disruption of the normal breeding and incubating behaviours.

Those species that are particularly vulnerable include those that fly infrequently and spend the majority of their time on the sea surface. For example, when the Amoco Cadiz spilled light crude, much of this formed a ‘chocolate mousse’ which smothered most of the seabirds that came into contact with the spill (*Camphuysen et al., 2005*). Similarly, Erika, Prestige and Tricolor tankers spilled (very) heavy fuel oil affected seabirds were immediately immobilised and smothered, with many so heavily oiled, that each corpse, untreated, weighed 2-3 times greater than their normal body mass (*Camphuysen et al., 2005*).

Spills can also have an indirect impact on seabirds by destroying food supply/sources, particularly for species restricted to a small area for foraging. However, mortality associated with oil spills is difficult to determine and few studies have successfully identified changes in population parameters.

When considering the potential environmental impact of oil spills on seabird populations, the volume of oil lost is not the most important factor in determining the effects on seabirds. For example, small amounts of oil in areas with high concentrations of sensitive birds may lead to extensive casualties, whereas large amounts of oil in areas with a few birds may have a much smaller impact on wildlife (*Burger, 1993; Camphuysen, 1998*).

The effects of an oil spill on the size of breeding seabird populations will depend on several factors in addition to the numbers of birds killed. The effects are likely to be more pronounced the smaller the affected population is, in relation to the number of birds killed. However, determining the size of the affected population can be difficult. In general, effects on breeding populations are likely to be larger and easier to assess when more adults are killed than juveniles (*Camphuysen et al., 2005*).

Differential impacts of oil spills on bird species has been found across the globe. In the northern hemisphere, oil spills mainly affect alcids (or auks e.g. puffin, guillemot, razorbill), (Piatt et al., 1990), while in the southern hemisphere, typically penguins are most affected (*Adams 1994; Goldsworthy et al., 2000*). Penguins are more susceptible because they spend considerably longer in the water than flying birds, are possibly less able to detect oil at sea, and even small amounts of oil on the plumage causes waterlogging, reducing insulation and buoyancy (*Goldsworthy et al., 2000*).

A study into the impacts to little penguin (*Eudyptula minor*) populations following a 'small' oil spill of approximately 325 tonnes of bunker fuel oil from the bulk ore carrier Iron Baron in northern Tasmania, Australia in 1995, estimated that between 10,000 and 20,000 penguins were killed as a result of the oil spill (*Goldsworthy et al., 2000*). The study indicated that, despite the relatively small amount of oil spilt by the Iron Baron, the impact on penguin populations was extensive. It was determined that the main factor affecting the survival of oiled and then cleaned and rehabilitated little penguins was the extent of oiling, as survival rates of individuals halved for every extra quarter of body oiled (*Goldsworthy and Geise, 1996*). In addition, indirect effects of oiling were observed, whereby oiling not only reduced the number of chicks raised by rehabilitated oiled penguins in the short-term, but also decreased the quality of young produced for at least two seasons following the spill (*Goldsworthy and Geise, 1996; Geise et al., 2000*).

Other areas where 'small' spills have resulted in the deaths of many thousands of seabirds, include the Apex Houston spill along the central Californian coast, involving only 87 tonnes of crude oil, but killing an estimated 10,577 seabirds (*Page et al. 1990*); and the Nestucca barge, which spilt 770 tonnes of bunker fuel, and killed an estimated 56,000 seabirds (*Ford et al. 1991*). At the other end of the scale, in terms of volume of oil, the loss of 36,000 tonnes of crude oil from the Exxon Valdez killed an estimated 350,000 to 390,000 birds (Burger and Fry 1993). Another large recorded spill event, the loss of 19,000 tonnes of heavy fuel oil from the tanker Erika off the coast of northern Brittany, France in 1999, resulted in a major ecological disaster for seabirds wintering in the Bay of Biscay (*Law et al., 2005*). Among different species oiled, the common guillemot (*Uria aalge*) appeared to be the most affected species (nearly 70,000 birds were found dead or oiled on beaches). The at-sea populations of some species (e.g. razorbill and common scoter) declined during the two years following the accident. Some less abundant seabird species in the northern Bay of Biscay decreased significantly. These included Divers (*Gavia* sp.) and the Northern fulmar (*Law et al., 2005*).

6.10.6 Mitigation Measures –Oil Spills

Oils spills, particularly from a large well blowout, represent the highest risk to the environment from the proposed drilling campaign. Therefore, it will be critical to implement a range of mitigation measures, including robust spill contingency planning, to prevent the spill happening at all.

A number of measures will be implemented by FOGL to reduce the risk of oil spills from the drilling rig and associated vessels and minimise the impact of any spill that may occur:

- Managing potential drilling hazards and following established drilling safety standards to minimise the risk of control loss;
- Comprehensive operational planning and risk assessment and provision of suitable specification equipment for drilling (BOP etc);
- An Oil Spill Contingency Plan and Emergency Response Plan will be fully implemented;
- Interface of the Oil Spill Contingency Plan with the FIG National Oil Spill Contingency Plan;
- Ensure robust contingency planning and risk assessment and provision of suitable response capability, most importantly effective dispersant and dispersant spraying equipment, as this will be the most realistic option of active response in the harsh weather conditions of the Falklands offshore; and ensure availability of aerial surveillance services;
- Training of personnel with respect to the handling and deployment of oil spill response equipment;
- All vessels and the drilling rig will comply with IMO/MCA codes for prevention of oil pollution and vessels will have onboard Shipboard Oil Pollution Emergency Plans (SOPEPs);
- As far as possible, support vessels with an established track record of similar weather and operating conditions to the area will be used;
- Approach procedures and poor weather operational restrictions for visiting vessels and transfer operations at the drilling rig;
- Audits of the drilling rig and vessels including detailed lists of requirements in terms of spill prevention procedures that must be in place;
- Regular maintenance and inspection of equipment and high spill risk points (in particular bunkering hoses, bunds, storage tank valves etc.);
- Lube and hydraulic oil will be stored in tanks or sealed drums which pose a minimal risk of spillage. In addition, drums and storage tanks for hydrocarbons will be well secured and stored in bunded areas, all of which will be properly maintained and inspected;
- Availability of oil spill kits on board the rig and vessels to clean up any deck spills or leaks and suitable storage and disposal procedures for waste oil;
- Procedures in place for bunker transfer to minimise the risk of spillage; and
- Use of bulk handling methods and non return valves for diesel transfer to reduce the risk of spillage.

Even with comprehensive prevention measures in place, the residual risk of an oil spill remains, and integral to FOGL's operations is the development of detailed and fully tested contingency response plans appropriate to the local environment. An approved Oil Spill Contingency Plan (OSCP) will be in place for the proposed drilling operations, including access to Tier 1, 2 and 3 resources through membership with Oil Spill Response Limited. Oiled wildlife response service will be also provided through the membership with Oil Spill Response Limited.

6.10.7 Conclusions – Oil Spills

On the basis of accidental events statistics compiled for offshore exploration activity, the risk of a major crude oil spill or blowout during exploration, appraisal and development drilling is considered to be very low. However the significance of impacts on the sensitive environment of Falkland Islands from the worst case accidental blow out is categorised as major, based on the assumption that the above mitigation measures are implemented.

The impacts from large diesel spills are considered to be of minor significance due to localised effects, and fast dispersion rates. Historical data suggest that small diesel spills from rigs and vessels of less than one tonne represent the most likely oil spill scenario. Impacts from diesel spills of this magnitude and frequency would be negligible.

6.10.8 Chemical Spills

Chemical spills to the marine environment can have a number of environmental and economic impacts. Apart from drilling muds, the chemical inventory on drill rigs/ships and supply vessels may include a variety of materials for use in drilling, completion, cementing and contingency operations. All chemicals to be used during the proposed drilling campaign are registered under OSPAR (HOCNF) and majority of them are identified as PLONOR (Pose Little or No Risk).

The environmental implication of a chemical spill is largely dependent on the type of chemical involved, the size and location of the spill and the weather conditions at the time. The actual hazard presented by a spill will depend on the exposure concentration, which is determined by the quantity and rate of spillage and the dilution and dispersion rates. These factors will differ according to whether the spill takes place at the sea surface or seabed.

The dilution and dispersion of a sea surface spill is likely to be high in offshore Falkland Island waters. If large waves occur, this will effectively disperse the spill. The spill will be diluted as it sinks and will be moved by tidal currents and wave activity. Diluted chemicals would be carried with the body of ambient seawater and gradually disperse and degrade. Although residual concentrations might be detectable within a circle of a tidal motion, it will only be within a very limited area and for a short period of time.

The fate of a spill at seabed level will depend on the properties of the chemical. If the chemical is denser than seawater it may spread over the seabed and become mixed within the substrate causing potential harm to the benthic community. Given the predominantly benign and low toxic drilling, cementing and other rig chemicals to be used, the overall impacts to the seabed are expected to be minor.

With regard to chemical use, the following measures will be used to control and minimal the risk of chemical loss or spillage:

- Storage and transportation of chemicals on the drilling rig will be in line with industry-standard procedures and best practice, which have been designed to minimise the risk of loss of containment and impacts upon human health and the environment;
- Storage of chemicals in designated areas and labelled containers.
- Storage and handling on board will be subject to strict provisions in terms of environmental protection and human safety.
- Good housekeeping standards to be maintained on the rig to control the amount of hydrocarbons and other contaminants entering the drainage system. Hazardous materials will be contained or bunded with no residues/spills permitted to enter the overboard drainage system.
- The Rig and support vessels will be equipped with Tier 1 spill response equipment (e.g. absorbent pads) to contain and collect spills. Crews will be trained in the use of such materials and contingency measures will be implemented for even the smallest of spills.

6.11 Cumulative and Transboundary Impacts

Cumulative impacts are impacts that act together with other impacts (including those from concurrent or planned future third party activities) to affect the same environmental resource or receptor.

The potential for cumulative impacts will arise from the drilling operation itself during which time the rig and support vessels will pose an additional shipping hazard in the area and from the legacy it will leave in terms of atmospheric greenhouse gases and the cuttings and mud discharged. However it is not anticipated that the short-term exploratory drilling campaign will significantly, or permanently, add to these existing cumulative impacts.

The rig will be shared by two operators, each drilling their respective wells in a programmed sequence. Therefore there is unlikely to be any overlap in operations. In addition, the wells being planned by other operators are located a considerable distance away, so the likelihood of any spatial overlap of impacts from different drilling operations is considered to be remote.

Cumulative waste generation from the drilling campaign will be minimised and managed through the implementation of a Waste Management Plan, a document which will define specific waste handling/disposal routes and procedures.

In summary, cumulative environmental effects from the planned exploration programme are considered to be minor given the short term nature of the drilling and low level of exploration activities in the east and south Falkland Basins.

Transboundary impacts from the proposed project may involve beaching of oil onto the Argentinean coast and South Georgia. However, the probability of beaching is extremely low (1.22%) and was assessed without taking into consideration any response mitigation measures being implemented for the duration of 10 day of intensive blow out release. Therefore, the significance of transboundary impacts is considered minor, provided the above mitigation measures are implemented.

7 Management Framework

7.1 Introduction

FOGL operate under an integrated Health Safety and Environmental Management System (HSEMS), which is detailed below.

HSE management procedures are incorporated into relevant business functions which reinforce the Company's philosophy that management of HSE issues is an integral part of FOGL's business activities.

The application of the HSEMS during the drilling of the proposed exploration wells offshore the Falkland Islands will ensure that the FOGL's Health, Safety, Environmental and Social Policy (Figure 7.1) is followed at all times and that the Company's responsibilities under all relevant regulations are met.

7.2 Health, Safety and Environment Management System

FOGL's business comprises the exploration for oil and gas around the Falkland Islands. Operational activities in general include seismic surveys; the design, drilling and testing of wells; and the assessment of hydrocarbon reserves.

FOGL conducts these activities using a variety of contractors. The focus of this system will therefore be on the management of these contractors to ensure that they uphold FOGL's management philosophies.

FOGL operates under an integrated HSE Management System, which ensures:

- Effective management of HSE risks;
- Clear assignment of responsibilities;
- Compliance with applicable regulations; and
- Continuous improvement.

The system documentation hierarchy is illustrated in the triangle depicted in Figure 7.2:

- At the apex, the HSES Policy demonstrates the commitment and intentions of the Company;
- At the intermediate level is the HSEMS which drives the implementation of HSE Policy across the Company. From a documentation viewpoint the HSEMS currently consists of:
  - **HSEMS Framework** which provides a brief overview of the structure and content of the management system as well as a summary of the FOGL management and staff roles and responsibilities to ensure its effective implementation;
  - **HSE Procedures** which provide detail on how the HSEMS should be implemented.
  - **Project Specific Plans** which provide detail on how HSE will be managed for each FOGL project throughout its lifecycle.
- At the base of the triangle are the Bridging Documents (or Management System Interface Documents 'MSID's) linking FOGL's system with its various contractors' HSEMS, Operating Standards, and Procedures & Guidelines.

The system is goal-oriented and allows sufficient flexibility for each project to achieve these goals in a manner which best suits the Company business.

Figure 7.1. FOGL Health, Safety, Environmental and Social Policy

Falkland
Oil and Gas Limited

Health, Safety, Environmental and Social (HSES) Policy

Falkland Oil and Gas Limited ('FOGL' or 'The Company') is committed to maintaining high standards of health, safety, environmental and social performance across all its oil and gas exploration and development operations. To achieve this we will:

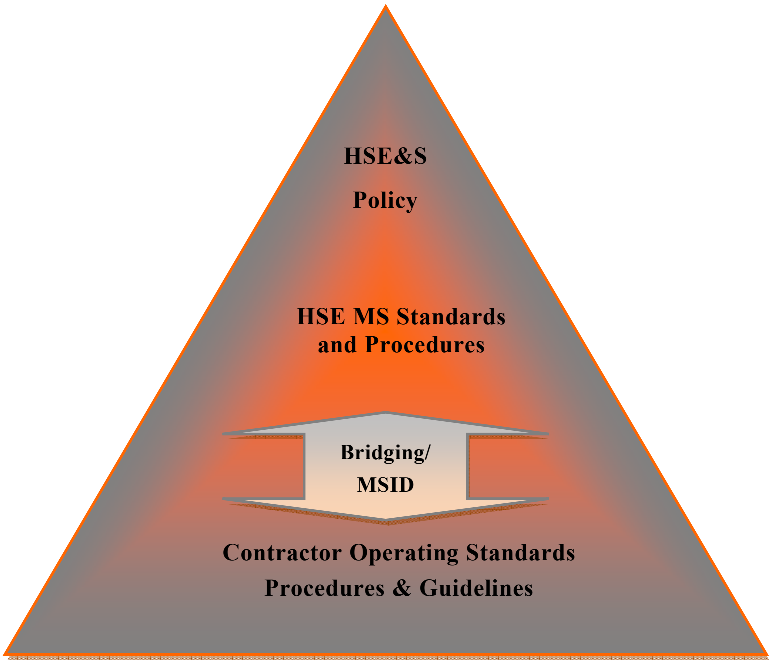
- As an integral part of our business, identify, assess and manage the HSES risks to people, the environment and assets in order to avoid adverse direct or indirect effects from our operations.
- Ensure that our operations comply, as a minimum, with applicable health, safety, environmental and social laws and regulations, as well as best practicable industry standards.
- Maintain high ethical standards in carrying out business activities.
- Provide necessary leadership and resources to enable effective HSES management throughout our organisation.
- Prevent and minimise the impact of our operations on the environment.
- Ensure continuous improvement of HSES performance through the setting of objectives and targets and focused auditing, reviews and external benchmarking.
- Select competent staff, contractors and suppliers to manage and support the business.
- Ensure that a high priority is placed on emergency preparedness and contingency planning, and that any plans are tested regularly to ensure that any incidents are responded to in a timely and effective manner.
- Foster a culture where accidents, incidents and near misses are reported and investigated, and the lessons learned are shared.
- Consult with and respond to the concerns of our stakeholders on our health, safety, environmental and social performance.
- Ensure that this policy is: - clearly displayed in all FOGL premises and operational sites, provided to all contractors, and made publicly available.

The Company's directors, employees and contractors have a responsibility for maintaining high HSES standards and this Policy will be used to guide their activities.

Tim Bushell
Chief Executive

Effective Date: June 2011

Figure 7.2. FOGL HSE Management System Structure



7.3 HSE Management System Process

The HSEMS is consistent with the logic of existing national and international models for HSE management (e.g. HS (G) 65, ISO 14001, OHSAS 18001, and OGP). The management process is structured around the six Steps of 'policy, organise, plan, implement, monitor and review', to ensure continual improvement in performance. These steps are supported by:

- A set of Performance Standards which define the performance required to meet the HSEMS requirements;
- A set of Expectations which list the actions required to satisfy each Performance Standard.

The process is driven by the HSES Policy, which sets out the Company's HSE commitment and which will be made available to the public and those working for and on behalf of the organisation as necessary.

This overall HSEMS Process is illustrated in Figure 7.3 which shows the relationship of the "steps" and their supporting "Performance Standards".

Policy - The system is driven by the HSES Policy, which sets out the Company's expectations and commitments to HSE and social performance. The policy provides a framework for establishing performance goals, from which annual targets are established. Project specific HSE Plans for objectives and targets will be generated by relevant FOGL Managers and reviewed by the responsible directors. Previous performance and the risk registers will be considered in plan preparation. The policy is made available to the public and those working for and on behalf of the organisation as necessary.

Organise – The organisational structure defines the resources and responsibilities required to achieve the Company objectives. All personnel must have the competence and training to meet those responsibilities. It also provides the structure for effective communication both internally and externally. Where internal resources are not available, procedures are developed, and external resources utilised to ensure effective contractor selection and management.

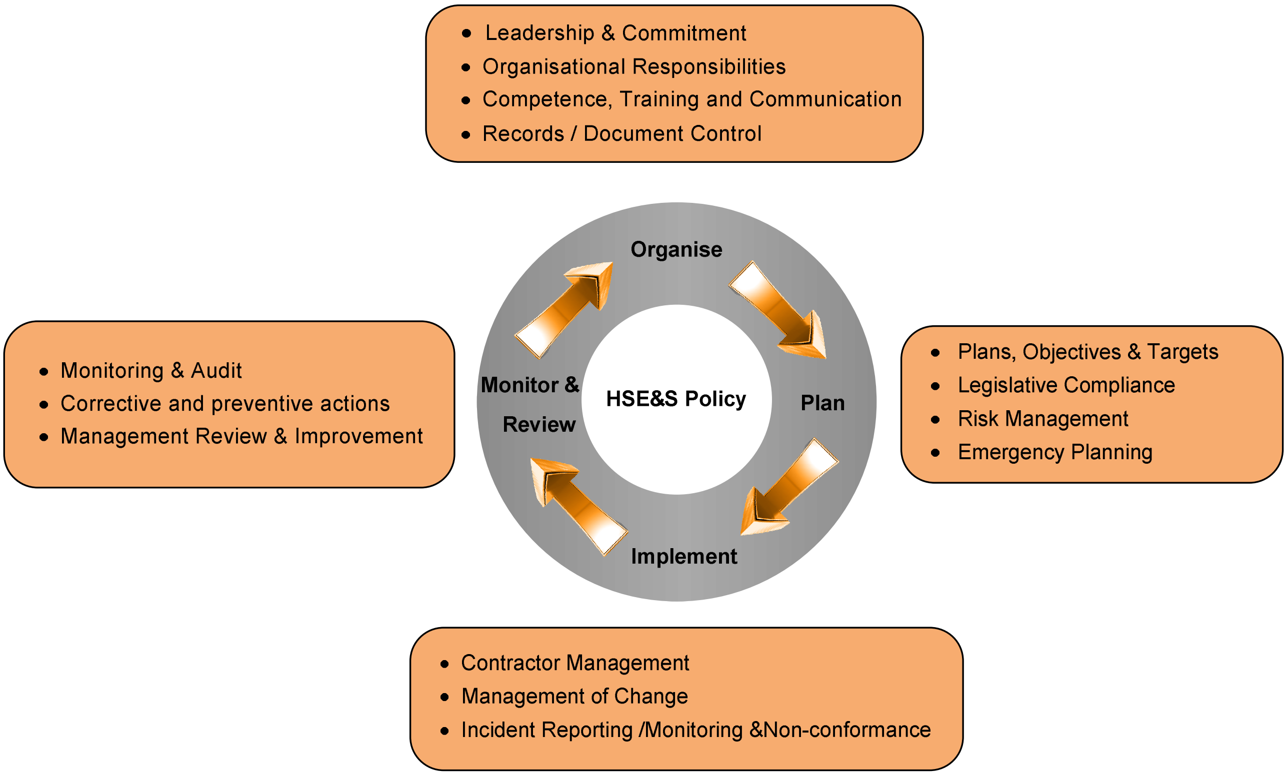
Plan - Potential hazards and risks associated with new and planned activities are identified and appropriate measures to control them are introduced. Established control measures will also be reviewed for identified hazards and risks. The management plan will define activities, responsibilities and deliverables, and enable achievement of targets. Competent contractors are selected with appropriate HSE Management Systems.

Implement - Competent contractors are selected and managed to undertake specialist tasks. Incidents are reported and monitored and the findings used to guide actions to prevent recurrence. Facilities will be operated and maintained in order to mitigate risks and to meet legal requirements. Significant changes made to the organisation, programmes and procedures will be subject to the change management process.

Monitor - Routine monitoring and audits, together with inspections, are undertaken to assess and where necessary improve HSE performance and the suitability of the management system. Management reviews the system annually and areas for continual improvement identified and implemented.

Audit and Review - Regular audits are held to ensure the effective functioning and continued suitability of the management system. Performance against standards is reported, reviewed and assessed. Areas for improvement are identified and action plans are developed and implemented.

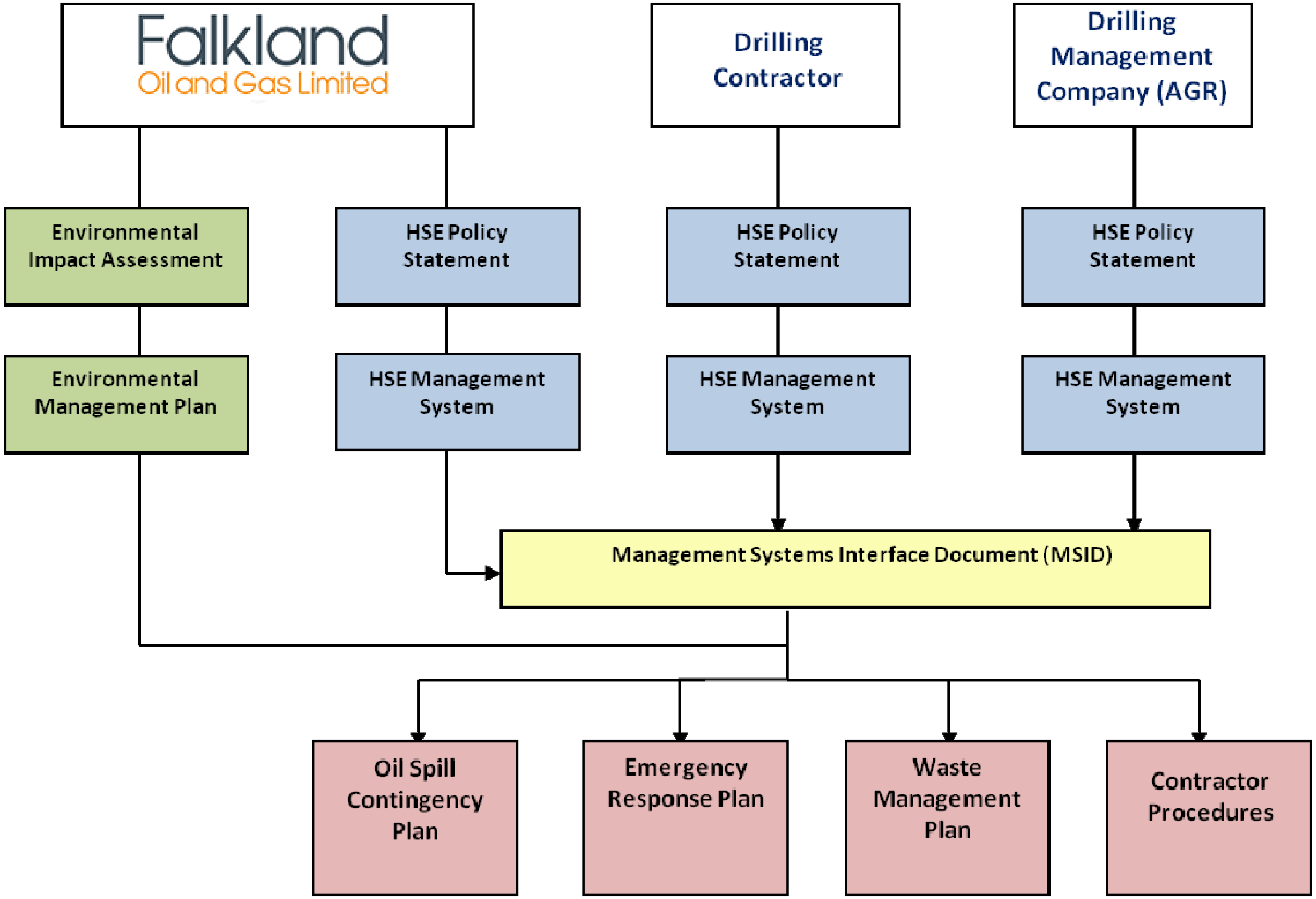
Figure 7.3. HSE Management System Framework



7.4 Drilling Programme Management Framework

The FOGL management system is not certified and, as FOGL does not undertake operations itself, is based on the supervision and administration of contractors. The HSE Policy Statement and HSE Management System set out FOGL's priority goals, expectations and commitments and how these will be applied within the framework outlined in Figure 7.4 below:

Figure 7.4. HSE Management Control for Proposed Drilling Operations



HSE management of the proposed drilling programme will be conducted within a comprehensive framework comprising of:

- FOGL's Health, Safety, Environmental and Social Policy Statement;
- FOGL's Health, Safety and Environmental Management System (HSEMS);
- Drilling Contractor's Management HSE Policy Statement;
- Well Management Contractor's HSE Policy Statement;
- Drilling Contractor's Safety Management System;
- Well Management Contractor's Safety Management System;
- Management System Interface Document (MSID) (equivalent to the bridging document of Figure 7.2);
- Drilling Contractor and Well Management Contractor operational controls and specific HSE procedures. Included within these document are:
    - Policies, Standards and Procedures;
    - Safety Management;
    - Emergency Response;
    - Incident Reporting and Incident Investigation;
    - Roles & Responsibilities;
    - Training and Competence;
    - Environmental Considerations;
    - Risk Management;
    - Quality Assurance;
    - Organisation;
    - Document Control.

7.5 Roles and Responsibilities

As a licence holder, FOGL is ultimately accountable and responsible for the HSE management of the proposed drilling operations as well as all activities associated with their operations, even though many of these will be undertaken by contracted third parties.

FOGL will be accountable for activities executed on its behalf, even though the direct responsibility for HSE management, legal compliance and adherence to FOGL company policy will fall to the contracted parties. Specific operations will therefore be managed within third party management systems. The FOGL HSEMS sets standards and expectations against which those third party systems will be assessed.

Clear documented responsibilities, lines of communication and operational procedures will be established between FOGL, the well management contractor (AGR), and the drilling contractor (Ocean Rig) in the MSID. A summary of responsibilities is discussed below and demonstrated in Figure 7.5.

FOGL

- FOGL will ensure that the project is carried out in accordance with the corporate commitments and policies, and in accordance with all applicable legal requirements.
- FOGL will ensure that any conditions of the environmental approvals, such as reporting requirements or follow-up activities, are satisfied.
- FOGL will ensure that the Project operates within a comprehensive Incident Management Plan and implements an Oil Spill Response Plan in accordance with modelling studies and expert advice.
- FOGL will resolve any complaints, claims or disputes arising from drilling operations with the Falkland Islands Government and other affected government organisations and using testimony provided by independent observers, as necessary and appropriate.

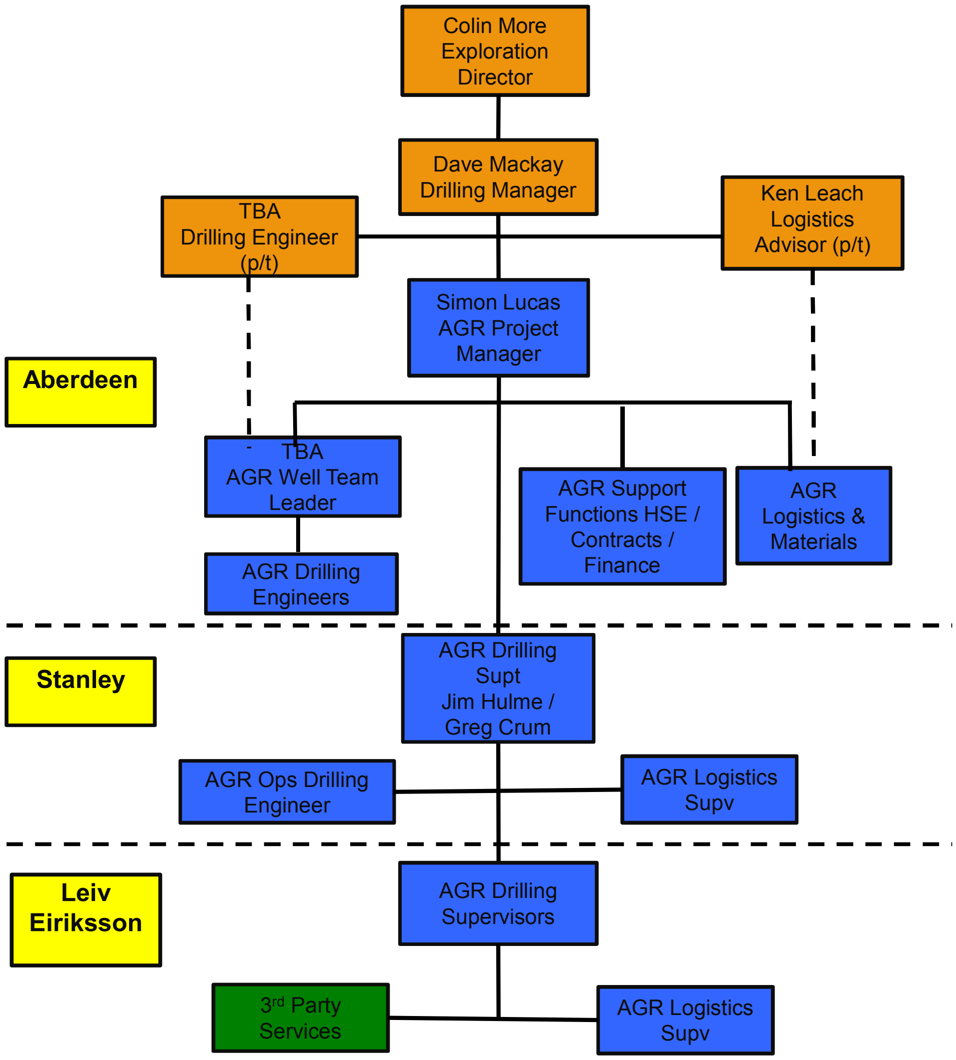
Well Management Contractor (AGR)

- AGR will ensure that the conduct of the operations by themselves and the drilling contractor will comply with the requirements of this EIS, the drilling programme, and all applicable legal requirements.
- The referenced standards and guidelines (IMO, MARPOL etc.) will be complied with throughout the drilling programme and records of discharges and waste transfers will be maintained as per normal operating practices.
- Any spills or abnormal releases will be recorded and reported to the appropriate authorities (for oil, chemicals, waste or process materials, released to air or water)

Drilling Rig Contractor - Ocean Rig

- Are responsible for obtaining a Safety Case for Falklands Operations and complying with the Safety Case. The Safety Case addresses Emergency Response Plans. Whilst this document is primarily focused on safety of personnel there is an overlap with environmental matters as many environmental risks also pose a risk to personnel safety and health.
- Are Duty Holder and responsible for management for all activities onboard the rig including 3rd party contractors.
- Ocean Rig's senior person onboard the installation is the Offshore Installation Manager who has ultimate responsibility for, and authority, over all personnel onboard the rig.
- Ocean Rig will ensure that its operations will comply with the requirements of this EIS, and all applicable legal requirements.

Figure 7.5. FOGL/AGR HSE Management Control for drilling operations



7.6 Management System Interface Document

In order to ensure that operational and emergency primacy, interfaces and procedures are clearly defined, a review of FOGL and contractors management systems will be undertaken resulting in a Management System Interface Document (MSID).

The MSID will be prepared in accordance with the Step Change In Safety 'Health and Safety Management System Interfacing' guidelines. The MSID document will have the following objectives:

- To define roles and responsibilities;
- To define reporting requirements;
- To identify any variations in policies and procedures between the parties and to clarify which shall take precedence;
- To identify normal operational procedures for the wells;
- To identify interfaces and procedures in the event of an incident.

The Management System Interface Document will be developed and implemented before drilling commences.

7.7 Oil Pollution Emergency Plan

A dedicated Oil Spill Contingency Plan (OSCP) will be developed in support of the proposed drilling campaign in the south and east Falkland Basin. It will be based on the results of the oil spill modeling scenarios including worst case blowout scenarios. The OSCP will provide for a multi-tier response dependent on the scale and type of spill. At the most extreme end of the scale (Tier 3), the OSCP will rely on mobilising specialist aircraft and personnel from Oil Spill Response Limited (OSRL) in the UK to provide large scale equipment and aerial dispersant spraying capability. The OSCP will also correspond with the plans of the FIG and its national oil spill contingency plans. Under OSRL membership, FOGL will also have an access to a specialist oiled wildlife response provided by Sea Alarm.

7.8 Rig Emergency Response Plan

A rig-specific Emergency Response Plan will be produced in cooperation with the drilling contractor and the well management contractor. This document will set out the roles and responsibilities, lines of communication and call out procedures, including support services such that any rig-based emergency can be effectively supported between the offshore and onshore teams.

7.9 FOGL Incident Management Plan

The FOGL Incident Management Plan (IMP) describes procedures and arrangements in place for the effective management of any incident or emergency which has the capability to become a major threat to personnel, the environment, assets and the Company. The IMP forms an integral part of FOGL's HSE Management System and meets the criteria set out in the 'Incident Management' section of the document.

Implementation of the IMP is intended to supplement the Management System Interface Document and is supported by the relevant operational al emergency management procedures associated with the rig, helicopters, supply vessels and onshore emergency response units.

7.10 Waste Management Plan

The purpose of the Waste Management Pan (WMP) is to provide practical guidance on the disposal of all wastes generated from FOGL drilling operations offshore the Falkland Islands.

Implementation of the Waste Management Plan is intended to supplement the MSID and is supported by the individual waste management plans associated with the rig, supply vessels and onshore waste management contractors.

7.11 Environmental Management Plan

In order to ensure that appropriate mitigation measures, identified following the EIA process, are implemented during the planning and drilling of the proposed exploration wells, an Environmental Management Plan (EMP) has been prepared (refer to Table 7.1). This will be further refined in conjunction with the MSID.

The plan identifies mitigation measures, actions required, and assigns responsibilities. The plan will act as a 'live' document to track progress through to cessation of drilling activities. It will provide guidance for the drilling contractor and can also be used by FOGL to monitor contractor performance with regard to environmental issues. Should monitoring indicate unacceptable environmental performance, the EMP provides a mechanism to initiate remedial action.

Table 7.1. Environmental Management Plan Mitigation Register (OR = Ocean Rig , the drilling rig contractor)

HAZARDS	ACTIONS / MITIGATION / MONITORING	Responsibility
Physical Presence and Footprint		
Rig & Vessels Presence; Well Abandonment	▪ Rig Exclusion zone (500 metres) to be implemented, monitored and patrolled by a standby vessel. ▪ The rig will have no seabed footprint as it is dynamically positioned. ▪ Drilling rig and vessels to carry relevant navigational & communication aids. ▪ The planned activities will be promulgated in advance through Notice to Mariners and VHF broadcast for the duration of the operations. ▪ The British Military will also be continually informed of the operational activities. ▪ The wells will be abandoned and seabed structures removed in accordance with FIG guidelines.	OR OR OR/Vessel masters, owners OR/AGR OR/AGR FOGL/AGR/OR
Routine Activities, Emissions and Discharges		
Noise	▪ Helicopter operations lower than 460 meters will be prohibited above marine mammal and seabird colonies identified as sensitive sites (refer to Figure 5.78) unless essential for safety purposes. ▪ Helicopter flights will adopt flight paths taking into account environmentally sensitive areas (refer to Figure 5.78). ▪ Small boat movements will be prohibited in the vicinity of marine mammals (cetacean and pinnipeds) unless absolutely necessary for personnel safety and will avoid rafts of seabirds. ▪ Rapid movement of vessels towards and in the vicinity of marine mammals will be avoided. ▪ Marine mammals and seabirds observed during the exploration activities will be recorded and the data passed to research bodies to gain a better understanding of their presence in the area.	AGR/OR plus Helicopter Contractor (CHC) and vessel masters, owners
Light	▪ Potential effects on nocturnal seabirds can be minimised by shielding external lights, subject to safety requirements.	OR/AGR
Atmospheric Emissions	▪ All engines, compressors and generators to be maintained and operated under manufacturers' standards. ▪ Use of low sulphur fuels (<1.5% sulphur) if possible. ▪ Regular monitoring of fuel consumption.	OR/AGR plus Helicopter contractor (CHC) and vessel

HAZARDS	ACTIONS / MITIGATION / MONITORING	Responsibility
	■ Use of non ozone depleting fire fighting foam. ■ Use of IMO certified low emission waste incineration unit.	masters, owners
Sewage, Grey Water and Kitchen Waste	■ Sewage from the rig and support vessels will be treated to MARPOL requirements prior to discharge at a distance greater than 12 miles from the nearest land, or discharged to appropriate reception facilities. ■ Organic kitchen waste will be macerated and discharged to sea. No discharge should be undertaken within 12 nm of the shore. ■ Regular monitoring of discharged effluent quality.	OR/AGR and vessel masters, owners
Other Waste	■ All Hazardous wastes, including any oil recovered from the slops tank or drains, will be segregated and stored for onward shipment to UK for treatment and disposal at appropriate licensed facilities. ■ All Non-hazardous waste will be segregated and stored for transfer to shore to be recycled and disposed in Falkland Islands in line with FIG authorisation; waste oils may be used for fuel locally ■ Wastes will be stored in designated containers and labelled appropriately. ■ All wastes will be managed and disposed of according to the Waste Management Plan, the Duty of Care and relevant legislation. ■ Waste transfers will be logged and recorded in the waste oil book and all transfer notes held for the required period. ■ All vessels and their discharges will be MARPOL compliant.	OR/AGR plus vessel masters, owners
Cement, Drill Cuttings and Drill Fluids	■ Planned use of Water Based Mud. ■ All chemicals registered under OSPAR (HOCNF) will be used, with chemicals identified as PLONOR (Pose Little or No Risk) being used wherever feasible. ■ Where non-PLONOR chemicals are required for operational or safety reasons, their use will be explained and justified. ■ Cuttings drilled using WBM will be treated to remove mud for reuse, and then discharged to sea. ■ Cement discharge will be minimised where possible to the UK recommended 10% (maximum estimated 25% discharge).	OR/AGR

HAZARDS	ACTIONS / MITIGATION / MONITORING	Responsibility
	■ Any oil on cuttings from the geological formation will be separated on the drilling unit. Cuttings will be monitored, handling and treated to assure no hydrocarbon contaminated cuttings with >1% oil are discharged.	
Drainage and Bilge Water	■ Bilge and drainage water will be treated to MARPOL standards (< 15 ppm oil in water). ■ Any oil contaminated drainage water will be routed to the separator or to the waste oil tank. Uncontaminated deck drains will be routed overboard. ■ An oil content meter will continuously monitor and sample the oil content within the drain line. When the meter detects a ratio in excess of 15 ppm the drains will be directly transferred into the holding tank. ■ A Bilge Pump and a Bilge Water Separator are installed for draining the Bilge Water Tank (fitted with a high oil alarm to meet IMO requirements), which discharges to sea.	OR/AGR
Ballast Water	■ Ballast water will be managed as agreed with FIG. Local ballasting and de-ballasting likely.	OR plus vessel masters, owners
Non-Routine Activities: Oil Spills		
Subsea Blowout	■ Managing potential drilling hazards, such as shallow gas, and following established drilling safety standards to minimize the risk of control loss. ■ The BOP will be installed to prevent blowout once drilling has progressed beyond the riser less stage. ■ As a fundamental aspect of drilling, downhole pressures will be constantly monitored and responded to in terms of the mud programme. ■ In the case of a well control incident, the well will be closed in at the Blow-Out Preventer (BOP). ■ Standard procedures of well monitoring and control will apply. The rig crew will be experienced and fully trained in regards to all matters associated with prevention and contingency measures. All key supervisors will have IWCF Well Control training. ■ The Rig and support vessels will be equipped with Tier 1 spill response equipment. ■ A project specific Oil Spill Contingency Plan will be in place, and prepared based on geological modelling and oil dispersion simulations.	OR/AGR OR/AGR/FOGL OR/AGR/FOGL FOGL

HAZARDS	ACTIONS / MITIGATION / MONITORING	Responsibility
	▪ Personnel trained in oil spill response. ▪ The option for relief well drilling in the event of an emergency will be built into the drilling planning programme. ▪ Emergency planning for deployment of a capping device in the event of an uncontrolled blowout.	OR/AGR/FOGL FOGL/AGR FOGL/AGR
Fuel Tank Rupture	▪ Regular maintenance of fuel storage tanks to ensure their fulfilment of all regulatory requirements for offshore use, will limit the possibility of rupture or leaks. ▪ Alarm systems fitted in fuel tanks will warn of high fuel levels and should ensure that the possibility of spillage from the drilling rig and support vessels is minimised. ▪ A project specific Oil Spill Contingency Plan will be in place.	OR/AGR plus vessel masters, owners OR/AGR/FOGL
Vessel Collision	▪ Notification of planned operations to all relevant maritime authorities and representative fishing organisations. ▪ The Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) will be complied with. ▪ Drilling rig will carry all relevant navigational & communication aids. ▪ A minimum distance of approach of 500 m will be applied for all non-relevant traffic with the assistance of support and standby vessels. ▪ The standby vessels will continually monitor vessels and their positions during drilling to ensure no navigational obstruction. ▪ An iceberg management plan will be adopted to help minimise the risk of collision with icebergs. ▪ A full Spill Contingency Plan will be in place to control and recover from incidents.	OR/AGR OR/AGR/FOGL
Spill During Re-fuelling	▪ Refuelling operations will be conducted in relatively calm weather conditions during light hours, where operationally practical. ▪ Strict monitoring of the refuelling operations will be carried out. ▪ Alarm systems fitted in fuel tanks will warn of high fuel levels and should ensure that the possibility of spillage from the drilling rig and support vessels is minimised.	OR/AGR OR/AGR/FOGL

HAZARDS	ACTIONS / MITIGATION / MONITORING	Responsibility
	■ Diesel and heavy fuel oil spill scenarios are covered in the Oil Spill Contingency Plan. No heavy fuel oil used planned.	
Non-Routine Activities: Chemical Spills		
Mud, Cement and Other Chemicals	■ With minor exceptions the chemicals stored on board will be of inherent low toxicity and classify as the lowest toxicity rating under the OSPAR chemical notification format. ■ Storage of chemicals in designated areas and labelled containers. ■ Storage and handling on board will be subject to strict provisions in terms of environmental protection and human safety.	OR/AGR
	■ Good housekeeping standards to be maintained on the rig to control the amount of hydrocarbons and other contaminants entering the drainage system. Hazardous materials will be contained or bunded with no residues/spills permitted to enter the overboard drainage system. ■ The Rig and support vessels will be equipped with Tier 1 spill response equipment (e.g. absorbent pads) to contain and collect spills. Crews will be trained in the use of such materials and contingency measures will be implemented as appropriate for spill size.	OR/AGR/FOGL
Onshore Impacts		
Transport	■ Limited number of crew transfers (4 return flights in fortnight) over 90-100 days of drilling campaign. Occasional further flights. ■ Temporary vehicle movements, mainly to transfer personnel and equipment between Mt. Pleasant and Stanley airports. ■ Advanced planning to ensure flights and transfers are kept to a minimum. ■ Materials and equipment will be shipped from the UK mainly, in as few vessels as possible. ■ Materials will be unloaded to the base storage from FIPASS and re-loaded as necessary to FIPASS, with local short distance truck and crane movements.	AGR/OR

HAZARDS	ACTIONS / MITIGATION / MONITORING	Responsibility
Base storage and facilities	▪ Storage, warehouse, and office facilities will be constructed in the port area adjacent to existing facilities. ▪ Hazardous materials will be handled in accordance with FIG and industry standard requirements.	AGR, local base operator
Vessel Movements	▪ Refuelling and resupply will be provided from the FIPASS Port Facility at Stanley. A plan of the proposed schedule of movements for each vessel will be provided to the FIPASS Management to ensure timely and effective management of the port facility	AGR
Resource Use	▪ No operational materials to be sourced from Falkland Islands apart from fuel, water and food, subject to urgent requirements. ▪ Advanced planning of supplies and materials transfers by supply vessels. ▪ Storage of water for drilling purposes to minimise any impacts on the local community, if required. ▪ Water for drinking and domestic use will be sourced from the desalination plant onboard the rig.	AGR OR
Waste Disposal	▪ Disposal of Non-hazardous waste only at two landfill sites in accordance with FIG guidance and authorisation. ▪ Encourage recycling of metal and plastic containers for local re-use	OR/AGR

8 Conclusions

The assessment of potential environmental impacts from the proposed drilling programme has been carried out using a conservative precautionary approach. It is based on publicly available literature, unpublished research data, and inputs from stakeholder consultation; combined with the expert judgement of the RPS Energy consultants and the Falklands Island Government departments, Falkland Conservation, Birdlife International and NGOs. On the basis of the assessment conducted, a wide range of preventative and mitigation measures have been proposed.

Given the current operational commitments and proposed mitigation measures, it is considered that the routine drilling activities can be undertaken without significant impacts to the Falkland Islands' environment. However, in the event of a potential blowout under worst case scenario conditions (i.e. loss of control of the well due to failure of numerous redundant safety systems e.g. blow-out preventer; long term release of liquid hydrocarbons before capping device or relief well can be enacted), the impact is likely to be of major significance.

The cumulative environmental effects from the planned exploration programme are considered to be minor, given the short term nature of the drilling and low level of exploration activities in the east and south Falkland Basins.

Transboundary impacts from oil spills have a low probability of occurring and are assessed to be of minor significance, provided spill response is effectively mobilised and implemented as per the Oil Spill Contingency Plan.

9 Further Studies and Recommendations

Data Gaps

EIA process is heavily reliant on the accuracy and availability of the baseline environmental data. For the current EIA, a series of data gaps have been identified which are to be considered as an element of uncertainty contributing on the final conclusions:

- Absence of reliable scientific data on fish spawning and nursery grounds around Falklands Islands. Though a number of publications discuss this subject, there is insufficient coverage, or correlation between various results, to build up regional and temporal overviews of the spawning areas.
- Sparse information on the benthic environment, including protected habitats (i.e. cold coral colonies) offshore Falkland Islands. There is therefore a need for a strategic co-ordinated survey and monitoring programme.
- Comparatively little is known about the numbers and distribution of marine mammals in the offshore environment, their use of the area and its resources. Survey effort to date is limited to fishing observations and a single 'Seabirds at Sea' programme undertaken in 1998-2001. Therefore a need for a strategic co-ordinated survey and monitoring programme based on adequate scientific approach exists. Given weather conditions offshore Falklands, a programme of acoustic monitoring is also desirable to complement such visual surveys throughout the year.
- Existing MMO reports from rig site surveys and seismic surveys have not been collated into the main body of knowledge on cetaceans. With suitable co-ordination and methods development, existing cetacean data gathering could be improved and systematised.
- Few data, including the Seabirds at Sea programme, 1998-2001, and observations from fishing vessels, currently exist to indicate foraging areas for pinniped species along the Falklands Shelf. The first attempts to determine the offshore distribution of pinnipeds using tagging and satellite telemetry methods, began in 2000. However, in most cases the sample sizes were too small to be conclusive of pinniped distribution trends. A FI wide survey to assess the abundance and distribution of pinnipeds is highly desirable due to their high vulnerability to marine noise and oil spills.
- Comparatively little is known about the numbers and seasonal distribution of seabirds in the offshore environment, or their vulnerability to surface pollution at different times of the year. Fishing vessel observations are partially biased, as vessels tend to attract certain types of birds, whilst the Seabirds At Sea survey (1998-2001) effort was particularly low to the east and south of the Falkland Islands (i.e. the FOGL licence areas). Seabird tracking data has been collected since 1994, but is currently limited to a few species of protected petrels, albatrosses, and a small variety of penguin species. For example, the King penguin has been tracked during autumn foraging up to 200 kilometres northeast of the Falkland Islands coast (*Falklands Conservation & WWF, 2011*). The Rockhopper penguin has also been tracked as far north as latitude 41^{o} S in March to August 2011 (*Falklands Conservation).* This type of tracking data provides key information regarding the distribution and foraging patterns of birds for offshore environmental impact assessments.

General Recommendations- data gaps and data management

- Survey data (benthic, cetaceans, pinnipeds) collected by various operators should be designed to generate datasets that can support both strategic and site-specific approaches to environmental assessment.
- Falkland Islands marine monitoring and data gathering initiatives should be initiated and integrated across and between the various state agencies, research institutions and commercial operators.

- Environmental data (physical, chemical, biological and relating to other sea users) should be collated and held in a co-ordinated and readily accessible database at an identified location for use in future oil and gas-related environmental assessments.

Project Specific Recommendations

Project specific recommendations to enhance the knowledge of licensing area include:

- Use of marine mammal and seabird observers during drilling programme.
- Compiling and releasing seabed visual observations from ROV surveys where these provide information on seabed habitats or species.

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Appendix A

OCEAN RIG

LEIV ERIKSSON – THE EFFECTIVE ANSWER FOR

ULTRA-DEEP WATERS

AND HARSH ENVIRONMENTS

OCEAN RIG AS P.O. BOX 409, FORUS NO-4067 STAVANGER, NORWAY TEL +47 51 96 90 00 FAX +47 51 96 90 99 oras@ocean-rig.com www.ocean-rig.com

LEIV EIRIKSSON | OCEAN RIG AS

GENERAL

Year Completed: 2001
Builder: Dalian New Shipyard, China – baredeck
Outfitted: Friede Goldman Offshore, USA
Design: Trosvik Bingo 9000,6 columns, DP Class 3
Classification: DnV + 1A1 Column Stabilised Drilling Unit, UKVS, DYNPOS AUTRO, HELDK SH, CRANE, F-AM, DRILL

Leiv Eiriksson carries a Norwegian AoC (SUT) and a UK Safety case

MAIN DIMENSIONS

Length: 119.38m (391.68ft) Overall
Width: 85.50m (278.88ft) Overall
Moon-pool: 7m x 14.5m (22.9ft x 47.50ft)
Air Gap: 13.50m (44.29ft) Operating Draft

DRAFT AND DISPLACEMENT

Operating Draft: 23.75m (77.9ft)
Transit Draft: 12m (39.4ft)
Survival Draft: 21m (68.9ft)
Operating Displacement: 53,393mt (52,552 tons)
Transit Displacement: 38,243mt (37,640 tons)

DYNAMIC POSITIONING AND VESSEL CONTROL SYSTEM

Integrated Automation System

Dynamic Positioning System: SDP 32 (SDP 12 in Backup Control Room)
Power Management System: SVC (Simrad Vessel Control)

Position Reference Systems:
1 x DPS 4D – L1/L2 Dual-frequency GPS/GLONASS GPS Receiver, aided by a high performance IMU
1 x DPS 232 - L1/L2 Dual-frequency GPS/GLONASS GPS Receiver
2 x DPS 132 - L1/L2 Dual-frequency GPS Receiver.
Dual Spotbeam, dual Inmarsat-B and UHF / HF received corrections signals.

2 High Precision Acoustic Positioning, Simrad HIPAP, systems
1 HAIN (inertial navigation system) with Honeywell HG9900 IMU.
1 RMS (Riser Management System)

Sensors: 3 Gyro Compasses Serry SR 2100 Fiber Optic.
3 Motion Reference Units, Seatex MRU-5
3 Lambrect Wind Sensors

The Kongsberg SDP 32 DP system is a triple redundancy dynamic positioning system with a full range of functionality. The system is satisfying IMO 645 Class 3 and DNV AUTRO notation.

MACHINERY

Main Engines: 6 x Wärtsila 18V32 diesel engines, rated 7,500kW each, 10,200hp, total 61,200hp
Generators: 6 x ABB ASG 900 XUB generators, rated 7,300kW each, total 43,800 kW
Power Distribution: ABB
Propulsion: 6 x Rolls Royce UUC 7001 fixed pitch variable speed thrusters, rated 5,500kW each,
Total thrust: 600mt

OPERATING PARAMETERS

Water Depth:	2,286m (7,500ft)
Transit speed:	6 - 7 knots

DRILLING EQUIPMENT

Derrick:	Hydralift 170 x 40 x 40ft; 680mt (1,500,000 lbs)
Motion Compensators:	Hydralift 800-25 Passive / Active Crown Mounted Compensator • Rating: Static 680mt (1,500,000 lbs), Compensating 363mt (800,000 lbs) • Stroke: 25ft stroke
Drawworks:	Continental Emsco Electrohoist III, 3000hp
Rotary Table:	Varco BJ RSTT - 60 1/2"
Top Drive:	Hydralift HPS 750 2E AC Electric Drive • Rating: 680mt (1,500,000 lbs) • Torque: 90,840Nm (67,000ft lbs), continuous
Travelling Block:	Hydralift HTB 750-S
Pipe Handling:	• Hydralift, HydraRacker (pipe racker) • Hydralift, Back-up Racking System • Hydralift, Drillfloor Manipulator Arm • Hydralift, Iron Roughneck
Fwd pipe rack:	• Hydralift, Pipe Catwalk Machine • Hydralift, Knuckle-boom Pipe-handling Crane
Aft riser rack:	• Hydralift, Riser Catwalk Machine • Hydralift, Riser Gantry Crane
Riser Tensioner:	6 x Hydralift double, 91mt each (200,000 lbs); Total Capacity 1,089mt (2,400,000 lbs)
Cementing:	Dowell Schlumberger, Third Party free placement unit
Mud Pumps:	3 x Continental Emsco FC-2200, 2,200hp, 517 BAR (7,500psi)

CAPACITIES

Variable Deck Load:	• Operating: 7,222 mt • Survival: 7,222 mt • Transit: 6,534 mt
Liquid Mud:	1,657m3 (10,420 bbls)
Bulk Mud/Cement:	4 x 87.6m3 (3,094 cuft) – Total 350m3 (12,360 cuft)
Bulk Cement:	4 x 87.6m3 (3,094 cuft) – Total 350m3 (12,360 cuft)
Drill Water:	1,960m3 (12,330 bbls)
Potable Water:	1155m3 (7,265 bbls)
Fuel Oil:	4,631m3 (29,130 bbls)
Base oil:	406m3 (2,554 bbls)
Brine:	680m3 (4,277 bbls)

SUBSEA SYSTEMS

BOP: Cameron 18 ¾" 1,034 Bar (15,000psi), H2S service.
- Annulars: 2 each 690 Bar (10,000 psi)
- BOP Rams: 4 each 1,034 Bar (15,000psi)
- Choke and Kill: Cameron double master target valve 3 1/16" 15,000psi choke line

Wellhead Connector: Vetco Super HD H4
BOP Control System: Cameron MUX Control System with Multiplex modular control pods
BOP Acoustic System: Kongsberg BOP acoustic control

Cameron Hydraulic power unit with 345 Bar (5,000psi) accumulator pressure

Marine Riser:
- Vetco MR-10-GS dog riser,21" OD x 7/8" wall, rating 3,000,000 lbs;
  2 x 4 ½" ID Choke / Kill Lines; 1 x 4" ID Booster Line; 2 x 2 ½" Hydraulic Conduits Lines

Diverter:
- Vetco KFDS-CSO-500,

BOP Handling:
- Hydralift BOP and X-mas tree transporter,290mt capacity
- BOP Underhull Guiding System
- Gantry crane for BOP service 2 x 50 mt
- Rig outfitted for subsea completion and X-mas tree handling

Drillpipe: 5 ½" S-135 with HT55 tool joints
Drillcollars: 9 ½", 8 ¼" , 6 ¾"

MOORING

Winches: 2 x Ulstein Brattvåg single drum windlasses
Wire/Chain: 2 x 2.76" 84mm chain. 2 x 1000 meter lengths.
Anchors: 2 Bruce, 20 ton.
CRANAGE: 2 x Hydralift WOMCVC 3447, 75 mt
HELIDECK: EH 101 Helicopter, D = 22.8 meter
ACCOMMODATION: 120 berths + hospital
LIFE SAVING: 4 x 70-men lifeboats
1 x Man Over Board boat (MOB boat)
Escape Shute System (Selantic) with 8 x life rafts total capacity 240 men

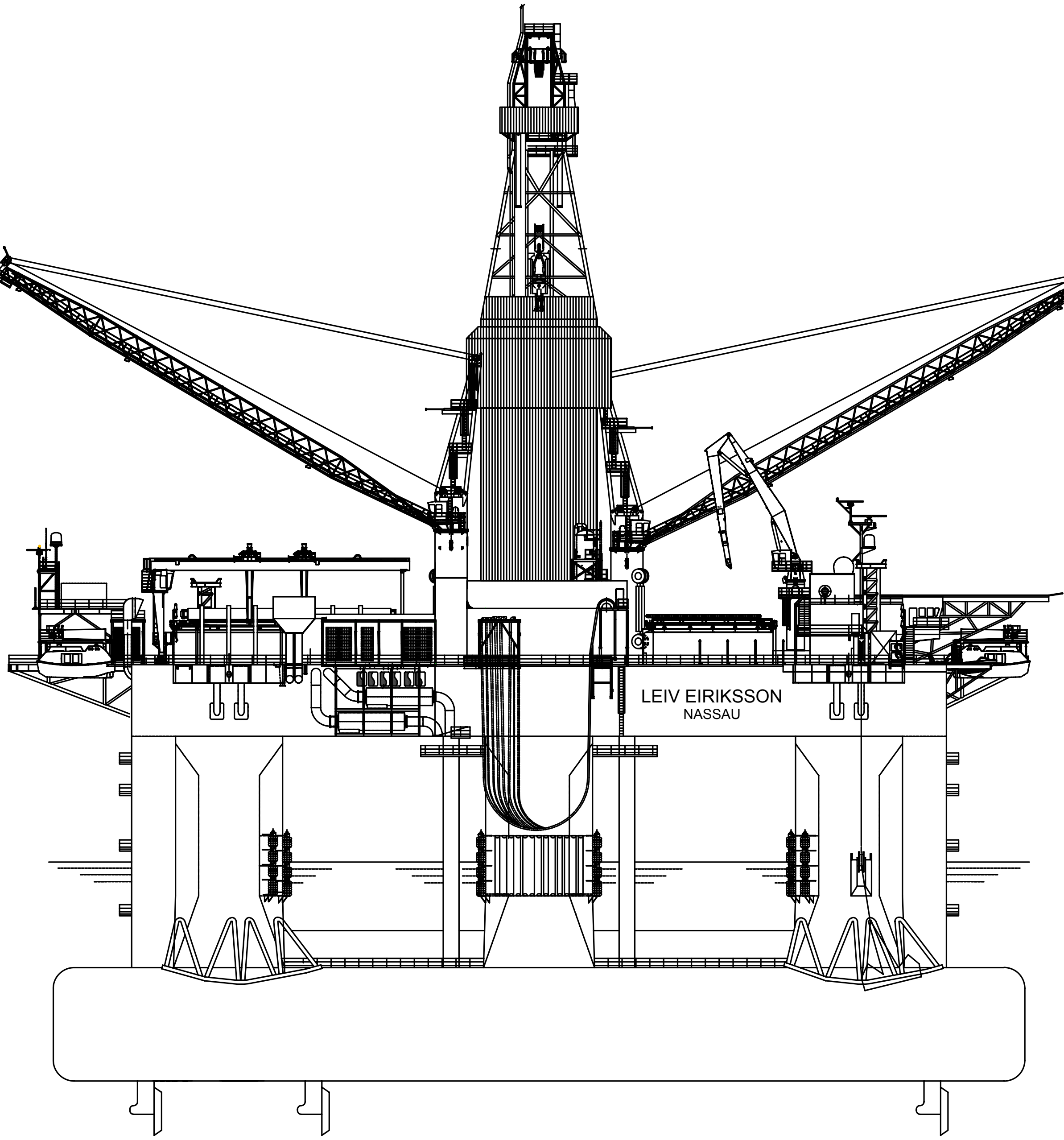
ADDITIONAL DATA

Leiv Eiriksson design temperature:
- Air (deck, trusses, columns); minus 20 deg Celsius
- Sea (pontoons); zero deg Celsius
- Water max; plus 35 deg Celsius

The Leiv Eiriksson is winterized for operation in temperatures down to minus 10 deg Celsius.
Leiv Eiriksson is designed for zero discharge

LEIV EIRIKSSON

OCEAN RIG AS



MAIN DIMENSIONS

Length:	119.38m (391.68ft) Overall
Width:	85.50m (278.88ft) Overall
Moon-pool:	7m x 14.5m (22.9ft x 47.50ft)
Air Gap:	13.50m (44.29ft) Operating Draft

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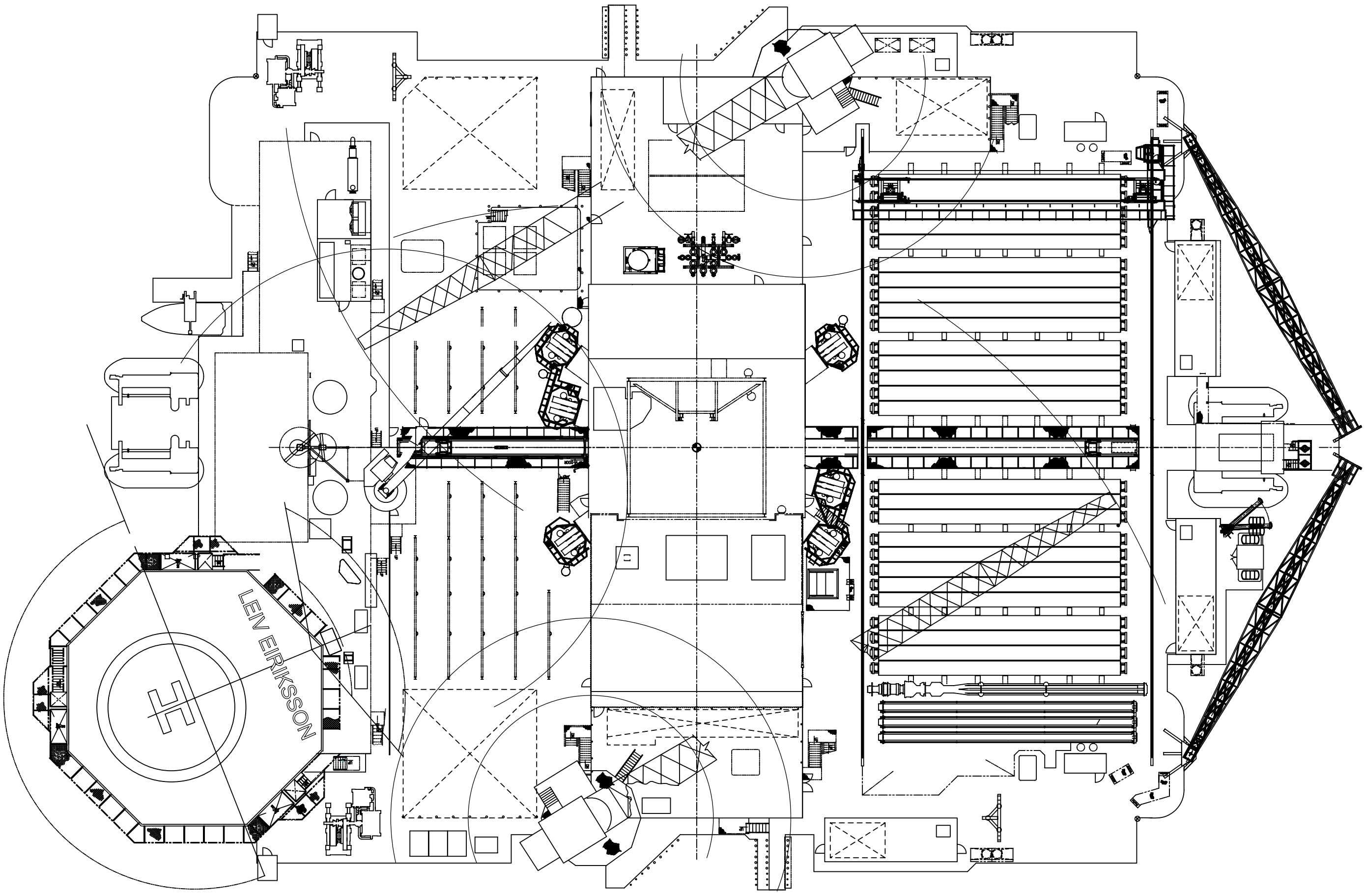

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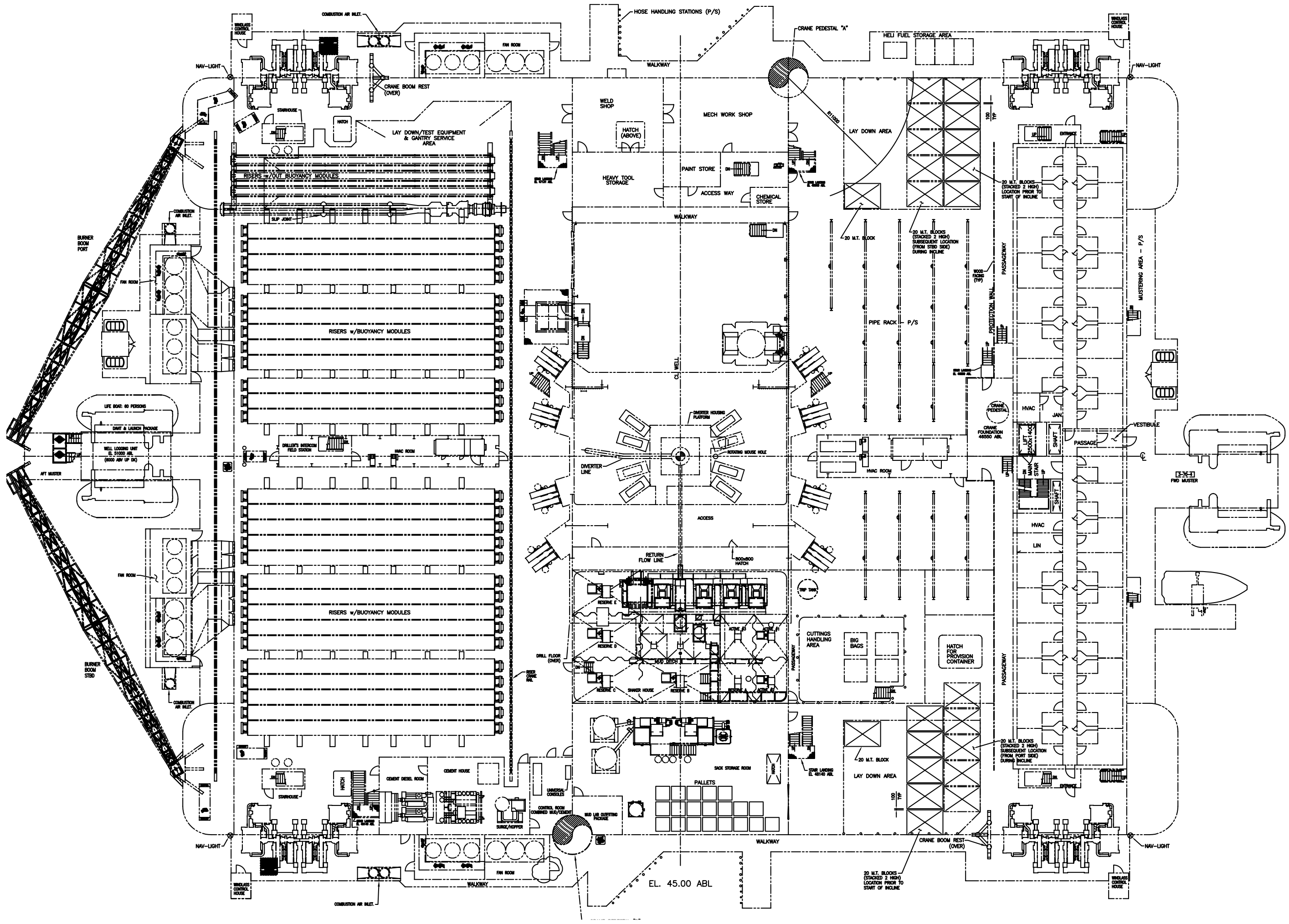
LEIV EIRIKSSON

OCEAN RIG AS



MAIN DIMENSIONS

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Moon-pool:	7m x 14.5m (22.9ft x 47.50ft)
Air Gap:	13.50m (44.29ft) Operating Draft

ADDITIONAL INFORMATION

The drilling units Leiv Eiriksson and Eirik Raude are 5th generation harsh environment, dynamically positioned semi-submersibles, capable of operating in water depths up to 2286 meter and 3000 meter. The dynamic positioning capability is to Class 3.
In addition Eirik Raude is capable of being moored in water depths of 70 meters to 500 meters. Both units are designed with zero discharge capability and have low emission power generation systems.

Leiv Eiriksson area of operation:

- West Africa Angola and Congo (Deep water)
- Atlantic Sea Ireland (Deep water harsh environment)
- West Of Shetland UK (Deep water harsh environment)
- Norwegian Sea Norway (Deep water harsh environment)
- Black Sea Turkey (Deep water)

Eirik Raude area of operation:

- Nova Scotia Canada (Deep water harsh environment)
- Newfoundland Canada (Deep water harsh environment)
- Cuba (Deep water)
- West Of Shetland UK (Deep water harsh environment)
- North Sea Norway (Shallow water harsh environment)
- Barents Sea (Shallow water harsh environment)
- Norwegian Sea (Deep water harsh environment)
- Gulf of Mexico USA (Deep water)
- West Africa Ghana (Deep water)

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Appendix B

Appendix B: HOCNS & HMCS

Until recently, the control of offshore chemical discharges was controlled under the Offshore Chemical Notification Scheme (OCNS). Within the UK, the OCNS has been succeeded by The Offshore Chemicals Regulations 2002, which introduced a new approach to the consideration of chemical use and their discharge, the Harmonised Mandatory Control Scheme (HMCS). The Falkland Islands Government (FIG) aims to follow the example of the UK with regard to offshore chemical use. Both the OCNS and the HMCS are discussed below.

Offshore Chemical Notification Scheme (OCNS)

The Offshore Chemical Notification Scheme (OCNS) requires that all chemicals used in offshore exploration and production be tested using standard test protocols. Chemicals are then classified based on their biological properties e.g. toxicity and biodegradability. The OCNS scheme was adopted in the UK in 1979 and formed the basis of the Oslo and Paris Commissions (OSPARCOM) Harmonised Offshore Chemical Notification Format (HOCNF) which was established under cover of the Paris Commission Decision 96/3. The objectives of the OCNS and HOCNF are to regulate and manage chemical use by the oil and gas industry and consequently to prevent unacceptable damage to the marine environment through the operational or accidental discharge of chemicals.

The scheme was originally voluntary in the UK and all chemicals were given an OCNS Category ranging from 0 to 4. The system was later altered to harmonise the system with those operated by other countries bordering the North Sea. The HOCNS classifies all chemicals into five groups, A to E, with Category A chemicals being the most toxic and least biodegradable and Category E chemicals considered to be the least harmful to the offshore environment.

In addition to being placed into one of the five HOCNS categories, substances known or expected to cause tainting of fish tissue or substances known or expected to cause endocrine disruption, if lost or discharged, will be identified with a special taint or endocrine disrupter (ED) warning.

Chemicals are categorised on the basis of a series of laboratory tests with particular reference to their ecotoxicological effect, the biodegradability of the chemical and the potential for bioaccumulation in marine species. The ecotoxicological data used to classify the toxicity of chemicals are the results of laboratory tests on aquatic indicator organisms. Acute toxicity is assessed and expressed as either:

- An LC50 – the concentration of the test substance in sea water that kills 50 percent of the test batch; and
- An EC50 – the concentration with a specified sub-lethal effect on 50 percent of the test batch.

The HOCNS grouping for a chemical is determined by comparing the results of toxicity tests for that chemical with the toxicity data given in Table B.1.

Table B.1. HOCNS Grouping Toxicity values (ppm) (Source: CEFAS, 2007)

HOCNS Grouping	A	B	C	D	E
Results for aquatic toxicity data (ppm)	<1	>1-10	>10-100	>100-1,000	>1,000
Results for sediment toxicity data (ppm)	<10	>10-100	>100-1,000	>1,000-10,000	>10,000

Aquatic toxicity - refers to the *Skeletonema costatum* EC_{50}, *Acartia tonsa* LC_{50}, and *Scophthalmus maximus* (juvenile turbot) LC_{50} test
Sediment toxicity - refers to the *Corophium volutator* LC_{50} test.

The categorisation also takes into account the chemicals potential to bio-accumulate and biodegrade and other aspects such as potential endocrine disruption. The bioaccumulation potential and biodegradation rate relates to the fate of a chemical within the marine environment. Bioaccumulation potential describes the net result of uptake, distribution, biodegradation and elimination of a substance within an organism, subsequent to exposure but within the environment. The partition coefficient between octanol and water (expressed as Log Pow) is used as an indication of the potential for a substance to be bioaccumulated. A high value indicates a tendency to accumulate in lipophilic ("oil liking") phases such as the fatty tissues of organisms, suspended particles or sediments. However, because of biodegradation and elimination processes, a high Log Pow does not necessarily imply bioaccumulation will occur. The classification outlined in Table B.2 is generally used to describe bioaccumulation potential.

Table B.2. Classification of Bioaccumulation Potential

Bioaccumulation Potential	Log P_{OW}
Low	<2
Medium	2-4
High	>4

Biodegradation of a substance refers to primary breakdown of the substance by living organisms, normally bacteria. A substance is considered readily biodegradable if 60 percent or more is broken down in 28 days during biodegradation tests. Values below this are considered not to be readily biodegradable.

Harmonised Mandatory Control Scheme (HMCS)

The OSPAR Decision introducing an HMCS for the use and discharge of chemicals offshore came into force through the Offshore Chemicals Regulations 2002. The regulatory regime requires operators to obtain a permit to use and discharge chemicals in the course of oil and gas exploration and production operations offshore.

Qualitatively and quantitatively assess the nature, significance and probability of impacts on

The OSPAR Decision and its supporting Recommendations entered into force on 16 January 2001. The Decision requires offshore chemicals to be ranked according to their calculated Hazard Quotients relating to each chemical discharge under standardised platform conditions (HQ = ratio of Predicted Environmental Concentration (PEC) to Predicted No Effect Concentration (PNEC). It also obliges authorities to use the CHARM "hazard assessment" module as the primary tool for ranking. In the UK this is carried out by a multidisciplinary team at the CEFAS Burnham Laboratory. From this information, operators assess and select their chemical need, calculating PEC:PNECs for actual conditions of use (utilising the CHARM module as appropriate) and bearing in mind the objective of the HMCS to identify substances of concern for substitution and ranking of others to support moves towards the use of less harmful substances. Inorganic chemicals and organic chemicals with functions for which the CHARM model has no algorithms will continue to be ranked using the existing HOCNS hazard groups defined above.

A series of ranked lists are maintained on the CEFAS web site which use a banding system to rank organic chemicals of similar function according to PEC: PNEC "Hazard Quotients" calculated using the CHARM model. The band definitions are given in Table B.3.

Table B.3. Classification of Bioaccumulation Potential

HQ Banding	HQ Value
Gold	0>x<1
Silver	1=<x<30
White	30=<x<100
Blue	100=<x<300
Orange	300=<x<1000
Purple	1000=<x

The minimum data set of actual values and the parameters used by CEFAS to calculate them are disclosed to chemical suppliers on “templates”. The suppliers then pass these on to operators to enable the calculation of site-specific risk assessments (RQs) for any chemicals they may want to use. Some chemicals are generated and or used in-situ on offshore installations, e.g. Sodium Hypochlorite, and don't fall under the remit of any one supplier.

The properties of substances on the OSPAR List of Substances/Preparations Used and Discharged Offshore, Which Pose Little Or No Risk to the Marine Environment (PLONOR) are sufficiently well known that the UK Regulatory Authorities do not require them to be tested. This list is reviewed annually and the notification requirements for these chemicals are given in the PLONOR document.

Appendix C

RIG SITE SURVEY
OFFSHORE FALKLAND ISLANDS
FIDA 42/02 LOLIGO

Survey Period: 14 – 22 January 2009
Report Number: 9763V2.1

Volume 2 of 5: Environmental Baseline Survey

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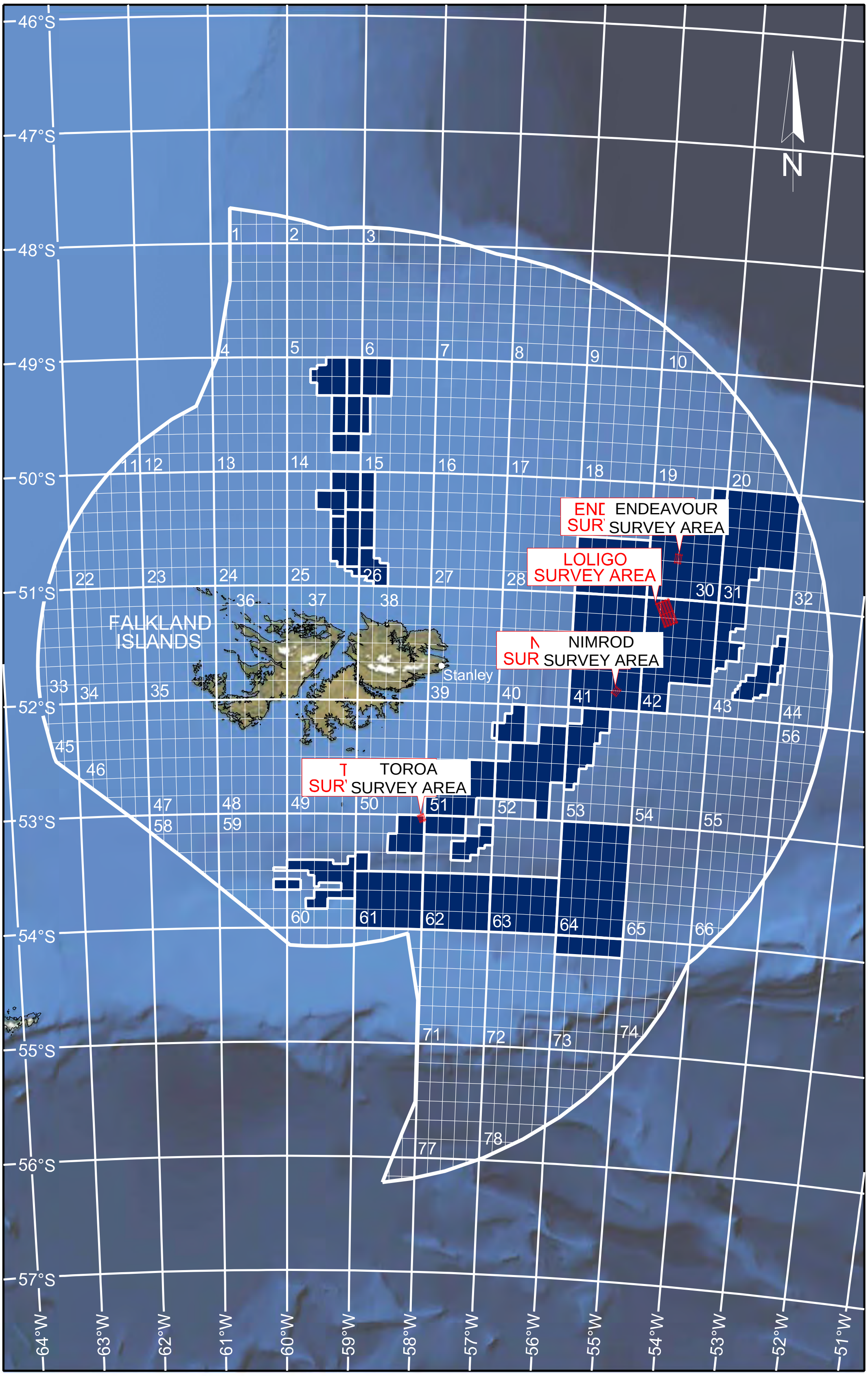
1	Issued as Final	D. Sutherland	P. Collins	R. Walters	15 September 2009
0	Issued as Proof	G Harris-Bryant	P. Collins	R. Walters	22 May 2009
Rev	**Description**	**Prepared**	**Checked**	**Approved**	**Date**



FRONTISPIECE

DOCUMENT ARRANGEMENT

9763V1	OPERATIONS
9763V2	**LOLIGO ENVIRONMENTAL BASELINE SURVEY**
9763V3	TOROA ENVIRONMENTAL BASELINE SURVEY
9763V4	ENDEAVOUR ENVIRONMENTAL BASELINE SURVEY
9763V5	NIMROD ENVIRONMENTAL BASELINE SURVEY
27.2008-2273	LOLIGO SHALLOW HAZARDS ASSESSMENT
27.2008-2275	TOROA SHALLOW HAZARDS ASSESSMENT
27.2008-2277	ENDEAVOUR SHALLOW HAZARDS ASSESSMENT
27.2008-2274	NIMROD SHALLOW HAZARDS ASSESSMENT

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ABBREVIATIONS

%sat.	Percentage Saturation
BHPB	BHP Billiton
CPI	Carbon Preference Index
CLUSTER	Higher Agglomerative Cluster Analysis
CM	Central Meridian
DEFRA	Department of Environment Food and Rural Affairs
DO	Dissolved Oxygen
DTI	Department of Trade and Industry
EPA	Environmental Protection Agency
FA	Faunal Replicates A (grab samples)
FB	Faunal Replicates B (grab samples)
FGI	Fugro Geoconsulting Inc.
FSLTD	Fugro Survey Limited
FOC	Fractionated Organic Carbon
GC	Gas Chromatography
GC-MS	Gas Chromatography Mass Spectrometry
GC-FID	Gas Chromatography - Flame Ionisation Detection
ICPOES	Inductively Coupled Plasma Optical Emission Spectrometry
ICPMS	Inductively Coupled Plasma Mass Spectrometry
LAT	Lowest Astronomical Tide
LOI	Loss on Ignition
nC_{12-20}	Alkanes ranging from carbon numbers 12 to 20
$ng.g^{-1}$	Nanograms per gram
nMDS	Non-Metric Multidimensional Scaling
NPD	Naphthalene, Phenanthrene, Anthracene and Dibenziothene
OSPAR	Oslo and Paris Commission
PAH	Polycyclic Aromatic Hydrocarbons
PC	Physico-chemical sample (grab sample)
PRIMER	Plymouth Routines in Multivariate Ecological Research
SD	Standard Deviation
SIMPER	Similarity Percentage Analysis
SIMPROF	Similarity Profiling
TOM	Total Organic Matter
THC	Total Hydrocarbon Concentration
UCM	Unresolved Complex Mixture
UKOOA	United Kingdom Offshore Operators Association
$\mu g.g^{-1}$	Micrograms per gram
TM	Transverse Mercator
V	Coefficient of Variation
WAS	Wilson Auto-Siever
WGS84	World Geodetic System 1984

ABSTRACT

On the instructions of BHP Billiton Petroleum Falklands Corporation, Fugro Survey Limited (FSLTD) performed combined geophysical and environmental baseline surveys of four sites (Endeavour, Loligo, Nimrod and Toroa) offshore the Falkland Islands.

This report outlines the findings of the environmental baseline survey (EBS) conducted at the Loligo prospect (FIDA 42/02). This work was undertaken aboard the M/V Fugro Meridian between the 14th and 22nd January 2009 and comprised a combination of benthic sampling at five sampling stations for macrofaunal and physico-chemical analysis (using a 0.1 m^2 box corer) and water column profiling at a single station. A shallow hazards survey (acquisition of multibeam echo sounder, pinger and 2D high resolution seismic data) was conducted at the same time as the EBS and data obtained from this and from earlier borehole operations (which included ROV video footage) were also interpreted to assist with the environmental reporting.

Water depths in the study area ranged from approximately 1,305 m in the north-western corner to approximately 1,488 m at the base of a prominent escarpment in the central portion of area. The study area can be divided into two runs through the centre of the area. The western zone is generally characterised by smooth to slightly undulating seafloor topography, while the seafloor in the eastern zone is notably more irregular with a number of local peaks, depressions and scarps. The seabed sampling programs identified seafloor materials that predominantly consisted of fine to coarse sand, although areas of outcropping cemented material were identified from the geophysical and ROV data.

Levels of organic carbon were consistently low throughout the site, indicating minimal organic enrichment of the site's sediments. Hydrocarbon concentrations were also consistent and relatively low, although the concentrations seen in certain n-alkanes and polycyclic aromatic hydrocarbons suggested some diffuse petrogenic input to the site thought most likely to come from natural oil seeps. Heavy metal concentrations were low throughout the survey area, being found at levels thought typical for the types of sediments seen.

ROV data showed that a diverse, but patchily distributed, epifaunal community was present around the Loligo A and Loligo C borehole locations. The epifauna comprised seafans (gorgonians), hard corals (Scleractinia) and sponges (Porifera) and was restricted in distribution to areas of hard or consolidated substrate, these included the cobbles and boulders that were occasionally encountered and the areas of outcropping cemented sediment. An undifferentiated infaunal community occurred throughout the site, with no spatial distribution being evident within the infaunal data recorded. The infaunal community was dominated by polychaete worms, which contributed over 60% of the total number of species and over 80% of the total faunal abundance recorded.

Water column characteristics were thought typical of the region for the time of year, being closely comparable to those of the other sites surveyed to the east of the Falklands during the same survey programme. A distinct thermocline (layer of the water column in which temperature rapidly decreases) was evident between 50 m and 90 m depth, after which temperature gradually to a depth of 700 m, where there was a sudden, stepped increase in temperature, before the gradual decline in temperature with depth was resumed. The observed sudden increase in temperature at approximately 780 m depth was interpreted as evidence of a second body of water at this depth, extending to the seabed. Similar results were also observed at the nearby Loligo site. Dissolved oxygen saturation was shown to increase from the surface to approximately 50 m depth, before declining to the seafloor; the increase to supersaturated levels in the upper layer of the water column was thought to be due to planktonic photosynthesis. Little variation was evident in salinity, pH or turbidity.

SUMMARY OF SURVEY RESULTS

Central Point:

Geodetic Datum and Spheroid WGS84, TM (Southern Hemisphere) CM 60° W				
Location	**Easting [m]**	**Northing [m]**	**Latitude**	**Longitude**
Loligo	870 222.672	4 323 028.976	51° 07' 27.358" S	54° 42' 29.324" W

Study Area: A 26.2 km x 15.2 km survey grid orientated 339.5° / 69.5° with 15 main lines at 1500 m spacing and three cross lines at 7850 m spacing.

Environmental Survey Strategy: Seabed sampling was successfully undertaken at five stations (from 12 proposed stations) using a 0.1 m^2 box corer. Three samples including two faunal and one physico-chemical sample were retained at two stations while two macrofaunal replicates but no physico-chemical samples were obtained at stations 3 and 11. A physico-chemical sample, but no macrofaunal sample was obtained at station 8.

Water profiling was carried out at one location using a Valeport Midas 606+ CTD probe.

Video data obtained by ROV during bore hole operations at Loligo A and Loligo C were also analysed to assist with reporting.

Bathymetry: Water depths have been reduced to metres below Lowest Astronomical Tide (LAT).

Water depths in the study area ranged from approximately 1,305 m in the north-western corner to approximately 1,488 m at the base of a prominent escarpment in the central portion of area.

The study area can be divided into two distinct zones based on general seafloor morphology and character. The two areas are separated by a prominent escarpment that trends regionally north-northeast through the centre of the area; the gradient of this escarpment was commonly found to be around 20°, but locally exceeded 30°, with the depth increasing from approximately 1360 m to 1430 m. The western morphological zone was generally characterised by smooth to slightly undulating seafloor topography that sloped regionally down to the south-east at an average gradient of approximately 0.3 degrees. The seafloor in the eastern zone was notably more irregular in contrast to the western zone. Superimposed on the irregular topography were a number of local peaks, depressions and scarps.

Seabed Features: The evidence of the gravity coring, drilling and ROV programs suggested that seafloor materials predominantly consisted of fine to coarse sand or gravel throughout the area. These sediments may also have been cemented in parts of the area. The high-relief topographic features identified in the eastern morphologic zone may have represented uneroded remnants of locally harder or cemented seafloor materials.

Shallow Soils: In the 2D seismic data the base of Sequence I (Horizon 2) was identified as a prominent reflector throughout the western morphological zone. Sequence I sediments were largely absent from the eastern morphologic zone.

The BHP Billiton age dating program identified the sequence I sediments as largely Miocene, possibly with a very thin Pleistocene or Holocene cap. The sequence II sediments that were present at the surface throughout most of the eastern morphological zone ranged from the Oligocene to mid-Miocene.

Granulometry: Of the three stations successfully sampled for particle size analysis, all three stations showed similar levels of clay and silt particles. However only stations L2 and L4 had similar sediment types in which particles in the 1 phi unit to 3 phi unit (medium to fine sand) size range were particularly prevalent. The sediment sample acquired at L8 was observed to have a distinctly different sediment type, in which pebble particles (-2 to -4 phi units) were dominant. This sample had substantially lower proportions of both sand and fine material than stations L2 and L14. This would suggest similar oceanographic regimes at all stations with a thinner Holocene layer at L8

Organic Carbon: Both fractionated organic carbon (FOC) and total organic matter by loss on ignition (TOM by LOI) concentrations appeared relatively consistent across the sampling stations, the former ranging from 0.24% to 0.31% (stations L8 and L2, respectively) and the latter from 4.8% to 5.7% (stations L14 and L8, respectively).

Hydrocarbons Total hydrocarbon concentrations (THC) were relatively low at all stations, ranging from 2.3 $\mu g.g^{-1}$ to 4.2 $\mu g.g^{-1}$ (stations L2 and L14, respectively), though they were considered moderate given the remote nature of the site.

Total n-alkane and individual aliphatic concentrations reflected THC, but at their greatest at station L14. The lack of carbon-number preference in the n-alkanes was thought to be due to natural processes.

Total PAH concentrations showed the same general pattern as was observed for total hydrocarbons, with higher concentrations being recorded from stations L2 and L14 (133 $ng.g^{-1}$ and 162 $ng.g^{-1}$, respectively) than from station L8 (61 $ng.g^{-1}$). These levels of PAHs were lower than typical levels found in the North Sea and, given the remoteness of the region, these concentrations fall within expected levels.

Heavy / Trace Metals: The concentrations of heavy and trace metals were measured using inductively coupled plasma mass spectrometry following extraction by separate aqua regia and hydrofluoric acid (HF) digests. As would be expected given the differing stringency of the two extraction procedures, the concentrations measured by aqua regia digestion may suggest, to an extent, the level of biologically available metals, while concentrations measured by HF relate more to the total levels of metals present within the sediment.

The concentrations of heavy and trace metals at each station were lower than North Sea UKOOA values, indicating typical background levels for an unimpacted environment.

Macrofauna: The conspicuous epifauna observed from the ROV footage acquired at Loligo A and C were dominated by cnidarians. Gorgonians (sea fans and sea whips) were widely distributed and a hard coral, at least superficially similar to the cold water species *Lophelia pertusa*, was present as patchily distributed low relief thickets on consolidated sediment outcrops and scarps. The few areas of homogeneous muddy sand identified had no epifaunal cover. In certain areas (e.g. the depression adjacent to Loligo C) sparse epifaunal growth was seen from areas that appeared to be sand covered, as the colonies observed would have required hard attachment substrata. Insufficient data exists to classify the coral colonies as an Annex I habitat. Only one fish species could be identified with any confidence, the threadfin rockling *Gaidropsarus ensis* (or a close relative).

Of the dominant macrofaunal taxa identified from grab sample data, the vast majority were polychaetous annelids, the most abundant species being the onuphid *Kinbergonuphis oligobranchiata* and the ampharetid *Melinna* sp. 1. Crude abundance / dominance and univariate analyses of the infaunal data suggested that a single community occurred throughout the survey area. These findings were corroborated by the multivariate CLUSTER and SIMPROF analyses, which showed that all sample data could be grouped within a single statistically undifferentiated cluster.

Water Column Characteristics:

The surface temperature at the time of data collection was approximately 8.2°C and this remained relatively constant in the well mixed upper layers of the water column. Below this well mixed layer there was a distinct thermocline, before temperature decreased towards the seabed (where the minimum temperature of 2.9°C was recorded).

Salinity showed minimal variation throughout the water column, ranging from a minimum of 34.0 ppt at the surface to 34.5 ppt at the seabed. pH showed minimal variation throughout the water column, decreasing from approximately pH 8.3 at the surface to pH 8.1 at the seabed. Dissolved oxygen (DO) increased from a surface concentration of approximately 100% saturation (%sat.) to its maximum concentration of 123.2%sat. at around 50 m depth. It then decreased rapidly over the course of the thermocline, before gradually decreasing to the seabed (minimum concentration of 47.3%sat.).

The water column appeared to comprise two water masses, the uppermost layer extends from the sea surface down to approximately 750 m and was characterised by relatively warm and well oxygenated water. Under this layer was a water mass that extended from 750 m to the seabed and was characterised by colder, more saline water containing less dissolved oxygen than the overlying layer.

1. INTRODUCTION

1.1 Scope of Work

On the instructions of BHP Billiton Petroleum Falklands Corporation, Fugro Survey Limited (FSLTD) performed combined geophysical and environmental baseline surveys of four sites (Endeavour, Loligo, Nimrod and Toroa) offshore the Falkland Islands. The survey work was conducted from the vessel M/V Fugro Meridian during the period 5th December 2008 to 14th February 2009.

The geophysical surveys were required to identify and map potential drilling or rig installation hazards, occurring on or beneath the seabed, at the proposed locations. Specifically, this includes detection of shallow gas, determination of seabed topography and bathymetry, detection of shallow channelling or other shallow layers and identification of debris. This was achieved by a combination of wide scale bathymetric and sub-bottom profiling surveys across each site and closely spaced bathymetric, sub-bottom and 2D high resolution (2DHR) multichannel seismic acquisition to cover each of the proposed drilling locations. Bathymetric data were collected by simultaneous acquisition by multibeam and singlebeam echo sounders and sub-bottom data with a hull-mounted pinger. 2DHR seismic data were collected using a 96 channel 1200 m streamer and a six gun (140 cu. in.) source.

The environmental baseline surveys were required to provide baseline data relating to the physico-chemical and macrofaunal benthic environment, to characterise physical water column characteristics and to groundtruth features recorded by the multibeam echo-sounder data. The environmental surveys comprised sampling using a 0.1 m^2 box corer for benthic physico-chemical and macrofaunal analysis and water profiling using a deepwater conductivity, temperature and density probe (CTD) fitted with additional sensors to measure water column pH, dissolved oxygen (DO) and turbidity. ROV acquired seabed video data, obtained during earlier borehole operations at Loligo and Toroa, were also analysed to assist with characterisation of the benthic environment at these two sites.

An operations report (Report No. 9763 Volume 1) was produced by FSLTD following the completion of operations. FSLTD also produced separate environmental baseline survey reports for the four sites (Volumes 2 to 5). Fugro Geoconsulting Inc. (FGI) produced shallow hazards assessments for the four sites (Report Nos. 27.2008-2275, 27.2008-2273, 27.2008-2274 and 27.2008-2277).

This volume, Volume 2, details the results of the environmental baseline survey of the Loligo site, which was situated approximately 225 km to the east of Stanley, Falkland Islands in Falklands Island Designated Area (FIDA) block 42/02. The proposed well locations within the Loligo site are provided in Table 1.1.

Section 1 of this volume outlines the environmental survey strategy and Section 2 the field operations and results. Appendix A details the operations and methodologies, Appendix B the laboratory analysis and statistical methodologies, Appendix C the field personnel, Appendix D the field logs, Appendix E the particle size analysis results, Appendix F the hydrocarbon analysis, Appendix G the macrofauna analysis and Appendix H the correlations between different physico-chemical and macrofaunal parameters. The service warranty in Appendix I outlines the limitations of this report.

Table 1.1: Proposed Well Coordinates

Geodetic Datum and Spheroid WGS84, TM (Southern Hemisphere) CM 60° W				
Location	**Easting [m]**	**Northing [m]**	**Latitude**	**Longitude**
Loligo 1	870 830.50	4 326 381.00	36° 22' 13.76635" S	52° 10' 37.90747" W
Loligo 2	870 276.00	4 327 788.00	36° 22' 50.56175" S	52° 10' 55.83964" W
Loligo 3	869 710.00	4 329 238.00	36° 23' 28.47657" S	52° 11' 14.14371" W
Loligo A	871 791.00	4 317 440.50	36° 18' 19.84341" S	52° 10' 06.84553" W
Loligo B	869 714.25	4 320 783.00	36° 19' 47.32100" S	52° 11' 14.00627" W
Loligo C	868 559.75	4 325 684.00	36° 21' 55.53683" S	52° 11' 51.34205" W

1.2 Environmental Survey Strategy

Box corer sampling stations were selected for provision of environmental baseline data and as such six (stations L1 to L6) were located 50 m downstream (north-east) of the six proposed drilling locations. The remaining nine environmental sample locations were positioned to investigate the wider survey area, being situated in the extremes of the site and in areas of interest such as large depressions or potential habitat changes. The locations were selected by BHP Billiton (BHPB), Houston in conjunction with onboard FSLTD personnel using preliminary bathymetric data and MBES backscatter data for assessment of surface sediment type. The coordinates of the 15 box corer sampling locations originally proposed are provided in Table 1.2 and these are spatially displayed in Figure 2.1.

After consultation with the client after arrival on site the number of box corer sampling stations was reduced from 15 stations to 12 stations, the stations omitted from the campaign being stations L6, L7 and L9. Difficulties with sampling, which were thought to be due to coarse or consolidated sediments and / or strong currents, meant that only 11 samples were retained. Two replicates from four stations (stations L2, L3, L11 and L14) were completely screened over a 0.5 mm mesh and fixed for macrofaunal analysis. Single samples from three stations (stations L2, L8 and L14) were sub-sampled for physicochemical analysis.

In addition to the box corer sampling water profile data were collected at a single location (WCP120), the coordinates of which are provided in Table 1.2. At this station conductivity (to derive salinity), temperature, pressure (to derive depth), pH, dissolved oxygen (DO) and turbidity data were collected from the sea surface to just above the seabed.

Bore hole operations were conducted at the Loligo and Toroa sites between 8th December 2008 and 16th February 2009. Video data obtained by remotely operated vehicle (ROV) during this period were provided by Fugro Rovtech Ltd. and have been analysed to assist with the environmental baseline survey reporting. Data were obtained from the proposed locations Loligo A and Loligo C, adjacent to environmental stations L1 and L3.

Table 1.2: Proposed Sampling Locations

Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West				
Station	**Easting [m]**	**Northing [m]**	**Rationale**	**Samples / Data Collected**
L1	871 825	4 317 485	Approximately 50 m NE of Loligo A site.	NR / ROV
L2	869 745	4 320 825	Approximately 50 m NE of Loligo B site.	FA, FB, PC
L3	868 595	4 325 725	Approximately 50 m NE of Loligo C site.	FA, FB, ROV
L4	870 860	4 326 425	Approximately 50 m NE of Loligo 1 site.	NR
L5	870 310	4 327 830	Approximately 50 m NE of Loligo 2 site.	NR
L6	869 735	4 329 280	Approximately 50 m NE of Loligo 3 site.	NR
L7	862 330	4 331 585	Moderate to high amplitude sonic facies atop low amplitude, moderately reworked substrate.	NR
L8	871 680	4 329 980	Low amplitude sonic facies capping low amplitude, stratified depression fill material.	PC
L9	875 365	4 327 705	Low amplitude sonic facies atop homogenous re-worked soils in possible dune field.	NR
L10	869 655	4 324 380	Suspect this to be mounded reworked soils forming a dune within a large depression.	O
L11	868 840	4 323 370	Low amplitude sonic facies atop low amplitude, stratified depression fill material.	FA, FB
L12	871 215	4 319 870	Low to moderate amplitude sonic facies capping eroded, well-layered moderate amplitude substrate.	NR
L13	877 270	4 320 350	Moderate amplitude sonic facies atop reworked, low amplitude sediments, within possible dune field.	NR
L14	869 645	4 315 990	Moderate amplitude sonic facies atop low amplitude depression fill, below scarp.	FA, FB, PC
L15	874 170	4 313 245	Low to moderate amplitude sonic facies capping eroded, reworked low amplitude substrate.	O
WCP120	872 475	4 313 350	-	WP

ROV = ROV video footage; FA = fauna sample A; FB = fauna sample B; PC = physicochemical sample; WP = water profile; NR = no recovery; O = omitted from survey programme.

1.3 Comparative Data

Throughout this report comparison is drawn to data obtained from the other sites surveyed during the current survey program (Toroa, Endeavour and Nimrod). While both Endeavour and Nimrod were of broadly comparable sediment type, seabed topography and depth to the current survey area, it should be noted that the Toroa survey area was substantially shallower and was distinctly different in terms of both sediment type and seabed topography.

Pre- and post-drill surveys of FIDA 14/05 - B1 and FIDA 14/09 - Little Blue A (Gardline Surveys Limited, 1998a; Gardline Surveys Limited, 1998b) in the North Falkland Basin during February 1998 were undertaken in much shallower water depths than those of Loligo and were therefore considered unsuitable for comparison to the current survey data.

1.4 Survey Reference System

All coordinates provided in this report were referenced to the geodetic parameters provided in Table 1.3.

Table 1.3: Project Geodetic Parameters

Global Positioning System Geodetic Parameters [1)]	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984 (WGS84)
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	$^1/_f$ = 298.2572235630
Local Datum Geodetic Parameters [2)]	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984 (WGS84)
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	$^1/_f$ = 298.2572235630

Datum Transformation Parameters [2)] from WGS84 to WGS84								
Shift dX:	0.000	m	Rotation rX:	0.000	arcsec	Scale Factor:	0.000	ppm
Shift dY:	0.000	m	Rotation rY:	0.000	arcsec			
Shift dZ:	0.000	m	Rotation rZ:	0.000	arcsec			

Project Projection Parameters	
Grid Projection:	Transverse Mercator, Southern Hemisphere
UTM Zone:	N/A
Central Meridian:	60° 00' 00" West
Latitude of Origin:	00° 00' 00" S
False Easting:	500 000 m
False Northing:	10 000 000 m
Scale factor on Central Meridian:	0.9996
Units:	Metre

Notes:
1. Fugro Starfix navigation software always uses WGS84 geodetic parameters as a primary datum for any geodetic calculations.
2. This is the right-handed co-ordinate frame rotation convention used by the Fugro Starfix navigation software.

2. RESULTS

2.1 Field Operations

A total of 36 coring attempts were made at the 12 stations with only 11 good samples being retained (a 31% sampling success rate). Seven of the no-samples were due to the corer not triggering, four were retrieved with stones preventing spade closure (leading to sample washout), 12 returned little or no sediment and two attempts had to be aborted due to mechanical failure of the winch. A positioning tolerance of within a 50 m radius of the proposed location was agreed with the client prior to the start of the survey. The strong currents and water depth at the site meant however, that it was rarely possible to achieve this degree of accuracy and the client agreed to accept samples taken from outside the proposed radius of tolerance. The actual sampling coordinates are provided in Appendix D.1.

Of the 11 samples retained eight were processed for macrofaunal analysis, with paired replicates (samples FA and FB) being acquired from stations L2, L3, L11 and L14. The remaining three samples, which were acquired from stations L2, L8 and L14, were sub-sampled for physicochemical analysis.

Four water profiling attempts were made at LOLIGO WCP 120. The first two deployments returned erroneous data for several of the measured parameters, the second from last attempt acquired good data for all parameters except DO and the final attempt good data across all parameters.

2.2 Bathymetry and Seabed Morphology

The following text is taken from the Shallow Hazards Assessment produced by FGI (Report No. 27.2008-2273). A plot showing the survey area bathymetry is presented in Figure 2.1.

Water depths have been reduced to metres below Lowest Astronomical Tide (LAT) using predicted tidal data at Stanley, Falkland Islands, which lies approximately 230 km west-south-west of the Loligo site.

Water depths in the study area ranged from approximately 1,305 m in the north-western corner to approximately 1,488 m at the base of a prominent escarpment in the central portion of area. The study area can be divided into two distinct zones based on general seafloor morphology and character. The two areas were generally separated by a prominent escarpment (approximately 70 m in height) that trends regionally north-north-east through the centre of the area, although locally the trace of the escarpment is highly sinuous with an average gradient of 20° (locally exceeded 30° in places). The deepest water depths in the Loligo area occurred in a broad moat that follows the base of the escarpment. In the centre of the area, to the west of the main escarpment, the western morphologic zone is incised by a closed circular escarpment that forms the perimeter of a broad pit 85 m deep with an average diameter of about 2,700 m. The seafloor morphology inside the pit (1435 m) is similar to that of the eastern morphologic zone.

The western zone is generally characterised by smooth to slightly undulating seafloor topography that slopes regionally down to the south-east at an average gradient of approximately 0.3 degrees. No significant topographic features are observed in this zone.

The seafloor in the eastern zone, including the large circular pit, is notably more irregular in contrast to the western zone. Superimposed on the irregular topography are a number of local peaks, depressions and scarps. Seafloor gradients in the eastern zone are variable, mostly ranging between 0 and 5 degrees, but locally exceeding 20 degrees on some of the more prominent topographic features.

2.3 Seabed Features

The following text is taken from the Shallow Hazards Assessment produced by FGI (Report No. 27.2008-2273). Screen grabs of ROV footage showing certain seabed features are presented in Figure 2.2.

The evidence of the gravity coring, drilling and ROV programs suggested that seafloor materials predominantly consisted of fine to coarse sand (Figure 2.2, Plate 1) or gravel throughout the area. These sediments also appeared to have been cemented in parts of the area. The 2D seismic data indicated that properties of these sediments, such as consolidation, degree of cementation and/or grain size, were probably variable. In particular, the high-relief topographic features identified in the eastern morphologic zone may have represented uneroded remnants of locally harder or cemented seafloor materials.

ROV footage showed that variable proportions of rock material, ranging in size from pebbles to small boulders, were present at the proposed Loligo A and Loligo C locations (Figure 2.2, Plates 2 and 3) and the ROV recovered a number of very dense rocks with a rounded shape from these areas. Analysis of these rocks suggested that they may have been transported by icebergs before being dropped to the seafloor (BHPB, 2009). The green and black sand seen in the samples was determined to be glauconite (see Figure 2.3).

The ROV footage obtained from the depression adjacent to the Loligo C location identified a scarp of consolidated (or possibly cemented) material below the scarp (Figure 2.2, Plate 6), and boulder size fragments and / or outcrops of the same material were also identified within the depression (Figure 2.2, Plate 5). Analysis of rock samples recovered by the ROV indicated that the rock had formed in situ. These rocks had a low density and contained high concentrations of volcanic ash, diatoms and glauconite. Geophysical data indicated that this type of rock may underlie a thin surficial sand across the entire western morphologic zone and contributed to the smooth, uneroded nature of the seafloor. The patchily distributed, but locally dense epifaunal growth within the depression and surrounding its rim also suggested that consolidated sediments underlay a surficial veneer of sand in places (Figure 2.2, Plate 4).

2.4 Shallow Soils

The following text is taken from the Shallow Hazards Assessment produced by FGI (Report No. 27.2008-2273).

In the 2D seismic data the base of Sequence I (Horizon 2) was identified as a prominent regional reflector that was mapped throughout the western morphologic zone. Sequence I and Horizon 2 are absent in most of the eastern morphologic zone, including specifically at the location of the Loligo-A (alt) boring. In the eastern zone, Sequence I sediments appeared to be present only in the topographically higher areas. The thickness of sequence I ranged from less than a metre in the eastern morphologic zone to 44 m below the topographic high in the depression to the south-east of Loligo C.

The Loligo-C boring identified the sediments in Sequence I (below the near surface rock) as fine sand with some pockets of silt and clay. Some cemented pockets were also observed. The BHPB age dating program indicated that these sediments date mostly from the Miocene, possibly with a very thin Pleistocene/Holocene cap.

The upper unit of Loligo C Sequence II, which outcropped throughout the eastern morphologic zone, was identified from the borings as medium dense elastic silt. This sequence was sampled at the seafloor by the Loligo A-alt boring. The BHPB age dating analysis suggested that these sediments range from the Oligocene to Mid-Miocene.

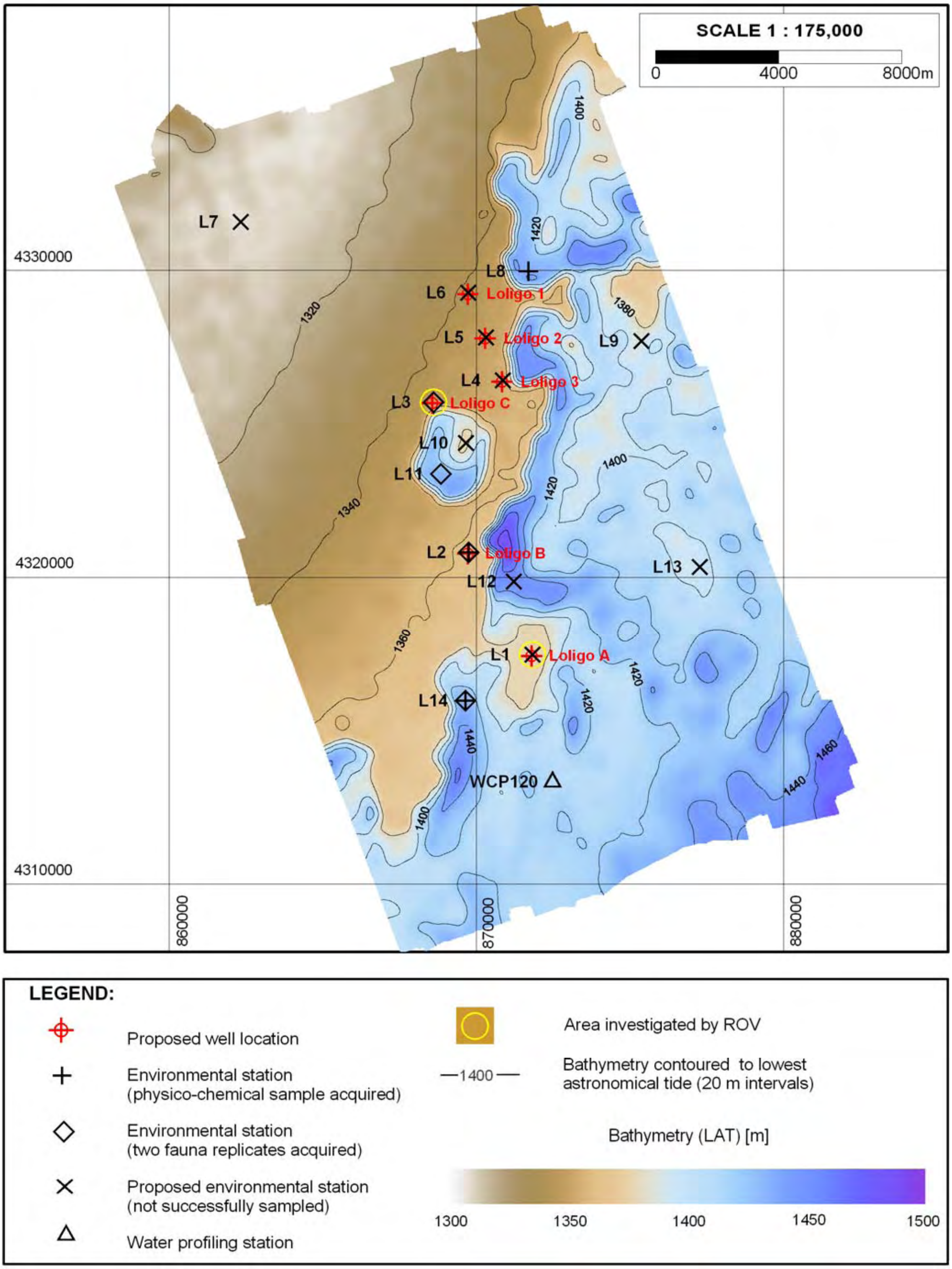

Figure 2.1: Survey Bathymetry Showing Sampling Locations

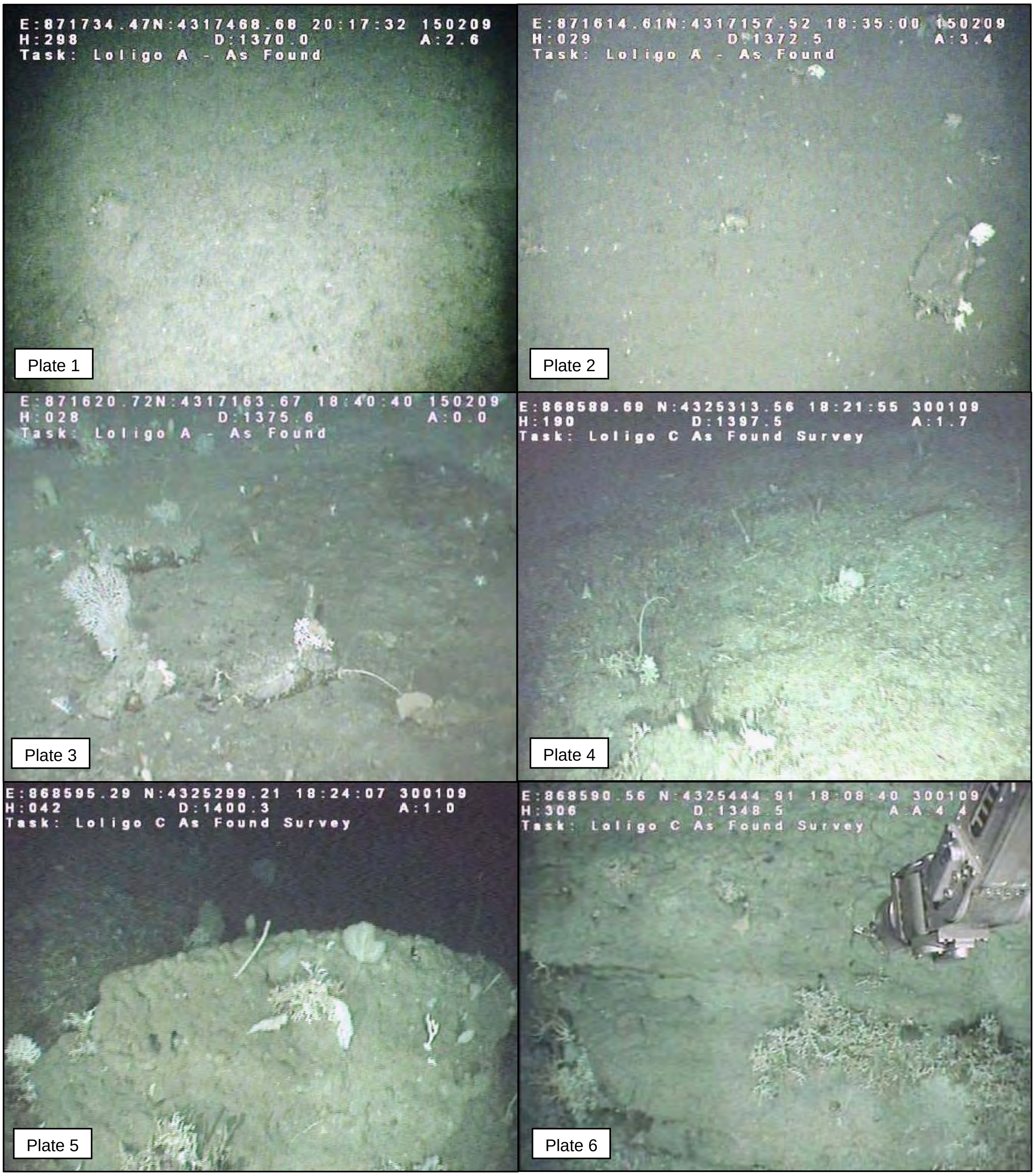

Plate 1: Homogeneous muddy fine sand in the vicinity of the proposed Loligo A location

Plate 2: Muddy fine sand with some coarse material (pebbles and gravel) in the vicinity of the proposed Loligo A location

Plate 3: Muddy fine sand with a moderate proportion of coarse material in the vicinity of the proposed Loligo A location

Plate 4: Low-relief sand covered hard material in the depression near Loligo C

Plate 5: A boulder or isolated outcrop of consolidated material in the depression near Loligo C

Plate 6: The sheer scarp of consolidated material bordering the depression near Loligo C

Figure 2.2: Screen Grabs of ROV Footage, Showing Notable Seabed Features

2.5 Particle Size Distribution

Particle size analysis (PSA) was performed using wet sieving techniques and laser diffraction. Results are summarised in Table 2.1, with a description of the sediment type of each sample also given based on the Wentworth Classification (Buchanan, 1984). The particle size distributions of the three samples analysed are shown in Figure 2.3, alongside photographs of the samples themselves, and key parameters are spatially represented in Figure 2.4 and Figure 2.5. The full dataset is presented in Appendix E.

Table 2.1: Summary of Particle Size Analysis

Station		Depth [m]	Mean [µm]	Mean Phi	Sorting	Coarse [%]	Sand [%]	Fines [%]	Graphical Mean / Wentworth
L2		1365.0	178.6	2.49	1.84	1.8	79.7	18.5	Poorly sorted fine sand
L8		1438.0	4911.9	-2.30	2.84	73.5	21.2	5.3	Very poorly sorted
L14		1434.0	137.4	2.86	2.19	2.0	71.7	26.3	Very poorly sorted fine
Current Survey	Mean	1412.3	1742.6	1.02	2.29	25.7	57.5	16.7	Very poorly sorted medium sand
	SD	41.0	2744.8	2.88	0.51	41.3	31.7	10.6	
Endeavour	Mean	1372.0	156.5	2.71	2.34	4.3	69.1	26.5	Very poorly sorted fine sand
	SD	23.1	35.9	0.36	0.24	4.7	4.7	4.6	
Nimrod	Mean	1283.7	179.3	2.51	2.31	6.2	71.3	22.6	Very poorly sorted fine sand
	SD	13.7	37.3	0.30	0.32	4.0	5.4	3.9	
Toroa	Mean	620.0	31.4	5.00	1.54	0.0	22.2	77.8	Poorly sorted coarse silt
	SD	43.9	1.7	0.08	0.01	na	1.9	1.9	

Granulometry definitions: coarse material: >2 mm; sand: 63 µm to 2 mm; fines: <63 µm. SD: Standard deviation.

Examination of the sample photographs (examples of which are provided in Figure 2.3) suggested that similar sediments occurred at all of the stations that were successfully sampled. The field logs (Appendix D.2) described all samples as comprising a surficial layer of silty fine sand of a predominantly light olive grey colour (Munsell classification 5Y / 2 / 6), but with black sand particles. In most samples this was shown to overly coarser (gravel and pebble) material in a matrix of similar sands. The difficulty in obtaining samples from the majority of stations may have been at least partially due to the lack of the corer's ability to penetrate these coarse underlying sediments, or to sample washout on recovery when such sediments stuck in the corer spades. It is however also possible that lack of sampling success was also due to the presence of very consolidated (or cemented) sediments, as seen from sections of the ROV footage (Figure 2.2).

Of the three stations successfully sampled two (stations L2 and L14) appeared to have similar sand dominated sediment types in which particles in the 1 phi unit to 3 phi unit (medium to fine sand) particle size range were particularly prevalent. The particle size distributions of these stations also showed a clearly elevated tail through the fines range (> 4 phi units), which equated to proportions of fine material of 18.5% and 26.3% for stations L2 and L14, respectively.

The sample acquired at station L8 was shown to have a distinctly different sediment type, in which pebble (-2 phi unit to -4 phi unit) particles were dominant. This sample had substantially lower proportions of both sand and fine material than stations L2 and L14. This is most likely due to the presence of a thinner Holocene sand layer in the vicinity of station L8, however it is also possible that its differing composition resulted from the sampling technique employed. Examination of the photographs of sample L8 PC showed that it was a small sample (> 10 cm deep), which may have partially 'washed out' on recovery (Figure 2.3). This may have resulted in the loss of both the surface material and of the muddy sand matrix that accompanied the underlying gravel and pebble layer. The small amount of (presumably surficial) sand material present in sample L14 PC appeared similar to the surface sediments of the other samples.

The particle size data from stations L2 and L14 were very similar to those of stations from the comparably deep sites sampled during the survey program (Endeavour and Nimrod), whose sediments also comprised muddy medium and fine sands. The sediments of the shallower Toroa site were shown to be very different from those of the deeper sites, comprising poorly sorted silts with minimal sand and no coarse material (Table 2.1). The sample from station L8 was shown to be very different from all of the other samples acquired. The inter-relationships between the stations sampled at the different sites were further explored using multivariate statistical analysis (Section 2.5.1).

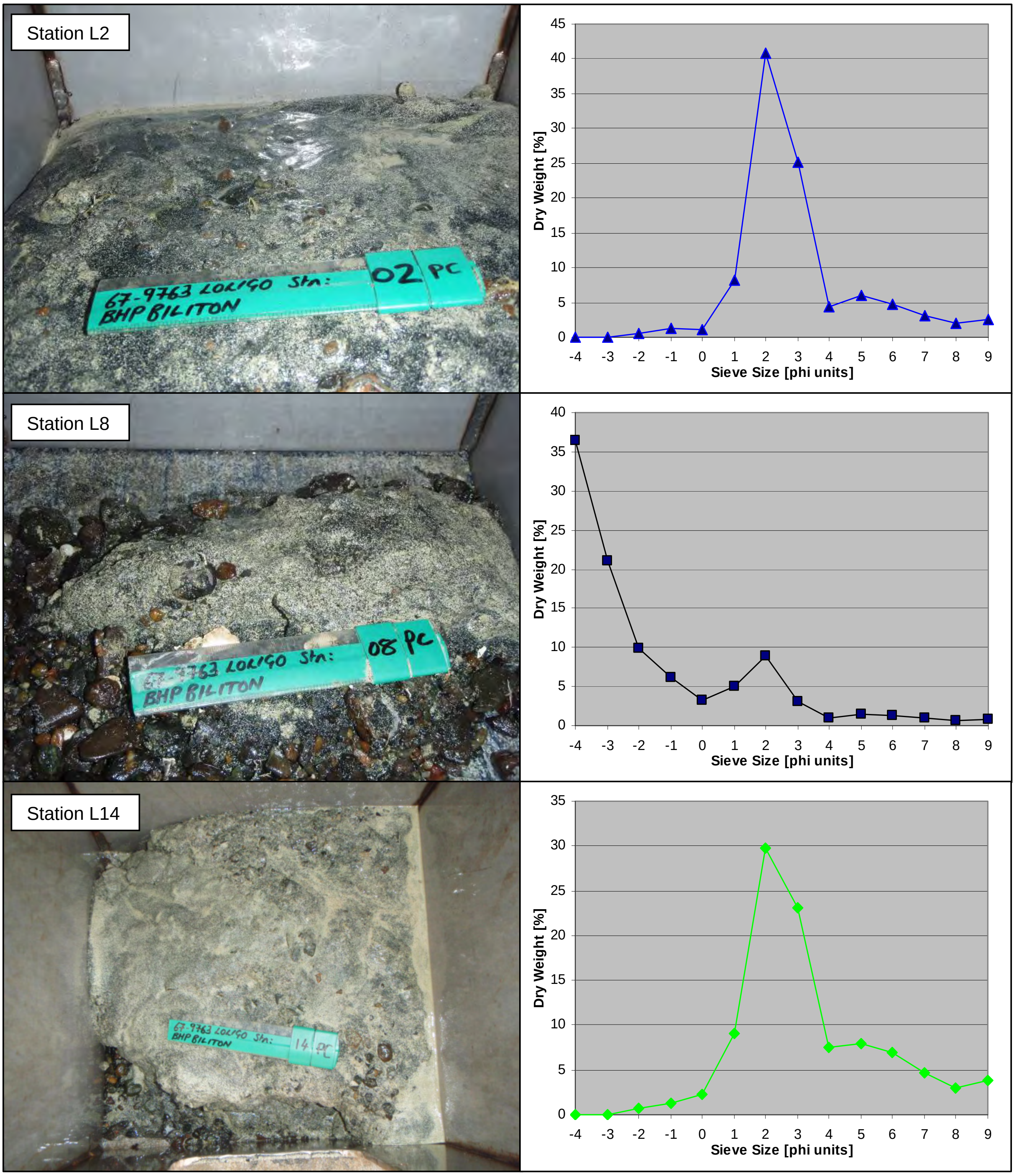

Figure 2.3: Particle Size Analysis – Sample Photographs and Particle Size Distributions

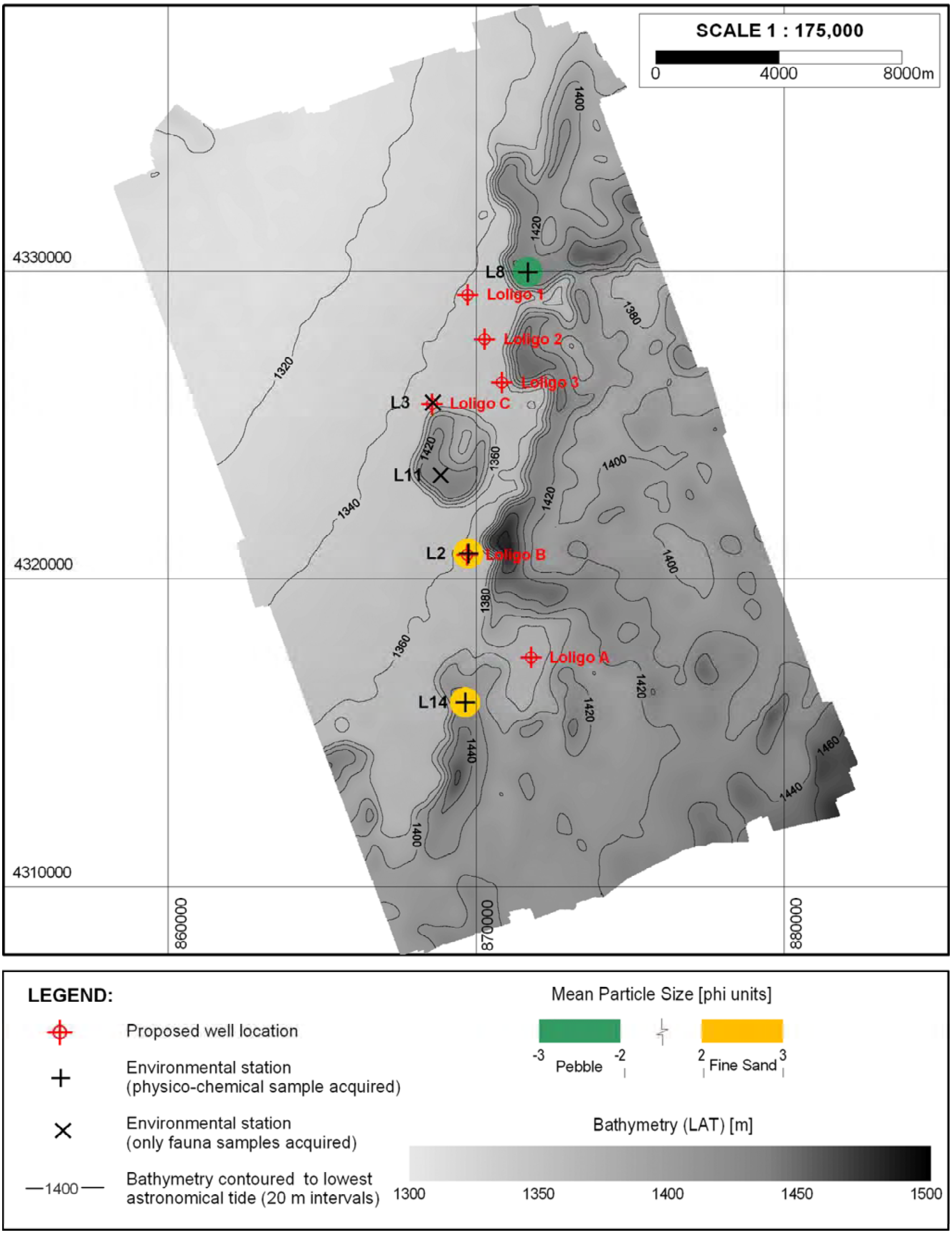

Figure 2.4: Particle Size Analysis – Mean Phi

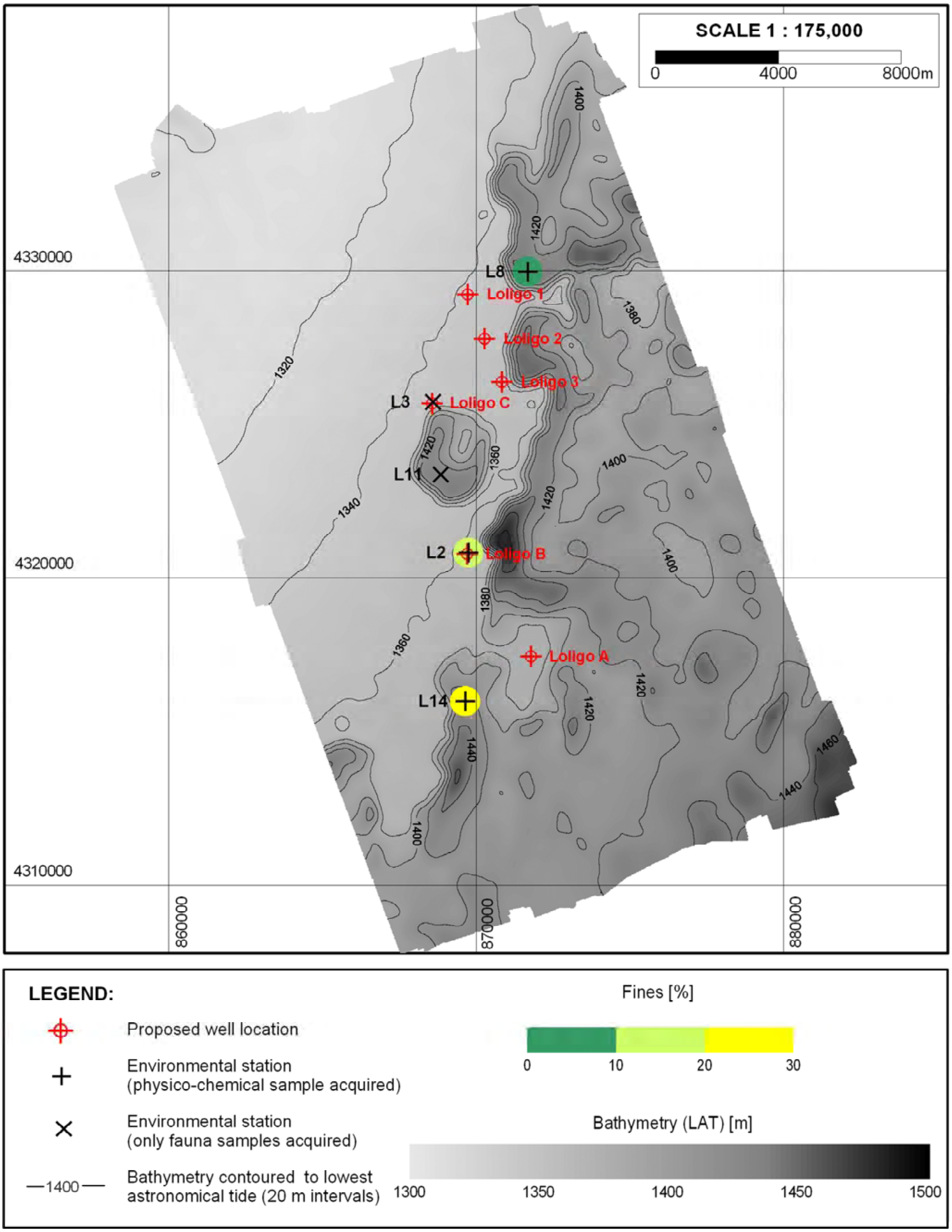

Figure 2.5: Particle Size Analysis – Fines

2.5.1 Multivariate Analysis

An overarching multivariate analysis of all of the sample data was used to further explore relationships between samples acquired at different sites over the course of the survey program.

Analysis was undertaken using the Plymouth Routines in Multivariate Ecological Research (PRIMER) v6.0 statistical package (Clarke & Gorley, 2006). The data were aggregated at 1 phi unit sieve size classes before being analysed using two techniques – cluster analysis, which outputs a dendrogram displaying the relationships between data based on the Bray-Curtis similarity measure and non-metric multi-dimensional scaling (nMDS) in which the data are ordinated as a 2-dimensional "map".

The dendrogram displayed in Figure 2.6 shows patterns in untransformed particle size data similarities. The PRIMER v6.0 similarity profiling (SIMPROF) algorithm was used to identify statistically significant differences between the data ($P = 0.05$), with statistically significant splits shown as black lines and non-significant splits as red lines. Examination of the relationships identified by SIMPROF suggested that the algorithm may have over differentiated the data, as such a slice was overlain on the plot (at a Bray-Curtis similarity of 80%) to differentiate two clusters (clusters A and B) and a single outlier (station L8), which would have been differentiated at a higher significance level ($P < 0.05$). Cluster A comprised all of the stations sampled at Toroa and cluster B all of the stations at Loligo, Endeavour and Nimrod, with the exception of station L8 (the outlier).

The nMDS analysis conducted (not shown) also clearly differentiated the clusters and outlier with minimal stress (stress value of 0.01). The high degree of difference between the clusters and outlier resulted in the stations which comprised each cluster being almost indistinguishably superimposed upon each other.

Examination of the sample photographs clearly supported the findings of these analyses, with all of the samples from the deeper sites appearing similar. The identification of station L8 as an outlier may again suggest that the sample had been disturbed on recovery, as speculated in Section 2.5.

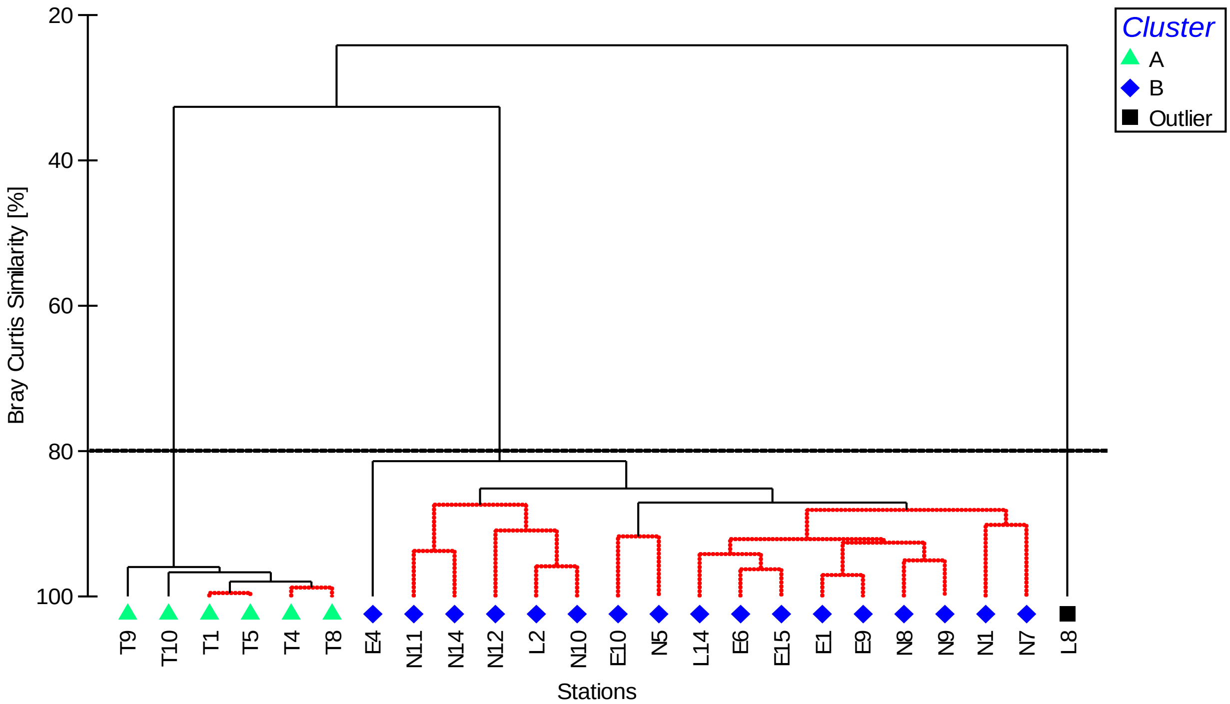

Figure 2.6: Dendrogram by Bray-Curtis Similarity of Particle Size Data for 1 Phi Unit Size Classes

2.6 Organic Carbon Analysis

Organic matter, primarily comprising detrital matter and naphthenic materials i.e. carboxylic acids and humic substances, performs an important role in marine ecosystems providing a source of food for suspension and deposit feeders, which may then be predated by carnivores. This has led to the suggestion that variation in benthic communities is, in part, caused by the availability of organic carbon (Snelgrove & Butman, 1994). Organic carbon is also an important adsorber (scavenger) of heavy metals and may be of use in interpreting the distribution of metals (McDougall, 2000).

Loss on ignition (LOI) provides a rapid and inexpensive means of determining the organic contents of clay-poor calcareous sediments and rocks with precision and accuracy comparable to other, more sophisticated geochemical methods (Dean, 1974). However LOI is generally considered a coarse indication of total organic matter (TOM) in sediments and is subject to errors. The first source of error to consider is over-estimation of organic content, due to loss of non-organic substances at 450°C; these include water of crystallisation, volatile oxides and carbonates, especially magnesium carbonate and the bodies of living organisms. Another source of error is the initial drying of the sample at 50°C. This process will drive off volatile hydrocarbons before the pre-ignition weighing, and hence act to reduce the TOM figure.

Table 2.2: Summary of Organic Carbon Analyses

Station		Fines [%]	Fractionated Organic Carbon [% Carbon]	Total Organic Matter [% Loss on Ignition]
L2		18.5	0.31	5.4
L8		5.3	0.24	5.7
L14		26.3	0.26	4.8
Current Survey	Mean	16.7	0.27	5.3
	SD	10.6	0.04	0.5
Endeavour	Mean	26.5	0.36	4.8
	SD	4.6	0.04	0.5
Nimrod	Mean	22.6	0.27	6.8
	SD	3.9	0.02	0.8
Toroa	Mean	77.8	0.73	6.0
	SD	1.9	0.05	0.8

SD = standard deviation of dataset

Both FOC and TOM concentrations appeared relatively consistent across the sampling stations, the former ranging from 0.24% to 0.31% (stations L8 and L2, respectively) and the latter from 4.8% to 5.7% (stations L14 and L8, respectively). There was no spatial pattern evident in either measure across the site, although FOC appeared to mirror fines content to some degree.

Comparison with the data collected from the other survey sites showed that FOC concentrations were similar to those of the sediments at the comparably deep Endeavour and Nimrod sites, but far lower than at the shallower Toroa site. This appeared likely to be the result of differences in sediment type as Toroa had a finer silt-dominated sediment. A correlation calculated using the Pearson's product moment coefficient identified a highly statistically significant correlation ($P < 0.01$) between FOC and fines content across the four sites. No comparable trend was evident in TOM concentration across the wider survey area, suggesting that variable amounts of inorganic carbon were present, biasing the results of TOM analyses.

2.7 Hydrocarbon Analysis

Hydrocarbon concentrations (total hydrocarbon concentrations, total n-alkanes and carbon preference index (CPI)) are summarised for each station in Table 2.3, while values for individual n-alkanes are given in Table 2.4. Gas chromatography (GC) traces showing the aliphatic hydrocarbon traces for each station and labelled with individual n-alkanes (nC_{12-36}) are contained in Appendix G.1. The isoprenoid hydrocarbons, pristane (Pr, IP18) and phytane (Ph, IP19) are marked together with the internal standards heptamethylnonane (A), D34 hexadecane (B), chlorooctadecane (C) and squalane (D).

As there is currently no oil and gas production or processing underway in the vicinity of the survey area, minimal data are available regarding background hydrocarbon. The sites remoteness from land would suggest minimal terrestrial influence and what hydrocarbons did occur would therefore most likely be from autochthonous (*in situ*) sources. The hydrodynamic regime of the site is largely under the influence of the Malvinas / Falkland Current, a northerly flowing branch of the Circumpolar Current that introduces cold water (mean sea surface temperature of 6°C) to the area (Gyory *et al*, 2009). As well as meaning that minimal inputs from terrestrial sources (both natural and anthropogenic) are likely to occur at the site, the high productivity resulting from this Antarctic influence may result in comparatively high hydrocarbon inputs from planktonic organisms.

Understandably, much of the previous research into hydrocarbon inputs to the marine environment has been focused on areas where oil and gas production is underway or where there are significant terrestrial inputs to the marine environment. This research has led to the development of industry standard ratios for comparing petrogenic and biogenic hydrocarbon inputs such as the carbon preference index (CPI) and the pristane / phytane ratio. Although these analyses are included in this report, they are only intended to be used as baseline measures (to be compared to post-drill monitoring data) and cannot realistically be compared with ratios measured in less remote and / or more highly developed marine systems.

Table 2.3: Summary of Hydrocarbon Concentrations [$\mu g.g^{-1}$ dry weight]

Station		Fines [%]	THC	n-Alkanes (nC_{12-36})	UCM	CPI			Pr	Ph
						nC_{12-20}	nC_{21-36}	nC_{12-36}		
L2		18.5	2.3	0.20	1.6	0.90	1.44	1.17	0.025	0.007
L8		5.3	2.5	0.23	1.5	0.95	0.97	0.96	0.023	0.008
L14		26.3	4.2	0.31	2.9	1.05	1.09	1.07	0.037	0.013
Current Survey	Mean	16.7	3.0	0.25	2.0	0.97	1.17	1.07	0.028	0.009
	SD	10.6	1.0	0.06	0.8	0.08	0.24	0.11	0.008	0.003
Endeavour	Mean	26.5	5.4	0.41	3.2	0.98	1.02	1.01	0.036	0.008
	SD	4.6	1.0	0.06	0.6	0.07	0.09	0.08	0.009	0.003
Nimrod	Mean	22.6	3.7	0.31	2.4	0.95	1.01	0.99	0.031	0.009
	SD	3.9	0.3	0.05	0.3	0.05	0.08	0.05	0.003	0.002
Toroa	Mean	77.8	8.7	0.65	5.7	1.16	1.12	1.12	0.086	0.021
	SD	1.9	1.1	0.09	0.6	0.03	0.24	0.13	0.007	0.003

THC = total hydrocarbon concentration; UCM = unresolved complex mixture; CPI = carbon preference index (ratio of the sum of odd- to the sum of even-carbon alkanes); Pr = pristane; Ph = phytane; and SD = standard deviation.

2.7.1 Total Hydrocarbon Concentrations

Total hydrocarbon concentrations (THC) were moderate throughout the stations, ranging from 2.3 $\mu g.g^{-1}$ to 4.2 $\mu g.g^{-1}$ (stations L2 and L14, respectively). There was no clear relationship between the proportion of fine sediments and THC, though the highest recorded concentration at station L14 may suggest that areas with higher proportions of finer particles (with which higher levels of hydrocarbons are often associated; Benson and Essien, 2009) may have higher THC. Although low in comparison to background data in other parts of the world, these concentrations were perhaps higher than would be expected from a pristine site with no petrogenic inputs. The levels recorded suggested diffuse petrogenic input to the sites, possibly from natural oil seeps, and this was supported by the following analyses of n-alkane and polycyclic aromatic hydrocarbon (PAH) concentrations (Sections 2.7.2 and 2.7.4). The levels of THC significantly correlate with FOC, suggesting that THC may also relate to plankton in the water column.

The Loligo stations had the lowest mean THC of the four sites surveyed (Table 2.3). The highest THC was recorded from the shallow, muddy Toroa site and the second highest level from Endeavour. This trend appeared likely to relate to the fines content of the sites' sediments, with a highly statistically significant Pearson's product moment correlation ($P < 0.01$) being calculated between THC and fines when all four sites were considered together. This correlation remained highly significant ($P < 0.01$) when only the three deep sites were considered.

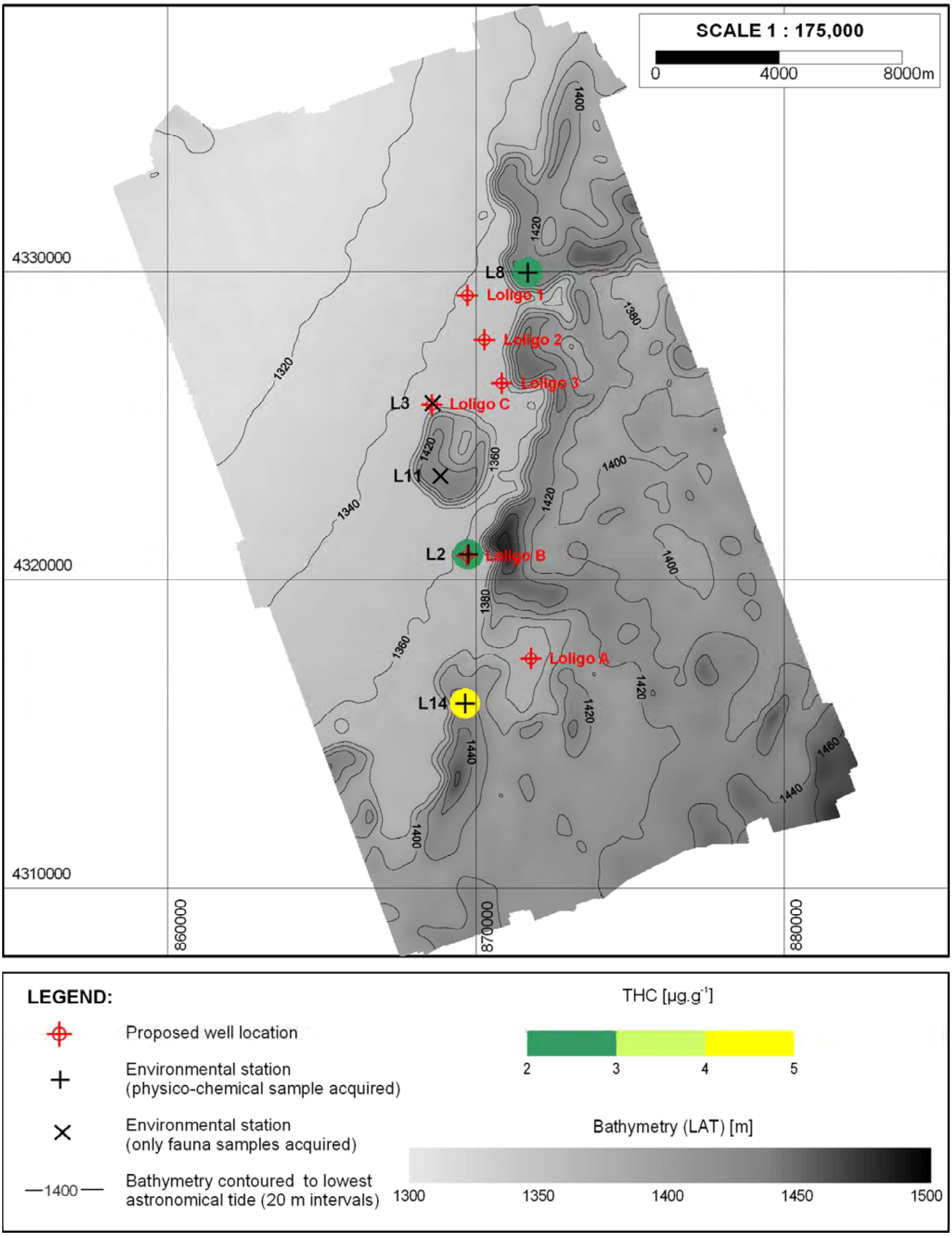

Figure 2.7: Hydrocarbon Analysis – Total Hydrocarbon Concentration [µg.g^{-1}]

2.7.2 Alkanes

Concentrations of individual alkanes are shown in Table 2.4 and the alkane distribution at station L14 is shown graphically in the GC trace in Figure 2.8.

N-Alkanes

Total n-alkane and individual aliphatic concentrations reflected THC in generally being low, though greater than expected given the remote nature of the survey site.

Examination of the distributions of in n-alkane concentrations is frequently used to assess inputs of hydrocarbons to the marine environment. Marine phytoplankton have been shown to preferentially synthesize short-chain, odd carbon numbers (nC_{15-21}) (Blumer *et al.*, 1971) whereas terrestrially-derived n-alkanes from the wax cuticles of higher plants typically comprise long-chain, odd carbon number n-alkanes (nC_{25-33}) (Eglinton *et al*., 1962). Given the remote location of the survey area, any terrestrial inputs into the marine environment would be very limited. The even distributions found in the n-alkanes in the nC_{15-21} range may indicate the co-occurrence of inputs from zooplankton, which are known to preferentially synthesise even carbon number n-alkanes in this range, along with the odd carbon number inputs from phytoplankton (Hauschildt *et al*, 1999).

While the distributions recorded from the three sampling stations appeared similar in most aspects, the station L8 and L14 data exhibited distinct spikes at nC_{36} of 24.7 $ng.g^{-1}$ and 28.1 $ng.g^{-1}$, respectively, which at both stations dwarfed inputs from any other single n-alkane. Only a slight increase at this chain length was evident at station L2 (5.4 $ng.g^{-1}$). Hauschildt *et al* (1999) postulated that the presence of long chain n-alkanes (nC_{36} and above) in benthic sediments may indicate the incorporation of biomass from coccolithophores (calcified phytoplankton). During December 2008 (and at the same time of year for at least the last ten years) extensive coccolithophore blooms have been documented on the Patagonian shelf (Balch, 2009); it is likely that inputs from these may have entered the benthic environment at Loligo.

Carbon Preference Index

The carbon preference index (CPI) is used to assess the relative contribution from petrogenic and biogenic sources in hydrocarbon samples and is determined by calculating the ratio of the sum of odd- to the sum of even-carbon alkanes. The range of alkanes from nC_{21-36} is of particular interest as odd carbon n-alkanes from terrestrial plants elute in this region. Pristine sediments exhibiting a predominance of odd number biogenic alkanes might be expected to have a CPI value of greater than 2.0, while crude oil or refined products show no preference for odd or even n-alkanes and achieve a CPI close to unity (1.0) (McDougall, 2000). Some caution should probably be applied when assessing inputs using this measure however as naturally occurring mature organic matter can show no carbon number preference and even-carbon number preferences have been identified as the result of natural (current or relic) events such as anoxia or hypersalinity (Chaler *et al*, 2005). Where n-alkanes are present at low levels the CPI ratio is also very susceptible to bias resulting from minor natural variations in individual n-alkane concentrations.

Examination of CPI in the context of the current survey area may not be appropriate as it is largely reliant on the presence of odd-carbon number n-alkanes from the cuticular waxes of terrestrial plants to offset petrogenic inputs with no carbon number preference. As the site is a considerable distance from land and is subject to a largely Antarctic hydrodynamic regime which would thus limit terrestrial plant inputs, CPI should only be considered as a baseline measure to which post-drill data could be compared at a later date.

CPI ratios for all n-alkanes across the site were close to unity, ranging from 0.96 at station L8 to 1.17 at station L2; the high concentrations of nC_{36} measured at stations L8 and L14 strongly biased the CPI of these stations towards unity.

Pristane and Phytane

Pristane and phytane are isoprenoid alkanes which are common constituents of crude oils. However, phytane is generally absent or only present at low levels in uncontaminated natural systems (Blumer and Snyder, 1965). A presence of both isoprenoids at similar levels is typically taken as an indication of petroleum contamination. It should be noted however that interpretation of the pristine / phytane ratio is difficult due to its erratic nature. The low concentrations of these isoprenoid alkanes mean that relatively insignificant changes in concentrations only marginally above the limit of detection can produce substantial changes in ratio values. This, coupled with evidence for the natural occurrence of phytane in older sediments and the confusing variation of sedimentary pristane (induced by variability in phytoplankton numbers) (Blumer and Snyder, 1965), cast doubt on the reliability of this index. As a consequence, the pristane / phytane ratio should only be used to corroborate the findings of more reliable measures.

Pristane concentration ranged from 22.7 $ng.g^{-1}$ to 37.1 $ng.g^{-1}$ (stations L8 and L14, respectively) and phytane concentration from 7.2 $ng.g^{-1}$ to 12.9 $ng.g^{-1}$ (stations L2 and L14, respectively). Although pristane was found at far higher concentrations than phytane, the latter was still recorded at levels which would be considered high for background stations in more highly developed parts of the world. The very high concentrations of pristane seen may have resulted from the incorporation of crustacean zooplankton biomass into the sites sediments. In a laboratory experiment Avigan and Blumer (1968) demonstrated the ability of copepods of the genus *Calanus* to convert phytol (a diterpenyl alcohol found in the phytoplankton on which they feed) to pristane. They suggested that synthesis of pristane by calanoid copepods (which often dominate zooplankton populations) may be the most important source of the isoprenoid in both animal tissues and geological formations.

Table 2.4: Individual Aliphatic Concentrations [ng.g^{-1} – dry weight]

N-Alkane [ng.g^{-1}]	Station		
	L2	L8	L14
nC_{12}	4.5	6.0	5.7
nC_{13}	5.9	7.5	9.1
nC_{14}	7.3	6.9	9.1
nC_{15}	13.2	13.7	20.6
nC_{16}	12.2	10.5	14.8
nC_{17}	9.7	10.2	14.5
nC_{18}	11.1	10.9	14.9
nC_{19}	11.5	9.8	14.8
nC_{20}	9.6	9.0	11.8
nC_{21}	12.9	10.5	15.3
nC_{22}	8.4	7.6	11.9
nC_{23}	7.0	6.3	10.2
nC_{24}	7.2	6.7	9.5
nC_{25}	7.6	8.5	12.4
nC_{26}	7.3	12.9	11.2
nC_{27}	9.9	10.2	14.2
nC_{28}	6.2	7.2	10.5
nC_{29}	9.7	13.9	18.2
nC_{30}	4.0	4.8	7.8
nC_{31}	11.5	15.4	21.2
nC_{32}	5.2	7.1	8.9
nC_{33}	5.1	6.9	8.5
nC_{34}	1.7	4.5	6.3
nC_{35}	1.7	1.8	2.2
nC_{36}	5.4	24.7	28.1
Pristane	24.9	22.7	37.1
Phytane	7.2	8.4	12.9
THC [µg.g^{-1}]	2.3	2.5	4.2
UCM [µg.g^{-1}]	1.6	1.5	2.9
Total n-Alkanes [µg.g^{-1}]	0.20	0.23	0.31
CPI (nC_{12-20})	0.90	0.95	1.05
CPI (nC_{21-36})	1.44	0.97	1.09
CPI (nC_{12-36})	1.17	0.96	1.07

THC = total hydrocarbon concentration; UCM = unresolved complex mixture; CPI = carbon preference index (ratio of the sum of odd- to the sum of even-carbon alkanes).

2.7.3 Gas Chromatogram (GC) Traces

An example GC trace (station L14) is provided in Figure 2.8 and plots for the remaining stations are presented in Appendix F.

Inspection of the GC traces (in conjunction with the individual n-alkane values in Table 2.4) showed a low level homologous series of n-alkanes from approximately nC_{13-24} at all stations, possibly indicative of petrogenic inputs from natural oil seeps (see Figure 2.8 and Appendix F). The odd-carbon dominated series of n-alkanes in the nC_{25-31} range were also evident, being superimposed over this homologous series. The elevated concentrations of nC_{36} noted at stations L8 and L14, which may have related to inputs of coccolithophore biomass, were also clearly evident as a spike on the GC traces.

A low level unresolved complex mixture (UCM) was evident in all traces in the range nC_{28-35}, the UCM largely comprises weathered hydrocarbons (which can be either natural or anthropogenic in origin) that cannot be resolved by the GC. The low level UCM apparent on the Nimrod traces (Figure 2.8 and Appendix F) was consistent with the undeveloped, remote nature of the site.

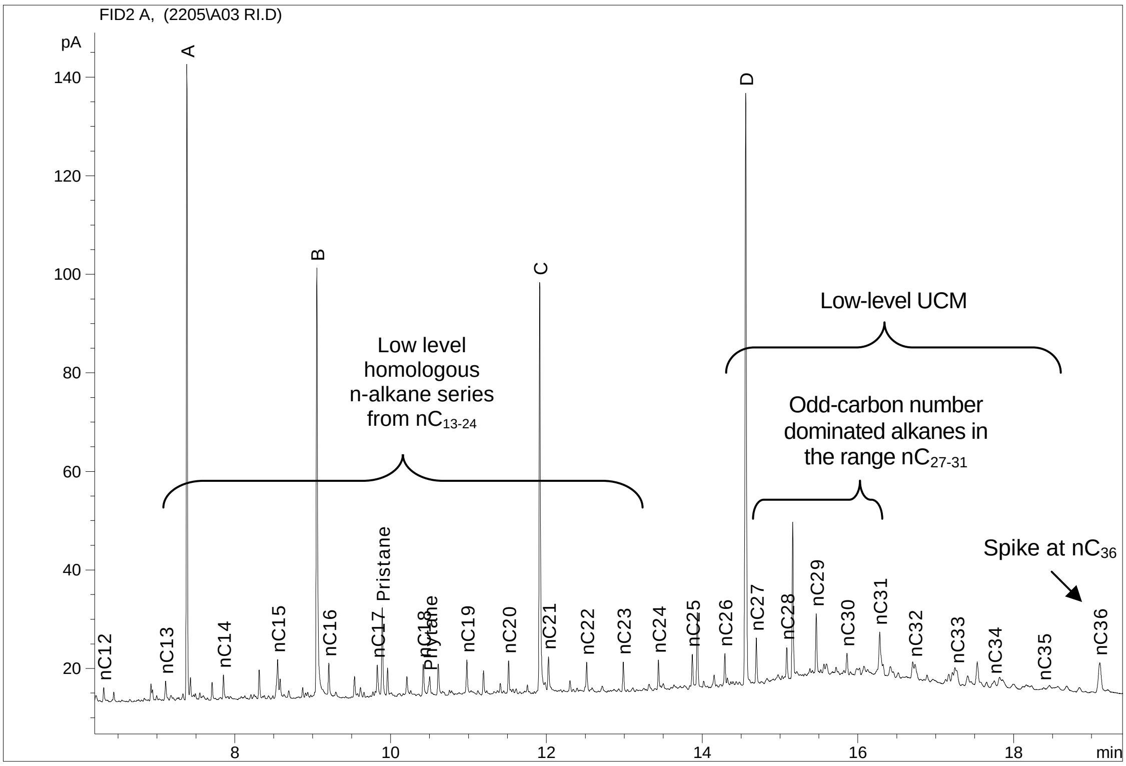

Figure 2.8: Hydrocarbon Analysis – Gas Chromatography Trace (Station L14)

2.7.4 Polycyclic Aromatic Hydrocarbons (PAHs)

A summary of results obtained from polycyclic aromatic hydrocarbons (PAH) analysis is presented in Table 2.5. Concentrations of individual fractions in the EPA (U.S. Environmental Protection Agency) 16 PAHs are shown in Table 2.7 and concentrations of individuals fractions in DTI (Department for Trade and Industry: now Department for Energy and Climate Change (DECC)) specified PAHs are shown in Table 2.7.

Polycyclic aromatic hydrocarbons (PAHs) are evident throughout the marine environment (Laflamme & Hites, 1978), with background sources including plant synthesis and natural petroleum seepage. However, these natural inputs are dwarfed in comparison to the volume of PAHs arising from the combustion of organic material such as forest fires and the burning of fossil fuels (Youngblood & Blumer, 1975). These pyrolytic sources tend to result in the production of heavier weight 4 – 6 ring aromatics (but not their alkyl derivatives) (Nelson-Smith, 1972). However the pyrolytic input in the survey area will be minimal due to the remote location of the Falkland Islands.

Another PAH source is petroleum hydrocarbons, often associated with localised drilling activities and natural petroleum seeps. These are rich in the lighter, more volatile 2 - 3 ring aromatics (NPD; naphthalene (128), phenanthrene, anthracene (178) and dibenzothiophene (DBT) with their alkyl derivatives). As the lightest and most volatile fraction, the NPD are the dominant PAH in petrogenic hydrocarbons but is quickest to degrade and weather over time.

Total Polycyclic Aromatic Hydrocarbons

Total PAH concentrations were moderate when compared to 'background' concentrations in the North Sea and NE Atlantic Margin (UKOOA 2001, AFEN 1998), although rather higher than would usually be expected for a geographically remote area. PAH levels showed the same general pattern as observed for total hydrocarbons, with higher concentrations being recorded from stations L2 and L14 (133 $ng.g^{-1}$ and 162 $ng.g^{-1}$, respectively) than from station L8 (61 $ng.g^{-1}$) (Table 2.5 and Figure 2.9). This appeared likely to relate to the proportion of fine material at the stations, with a statistically significant Pearson's product moment correlation ($P < 0.05$) being calculated between total PAH concentration and this variable.

Mean total PAH concentrations were higher than at the other comparably deep sites surveyed, the mean at Endeavour being 84 $ng.g^{-1}$ and at Nimrod being 70 $ng.g^{-1}$, but lower than at the shallower (and muddier) Toroa (224 $ng.g^{-1}$). This again suggested a relationship between total PAH concentration and the proportion of fine sediment, which were found to correlate highly significantly ($P < 0.01$) when the data from all sites were tested together using the Pearson's product moment coefficient. This correlation, however, disappeared when only the deep sites were considered.

Table 2.5: Summary of Polycyclic Aromatic Hydrocarbon Concentrations [ng.g^{-1} dry weight]

Station		Sum All PAH (2-6 Ring)	Sum NPD	Sum 4-6 Ring	NPD / 4-6 Ring Ratio	Total EPA 16
L2		133	115	18	6.4	10.8
L8		61	50	11	4.5	6.9
L14		162	140	22	6.4	11.2
Current Survey	Mean	119	102	17	5.8	9.6
	SD	52	46	6	1.1	2.4
Endeavour	Mean	84	66	17	3.9	7.7
	SD	23	17	6	0.6	1.8
Nimrod	Mean	70	55	15	3.6	7.3
	SD	13	12	1	0.6	1.0
Toroa	Mean	224	166	58	2.9	21.5
	SD	18	19	4	0.5	0.9

NPD = 2-3 ring PAH (naphthalene (128), phenanthrene, anthracene (178) and dibenzothiophene (DBT) with their alkyl derivatives); 4-6 Ring PAH = fluorathene, pyrene (202), benzanthracene, benzphenanthrene (228), 252, 276).

NPD and 4-6 Ring PAH

Concentrations of NPD mirrored total PAH concentration, ranging from 50 ng.g^{-1} to 140 ng.g^{-1} (stations L8 and L14, respectively) as did 4-6 ring PAH concentration, which ranged from 11 ng.g^{-1} to 22 ng.g^{-1} (stations L8 and L14, respectively). The NPD / 4-6 ring PAH ratio was 4.5 at station L8 and 6.4 at both station L2 and station L14. The reason for the relatively high concentrations of NPD (of which alkyl derivatives of naphthalene were found to be dominant – see Section 2.7.4) may relate to diffuse inputs from natural oil seeps in the vicinity of the survey area. The minimal concentration of 4-6 ring PAH is most probably attributable to the remote nature of the site and therefore lack of local pyrolytic sources of PAH.

Mean concentration of NPD was substantially higher than at the comparably deep Endeavour and Nimrod (66 ng.g^{-1} and 55 ng.g^{-1}, respectively) and the concentrations at station L2 and L14 were considerably higher than the maxima recorded from these other sites (92 ng.g^{-1} at station E10). While mean NPD concentration was lower than at Toroa the disparity between the two sites was probably less than would be expected given Toroa's higher total PAH concentrations. 4-6 ring PAH concentration at Loligo appeared closely comparable to Endeavour and Nimrod but was much lower than at Toroa, and this, in combination with its proportionally higher NPD concentration, resulted in it having the highest NPD / 4-6 ring PAH ratios recorded.

A preliminary examination of diagnostic PAH concentrations from the Toroa site (specifically comparative concentrations of methyl-phenanthrenes) suggested that there were inputs of crude (rather than refined) oil to this survey area (ERT, 2009), which may have related to inputs from hydrocarbon seeps. The elevated NPD seen at Nimrod may also indicate diffuse regional inputs from seeps.

Table 2.6: Individual Polycyclic Aromatic Hydrocarbon Concentrations – EPA 16 [ng.g^{-1} dry weight]

PAH Fraction	Station		
	L2	L8	L14
Naphthalene	2.5	1.4	1.8
Acenaphthylene	1.3	0.4	1.1
Acenaphthene	0.9	0.3	0.7
Fluorene	1.0	0.3	1.2
Phenanthrene	1.4	1.4	1.9
Anthracene	0.1	<0.1	<0.1
Fluoranthene	0.5	0.4	0.6
Pyrene	0.8	0.8	1.3
Benzo(a)anthracene	0.2	0.2	0.3
Chrysene	0.4	0.5	0.6
Benzo(b)fluoranthene	0.6	0.5	0.7
Benzo(k)fluoranthene	0.2	0.2	0.3
Benzo(a)pyrene	0.2	0.1	0.2
Indeno(123cd)pyrene	0.2	0.1	0.1
Benzo(ghi)perylene	0.3	0.2	0.3
Dibenzo(ah)anthracene	0.2	0.1	0.1
Total EPA 16	**10.8**	**6.9**	**11.2**

EPA 16 Polycyclic Aromatic Hydrocarbons Concentrations

The United States Environmental Protection Agency (EPA) identified 16 priority pollutant PAH fractions to be used for assessment of air, water and sediment quality; the EPA 16 are used globally in assessments of contamination relating to both environmental and human health studies. The concentrations of the EPA 16 fractions are provided in Table 2.6**.**

Total EPA 16 PAH concentrations ranged from 6.9 ng.g^{-1} (station L8) to 11.2 ng.g^{-1} (station L14). Out of the EPA 16 the individual PAH found at the highest concentration (when concentrations were summed across the three samples) was naphthalene, which was found at concentrations ranging from 1.4 ng.g^{-1} (station L8) to 2.5 ng.g^{-1} (station L2). The PAH found at the second highest concentration was phenanthrene, which was detected at concentrations ranging from 1.4 ng.g^{-1} (stations L2 and L8) to 1.9 ng.g^{-1} (station L14).

Total EPA 16 concentration across the four sites mirrored THC and total PAH concentration in being highest at Toroa and at its second highest concentration at Loligo.

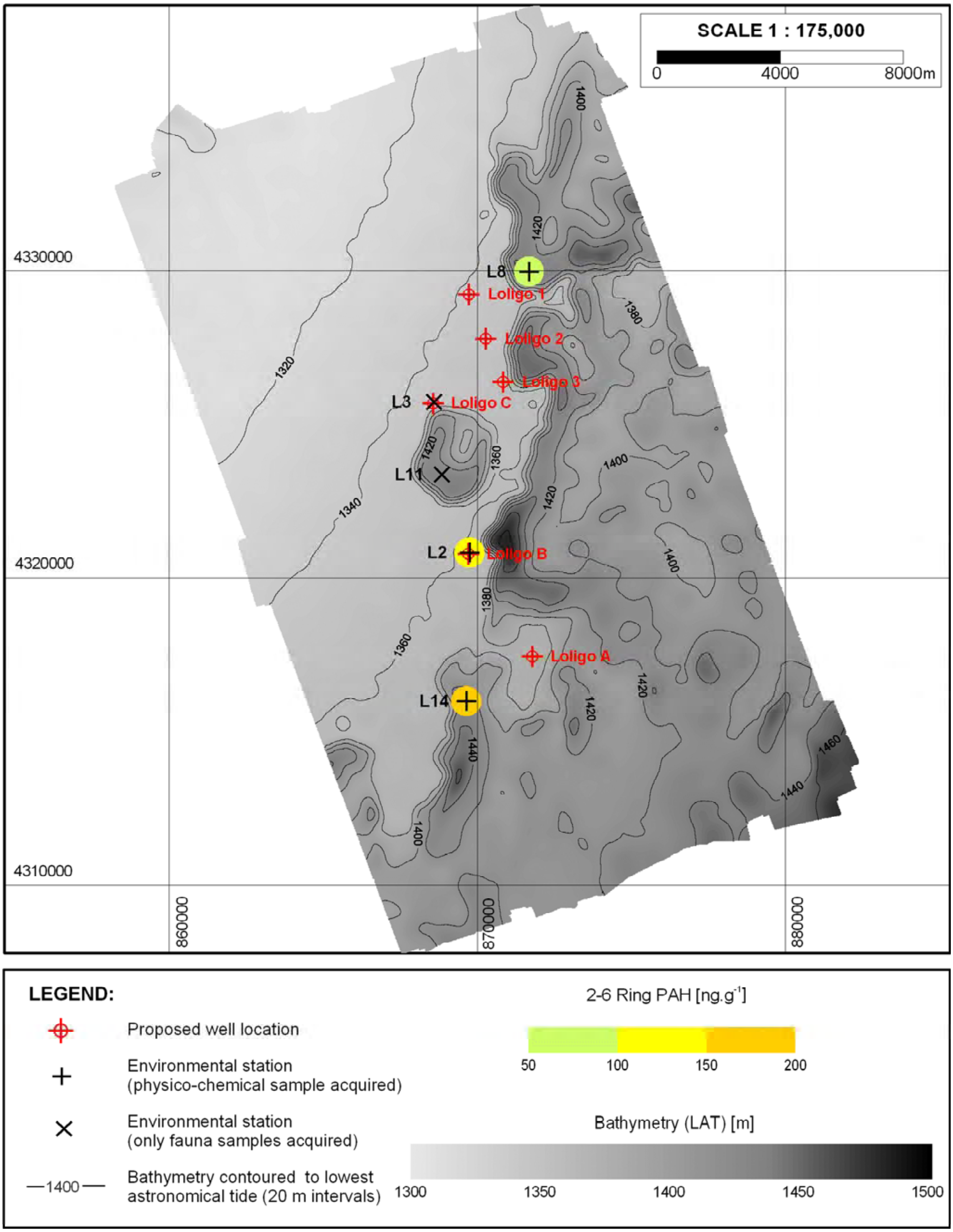

Figure 2.9: Hydrocarbon Analysis – Total PAH Concentration [ng.g^{-1}]

2.7.5 Parent / Alkyl Distributions

An example parent / alkyl distribution plot is shown in Figure 2.10 and this and the plots for the remaining stations are presented in Appendix G.2; the concentrations of individual parent / alkyl groups are provided in Table 2.7.

As suggested by the summary PAH data all of the distributions were highly skewed towards NPD, in areas where oil production and / or processing occurs this would generally be considered indicative of contamination, but at Loligo, which is presumed to be a pristine site, this skewing appeared more likely to be due to natural influences. Alkyl homologues of naphthalene (C_2-, C_3- and C_4-naphthalene) made the greatest contribution to PAH concentration at all stations, cumulatively contributing between 65.5% (station L8) and 77.7% (station L2) of their total PAH content. The concentrations of individual alkyl homologues of naphthalene were found at concentrations ranging from 10 $ng.g^{-1}$ (C_4-naphthalene at station L8) to 47 $ng.g^{-1}$ (C_3-naphthalene at station L14). Naphthalene and its alkyl derivatives are dominant components of crude oils, but while naphthalene weathers easily its alkyl homologues increase in persistence with increasing alkylation (Irwin *et al*, 1997). The source of the naphthalene derivatives detected in the current survey would appear consistent with the presence of diffuse petrogenic inputs of PAH from which the parent compound had been weathered away.

The parent / alkyl distributions identified were similar to those of the comparably deep sites (Endeavour and Nimrod) in being strongly petrogenically skewed. Naphthalene homologues were also dominant among the PAH at these other sites, although they were found in lower concentrations than at Loligo, as was reflected by their lower NPD / 4-6 ring ratios. PAH distributions at the shallower Toroa site were also petrogenically skewed and naphthalene-dominated, but to a lesser extent than those of the deeper sites.

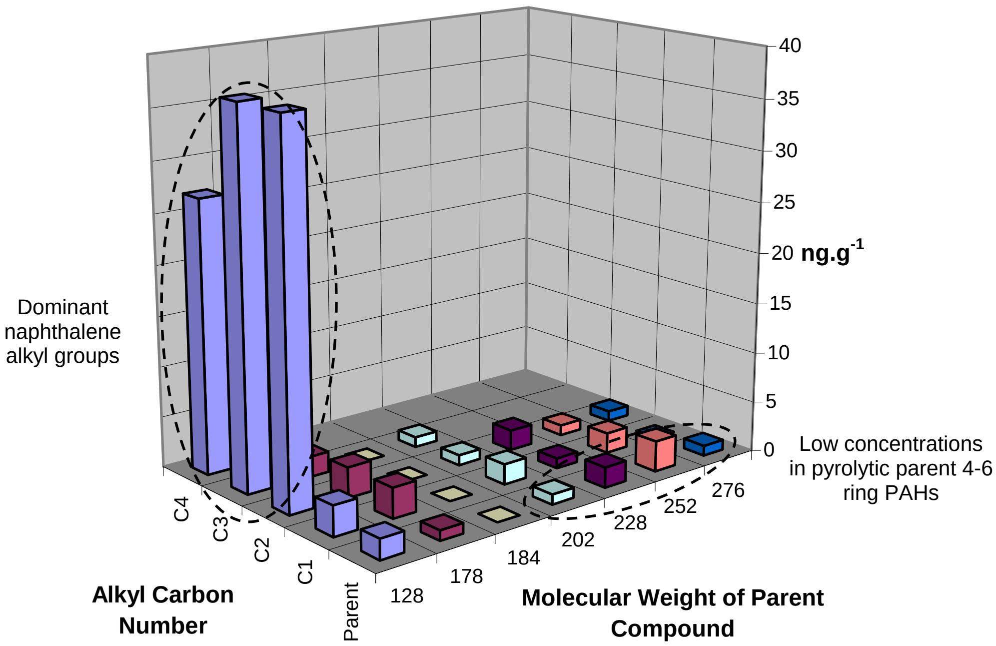

Figure 2.10: 2-6 Ring PAH Parent / Alkyl Distribution – Station L2

Table 2.7: Individual Polycyclic Aromatic Hydrocarbon Concentrations – DTI Specification [ng.g^{-1} dry weight]

PAH Fraction	Station		
	L2	L8	L14
Naphthalene (128)	2	1	2
C1 128	3	2	3
C2 128	37	14	40
C3 128	37	14	47
C4 128	27	10	32
TOTAL 128	**106**	**41**	**124**
Phenanthrene/Anthracene (178)	1	1	2
C1 178	3	3	4
C2 178	3	3	5
C3 178	2	2	4
TOTAL 178	**9**	**9**	**15**
Dibenzothiophene (DBT)	<1	<1	1
C1 184	<1	<1	<1
C2 184	<1	<1	<1
C3 184	<1	<1	<1
TOTAL 184	**<1**	**<1**	**1**
Fluoranthene/Pyrene (202)	1	1	2
C1 202	2	1	2
C2 202	1	1	2
C3 202	1	1	1
TOTAL 202	**5**	**4**	**7**
Benzanthracenes/Benzphenanthrenes (228)	2	1	2
C1 228	1	1	2
C2 228	2	1	2
TOTAL 228	**5**	**3**	**6**
m/z 252	3	2	4
C1 252	2	1	3
C2 252	1	1	1
TOTAL 252	**6**	**4**	**8**
m/z 276	1	<1	1
C1 276	<1	<1	<1
C2 276	1	<1	<1
TOTAL 276	**2**	**<1**	**1**

NPD = 2-3 Ring PAH (naphthalene (128), phenanthrene, anthracene (178) and dibenzothiophene (DBT) with their alkyl derivatives; 4-6 Ring PAH = fluorathene, pyrene (202), benzanthracene, benzphenanthrene (228), 252, 276; DTI = Department for Trade and Industry

2.8 Heavy and Trace Metal Analysis

The concentrations of all of the heavy and trace metals analysed (aluminium, arsenic, barium, cadmium, chromium, copper, iron, lead, mercury, nickel, tin, vanadium and zinc) were measured using inductively coupled plasma mass spectrometry (ICPMS) or inductively coupled plasma optical emission spectrometry (ICPOES) following extraction by separate aqua regia and hydrofluoric acid (HF) digests. The aqua regia digestion technique was applied to provide an indication of metal concentrations that may have been available to uptake by the biota associated with the sediments. It involves a preliminary cold digest of the sample with nitric acid prior to addition of hydrochloric acid for a heated digest; this method provides a 'partial' estimate of metal concentration, aqua regia being an effective solvent for most metal sulphates, sulphides, oxides and carbonates. The more stringent HF extraction technique was employed as it provides a 'near total' estimate of metal concentration, HF being capable of breaking down silicate structures that bind metals within sediments. Neither method provides an accurate estimate of bioavailable heavy and trace metal concentration (i.e. the concentration available to the food chain). Calculating bioavailable metal concentrations is notoriously difficult as metals take different forms (with varying degrees of bioavailability) under different physico-chemical conditions (Tack and Verloo, 1995).

Heavy and trace metals are a natural component of both marine and terrestrial sediments, the latter entering marine systems via rivers and run-off. Heavy metals occur naturally in highest concentration in rock of volcanic origin and volcanic particles can also be atmospherically transferred to marine systems. The main anthropogenic source of heavy metal contamination is the mining industry, but they are also produced in a range of other industries (Siegel, 2002). While the majority of anthropogenic heavy metal contaminants probably enter marine systems via rivers, atmospheric transfer following combustion (especially of coal) is also likely to contribute to systems' heavy and trace metal loads. Barium is of particular interest in areas where previous drilling activity has taken place, and can inform on any subsequent impacts that drilling may have had on the seabed. It is usually present in the form of barite, although barite itself is insoluble in seawater and has a low bioavailability and toxicity to marine organisms other heavy metals can be found as contaminants within barite source rock.

A summary of results for the heavy and trace metal analyses is provided in Table 2.8. As would be expected given the differing stringency of the two extraction procedures, the concentrations measured by aqua regia digestion were much lower than those measured by HF digestion. Mercury concentration was below detectable limits with either extraction technique and cadmium and tin concentrations were not quantifiable by aqua regia digestion. The concentrations of heavy and trace metals appeared consistent across the site.

Heavy and trace metal concentrations are thought to generally increase with fines content, as sediments with higher levels of fines have a greater surface area onto which metals can be adsorbed. This trend was not apparent within Loligo where concentrations calculated by aqua regia extraction were generally highest at station L8, the station with the highest proportion of coarse material, while those calculated by HF extraction were generally highest at station L2, the station with the highest proportion of sand material and a moderate proportion of fines.

As would be expected given the isolated nature of the site, barium concentrations were low, ranging from 107 $\mu g.g^{-1}$ to 157 $\mu g.g^{-1}$ (stations L2 and L8, respectively) for the aqua regia digest) and from 271 $\mu g.g^{-1}$ to 366 $\mu g.g^{-1}$ (stations L2 and L14, respectively) for the HF digest (Figure 2.11).

Comparison of the HF digest data to that of the other sites surveyed revealed some interesting trends in the data. Substantially higher levels of arsenic, chromium and iron were found at the three comparably deep sites (Loligo, Nimrod and Endeavour) than at the shallower, muddier Toroa, resulting in significant or highly significant positive correlations ($P < 0.05$) being calculated between these variables and depth, and significant or highly significant negative correlations ($P < 0.05$) being calculated against fines content when all sites were considered together. These correlations were not evident when the deep sites were considered in isolation. The opposite trend was observed for aluminium, which appeared substantially higher at Toroa, and gave a highly significant negative correlation when all sites were considered together. The HF digestion copper content was also higher at Toroa than the other sites, although the aqua regia concentration did not correlate significantly with depth or fines. It appeared likely that these trends were indicative of differences in the constitution of the sites' sediments, with the higher proportions of iron and chromium at the deeper sites possibly resulting from the presence of volcanic ash (BHPB, 2009). Clay particles contain aluminium in their structure, and this explains the observed trend with aluminium concentration and depth and fines content in this survey. Siegel (2002) documented comparative concentrations of a number of metals in basalt and oceanic clay. Metals that were found in higher concentrations in basalt than in the clay included iron (8.6% as opposed to 6.5%) and chromium (185 $\mu g.g^{-1}$ as opposed to 90 $\mu g.g^{-1}$), while those that were found in higher concentrations in oceanic clay included copper (250 $\mu g.g^{-1}$ as opposed to 94 $\mu g.g^{-1}$).

There were too few samples taken at the Loligo site for meaningful statistics to be performed on the Loligo data alone.

Table 2.8: Heavy and Trace Metal Concentrations – Aqua Regia and HF Digestion [µg.g^{-1} dry weight]

Station		Fines [%]	Heavy and Trace Metals [µg.g^{-1} dry weight by Aqua Regia Digest]												
			Aluminium	Arsenic	Barium	Cadmium	Chromiu	Copper	Iron	Lead	Mercury	Nickel	Tin	Vanadiu	Zinc
L2		18.5	3710	3.4	107	<0.1	84.8	14.9	17600	5.2	<0.1	7.9	0.6	24.9	45.2
L8		5.3	5330	4.0	157	<0.1	73.8	14.7	29000	5.7	<0.1	10.6	0.5	41.6	57.2
L14		26.3	5440	3.9	151	<0.1	87.1	10.1	24200	4.6	<0.1	10.0	0.5	39.6	55.8
Current Survey	Mean	16.7	4520	3.8	138	n/a	81.9	13.2	23600	5.2	n/a	9.5	0.5	35.4	52.7
	SD	10.6	1146	0.3	27	n/a	7.1	2.7	5724	0.6	n/a	1.4	0.1	9.1	6.6
Endeavour	Mean	26.5	4016	1.8	143	0.12	33.4	10.9	18080	1.9	n/a	23.4	n/a	13.9	31.1
	SD	4.6	1135	0.8	29	0.01	9.8	1.2	6715	0.4	n/a	4.1	n/a	4.2	5.6
Nimrod	Mean	22.6	5376	2.5	168	0.11	46.4	10.9	27156	3.2	n/a	22.5	n/a	19.7	36.3
	SD	3.9	1084	0.7	39	0.01	13.1	2.9	6602	0.7	n/a	1.2	n/a	3.3	4.0
Toroa	Mean	77.8	7263	1.0	108	0.10	14.8	12.1	13983	2.9	n/a	10.5	n/a	25.6	41.8
	SD	1.9	367	0.2	15	0.00	2.4	1.1	708	0.7	n/a	1.3	n/a	3.7	2.8

Station		Fines [%]	Total Heavy and Trace Metals [µg.g^{-1} dry weight by HF Digest]												
			Aluminium	Arsenic	Barium	Cadmiu	Chromiu	Copper	Iron	Lead	Mercury	Nickel	Tin	Vanadiu	Zinc
L2		18.5	25800	2.6	271	0.9	185.0	16.1	127000	6.9	<0.1	15.5	1.7	37.7	41.0
L8		5.3	26700	2.7	350	0.9	141.0	14.6	116000	6.8	<0.1	13.4	1.1	38.6	38.5
L14		26.3	38300	2.5	366	0.9	125.0	10.9	89600	7.9	<0.1	14.0	1.1	39.0	39.3
Current Survey	Mean	16.7	30267	2.6	329	0.9	150.3	13.9	110867	7.2	n/a	14.3	1.3	38.4	39.6
	SD	10.6	6972	0.1	51	0.0	31.1	2.7	19221	0.6	n/a	1.1	0.3	0.7	1.3
Endeavour	Mean	26.5	23467	6.7	307	1.1	128.7	9.1	71083	6.1	n/a	7.5	1.4	36.3	54.9
	SD	4.6	5918	0.5	69	0.1	27.7	2.0	36286	0.8	n/a	0.6	0.4	1.9	16.3
Nimrod	Mean	22.6	30522	5.3	342	0.4	136.2	10.7	98167	6.2	n/a	13.3	1.1	67.0	75.3
	SD	3.9	7368	0.7	93	0.1	24.5	1.6	13462	1.2	n/a	1.3	0.2	2.2	6.7
Toroa	Mean	77.8	59418	1.4	407	1.0	32.1	13.7	22380	6.2	n/a	12.2	1.3	54.1	41.6
	SD	1.9	2545	0.1	9	0.0	4.5	1.4	489	0.7	n/a	1.3	0.2	0.9	3.7

SD= standard deviation of dataset; na = not applicable

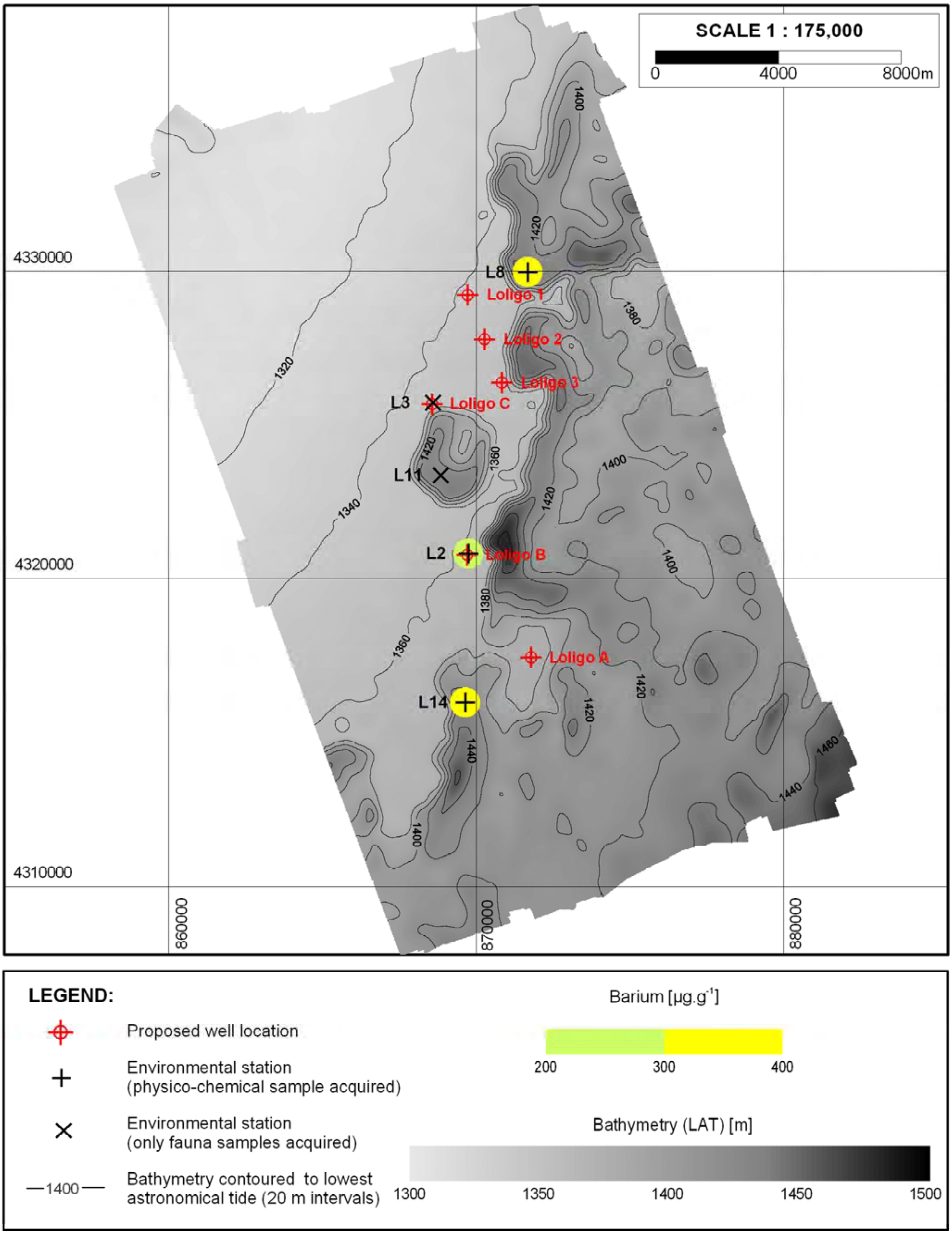

Figure 2.11: Heavy and Trace Metal Analysis – Barium [µg.g^{-1} Dry Weight by HF Digest]

2.9 Benthic Macrofauna

2.9.1 Epifauna

ROV obtained video footage, taken during bore hole operations at the proposed locations Loligo A and Loligo C, were analysed to assess the epifaunal communities of these two locations. To maximise the coverage of the footage analysed only the longer video transects were examined in detail; logs of the habitats and fauna identified from these video files are provided in Appendix D. Example screen grabs taken from the ROV video footage are provided in Figure 2.12.

The sessile epifauna identified were recorded from areas with outcropping consolidated (or possibly cemented) substrata or areas with exposed coarse sediments (pebbles, cobbles and boulders) as these were the only habitats with suitable attachment substrata. The few areas of homogeneous muddy sand identified had no epifaunal cover. In certain areas (e.g. the depression adjacent to Loligo C) sparse epifaunal growth was seen from areas that appeared to be sand covered, as the colonies observed would have required hard attachment substrata, it was assumed that this sand was present as a thin veneer over a hard substrate or coarse sediment.

The most prominent colonial epifauna encountered across the site were cnidarians, these included at least two species of gorgonian (soft corals) and at least one species of scleractinian (hard or stony coral). The gorgonians included a characteristic “sea fan” form, which was found throughout the site on both isolated cobbles and boulders (Figure 2.12, Plates 3 and 4) and on outcrops of consolidated sediment (Figure 2.12, Plate 6). A less frequently encountered gorgonian form were “sea whips”, which tended to be restricted to consolidated sediment areas (with or without a veneer of sand) (see Figure 2.2, Plates 4 and 5). While not as widely distributed as the gorgonians, scleractinians were occasionally seen in considerable density, almost completely covering the seabed in places, forming low thickets (approximately 120 mm high) over the consolidated sediments of the scarp seen to the south of Loligo C (Figure 2.2, Plate 1). Examination of the ROV footage (Figure 2.2, Plate 1) and coral fragments recovered in the box corer (Figure 2.2, Plate 2) suggested that the coral was at least superficially similar to the cold water coral *Lophelia pertusa*, a widely distributed species which has previously been recorded as far south as the Brazilian slope (OBIS, 2009). Unlike most tropical scleractinians *L. pertusa* is azooxanthellate (it does not rely on symbiotic algae to obtain nutrients) and this allows it to extend well below the photic zone (upper layers of the water column which light can penetrate). Existing ecological data for *L. pertusa* suggest that its range would not extend to the Falkland slope due to the low seabed temperature recorded (2.9°C). ICES (2002) state that *L. pertusa* prefers oceanic waters with a temperature of between 4°C and 12°C and a relatively high tidal flow (to facilitate filter feeding); the coral identified from Loligo may instead be a superficially similar Antarctic species, capable of withstanding colder waters.

Although more sparsely distributed than the cnidarian taxa, sponges (phylum Porifera) were prominent in some areas (Figure 2.2, Plates 3 and 5). At least three species were observed, a large globular species with multiple oscula (orifices) (Figure 2.2, Plate 5), a small pedunculate (stemmed) species and an orange encrusting species (Figure 2.2, Plate 3).

Of the free-living taxa recorded the most abundant were brittle stars (class Ophiuroidea), which sometimes formed dense aggregations on consolidated sediment outcrops (Figure 2.2, Plate 1). The epifaunal habit of the ophiuroid seen suggested it was a filter feeder. Shrimps (presumably members of the Carridea) were occasionally seen throughout the ROV footage as were small fish. The only fish species that could be identified with any degree of confidence was a rockling, which appeared at least superficially similar to the threadfin rockling *Gaidropsarus ensis*. This is principally a North Atlantic deepwater species, but projections of suitable habitat suggest that its range may extend to the Patagonian shelf (Fishbase, 2009)

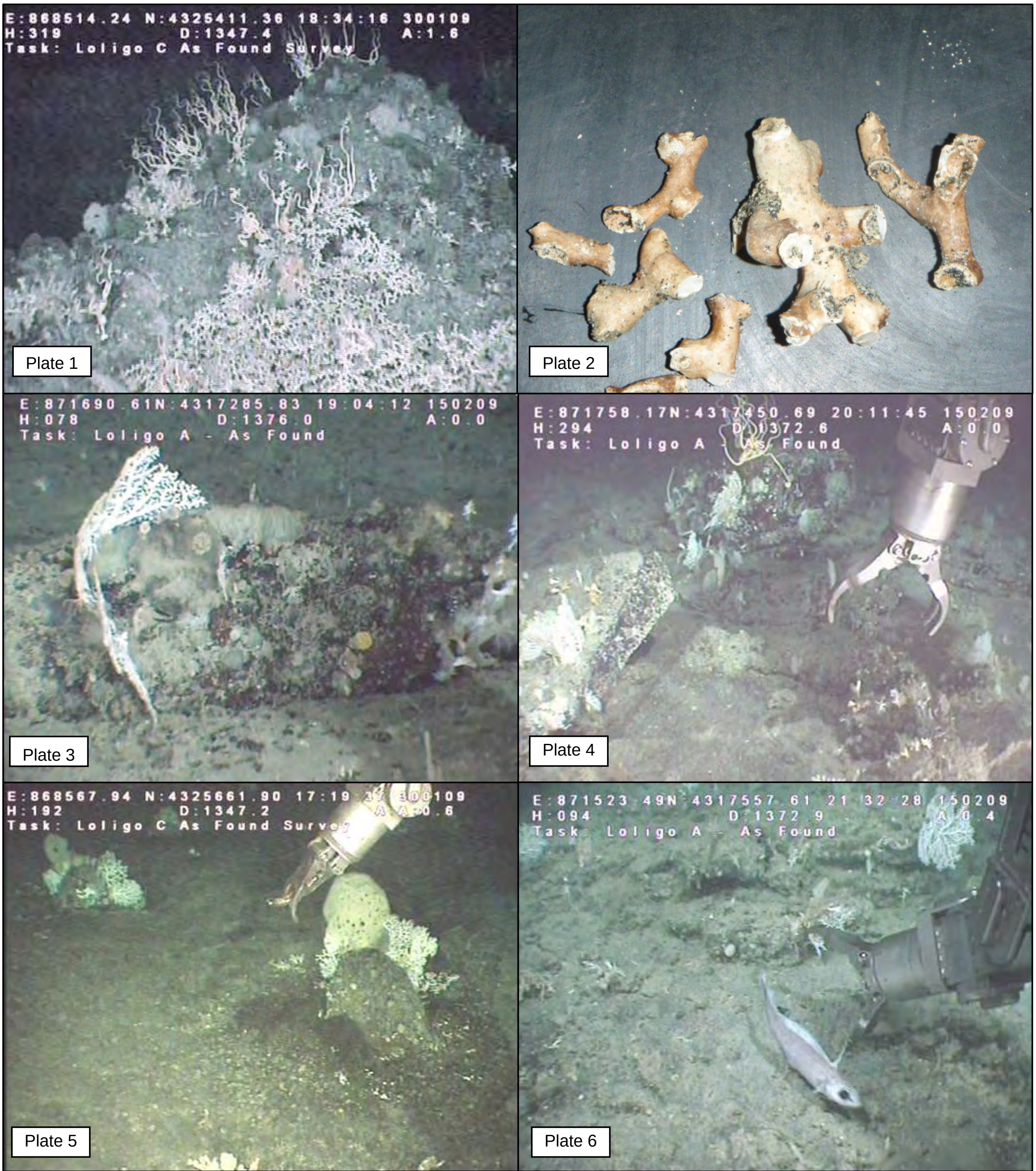

Plate 1: Dense coverage of a hard coral (possibly *Lophelia pertusa*) with filter-feeding brittle-stars (Ophiuroidea) on a consolidated sediment outcrop in the depression near Loligo C

Plate 2: Fragments of dead hard coral (possibly *L. pertusa*) taken in a box corer sample

Plate 3: A gorgonian and a faunal turf comprising Hydrozoa / Bryozoa and sponges (Porifera)

Plate 4: A sea fan (Gorgonacea), brittle-star (Ophiuroidea) and a faunal turf comprising Hydrozoa / Bryozoa and juvenile hard coral colonies seen near Loligo A

Plate 5: Sponges (Porifera) and hard corals on cobbles near Loligo C

Plate 6: A fish (possibly the threadfin rockling *Gaidropsarus ensis*), with sea fans (Gorgonacea) and hard corals on a consolidated sediment outcrop near Loligo A

Figure 2.12: Screen Grabs of ROV Footage, Showing Examples of Epifaunal Taxa

2.9.2 Infauna

Two 0.1 m^2 macrofaunal box core samples were analysed from each of the four stations successfully sampled (stations L2, L3, L11 and L14), giving a total of eight samples. Macrofaunal data were derived from the taxonomic analysis of all of these samples, with individuals of macrofaunal taxa being identified, enumerated and expressed as abundance per sample (0.1 m^2) and per station (0.2 m^2). The full macrobenthic dataset is presented in Appendix H.

Newly settled juveniles of benthic species may at times dominate the macrofauna, but due to heavy natural post-settlement mortality, they should be considered an ephemeral component and not representative of prevailing bottom conditions (OSPAR Commission, 2004). In this survey 2 (2.6%) of the 78 taxa recorded in total represented juveniles. Subsequent analysis was undertaken on data that excluded juveniles in keeping with the procedures recommended by OSPAR. Records of three taxa representing indeterminate specimens that may have been represented elsewhere in the dataset were also excluded from the dataset.

A total of 73 discrete macrofaunal taxa were found during the course of this survey, excluding the two juvenile and three indeterminate taxa, records for which were not included in the analysis (Appendix H). Of the taxa recorded 45 (61.6%) were annelid, 14 (20.5%) were crustacean, 10 (13.7%) were molluscan and two (2.7%) were echinoderm. Representatives of the Sipuncula and Chelicerata made up the two taxa (2.7% of the total) which belonged to other phyla (see Figure 2.13 and Table 2.9). In terms of abundance the Annelida were overwhelmingly dominant, representing 81.1% of the 312 individuals recorded in total from the samples. The Crustacea, which contributed 10.6% of the total abundance, were the second most abundant phylum, followed by the Mollusca (4.5%) and representatives of other phyla (4.7%). Echinoderms contributed just 0.6% of the total faunal abundance recorded. Percentage abundances of phyla identified in the current survey were generally comparable to those determined by Blake and Narayanaswamy (2004) in Antarctica; 67% Polychaeta, 20% Crustacea and 13% remaining phyla.

Table 2.9: Abundance of Taxonomic Groups

Phyla	Number of Taxa	Total Taxa [%]	Abundance	Total Abundance [%]
Annelida	45	61.6	253	81.1
Crustacea	14	20.5	32	10.6
Mollusca	10	13.7	14	4.5
Echinodermata	2	2.7	2	0.6
Others	2	2.7	11	3.5
Total	73	100.0	312	100.0

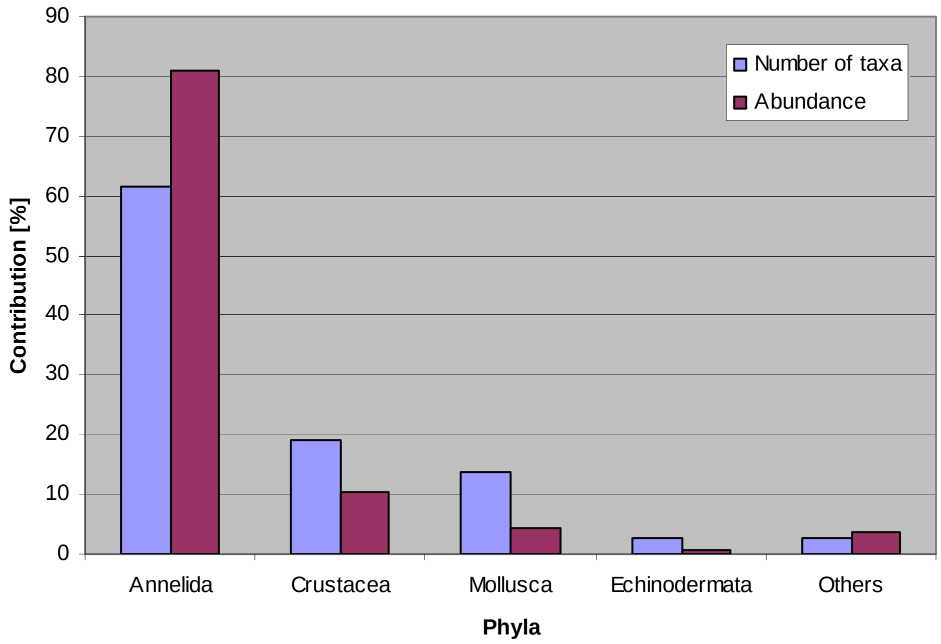

Figure 2.13: Abundance of Taxonomic Groups

The dominant taxa recorded from the survey area are shown in Table 2.10. As would be expected given the predominance of the phylum overall, the majority of the dominant taxa belonged to the Annelida; of the taxa shown all but two (sipunculans and the tanaid crustacean *Apseudes*? sp. 1) were polychaetous annelids. The most abundant species overall was the onuphid polychaete *Kinbergonuphis oligobranchiata*, which was recorded at a mean abundance of 9.3 individuals per sample, and the second most abundant species the ampharetid polychaete *Melinna* sp. 1, which was recorded at a mean abundance of 6.6 individuals per sample. The remainder of the dominant taxa identified were of comparatively low abundance, all being recorded at mean abundances of less than 1.4 individuals per sample.

The frequencies of occurrence calculated showed that only *K. oligobranchiata* occurred in all of the samples acquired, the remainder of the dominant taxa occurring in 6 (75%) of the samples or fewer. Examination of the data suggested that these relatively low frequencies were indicative of patchiness in the distributions of individual taxa, rather than of the presence of multiple, spatially differentiated communities, as there was clear overlap in the abundance distributions across the different samples.

By ranking the taxa recorded for each sample in terms of abundance and summing the rank scores for all samples to give the overall rank dominance for each taxon, it is possible to examine which species were consistently dominant throughout the survey area (Table 2.10). This method is less susceptible to bias toward species which may occur in higher densities in a smaller proportion of samples. The rank dominance scores calculated generally appeared consistent with rank abundance, again suggesting that a single benthic community occurred across the site. The only notable disparity between the rankings was seen in the chaetopterid polychaete *Spiochaetopterus typicus* (abundance rank of 8 and dominance rank of 29), this was not however, indicative of a particularly unusual distribution in this species, but was instead an artefact of the technique used. *Spiochaetopterus typicus* was of low abundance (and dominance) in all but one of the samples in which it was recorded and was found at its highest abundance in sample L3-FB, this was the least diverse of the samples acquired which had the effect of down-weighting *S. typicus'* overall score.

Table 2.10: Dominant Taxa by Abundance and Dominance Rank for Samples [0.1 m^2]

Taxon	Rank	Mean	Frequency [%]	Rank
Kinbergonuphis oligobranchiata	1	9.3	100.0	1
Melinna sp. 1	2	6.6	75.0	2
Caulleriella? sp. 1	3	1.4	50.0	4
Sipuncula indet.	4	1.3	62.5	3
Chone / *Jasmineira* sp. 1	4	1.3	75.0	5
Cirrophorus cf. *forticirratus*	6	0.9	37.5	6
Euchone sp. 1	6	0.9	62.5	9
Nothria anoculata	8	0.8	62.5	8
Spiochaetopterus typicus	8	0.8	62.5	29
Apseudes? sp. 1	8	0.8	25.0	7
Aphelochaeta sp. 1	12	0.5	12.5	9
Aricidea (*Allia*) cf. *hartmani*	12	0.5	37.5	9
Notoproctus sp. 1	12	0.5	25.0	9

2.9.3 Primary Variables and Univariate Analysis

The primary variables numbers of taxa (S) and abundance (N) have been calculated together with the univariate measures richness (D), evenness (J′), dominance (1-λ) and Shannon-Wiener diversity (H′) for sample (0.1 m^2) and station (0.2 m^2) data (Table 2.11 and Table 2.12, respectively) using the PRIMER v 6.0 DIVERSE procedure (Clarke & Gorley, 2006).

Margalef's richness (D) is a simple measure calculated from the number of taxa and abundance. Pielou's evenness (J′) and the reciprocal of Simpson's dominance (1- λ) are measures of equitability (i.e. how evenly the individuals are distributed among different species), low evenness indicates that a sample is dominated by one or a few highly abundant species whereas high evenness means that total abundance is spread more evenly among the constituent species. The Shannon-Wiener index (H′) (Shannon & Weaver, 1949) combines both the components of species richness and evenness to calculate a measure of diversity. See Magurran (1988) for further discussion of these indices.

Sample Data (0.1 m^2)

Values for primary and univariate parameters calculated for sample data are presented in Table 2.11. Both the number of taxa and abundance were shown to be highly variable across the site, with coefficients of variation (V – standard deviations expressed as percentages of the mean) of 38.7% and 56.8%, respectively. The high variability in these parameters was reflected in the moderate variation in richness (V = 27.2%). The equitability-biased variables (Pielou's evenness, the reciprocal of Simpson's dominance and Shannon-Wiener diversity) were relatively constant across the samples; all of these parameters suggested that a similarly structured non-dominated community occurred across the survey area.

Table 2.11: Primary and Univariate Parameters by Sample [0.1 m^2]

Station	No of Taxa [S]	Abundance [N]	Richness [D_{MG}]	Evenness [J']	Dominance [1-λ]	Shannon-Wiener [H']
L2-FA	15	19	4.75	0.959	0.965	3.75
L2-FB	17	34	4.54	0.801	0.841	3.27
L3-FA	17	30	4.70	0.920	0.933	3.76
L3-FB	8	13	2.73	0.958	0.923	2.87
L11-FA	10	23	2.87	0.785	0.798	2.61
L11-FB	22	63	5.07	0.788	0.855	3.51
L14-FA	28	71	6.33	0.807	0.878	3.88
L14-FB	24	59	5.64	0.837	0.907	3.84
Mean	17.6	39.0	4.58	0.857	0.888	3.44
SD	6.8	22.2	1.24	0.076	0.055	0.48
V	38.7	56.8	27.2	8.9	6.2	13.9

SD = standard deviation of dataset; V = coefficient of variation of dataset.

Station Data (0.2 m^2)

Values for primary and univariate parameters calculated for station data (0.2 m^2) are presented in Table 2.12. Unsurprisingly most of the parameters increased and the variability within them was reduced in comparison to the sample data, this was attributed to species accumulation (the detection of an increased number of rare species) when the samples were aggregated at station level. Interestingly mean evenness was lower within the station data and showed slightly increased variability; this was largely due to the comparatively low species accumulation when the station L11 samples were combined (13 of the taxa recorded at this station being present in both samples).

The primary parameters for the station data (0.2 m^2) are spatially presented in Figure 2.14 and Figure 2.15.

Table 2.12: Primary and Univariate Parameters by Station [0.2 m^2]

Station	No of Taxa [S]	Abundance [N]	Richness [D_{MG}]	Evenness [J']	Dominance [1-λ]	Shannon-Wiener [H']
L2	27	53	6.55	0.841	0.898	4.00
L3	21	43	5.32	0.931	0.947	4.09
L11	27	86	5.84	0.748	0.840	3.56
L14	42	130	8.42	0.791	0.896	4.26
Mean	29.3	78.0	6.53	0.828	0.895	3.98
SD	9.0	39.2	1.36	0.079	0.044	0.30
V	30.6	50.3	20.8	9.5	4.9	7.6

SD = standard deviation of dataset; V = coefficient of variation of dataset.

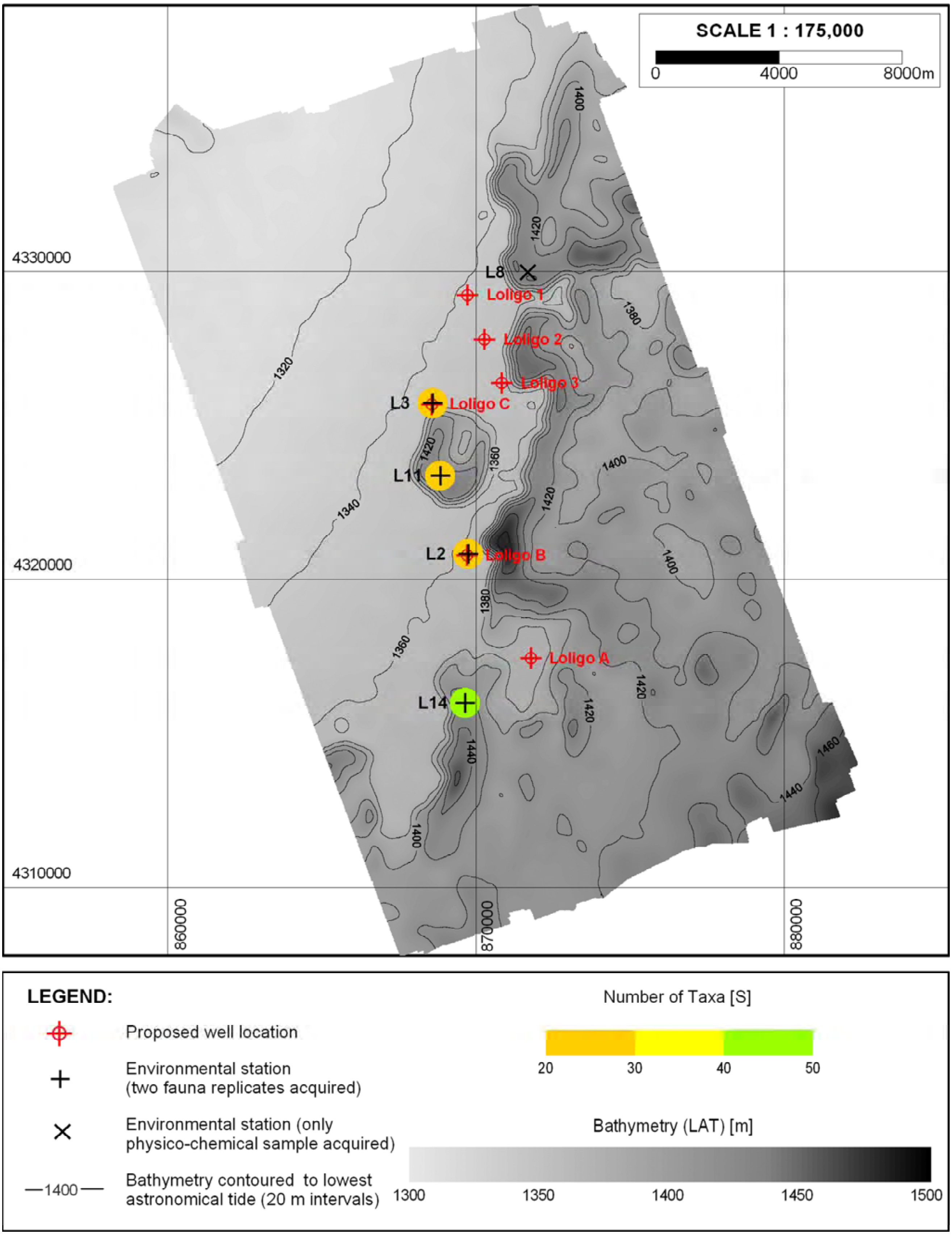

Figure 2.14: Macrofaunal Analysis – Number of Taxa [S]

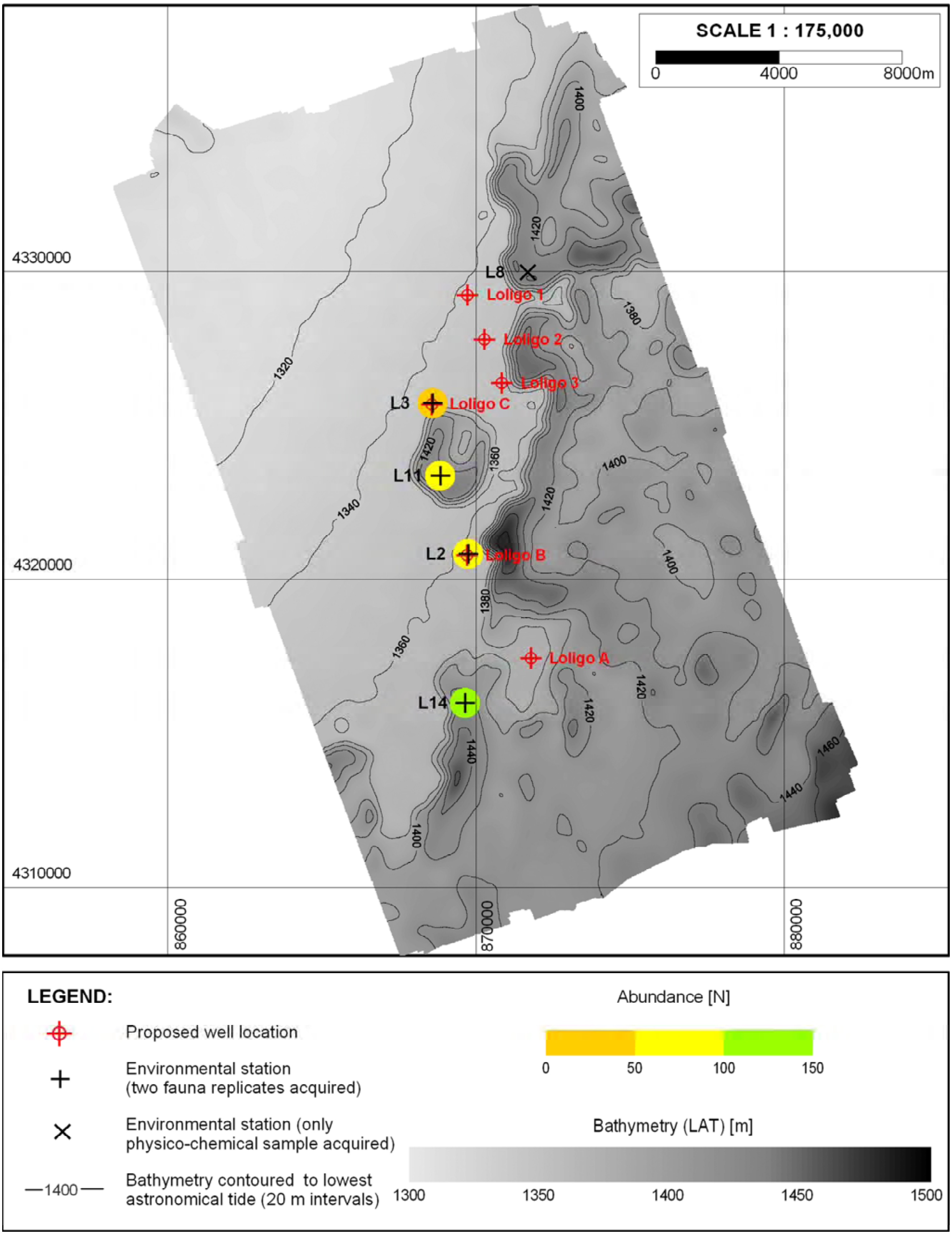

Figure 2.15: Macrofaunal Analysis – Number of Individuals [N]

2.9.4 Species Accumulation and Richness Estimation

The species accumulation plot displayed in Figure 2.16 was generated using PRIMER v6.0. The observed number of taxa obtained through repeated sampling (S_{obs}) were cumulatively plotted, as were richness estimates from repeated sampling as calculated by the Chao1, Chao2, Jacknife1 and Jacknife2 formulae (see Chao (2005) for further discussion of these indices). All of the displayed curves were smoothed (by random permutation of the data points) to aid interpretation.

The observed species accumulation curve was of reasonably constant slope and appeared unlikely to be close to reaching its asymptote; this suggested that a number of taxa present in the survey area had not been detected by the sampling undertaken. The richness estimators also suggested that the survey area had not been fully described, with estimates for the total macrofaunal diversity of the area ranging from 105.0 taxa (Chao1) to 139.0 (Chao2) in comparison to the 73 taxa observed. These estimates suggested that between 52.5% and 69.5% of the area's total macrofaunal diversity had been detected. Sampling in this survey area was difficult given the hard ground, resulting in many attempted samples not being successful and therefore the number of taxa detected was not as high as may have been. However, these values suggested that approximately two thirds of the total diversity had been determined and this would generally be considered adequate for establishment of baseline conditions. An overarching multivariate analysis of all four survey sites (Section 2.9.6) suggested that the same community was present at all three comparably deep sites (Nimrod, Loligo and Endeavour). Species accumulation analysis of data for all of these sites suggested that a high proportion (greater than 66%) of this community's total diversity had been detected.

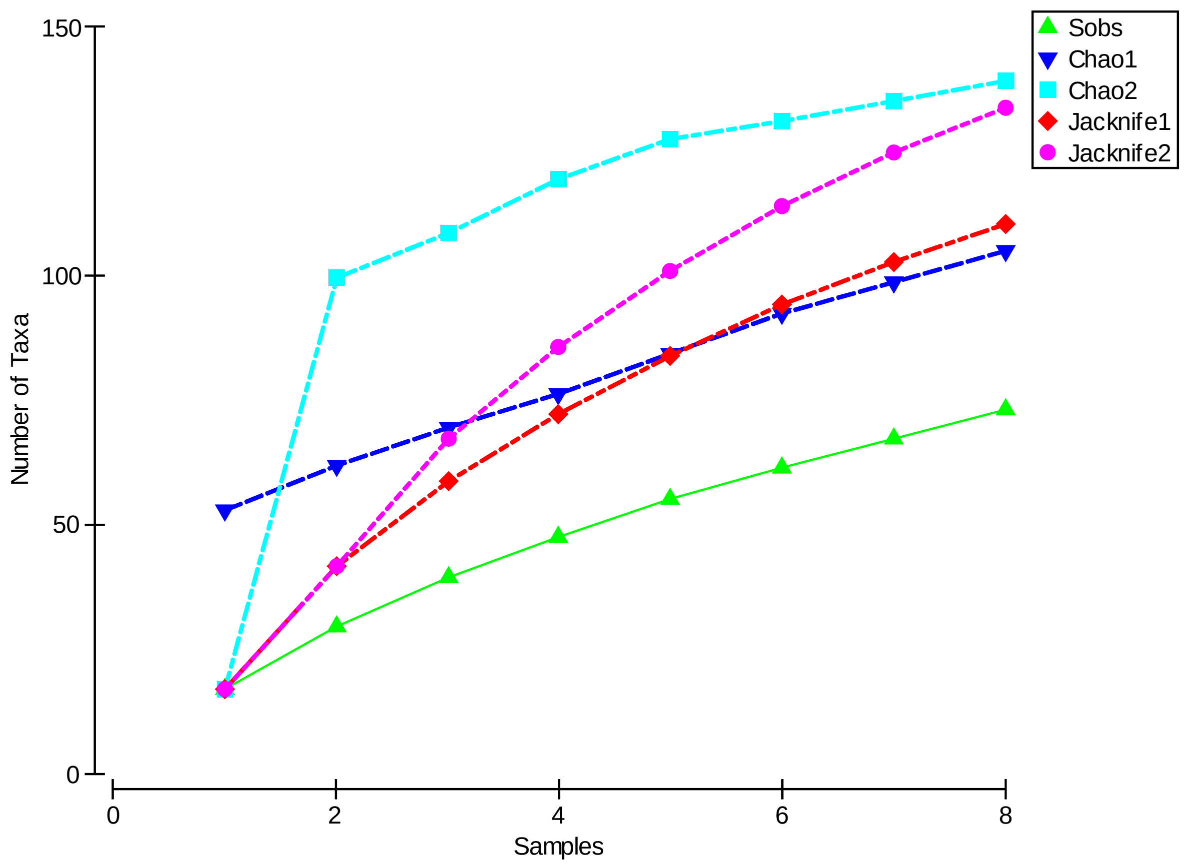

Figure 2.16: Species Accumulation Plot

2.9.5 Multivariate Analysis

Multivariate analysis of data allows a more thorough examination of differences between sites that cannot be achieved by examination of univariate measures alone. Multivariate analysis preserves the identity of species when calculating similarities between data, whereas this information is lost when computing univariate measures.

Analysis was undertaken using the Plymouth Routines in Multivariate Ecological Research (PRIMER) v6.0 statistical package (Clarke & Gorley, 2006). Two techniques have been used here to illustrate and identify differences in the sample data – cluster analysis, which outputs a dendrogram displaying the relationships between data based on the Bray-Curtis similarity measure and non-metric multi-dimensional scaling (nMDS) in which the data are ordinated as a 2-dimensional "map".

The dendrogram displayed in Figure 2.17 shows patterns in square root transformed sample data (0.1 m^2) similarities. The PRIMER v6.0 similarity profiling (SIMPROF) algorithm was used to identify statistically significant differences between the data ($P < 0.05$); this algorithm would identify statistically significant splits as black lines and non-significant splits as red lines on the dendrogram. All of the samples acquired were combined in a single cluster, with no statistically significant differences being identified between them.

As there was no significant grouping in the data, the nMDS ordination (Figure 2.18) appeared to be of no benefit to the analysis, with the real data relationships having clearly been distorted when the dataset was represented on a 2-dimensional plane. For example the nMDS plot suggests that sample L14-FA is more similar to sample L14-FB (with which it has a Bray-Curtis similarity of 41.2%) than to samples L2-FA and L2-FB (with which it has similarities of 41.5% and 42.0%, respectively). The degree of distortion in the plot is evident from the moderate stress value calculated (0.11).

The analyses were re-run for aggregated station data (0.2 m^2) (not shown) and again failed to identify any statistically significant differentiation within the dataset.

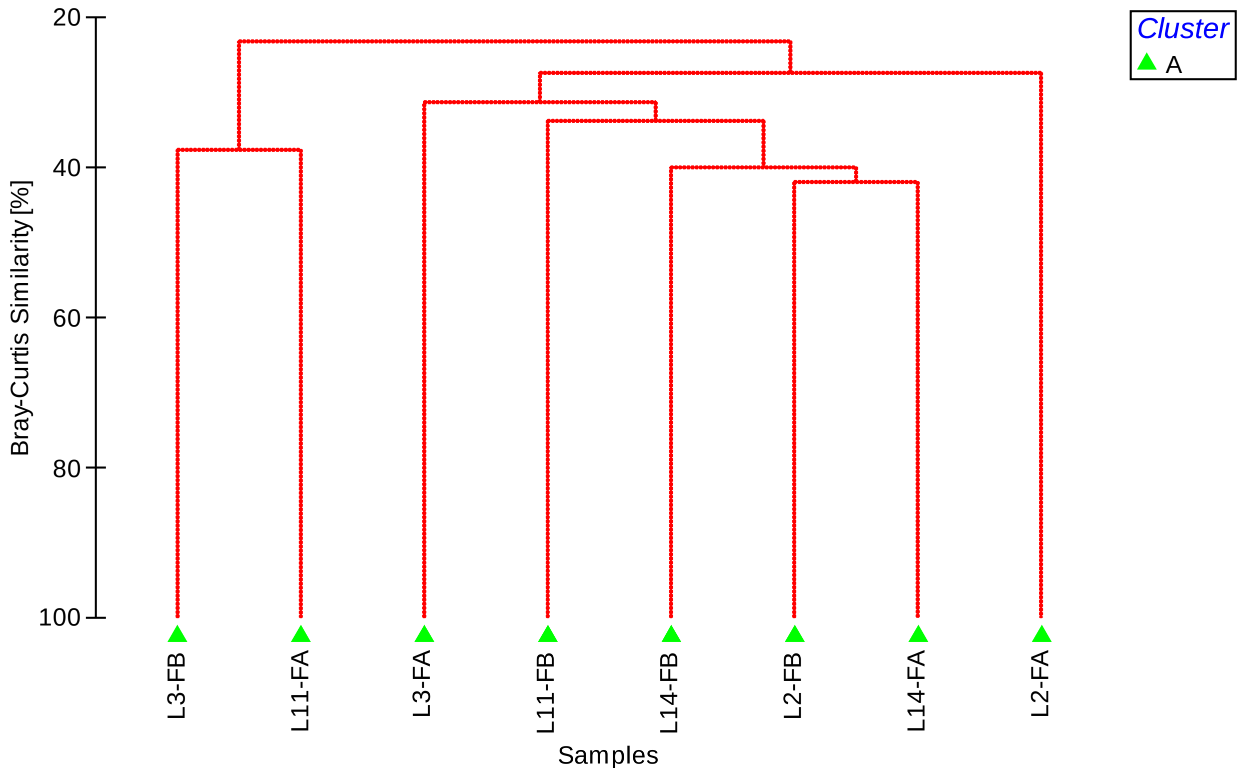

Figure 2.17: Dendrogram by Bray Curtis Similarity for Square Root Transformed Sample Data

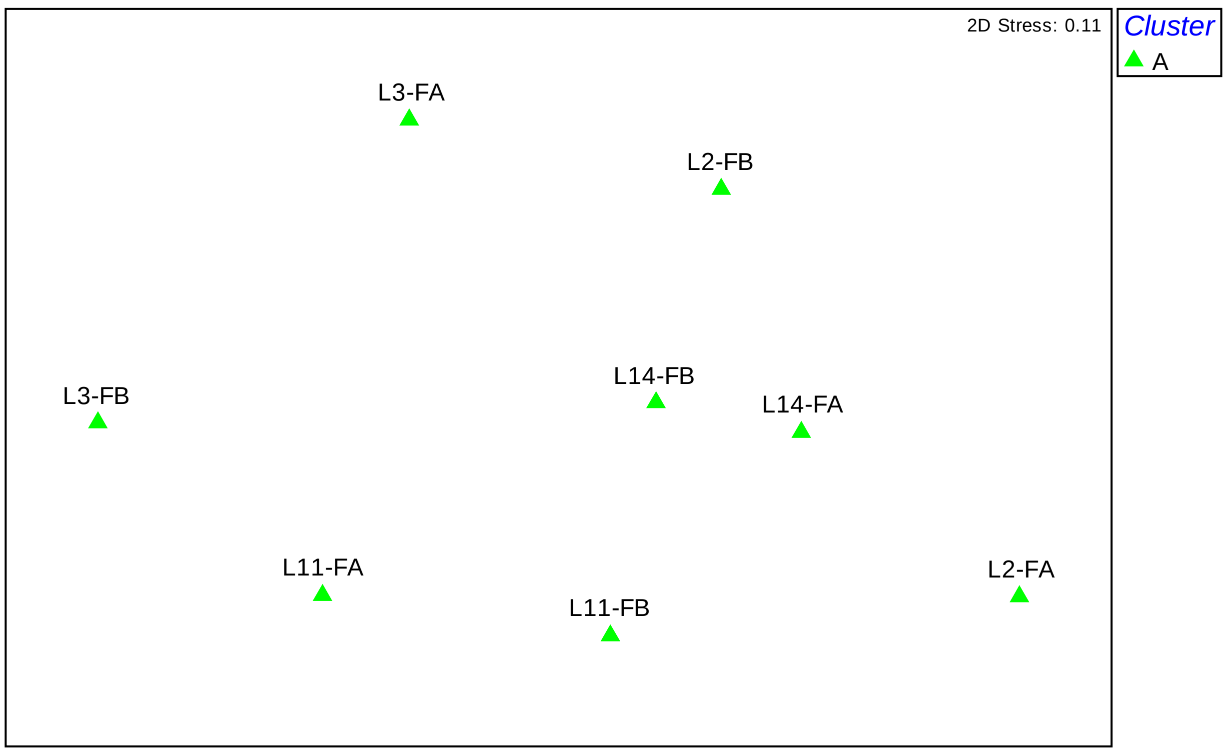

Figure 2.18: nMDS by Bray Curtis Similarity for Square Root Transformed Sample Data

The PRIMER similarity percentage analysis (SIMPER) routine was run on the square root transformed sample dataset. SIMPER analysis was used to identify the taxa which contributed the greatest level of similarity within cluster A.

The characterising taxa for cluster A are shown in Table 2.13. Unsurprisingly, given the lack of community differentiation, the numerically dominant polychaetes *Kinbergonuphis oligobranchiata* and *Melinna* sp. 1 contributed the greatest degree of similarity within the cluster (31.7% and 15.0%, respectively).

Table 2.13: SIMPER Results Showing the Top Five Characterising Taxa for Cluster A

Taxa	Mean Abundance (Non-Transformed)	Mean Abundance (√ Transformed)	Contribution to Similarity [%]	Cumulative Contribution [%]
Kinbergonuphis oligobranchiata	9.3	2.8	31.7	31.7
Melinna sp. 1	6.6	2.0	15.0	46.7
Chone / *Jasmineira* sp. 1	1.3	0.9	7.5	54.1
Euchone sp. 1	0.9	0.7	6.7	60.8
Spiochaetopterus typicus	0.8	0.7	5.9	66.8

2.9.6 Overview Multivariate Analysis

CLUSTER and Non-Metric Multidimensional Scaling (nMDS) Analysis

The multivariate techniques applied to the macrofaunal data for individual sites were repeated for the combined dataset for all four sites. In order to validly apply these techniques to the larger dataset the data had to be re-standardised to ensure the independence of variables within it, the dataset used is provided in Appendix G.3.

The dendrogram displayed in Figure 2.20 shows patterns in square root transformed sample data (0.1 m^2) similarities. The PRIMER v6.0 similarity profiling (SIMPROF) algorithm was used to identify statistically significant differences between the data ($P < 0.05$), showing statistically significant splits as black lines and non-significant splits as red lines on the dendrogram. The samples acquired at the Toroa site were split between two clusters (clusters A and B), as seen in the multivariate analysis conducted for this site alone (Report No. 9763V3). All of the samples acquired from the comparably deep sites (Loligo, Endeavour and Nimrod) were grouped within a single statistically undifferentiated cluster (cluster C), suggesting that a single benthic community was present throughout these deeper areas. Despite this lack of statistically significant differentiation there did appear to be clear grouping of the samples according to the site from which they were acquired. Examination of the data suggested this resulted from variations in the abundance of taxa, rather than from differing taxonomic composition; this variation was explored further using SIMPER analysis (following sub-section).

While the differentiation of the Toroa samples from those of the deeper sites is clearly shown in the nMDS ordination (Figure 2.19), within cluster relationships appear to be poorly represented. The cluster B samples for example, are clearly separated within the plot. This high stress value of 0.21 for the ordination suggested a high degree of distortion within the data relationships.

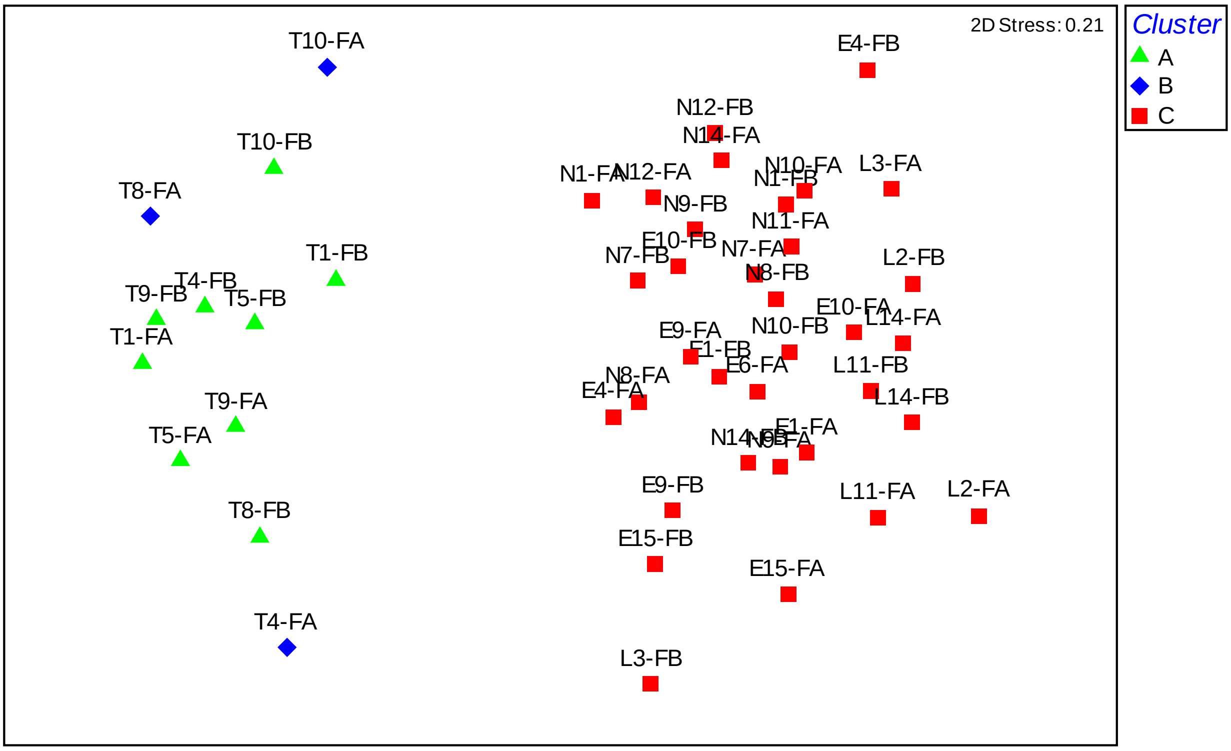

Figure 2.19: nMDS by Bray Curtis Similarity for Square Root Transformed Sample Data [0.1 m^2] for All Sites

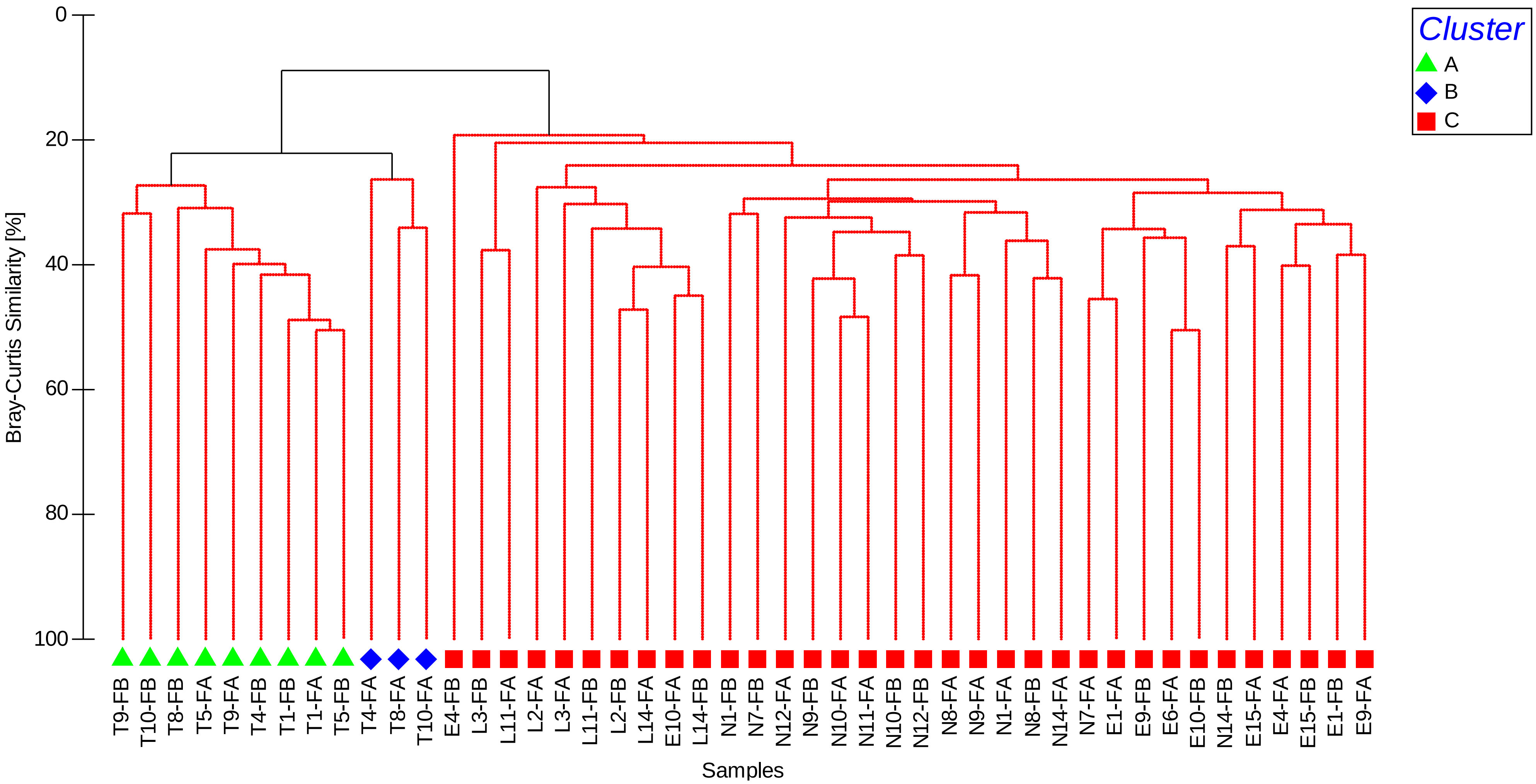

Figure 2.20: Dendrogram by Bray Curtis Similarity for Square Root Transformed Sample Data [0.1 m^2] for All Sites

SIMPER Analysis

SIMPER analysis of square root transformed sample data [0.1 m^2] was used to identify the taxa that contributed the greatest degree of similarity within clusters A to C. The characterising taxa of cluster C, which represented the community present throughout the deeper survey areas, are shown in Table 2.14; those of the Toroa community (clusters A and B) are discussed in the Toroa volume (Report No. 9763V3).

The species that by far contributed the highest degree of similarity within cluster C was the onuphid polychaete *Kinbergonuphis oligobranchiata* (30.9%) and it was this species that was consistently dominant in the individual analyses conducted for the three comparably deep sites (Loligo, Endeavour and Nimrod). The second and third greatest contributors to within cluster similarity were the ampeliscid amphipod *Ampelisca* sp. 2 and the ampharetid polychaete *Melinna* sp. 1. The fact that these species were of considerably lower mean abundance, and thus contributed much lower similarity, than *K. oligobranchiata* resulted from their differing prominence at the three deeper sites. *Melinna* sp. 1 was the second most abundant taxon at both Loligo and Endeavour, being found at sufficiently high abundance to perhaps be considered co-dominant with *K. oligobranchiata*, whereas at Nimrod *Ampelisca* sp. 2 (as represented by all but two individuals within the aggregated Ampeliscidae) was the second most abundant taxon.

Table 2.14: SIMPER Results Showing the Top Five Characterising Taxa for Cluster A

Taxa	Mean Abundance (Non-Transformed)	Mean Abundance (√ Transformed)	Contribution to Similarity [%]	Cumulative Contribution [%]
Kinbergonuphis oligobranchiata	6.7	2.4	30.9	30.9
Ampelisca sp. 2	1.7	1.1	9.4	40.2
Melinna sp. 1	3.2	1.3	8.3	48.5
Sipuncula	1.1	0.8	5.4	53.8
Spiochaetopterus typicus	0.6	0.5	3.6	57.4

Richness Estimation

Established richness estimation techniques (Chao1, Chao2, Jacknife1 and Jacknife2) were used to assess the efficacy of sampling within the sites' communities.

Multivariate analysis of stations data for the Toroa site suggested that it comprised a single undifferentiated community (FSLTD Report No. 9763V3), so richness estimates were based on accumulation across the combined cluster A and B samples. The estimates ranged between 145.9 (Jacknife1) and 181.0 (Chao2) taxa in comparison to the 101 taxa observed, suggesting that between 55.8% and 69.2% of the community's total diversity had been detected. The observed number of taxa and richness estimates differed slightly from those of the individual site report (Report No. 9763V3) due to the different taxonomic standardisation undertaken prior to the overview analysis.

The estimated total richness of the deeper (cluster C) community ranged between 213.1 taxa (Chao1) and 245 taxa (Jacknife2) in comparison to the 163 taxa recorded in total. These estimates suggested that a high proportion (between 66.3% and 76.5%) of the total community diversity had been detected.

2.9.7 Discussion of Macrofaunal Results

The cold water influence to the Patagonian Shelf Large Marine Ecosystem (LME) means that it is one of the world's most productive and complex marine environments, and is considered a Class I, highly productive ecosystem. The Patagonian Shelf LME extends from approximately -37° to -55° latitude. Annual means for primary productivity ranged from 271 g.carbon.cm^{-2}.yr^{-2} to 329 g.carbon.cm^{-2}.yr^{-2} between 1998 and 2006 (the mean across this period being 296 g.carbon.cm^{-2}.yr^{-2}) (Heileman, 2008).

In comparison the Celtic – Biscay Shelf LME extends from 43° to 60° latitude, and is identified as a Class II, moderately productive ecosystem. It is influenced by the North Atlantic Drift in the north, and by the Azores Current in the south. Annual means for primary productivity ranged from 215 g.carbon.cm^{-2}.yr^{-2} to 233 g.carbon.cm^{-2}.yr^{-2} between 1998 and 2006 (the mean across this period being 225 g.carbon.cm^{-2}.yr^{-2}; Aquarone et al., 2008). South of this ecosystem, but still comparable in latitude to the Patagonian Shelf LME (approximately 36° to 45° latitude) is the Iberian Coastal LME. This ecosystem is also considered a class II moderately productive ecosystem, with annual means for primary productivity ranging from 144 g.carbon.cm^{-2}.yr^{-2} to 164 g.carbon.cm^{-2}.yr^{-2} between 1998 and 2006 (the mean across this period being 156 g.carbon.cm^{-2}.yr^{-2}; Aquarone et al., 2008).

Little information is available regarding the benthic marine communities of shelf and slope habitats offshore the Falkland Islands, or indeed for the neighbouring Patagonian Shelf. Perhaps the most comprehensive review of the wider area was produced by Bastida *et al* (1992), although this only focussed on areas of the shelf with depths of less than 200 m and their analysis was limited in scope to three phyla, the Mollusca, Echinodermata and Bryozoa. In this review they suggested that the outer shelf represented a separate zoogeographic district under the influence of the Malvinas / Falkland Current, a northerly flowing branch of the Circumpolar Current that introduces cold water (mean sea surface temperature of 6°C) to the area (Gyory *et al*, 2009). Bastida *et al* (1992) found that their outer shelf district contained a high number of species which were not found further up the shelf and suggested that this was due to cold water influence.

Of the dominant taxa identified the vast majority were polychaetous annelids. The most abundant species overall, the onuphid polychaete *Kinbergonuphis oligobranchiata*, was first described from the slope off Argentina (Fauchald, 1982) and appears limited in distribution to the Southwest Atlantic, where it has previously been recorded from depths ranging from 512 m to 903 m (Smithsonian Institution, 2009). It is presumed that *K. oligobranchiata* is, like other onuphids, an omnivorous scavenger (Fauchald and Jumars, 1979). The second most abundant species overall, the ampharetid polychaete *Melinna* sp. 1, belongs to a sub-family (Melinninae) that is largely restricted to deep water; ampharetids are all surface deposit feeders (Rouse and Pleijel, 2001). Of the remaining dominant taxa all but two were polychaetes, the exceptions being sipunculans (peanut worms) and the tanaid crustacean *Apseudes*? sp. 1. Although the majority of dominant taxa within the survey areas community were deposit feeders, omnivorous scavengers were also present (the onuphids *K. oligobranchiata* and *Nothria anoculata* and tanaid *Apseudes*? sp. 1), as were filter feeders (the sabellid polychaetes *Chone* / *Jasmineira* sp. 1 and *Euchone* sp. 1 and the chaetopterid polychaete *Spiochaetopeterus typicus*).

None of the species recorded had been documented by Bastida *et al* (1992). This is unsurprising given that the current survey area was deeper (1365 m to 1438 m below LAT) and had substantially lower seabed temperatures (2.9°C) in comparison to the Bastida *et al* (1992) study area. The species described solely from their outer shelf biogeographic district were found at depths of 83 m to 192 m where seabed temperatures ranged from 4.3°C to 7.5°C.

Crude abundance / dominance and univariate analyses of the macrofaunal data suggested that a single community occurred throughout the survey area. These findings were corroborated by the multivariate CLUSTER and SIMPROF analyses, which showed that all sample data (and aggregated station data) could be grouped within a single statistically undifferentiated cluster. SIMPER analysis showed that the greatest degree of similarity within this cluster was contributed by the numerically dominant *Kinbergonuphis oligobranchiata* and *Melinna* sp. 1, which cumulatively contributed nearly half of the inter-sample Bray-Curtis similarity.

2.10 Water Column Characteristics

Four water profiling attempts were made at LOLIGO WCP 120. The first two deployments returned erroneous data for several of the measured parameters, the third attempt acquired good data for all parameters except dissolved oxygen (DO) and the final attempt acquired good data across all parameters. The results for relevant parameters (temperature, salinity, pH, DO and turbidity) obtained from the final profile are presented in Figure 2.21; this profile was acquired over the course of approximately one hour from 1113 on February 2nd 2009.

The water profile data showed the normal, expected temperature and salinity characteristics in the surface waters. There was a distinct thermocline at 50-75 m depth. There were general trends of declining dissolved oxygen, temperature and pH and increasing salinity with depth. There was evidence of the presence of a different body of water at a depth of ~760 m, which appeared to extend to the seabed. This lower body of water was warmer, more saline, and of lower pH than the water directly above it, but the general trends of declining oxygen content, temperature and pH down the water column were maintained.

2.10.1 Temperature

The surface temperature at the time of data collection was approximately 8.2°C and this remained relatively constant in the well mixed upper layers of the water column (between the surface and approximately 50 m depth). Below this well mixed layer there was a distinct thermocline over which the water temperature rapidly descended to 5.3°C at approximately 90 m depth. Below the thermocline the temperature declines gradually to a depth of approximately 760 m, where there is a slight temperature inversion, over which the temperature increases from 3.6°C to 3.8°C. Below this inversion temperature generally declines, although there are a series of slight temperature increases and decreases that suggested some mixing and / or stratification. These effects may indicate the influence of a different water body below this depth and are also evident (and perhaps more clearly so) in the salinity and pH profiles. The minimum temperature of 2.9°C was recorded just above the seabed (1217 m depth).

2.10.2 Salinity

Although salinity showed minimal variation throughout the water column, ranging from a minimum of 34.0 ppt at the surface to 34.5 ppt at the seabed. In the well-mixed surface layers, salinity remained constant at 34.0 ppt; it then showed a small but distinct increase over the course of the thermocline to approximately 34.2 ppt. From here it increased gradually to the temperature inversion at approximately 760 m depth, where it showed a second stepped increase, before fluctuating slightly but showing a general trend of increase to the seabed. The slight increase of salinity at the temperature inversion suggested inflow of a slightly more saline water body below this depth.

2.10.3 pH

pH showed minimal variation throughout the water column, decreasing from approximately pH 8.3 at the surface to pH 8.1 at the seabed. The decrease was gradual from the surface to the thermal inversion, where it showed a distinct, sharply stepped decrease, revealing the presence of a different water mass at this depth very clearly. After this it showed a general trend of decrease, with some degree of fluctuation, to the seabed.

2.10.4 Dissolved Oxygen

Dissolved oxygen (DO) increased from a surface saturation of approximately 100% (100%sat.) to its maximum of 123.2%sat. at around 50 m depth. From 50 m depth DO decreased gradually to 125 m depth before decreasing rapidly to approximately 165 m depth (from approximately 114%sat. to 90%sat.). DO was then shown to gradually decrease from this depth to the seabed, the minimum being 47.3%sat. The final 150 m of the upcast data were omitted from the profile shown (Figure 2.21) as they were thought to be erroneous, this may have resulted from the probe's inability to quickly compensate with temperature while being retrieved through the thermocline.

The supersaturation of the water column between the surface and 130 m depth could be considered indicative a phytoplankton bloom, possibly being related to the well documented coccolithophore bloom which is known to occur annually over the Patagonian Shelf at the time at which the survey was conducted (Balch, 2009). The depth at which the maximum DO was measured (50 m) may have coincided with the chlorophyll maximum. However, the level of super saturation measured was very high, and an alternative explanation could be that the probe was erroneously recording elevated DO concentrations in the surface waters. Despite this, a clear trend in the DO concentration throughout the water column was still evident.

2.10.5 Turbidity

Turbidity was uniformly low throughout the water column, with the majority of measurements being either 0 FTU (formazin turbidity units) or 0.003 FTU. The slightly increased turbidity of the mixed surface layers of water are not thought indicative of increased suspended solids load, but are instead likely to have resulted from sensor interference due to the presence of plankton within the euphotic zone. This is the depth to which sunlight intensity is sufficient to allow phytoplankton growth, and can be as deep as 200 m in very clear open ocean water.

2.10.6 Discussion of Water Profiles

The temperature, salinity and turbidity measured appeared broadly consistent with that of the other survey areas (Endeavour, Nimrod and Toroa), although only the neighbouring Endeavour site showed a comparable deep thermal inversion. The profiles suggest a second water mass was present at this site, from approximately 780 m depth to the seabed. The DO data appeared distinctly different from the other sites, none of which showed such a high degree of supersaturation (and subsequent sharp decline in oxygen saturation) in the surface layers of the water column. This was likely to have related to spatial or temporal differences in phytoplankton abundance.

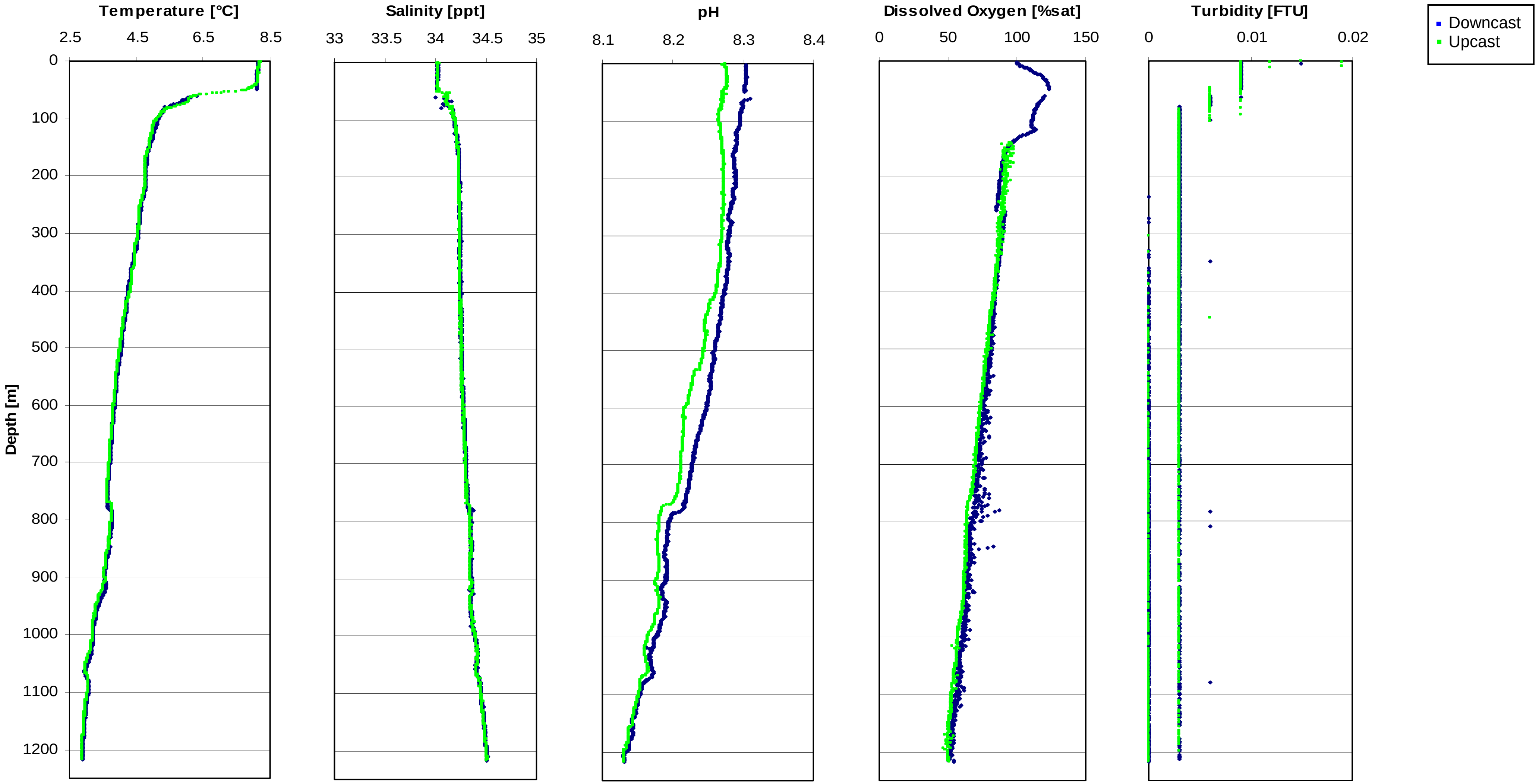

Figure 2.21: Profile Data for Individual Water Column Parameters

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A. SURVEY METHODOLOGIES

A SURVEY METHODOLOGIES

A.1 Sediment Sampling

Sediment samples were acquired at 5 stations (out of the 15 originally proposed). The difficulties with sampling encountered at the remaining stations were thought to relate to the presence of coarse or consolidated sediments and / or strong currents.

A1.1 Grab Sampling Operations

A 0.1 m^2 Box corer was used to collect sediment samples, operational procedures for this sampling are detailed below. Sampling operations are shown in Figure A2.1.

1. The corer was cleaned before each deployment and the wire rope and winch were kept grease-free to avoid contamination of the physico-chemical samples.
2. The grab was prepared for operations prior to arrival onsite. The master communicated to the deck via VHF radio when the vessel was steady on location and the corer was deployed.
3. Once the corer reached the seabed the on-line surveyor was informed (via VHF radio) and a fix was taken.
4. On recovery to deck, the corer inspection panels were removed and the sample judged for acceptability. A sample was deemed unacceptable in the following instances (and classified as a no-sample);
   - Evidence of surface sediment washout.
   - Inspection panels open or not closed properly, allowing potential sediment washout.
   - Sediment sample taken on an angle i.e. where the corer did not strike the seabed true, or where the seabed was not flat.
   - Disruption of the sample through striking the side of the vessel.
   - Sample was less than 10 cm deep (except where smaller samples were accepted by the Client)
   - Sample was more than the accepted range from the target location (this varied depending on the reason for the location of the station i.e. to investigate a general area or a localised feature).
   - The presence of a hagfish and / or mucous coagulants.
   - The sample was unacceptable to the Client Representative for any other reason.

Due to the difficulties encountered during sampling, both the sampling accuracy and sample depth criteria were relaxed under certain circumstances.

If the sample was accepted, it was retained for either macrofaunal or physico-chemical analysis.

Samples retained for macrofaunal analysis were thoroughly washed into the sediment collection tray and the grab was immediately redeployed (after obtaining permission from the Bridge).

If the sample was to be used for physico-chemical analysis, the bridge was informed and the vessel either held location while the sample was processed or transited immediately to the next station (if the required samples had been correctly acquired).

A1.2 Core Sample Processing

Each core sample (FA, FB and PC) was photographed (with a scale bar labelled with the sample details) and described in terms of the following characteristics:

1. Sample depth
2. Colour, taken from a Munsell chart, (where: hue denotes relation to red, yellow, green, blue and purple; value denotes lightness, and; chroma denotes strength or departure from a neutral of the same lightness)
3. Sediment classification
4. Layering (depth, colour of surface / subsurface layers and presence of anoxic layer)
5. Smell (presence of H_2S)
6. Fauna
7. Bioturbation (presence / absence)
8. Anthropogenic debris (e.g. drill cuttings, plastic bags)
9. Sediment pH, temperature and redox potential

A1.2.1 Macrofaunal Processing

The sample was thoroughly washed into the sediment collection tray. The retained sediment was then transferred to the semi-automated Wilson Auto-Siever (WAS) for sieving (0.5 mm mesh sieve).

After the sediment was transferred to the Wilson-Auto Siever the sediment was broken down using a low powered seawater hose. The finer sediment was removed through a 0.5 mm mesh sieve. The remaining residue was then transferred to a 5-litre bucket and preserved with ~10% buffered formal saline solution.

A1.2.2 Physico-Chemical Subsampling

The sediment was sub-sampled for particle size distribution, organic carbon, hydrocarbons and heavy metal analysis. Two subsamples were collected for heavy / trace metal analysis using a plastic scoop and stored in double-lined polyethene sealed bags. Two subsamples were collected for hydrocarbon analysis using an isopropyl alcohol-cleaned metal scoop and transferred to two 250 ml tins. Two subsamples were obtained for particle size analysis and stored in double-lined plastic sealed bags.

All physico-chemical samples were transferred to an onboard freezer (≤18°C) for storage until demobilisation. The samples were then shipped back in coolboxes to Fugro Survey Limited's Great Yarmouth office for redelivery to the relevant laboratories.

A1.2.3 Munsell Chart Analysis

The Munsell Colour System specifies colour on three colour dimensions; hue which refers to the pure colour, value which refers to the lightness of the colour and chroma which relates to the purity / intensity of the colour. A colour is fully specified by listing the three numbers for hue, value and chroma. This enables comparisons to be drawn between sediment types and individual sediment layers and helps to standardise individual perspectives of colours.

A small sample is taken from the grab sample and held on the finger in a well lit area. The Munsell Soil Colour Chart is then used to determine the best match of the three colour dimensions (Figure A2.1). The results are then recorded on the deck logs.

A.2 Water Column Profiling

Water profiling was conducted using a Valeport 606+ CTD, fitted with additional sensors to measure turbidity, pH and dissolved oxygen (DO); the technical specification of the profiler is provided in Table A.2.1. Operational procedures for water profiling are detailed below. Sampling operations are shown in Figure A2.1.

1. Prior to deployment the sensors were checked against certified standards (where available) and, if necessary, recalibrated.
2. The water profiler was attached to the wire a rope strop and jubilee clips. A weight was attached to the end of the lift wire (to keep the lift wire vertical in the water column and a USBL beacon was attached above it (to determine the profiler location and depth).
3. When the equipment was ready for deployment permission from the bridge was sought and given before deployment could commence.
4. The profiler was lowered to a depth where it was fully submerged and left to acclimatise for 5 to 10 minutes.
5. The profiler was then lowered at a speed 0.5 $m.s^{-1}$ to 1 $m.s^{-1}$ to just above the seabed and then recovered at a similar rate.
6. After recovery to deck the data was downloaded and checked (using a custom made QA spreadsheet) prior to redeployment or to changing operations.

Table A.2.1: Valeport 606+ Multi Parameter CTD Specifications

Physical Properties	
Housing	Titanium
Weight	15 kg (in air), 8.5 kg (in water)
Dimensions	88 mm Ø, 665 mm long
Depth rating	5000 m
Performance Specifications	
Memory	8 Mbyte solid state
Internal Power	8 x 1.5V alkaline cells
Sampling Rate	1, 2, 4 or 8 Hz
Sensor Specifications	
Conductivity	Range: 0.1 to 80 $mS.m^{-1}$ Accuracy: ± 0.01 $mS.m^{-1}$ Resolution: 0.004 $mS.m^{-1}$
Pressure	Range: up to 500 Bar (5000 m depth) Accuracy: ± 1% Resolution: 0.005% full scale
Temperature	Range: -5 °C to 35 °C Accuracy: ± 0.01 °C Resolution: 0.002 °C
Turbidity	Range: 0 FTU to 2000 FTU Accuracy: ± <2% up to 750 FTU (variable gain) Resolution: 0.005% full scale
DO	Range: 0%sat. to 200%sat. Accuracy: ± 1% Resolution: 0.005% full scale
pH	Range: 0 mV to 1000 mV Accuracy: ± 0.1 mV Resolution: 0.001 mV

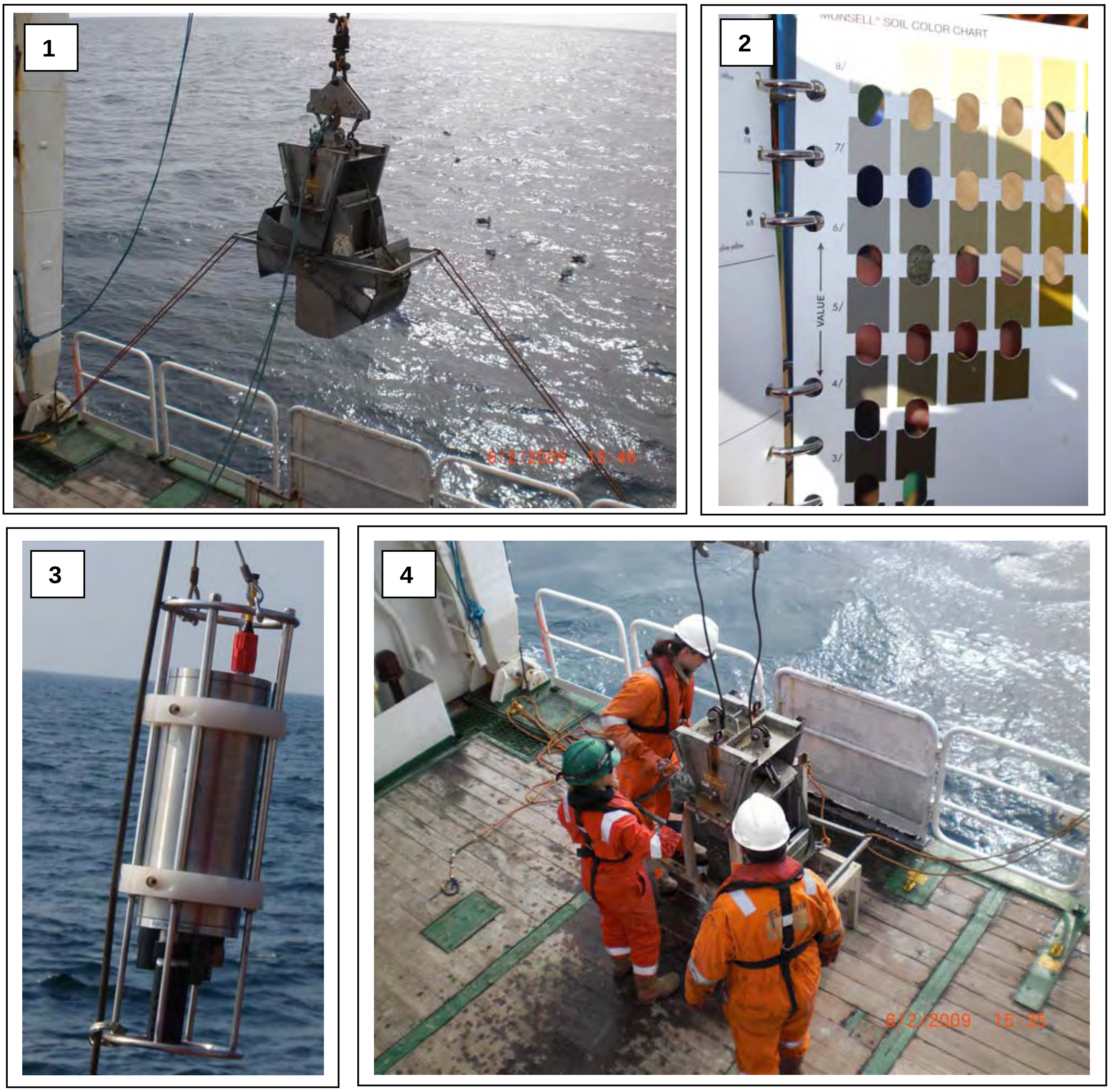


Plate 1: Deployment of the 0.1 m^2 box corer

Plate 2: The Munsell colour chart

Plate 3: The Valeport 606+ multi parameter data logger attached for deployment

Plate 4: Recovery of the 0.1 m^2 box corer

Figure A2.1: Sampling Operations

B. LABORATORY ANALYSIS AND STATISTICAL METHODOLOGIES

B LABORATORY ANALYSIS AND STATISTICAL METHODS

B1 Particle Size Analysis (PSA)

Particle size analysis was carried out by Fugro Alluvial Offshore Ltd. Wet sieving procedures were based on BS1377; part two; 1990 whilst laser diffraction was undertaken in accordance with Fugro Alluvial Offshore Ltd internal procedures, which comply with BS-EN-ISO 9001:2000. All analysis meets QA / QC requirements exacted by Fugro Survey Limited's internal procedures (BS/EN/ISO 9001).

The whole sediment sample was oven dried and weighed before being sieved through a 500 µm sieve. Sediment finer than 500 µm was riffled, to produce a representative sub-sample. This was soaked for 24 hours in sodium hexametaphosphate to fully disperse all particles. The sample was then passed through a Mastersizer 2000 laser particle analyser using an appropriate standard operating procedure (SOP). Results were then produced by the Mastersizer software.

The coarse and fine parts of the sample were then recombined, weighed, wet sieved through a 63 µm sieve, oven dried overnight, and then dry sieved through a series of mesh apertures corresponding to the whole phi units described by the Wentworth scale. The weight of the sediment fraction retained on each mesh was measured and recorded.

Raw data were processed in-house to describe particle size distributions in terms of phi mean, fraction percentages (i.e. coarse sediments, sand and fines) (Table B1.1), sorting (range of sediment sizes) (Table B1.2) and skewness (weighting of sediment fractions above and below the mean size) (Folk and Ward, 1957). Phi mean uses graphic mean (M):

$$M = \frac{\Phi 16 + \Phi 50 + \Phi 84}{3}$$

Table B1.1: Phi and Sieve Apertures with Wentworth Classifications

Phi Units	Microns [µm]	Sediment Description
≤-6→ -8	<256000 → 64000	Cobble
≤-2→ -6	<64000 → 4000	Pebble
≤-1→ -2	<4000 → 2000	Granule
>-1 → 0	<2000 → 1000	Very Coarse Sand
>0 → 1	<1000 → 500	Coarse Sand
>1 → 2	<500 → 250	Medium Sand
>2 → 3	<250 → 125	Fine Sand
>3 → 4	<125 → 63	Very Fine Sand
>4 → 5	<63 → 31.5	Coarse Silt
>5 → 6	<31.5 → 15.6	Medium Silt
>6 → 7	<15.6 → 7.8	Fine Silt
>7 → 8	<7.8 → 3.9	Very Fine Silt
>8 → 10	<3.9 → 1	Clay

Sorting (inclusive graphic standard deviation) uses the equation:

$$D = \frac{\Phi 84 - \Phi 16}{4} + \frac{\Phi 95 - \Phi 5}{6.6}$$

Table B1.2: Sorting Classifications

Sorting Coefficient	Sorting Classifications
≥0 → 0.35	Very well sorted
>0.35 → 0.50	Well sorted
>0.50 → 0.71	Moderately well sorted
>0.71 → 1.00	Moderately sorted
>1.00 → 2.00	Poorly sorted
>2.00 → 4.00	Very poorly sorted
>4.00	Extremely poorly sorted

B2 Sediment Chemistry Analysis

B2.1 Total Organic Matter – Loss on Ignition at 450 °C

Total organic matter by loss on ignition analysis was performed by TES Bretby, according to the following method statement.

A sample of the dried, ground, sample was sieved through a 425 µm sieve and accurately weighed into a crucible. The sample was then heated to 450°C, until constant weight was achieved. The loss of mass after heating was expressed as a percentage, and reported as Loss on Ignition.

Loss on ignition was calculated as:

$$\text{LOI (dry soil basis)} = (c-f)/c \times 100\% \text{ w/w}$$

Where: LOI = loss on ignition; c = weight of dried analysis sample [g]; f = weight of residue after ignition [g]

B2.2 Fractionated Organic Carbon (FOC)

Fractionated Organic Carbon (FOC) analyses were performed by TES Bretby, according to the following method statement.

The dry, homogenised sample was treated with acid, in order to remove inorganic carbon. The sample was then introduced into a heated reaction chamber with an oxidative catalyst. Organic carbon was oxidised to CO_2 and measured by non-dispersive infrared analysis. This method does not quantify volatile organic carbon, which should be determined by another technique. The limit of detection for this method was 0.10 % $^{w}/_{w}$.

B2.3 Hydrocarbon Analysis

Hydrocarbon analysis of sediments was performed by ERT (Scotland) Ltd in the U.K., according to the following method statement.

Note: extraction of hydrocarbons was undertaken on wet sediment samples. This technique is considered to extract a greater proportion of the target analytes than dry extraction methods: Wong & Williams (1980) estimated that around 16% of hydrocarbons determined by wet extraction procedures were lost as a consequence of the drying process. Comparison with baseline values from previous surveys or published literature should be undertaken with caution as it is often not clear whether wet or dry extraction has been employed.

B2.3.1 General Precautions

To effectively eliminate all possible sources of hydrocarbon contamination from the analysis the following precautionary measures were taken prior to sample work-up.

1. All solvents were purchased as high purity grade. Each batch was checked for purity by concentrating approximately 400 ml down to a small volume (<1 ml) and analysing by gas chromatography (GC).
2. All water used was distilled through an all glass still and dichloromethane / pentane extracted to minimise contamination from plasticisers.

3. All glassware was cleaned using an acid / base machine wash. The glassware was rinsed with acetone then finally with dichloromethane prior to use.
4. Procedural blanks, replicate analyses and laboratory reference material were run with each batch.

B2.3.2 Ultrasonication Extraction for Hydrocarbons in Sediment

Sediment samples were thawed, homogenised and accurately weighed into a 250 ml conical flask. A solution containing an appropriate amount of the following internal standards was added to each sample using a 100 µl microsyringe.

Aliphatic standards	Aromatic standards
heptamethylnonane	d8 naphthalene
d34 hexadecane	d8 acenaphthylene
1-chloro-octadecane	d10 phenanthrene
squalane	d10 pyrene
	d12 chrysene
	d12 perylene

Methanol (50 ml) was added and the solvent mixed with the sediment. Dichloromethane (DCM) (60 ml) was then added and the sample mixed again. The flasks were then capped with solvent cleaned aluminium foil and ultrasonicated for 30 minutes.

After being allowed to settle the solvent was decanted through a GF-C filter paper into a 1 litre separating funnel. The extract was then partitioned with 100 ml of DCM / pentane extracted distilled water and the DCM layer run-off into a clean 500 ml round-bottomed flask. The ultrasonic extraction was repeated a further two times using 50 ml DCM and 15 minutes of ultrasonication, each time the filtered extract was partitioned with the remaining methanol / water in the separating funnel. The DCM extracts were bulked and reduced in volume to approximately 2 ml using a rotary evaporator then further reduced to approximately 1 ml under a gentle stream of nitrogen prior to cleanup.

Correction factors for wet / dry sediments were obtained by drying a sub-sample of the homogenised sediment to constant weight at 110℃.

B2.3.3 Clean-Up of Extracts by Column Chromatography

Removal of polar material, including lipids was carried out using a silica gel column. The silica gel used was 70 to 230 mesh which was heated at 400℃ for at least four hours to remove impurities and residual moisture then stored at 200℃ prior to use. The sample extract was added to the silica gel column, containing 5 g of adsorbent and approximately 1 g of activated copper powder (for removal of free sulphur), and eluted with 35 ml of DCM / pentane (1:2). The eluant was reduced in volume using the evaporator to approximately 2 ml before being further reduced under a gentle stream of nitrogen to an appropriate volume and analysed by gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) (see Table B2.3)

Table B2.3: GC and GC-MS Techniques

	Gas Chromatography (GC)	Gas Chromatography-Mass Spectrometry (GC-MS)
Instrument	HP 6890 Series GC with 7673 autoinjector	ThermoFinnigan Trace GC - DSQ mass selective detector with AS3000 autoinjector
Column	100%-dimethylpolysiloxane bonded fused silica, 60 m, 0.25 µm film thickness, 0.32 mm internal diameter	(5%phenyl)-methylpolysiloxane bonded fused silica, 60 m, 0.25 µm film thickness 0.32 mm internal diameter
Carrier Gas	Hydrogen (constant flow 5 ml / min)	Helium (constant flow 1.4 ml / min)
Injector	On–column (1 µl injection)	Splitless, 250℃, split flow 40 ml / min, vent time 1 min (1 µl injection)
Oven Temperature Programme	80℃ - 1 min 80 to 320℃ at 15℃ / min 320℃ – 10 min 320 to 350℃ at 10℃ / min	60℃ - 1 min 60 to 120℃ at 15℃ / min 120 to 325℃ at 5℃ / min 325℃ – 9 min
Source / Detector Temperature	300℃ (FID)	280℃
Electron Energy	-	70 eV
Selected Ion Monitoring (SIM)	-	8 groups - 6 ions per group
Dwell Time (per ion)	-	0.05 second

B2.3.4 Method Specifications

Total Hydrocarbons by Gas Chromatography – Flame Ionisation Detection (GC-FID)
Total hydrocarbons were calculated using an internal standard method. Total hydrocarbon calibration was undertaken using average response factors obtained from the n-alkane standard solutions. The total area of the chromatogram between nC_{12} and nC_{36} was quantified.

Limit of Quantification (matrix and oil type dependent) = approximately 0.5 $\mu g.g^{-1}$ dry weight.

N-Alkanes, Pristane and Phytane
The n-alkanes between nC_{12} and nC_{36} were reported, as were the ranges between nC_{12} and nC_{20} and nC_{21} to nC_{36}. Carbon preference index (CPI) values (the ratio of odd to even carbon numbered compounds) for the same ranges were also calculated. Pristane and phytane (and associated ratio) were also quoted.

Calibration was undertaken using a range of n-alkane standard solutions containing the even carbon number compounds between nC_{12} and nC_{36} and a range of suitable internal standards. Individual response factors were calculated for each of the n-alkanes present in the calibration solution. Response factors for the non-calibrated n-alkanes (and pristane and phytane) were taken to be equivalent to closely eluting compounds. Limit of Quantification (matrix dependent) is approximately 1 $ng.g^{-1}$ dry weight per compound.

Polycyclic Aromatic Hydrocarbons
A full range of PAH and alkylated PAH were quantified as specified by Department of Trade and Industry (DTI) regulations (DTI, 1993).

Calibration was undertaken using a range of PAH standard solutions, a number of alkylated PAH, dibenzothiophene and a range of suitable internal standards. Individual response factors were calculated for each of the compounds present in the calibration solution. Response factors for the non-calibrated alkylated PAH were taken to be equivalent to closely related compounds.

Limit of Quantification (matrix and component dependent) = approximately 1.0 $ng.g^{-1}$ dry weight per component.

Quality Assurance

1. An independent standard solution was analysed with each batch of samples to verify instrument calibration.
2. Sample blanks were run with each batch.
3. At least one laboratory reference sample and one sample duplicate analysis was carried out for each study.
4. ERT participates in the Quasimeme international laboratory performance scheme.

B2.4 Heavy and Trace Metal Analysis

Heavy and trace metal analyses were performed by TES Bretby according to the following method statement.

B2.4.1 Sample Digestion Procedure

Partial Metals (Nitric Acid Extractable Metals - Aqua Regia Metals)
Samples were subjected to oxidative acid digestion using nitric acid and heating. Hydrochloric acid was added at the end of the digestion for element stability prior to analysis. Elements were identified and quantified by ICP-MS. The quantity of sample and digest taken was adjusted according to the concentrations of metals within the samples.

Total Metals (Hydrofluoric / Boric acid Extractable Metals) Mn, Fe, Ba, Sr & Al
Approximately 0.20 g of the sediment sample is accurately weighed out and placed in a PTFE bottle. 2.5 ml of Hydrofluoric acid are added. The bottle is placed in an oven at 105 ± 5℃ for approximately 30 minutes. The bottle is then allowed to air cool in a fume cupboard. 65 ml of 4% Boric acid is the added to the bottle .The contents are then mixed thoroughly and placed in a polypropylene flask and made up to 100 ml with deionised water. The sample is then analysed by ICP-OES

Total Metals (Hydrofluoric / Nitric acid Extractable Metals) Cr, Cu, Co, Ni, Zn, Mn, V, As, Pb & Cd
Approximately 0.10 g of the sediment sample is accurately weighed out and placed in a PTFE bottle. Approximately 1 ml of Hydrofluoric acid, 1ml of nitric acid and 1 ml of water are added and the bottle is placed in an oven at 105 ± 5℃ for approximately 60 minutes. The bottle is then allowed to air cool in a fume cupboard. The extract is transferred to a plastic beaker and evaporated to dryness. The residue is cooled and dissolved in 2 ml of nitric acid. This is transferred to a 100 ml volumetric flask and made up to volume. The metals concentrations in the extract are determined by ICP-MS

B2.4.2 Analytical Methodology

Inductively Coupled Plasma Optical Emission Spectrometry
The instrument is calibrated using dilutions of the 1 ml.=10 mg spectroscopic solutions. The final calibration solutions are matrix matched with the relevant acids. The calibration line consists of 5 standards.

Inductively Coupled Plasma- Mass Spectrometry
The instrument is calibrated using dilutions of the 1 ml = 10 mg spectroscopic solutions. The calibration line consists of 7 standards.

The analytes are ratioed against internal standards to take account of changes in plasma conditions as a result of matrix differences between standards and samples. Internal standards used should have a similar mass to the analyte ratioed to and should have similar ionisation properties to the analytes.

B2.4.3 Method Quality Control

Sample Batch QC: blank, blank spike, (matrix spiking and duplicate analysis on request)

Instrument QC:The following QC procedures are performed each day of analysis:

- Instrument tuning (tuning solution 10 µg/L Lithium, Cobalt, Yttrium, Cerium, Thallium)
- Continuing calibration using calibration blank (CCB) and standard (CCV)
- Independent quality control (IQC) standard for daily standard preparation traceability
- Internal standard monitoring.

The following QC checks are performed for each set of calibration standards prepared:

- Update calibration and check solution after IEC.
- 5-point initial calibration.
- Interelement correction (IES) Standard

B3 Macrofauna Analysis

B3.1 Sorting and Identification

On arrival at the laboratory samples were checked in and their details logged onto the job worksheet. They were then transferred from their 4% formaldehyde fixative to 70% Industrial Methylated Spirit (IMS) for safe handling and storage.

In order to extract the fauna from the samples they were washed, using a spray head, through a stack of sieves of graduated mesh. The bottom sieve in the stack was of the mesh size specified by the client (0.5 mm). The coarser (>2.0 mm) fractions separated by this process were transferred to trays of water and placed under a freestanding light source; the fauna was then extracted using forceps. To ensure efficient removal of smaller invertebrates from the less coarse (<2.0 mm) fractions, these were poured in small quantities into a Petri dish and examined under a stereo microscope. The animals were stored in labelled jars or vials filled with 70% IMS. At each stage of the extraction process care was taken to ensure that no animals remained on the sieves or in the containers used for sample fraction storage.

Specimens were identified to the lowest practicable taxonomic level (generally species) and enumerated using stereo and compound microscopy and dissection where appropriate. Non-enumerable colonial taxa were identified and their presence in the sample recorded by placing a "P" on the datasheet.

To ensure data quality and consistency various control systems were adhered to. Residues from the finer sample fractions were double-checked to ensure all of the fauna had been removed. The senior taxonomist also checked all of the identifications made. A reference collection of all fauna encountered during the survey was created and used to ensure consistency in identification.

Species data were entered into the environmental database (DES) and an Excel spreadsheet with the appropriate Marine Conservation Society (MCS) codes (Howson & Picton, 1997) was produced.

B3.2 Taxonomic Standardisation

Before undergoing statistical analysis, macrofauna data were reviewed to ensure the dataset was valid for statistical analysis. All taxonomically indistinct taxa were either aggregated to higher taxonomic levels or, if it was felt that this would result in the loss of important discriminatory information, excluded from the dataset.

In accordance with OSPAR Commission (2004) guidelines all juvenile, colonial, planktonic and meiofaunal taxa were excluded from further analysis, ensuring comparability between the data from surveys undertaken in different seasons. Macrofauna were taken to be those animals retained by a 1 mm sieve. Meiofauna are those animals retained by a 0.1 mm mesh (Lincoln & Boxshall, 1987). Taxa such as Nematoda, which may be retained by a 0.5 mm sieve, but will not have been consistently sampled, were also excluded from further statistical analysis.

B4 Statistical Analysis

Final data derived from the physico-chemical and macrofaunal samples were analysed using routines in the PRIMER (Plymouth Routines in Multivariate Ecological Research) v.6.0 software package (Clarke & Gorley, 2006). Correlations (between crude granulometric, physico-chemical and primary and univariate macrofaunal parameters) were calculated using the Pearson's product moment correlation coefficient. Multivariate methods were utilised to aid the interpretation of granulometric data and a combination of univariate and multivariate methods (as per OSPAR Commission (2004) guidelines) were used to aid identification of any underlying patterns in the benthic communities.

B4.1 Correlations

Granulometric, physico-chemical and macrofaunal parameters data were normalised prior to correlation analysis (by subtraction of their means, followed by division by their standard deviations). Correlations were then calculated between by generating resemblance matrices between variables by the Pearson's product moment coefficient, which uses the following formula:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}.$$

Where: X_i and Y_i = values and $\overline{X}$ and $\overline{Y}$ = variable means

B4.2 Primary and Univariate Variables

Diversity is typically thought to comprise two different factors: the number of species (species richness) and the equitability of species abundances (evenness or equitability) (Magurran, 1988). Thus a range of primary and derived univariate indices were calculated which attempt to quantify the species richness, evenness and a combination of both. The primary variables (number of individuals and species) and univariate variables (Shannon-Weiner diversity, Margalef's richness, Simpson's diversity and Pielou's evenness) were calculated for both the samples and the pooled replicates for each station using the PRIMER v6.0 DIVERSE procedure (Clarke & Gorley, 2006) (Table B4.4).

Table B4.4: Primary and Univariate Indices

Variable	Dominant Influence/s	Formula	Comment
Number of Species or Species Richness (S)	Richness	S Where: S = the total number of species.	The simplest measure of species richness.
Number of Individuals or Abundance (N)	-	N Where: N = the total number of individuals.	The simplest measure of abundance.
Shannon Weiner Index (H')	Richness + Evenness	$H' = -\sum_i p_i (\log p_i)$ Where: p_i is the proportion of the total count arising from the ith species.	The most widely used diversity index incorporating both species richness and equitability (Shannon & Weaver, 1949).
Margalef's Richness (D_{MG})	Richness	$D_{Mg} = \frac{(S-1)}{\log N}$ Where: S = total number of species; N = total number of individuals.	A simple index derived from a combination of the number of species (S) and total number of individuals (Clifford & Stevenson, 1975).
Pielou's Evenness or Equitability (J')	Evenness	$J' = \frac{H'}{\log S}$ Where: H' = Shannon-Wiener Index; S = total number of species.	A measure of how evenly individuals are distributed between species (Pielou, 1969).
Simpson's Dominance ($1-D$)	Evenness	$D = \sum \left[\frac{n_i (n_i - 1)}{N (N - 1)} \right]$ Where: n_i = number of individuals in the ith species; N = total individuals.	A measure of dominance weighted to the commonest species (Simpson, 1949). As D increases, diversity decreases, so the reciprocal ($1-D$) is more usually expressed.

B4.3 Species Accumulation and Richness Estimation

A species accumulation plot was generated using PRIMER v6.0. This cumulatively plotted the total number of taxa recorded at each station (S_{obs}) and can be used to qualitatively assess the efficacy of the macrofaunal sampling operations. The curve of a species accumulation plot for a community that had been fully sampled (i.e. from which all of the taxa present had been detected) would reach its asymptote (point of the curve with no slope), whereas the slope of an accumulation plot for an incompletely sampled community would remain positive throughout. The curves of the species accumulation plot were smoothed by permutation of the data points and calculation of the means of the permuted results.

The number of taxa observed at each station can be extrapolated to estimate the number of taxa present in the community as a whole ($\hat{S}$) using a variety of non-parametric functions. Four richness estimators (Chao1, Chao2, Jacknife1 and Jacknife2) were calculated using PRIMER v6.0 (Table B4.5) and plotted alongside the actual species accumulation (S_{obs}) curve. All of these richness estimators use the frequency of occurrence of rare taxa to estimate how taxa would accumulate should the community be infinitely sampled. For further discussion of these indices see Chao (2005).

Table B4.5: Richness Estimators

Variable	Formula	Comment
Chao1 ($\hat{S}_{chao1}$)	$\hat{S}_{chao1} = S_{obs} + \frac{F_1 (F_1 - 1)}{2 (F_2 + 1)}$ Where: F_1 = number of singletons (taxa of which only single individuals occur at a station) F_2 = number of doubletons (taxa of which two individuals occur at a station)	Bias-corrected estimator which uses the taxa that occur at a frequency of one or two individuals per station to estimate total community richness.
Chao2 ($\hat{S}_{chao2}$)	$\hat{S}_{chao2} = S_{obs} + \left(\frac{m-1}{m}\right)\left(\frac{Q_1 (Q_1 - 1)}{2 (Q_2 + 1)}\right)$ Where: m = total number of stations Q_1 = number of uniques (taxa that occur in one sample) Q_2 = number of duplicates (taxa that occur at two stations)	Bias-corrected incidence (presence / absence) estimator which uses the taxa that occur at one or two stations to estimate total community richness.
Jacknife1 ($\hat{S}_{j1}$)	$\hat{S}_{j1} = S_{obs} + Q_1 \left(\frac{m-1}{m}\right)$ Where: m = total number of stations Q_1 = number of uniques (taxa that occur in one sample)	First order incidence (presence / absence) estimator which uses the taxa that occur at one station to estimate total community richness.
Jacknife2 ($\hat{S}_{j2}$)	$\hat{S}_{j2} = S_{obs} + \left(\frac{Q_1 (2m - 3)}{m} - \frac{Q_2 (m - 2)}{m (m - 1)}\right)$ Where: m = total number of stations Q_1 = number of uniques (taxa that occur in one sample) Q_2 = number of duplicates (taxa that occur at two stations)	Second order incidence (presence / absence) estimator which uses the taxa that occur at one or two stations to estimate total community richness.

B4.4 Multivariate Analysis

A range of multivariate statistical analyses were conducted on the granulometric and macrofaunal data. These were undertaken with the statistical package Plymouth Routines in Multivariate Ecological Research (PRIMER) v6.0 (Clarke & Gorley, 2006). Multivariate analysis of community data allows a more thorough examination of differences between samples by preserving the identity of species when calculating similarities.

B4.5 Pre-treatment of Data

Prior to analysis data typically undergo transformation to down-weight the effect of dominant data components in determining inter-sample similarities. These transformations vary in their effect through: no transform; square root (√); fourth root / double square root (√√); logarithmic, and; reduction to presence / absence. At the former end of the spectrum (no transform) all attention is focused on the dominant components of the dataset, and at the latter end (reduction to presence / absence) equal weighting is applied to all components (Clarke & Warwick, 1994).

Granulometric data were aggregated to give percentage composition at 1.0 phi intervals prior to multivariate analysis.

Macrofaunal data underwent a square root transformation so that the analysis took account of all components of the community but retained some quantitative information.

B4.6 Similarity Matrices

A triangular similarity matrix was then produced from the transformed data, by calculating the similarity between every pair of replicate samples. In this case the Bray-Curtis similarity coefficient was used for macrofauna data (Bray & Curtis, 1957). This similarity measure is widely considered to be the most suitable similarity measure for community data (Clarke *et al*, 2006).

B4.7 Hierarchical Agglomerative Clustering (CLUSTER) and Similarity Profile Testing (SIMPROF)

The CLUSTER programme uses the similarity matrix to successively fuse samples into groups and groups into clusters according to their level of similarity. The end point of this process is a single cluster containing all the samples, which is displayed by means of a dendrogram with similarity displayed on one axis and samples on the other.

Similarity profile permutation tests (SIMPROF) were also be performed, to look for evidence of genuine statistically significant clusters, in samples which are *a-priori* unstructured (i.e. with no prior statistical design), as typically seen for a baseline survey such as this. By combining this significance testing with the CLUSTER function, dendrograms are produced indicating those clusters which are statistically significant. Statistically significant splits in dendrograms are illustrated as solid black lines, while non-significant splits are shown as dotted red lines.

B4.8 Non-Metric Multidimensional Scaling (nMDS)

nMDS also uses the similarity matrix, but unlike hierarchical agglomerative clustering nMDS simultaneously displays the similarity between all pairs of samples on 2 or 3 dimensional ordinations. In producing this low-dimensional ordination there is some distortion of the between sample similarities. The degree of distortion involved in producing an ordination gives an indication of the adequacy of the nMDS representation and is recorded as a stress value (Table B4.6):

Table B4.6: nMDS Stress Values

nMDS Stress	Adequacy of Representation for 2-Dimensional Plot
0.0 → ≤0.05	Excellent representation with no prospect of misinterpretation.
>0.05 → ≤0.1	Good ordination with no real prospect of a misleading interpretation.
>0.1 → ≤0.2	Potentially useful 2-d plot, though for values at the upper end of this range too much reliance should not be placed on plot detail; superimposition of clusters should be undertaken to verify conclusions.
>0.2 → ≤0.3	Ordination should be treated with scepticism. Clusters may be superimposed to verify conclusions, but ordinations with stress values >2.5 should be discarded. A 3-d ordination may be more appropriate.
>0.3	Ordination is unreliable with points close to being arbitrarily placed in the 2-d plot. A 3-d ordination should be examined.

B4.9 Similarity Percentages Analysis (SIMPER)

This programme calculates the individual contribution of different species to both the similarity of samples within a cluster group and the dissimilarity between different cluster groups. It is therefore possible to identify those species which are characteristic of a particular habitat and those species which act as discriminating species between habitats.

B5 ROV Video Analysis

Video footage acquired during bore hole operations were viewed to assist with determination of seabed features and epifaunal communities.

All video footage was provided in Mpeg format and viewed using the Elecard Player program. This software also allows screen grabs to be taken of individual frames and outputted as Jpeg files (at the full video resolution). A number of these example screen grabs were used in the subsequent reporting.

The video footage was initially viewed briefly and described on a file by file basis. This allowed the quality of each video file to be assessed and its degree of usefulness for further analysis to be determined (i.e. how much of the file provided usable footage of the seabed and what was each file's spatial coverage. Brief descriptions of the sediment type, seabed features and fauna noted from each clip were made.

A number of clips were then identified that appeared worthy of more detailed analysis; these were generally multiple files that jointly comprised the longer survey transects undertaken. These were viewed in real time (or where necessary to better characterise features, frame by frame) and detailed logs made for each significant change in habitat and / or epifaunal community. For each habitat / community change the following information was logged:

- Date and time acquired
- Location
- Video file(s)
- Start and end position of the habitat / community change
- Extent of habitat / community
- Sediment type / seabed morphology
- Fauna

B6 Data Presentation And Interpretation

B6.1 Data Presentation Using Contouring Software

The contouring and 3D surface mapping software package, Surfer, Version 8, was utilised to aid interpretation and visual representation of environmental data. By interpolating irregularly spaced geographical information (XYZ data) regularly spaced grid data may be produced. These grids may then be displayed in a number of forms, including contour and shaded relief maps.

Interpolation of environmental variables (discrete values for sampling stations) was undertaken according to the following criteria:

Bathymetry Interpolation	
Gridding Method	Nearest Neighbour
Search Radius	20 m
Contour Scaling	Coded on each figure
Grid Line Spacing	20 m

Environmental Variables Interpolation	
Gridding Method	Kriging
Search Radius	500 m
Contour Scaling	Coded on each figure
Grid Line Spacing	20 m
Image Scale	1 : 175,000

B6.2 Data Interpretation

Survey data were discussed in terms of variability within the site and across the wider area surveyed (all four sites), where possible indicating the likely mechanisms driving differences in recorded values at different sampling stations.

Summary data for the survey area (i.e. means and associated standard deviations) were compared to other sites sampled during the survey program.

C. PERSONNEL

Position	Name	Dates Working on Project
Party Chief	Trevor Rowland	01/12/08 – 10 /01/09
	Ian Ewing	10/01/09 – 14/02/09
Technical Co-ordinator	Roger Basford	01/12/08 – 10/01/09
	David Gibbs	10/01/09 – 14/02/09
Engineer	Terry Baccus	01/12/08 – 10/01/09
	James Smith	01/12/08 – 10/01/09
	Martin Holdsworth	01/12/08 – 10/01/09
	Tomasz Kuciarski	10/01/09 – 14/02/09
	Tim Bishop	10/01/09 – 14/02/09
	Tony Bellamy	10/01/09 – 14/02/09
Mechanical Engineer	Richie Cresswell	01/12/08 – 10/01/09
	Chhaganlal Mistry	10/01/09 – 14/02/09
Surveyor	Tony Bullen	01/12/08 – 10/01/09
	Anna Stolarczuk	01/12/08 – 10/01/09
	Derek Baitson	01/12/08 – 10/01/09
	Andy Dyer	10/01/09 – 14/02/09
	Crispian Roope	10/01/09 – 14/02/09
	Barry Earl	10/01/09 – 14/02/09
Data Processor	Brian Davidson	10/01/09 – 14/02/09
Geophysicist	Chris Martin	01/12/08 – 10/01/09
	Samantha Mead	01/12/08 – 10/01/09
	Mark Stephen	10/01/09 – 14/02/09
Seismic Processor	Matt Bartell	10/01/09 – 14/02/09
	Melissa Padilla	10/01/09 – 14/02/09
Environmental Scientist	Lea Fennelly	01/12/08 – 10/01/09
	Louisa Jones	01/12/08 – 10/01/09
	David Warner	10/01/09 – 14/02/09
	Julia Doran	10/01/09 – 14/02/09
	Kevin O'Connell	10/01/09 – 14/02/09
	Alessandro Icardi	10/01/09 – 14/02/09
MMO	Christina Mehle	01/12/08 – 10/01/09
	Richard Holt	10/01/09 – 14/02/09
Client Representative	Kirk MacDonald	01/12/08 – 10/01/09
	Noel Rogers	01/12/08 – 10/01/09
	Mark Campbell Jon	01/12/08 – 10/01/09
	Brian Sears	10/01/09 – 14/02/09
	Stefan Seyb	10/01/09 – 14/02/09
	Ben Brown	10/01/09 – 14/02/09
Medic	Mike Tierney	01/12/08 – 14/02/09

D. FIELD LOGS

D.1 SURVEY LOG

Date	Time	Station / Transect	Photo No./ Grab Type	Fix	Type	Depth [m]	Proposed Location [m]		Actual Location [m]		Distance from Location
							Easting	Northing	Easting	Northing	
14/01/09	07:57	15	Box Corer	35	No sample	1412	874170	4313245	874209	4313557	
14/01/09	10:49	14	Box Corer	37	No-trigger	1434	869645	4315990	869705	4316342	
14/01/09	13:43	14	Box Corer	39	FA	1434	869645	4315990	869724	4316357	367.0
14/01/09	15:26	14	Box Corer	42	FB	1434	869645	4315990	869671	4316276	287
14/01/09	17:47	14	Box Corer	45	PC	1434	869645	4315990	869722	4316255	277.0
14/01/09	19:47	1	Box Corer	46	No sample - sample contained coral	1375	871825	4317485	871911	4317715	
14/01/09	21:07	1	Box Corer	no fix taken	Aborted - presence of coral on previous drop	1375	871825	4317485	drop aborted		
19/01/09	06:44	13	Box Corer	49	No sample, stone in jaws	1400	877270	4320349	877243	4320447	
19/01/09	10:14	13	Box Corer	50	No sample	1401	877270	4320439	877209	4320409	
19/01/09	11:57	13	Box Corer	51	No sample	1399	877270	4320439	877246	4320302	
19/01/09	19:02	12	Box Corer	53	No sample	1455	871215	4319870	871141	4319989	
19/01/09	20:12	12	Box Corer	54	No sample	1455	871215	4319870	871141	4319973	
19/01/09	22:07	2	Box Corer	56	FA	1365	869745	4320825	869735	4320895	71.0
19/01/09	23:38	2	Box Corer	58	FB	1365	869745	4320825	869708	4320870	58.0
20/01/09	01:09	2	Box Corer	59	PC	1365	869745	4320825	869705	4320888	75.0
20/01/09	03:58	11	Box Corer	61	FA	1437	868840	4323369	868822	4323472	103.0
20/01/09	05:43	11	Box Corer	62	No-trigger	1436	868840	4323369	868819	4323473	
20/01/09	06:54	11	Box Corer	63	FB	1436	868840	4323369	868805	4323434	73.0
20/01/09	08:32	11	Box Corer	64	No sample	1435	868840	4323369	868803	4323428	
20/01/09	09:51	11	Box Corer	66	No sample, wire tangle	1435	868840	4323369	868780	4323410	
20/01/09	11:09	11	Box Corer	67	No sample	1436	868840	4323369	868795	4323412	
20/01/09	13:16	10	Box Corer	69	No sample	1375	869655	4324379	869620	4324377	
20/01/09	14:37	10	Box Corer	71	No sample	1376	869655	4324379	869601	4324378	
20/01/09	16:14	1	Box Corer	72	No-trigger	1375	871825	4317485	871811	4317519	
20/01/09	17:31	1	Box Corer	73	no sample	1375	871825	4317485	871781	4317539	
20/01/09	19:50	3	Box Corer	74	FA	1350	868595	4325725	868553	4325750	49.0
20/01/09	21:23	3	Box Corer	75	No-trigger	1350	868595	4325725	868540	4325742	
20/01/09	22:38	3	Box Corer	76	FB	1350	868595	4325725	868539	4325700	61.0
21/01/09	00:02	3	Box Corer	77	No sample	1350	868595	4325725	868540	4325698	
21/01/09	01:18	3	Box Corer	78	No sample	1350	868595	4325725	868569	4325701	
21/01/09	03:47	4	Box Corer	80	No-trigger	1359	870860	4326424	870828	4326435	
21/01/09	05:04	4	Box Corer	81	No sample	1357	870860	4326424	870809	4326464	
21/01/09	06:48	5	Box Corer	82	No-trigger	1352	870310	4327830	870259	4327882	
21/01/09	23:09	5	Box Corer	83	No sample	1352	870310	4327830	870337	4327903	
22/01/09	01:18	8	Box Corer	84	PC	1438	871680	4329980	871665	4330072	93.0
22/01/09	03:23	8	Box Corer	87	No sample	1438	871680	4329979	871709	4330053	

D.2 DECK LOG

Date	Time	Station	Grab	Fix	Volume [%]	Sediment Description	Layer 1				Smell Y\N	Redox	pH	Photo	COMMENTS
							Hue	Chroma	Value	Colour					
14/01/09	07:57	15	No sample	35	—										
14/01/09	10:47	14	Misfire	37	—										
14/01/09	13:43	14	FA	39	11cm	fine silty sand with underlying gravel	5Y	2	6	1:1 Light olive grey : black sand particles	N	100	7.8	Y	
14/01/09	15:26	14	FB	42	20cm	fine silty sand with underlying gravel	5Y	2	6	1:1 Light olive grey : black sand particles	N	171	7.8	Y	
14/01/09	17:47	14	PC	45	14cm	fine silty sand with underlying gravel	5Y	2	6	1:1 Light olive grey : black sand particles	N	140	7.8	Y	
14/01/09	19:47	1	No sample	46	—	Sample too small. Dead cold water coral found in sample									
14/01/09	21:07	1	No sample	no fix taken	—	Drop stopped while waiting for clarification if box cores were allowed to be taken in areas where coral was found to be present									
19/01/09	06:44	13	No sample	49	—	Stone in jaws									
19/01/09	10:14	13	No sample	50	—	Sample too small									
19/01/09	11:57	13	No sample	51	—	Stone in jaws									
19/01/09	19:02	12	No sample	53	—										
19/01/09	20:12	12	No sample	54	—										
19/01/09	22:07	2	FA	56	10cm	Silty sand	5Y	2	6	1:1 Light olive grey : black sand particles	N	105	7.8	Y	
20/01/09	23:38	2	FB	58	15cm	Silty sand with dark sandy particles	5Y	2	6	1:1 Light olive grey : black sand particles	N	142	7.8	Y	
20/01/09	01:09	2	PC	59	10cm	Silty sand with dark sandy particles	5Y	2	6	1:1 Light olive grey : black sand particles	N	154	7.8	Y	
20/01/09	03:58	11	FA	61	12cm	Silty sand with dark sandy particles	5Y	2	6	1:1 Light olive grey : black sand particles	N	125	7.9	Y	
20/01/09	05:43	11	Misfire	62	—	Misfire									
20/01/09	06:54	11	FB	63	17cm		5Y	2	6	1:1 Light olive grey : black sand particles	N	106	7.7	Y	

Date	Time	Station	Grab	Fix	Volume [%]	Sediment Description	Layer 1				Smell Y\N	Redox	pH	Photo	COMMENTS
							Hue	Chroma	Value	Colour					
20/01/09	08:32	11	NS	64	—	No Sample									
20/01/09	09:51	11	NS	66	—	Sample washed out									
20/01/09	11:09	11	NS	67	—	Sample too small									
20/01/09	13:16	10	NS	69	—	Sample too small									
20/01/09	14:37	10	NS	71	—	Sample too small									
20/01/09	16:14	1	NS	72	—	Misfire									
20/01/09	17:31	1	NS	73	—	Sample too small									
20/01/09	19:50	3	FA	74	10cm	Silty sand with dark sandy particles	5Y	2	6	1:1 Light olive grey : black sand particles	N	157	8	Y	
20/01/09	21:23	3	Misfire	75	—										Misfire
20/01/09	22:38	3	FB	76	10cm	Silty sand with dark sandy particles	5Y	2	6	1:1 Light olive grey : black sand particles	N	174	7.7	Y	
21/01/09	00:02	3	NS	77	—	Sample too small									
21/01/09	01:18	3	NS	78	—	Sample too small									
21/01/09	03:47	4	NS	80	—	Misfire									
21/01/09	05:04	4	NS	81	—	Silty sand with dark sandy particles	5Y	2	6	1:1 Light olive grey : black sand particles	N			Y	Sample too small. Silt and black sand
21/01/09	06:48	5	NS	82	—	Misfire									
21/01/09	23:09	5	NS	83	—									Y	Sample too small
22/01/09	01:18	8	PC	84	7cm	Silty sand with dark sandy particles	5Y	2	6	1:1 Light olive grey : black sand particles	N	145	7.7	Y	Sample too small for fauna
22/01/09	03:23	8	NS	87	—									Y	Sample too small

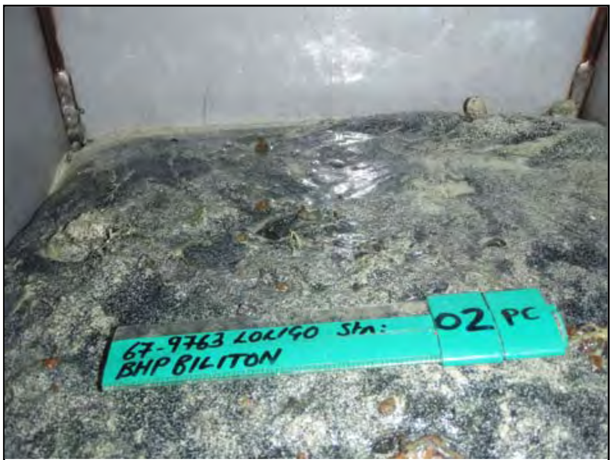
D.3 ROV VIDEO LOG

Date	Location	File(s)	Time	Video Coordinates [m]		Transect Distance	Sediment Type	Fauna
				Easting	Northing			
15/02/09	Loligo A	20090215213142_0.mpg	18:31:42	871610	4317145	24	Muddy fine sand with occasional coarse fragments (pebbles, cobbles and occasional small boulders)	Occasional gorgonians (sea fans) and scleractinians (hard corals) associated with coarse material
			18:38:23	871621	4317166			
15/02/09	Loligo A	20090215213142_0.mpg	18:38:23	871621	4317166	0	Muddy fine sand with a high proportion of coarse material	Occasional gorgonians and scleractinians, occasional sponges, dense faunal turf (bryozoan / hydroid) on exposed hard material
			18:43:44	871621	4317166			
15/02/09	Loligo A	20090215213142_0.mpg / 20090215214642_0.mpg	18:45:05	871616	4317167	146	Muddy fine sand with occasional coarse fragments (pebbles, cobbles and occasional small boulders)	Sparse gorgonians and scleractinians associated with coarse material
			18:55:53	871696	4317289			
15/02/09	Loligo A	20090215214642_0.mpg / 20090215220142_0.mpg / 20090215221642_0.mpg	18:55:53	871696	4317289	25	Muddy fine sand with a high proportion of coarse material	Occasional gorgonians and scleractinians, occasional sponges, bryozoan / hydroid turf on exposed hard material
			19:15:27	871712	4317308			
15/02/09	Loligo A	20090215221642_0.mpg	19:15:27	871712	4317308	24	Muddy fine sand with occasional coarse fragments (pebbles, cobbles and occasional small boulders)	Sparse gorgonians and scleractinians associated with coarse material
			19:16:40	871723	4317329			
15/02/09	Loligo A	20090215230753_0.mpg	20:07:53	871796	4317435	27	Muddy fine sand with occasional coarse fragments (pebbles, cobbles and occasional small boulders)	Sparse gorgonians and scleractinians associated with coarse material
			20:09:43	871772	4317448			
15/02/09	Loligo A	20090215230753_0.mpg	20:09:43	871772	4317448	43	Outcropping consolidated (possibly cemented) material with coarse material and a thin veneer of muddy fine sand	Occasional gorgonians and scleractinians, occasional sponges, dense bryozoan / hydroid turf on exposed hard material, ophiuroids (brittlstars), shrimp
			20:16:54	871734	4317468			
15/02/09	Loligo A	20090215230753_0.mpg	20:16:54	871734	4317468	22	Muddy fine sand with occasional coarse fragments (pebbles, cobbles and occasional small boulders)	Sparse gorgonians and scleractinians associated with coarse material
			20:18:23	871718	4317483			
15/02/09	Loligo A	20090215230753_0.mpg / 20090215232253_0.mpg / 20090215232406_0.mpg	20:18:23	871718	4317483	141	Muddy fine sand with a high proportion of coarse material	Occasional gorgonians and scleractinians, occasional sponges, bryozoan / hydroid turf on exposed hard material
			20:28:05	871610	4317574			
15/02/09	Loligo A	20090216000527_0.mpg / 20090216001256_0.mpg	21:05:27	871623	4317565	88	Muddy fine sand with a high proportion of coarse material	Occasional gorgonians and scleractinians, occasional sponges, bryozoan / hydroid turf on exposed hard material
			21:22:17	871536	4317554			
15/02/09	Loligo A	20090216001256_0.mpg	21:22:17	871536	4317554	9	Outcropping consolidated (possibly cemented) material with coarse material and a thin veneer of muddy fine sand	Numerous gorgonians and scleractinians, occasional sponges, dense bryozoan / hydroid turf on exposed hard surfaces
			21:22:59	871527	4317553			
15/02/09	Loligo A	20090216001256_0.mpg / 20090216002757_0.mpg	22:22:59	871527	4317553	12	Muddy fine sand with occasional coarse fragments (pebbles, cobbles and occasional small boulders)	Sparse gorgonians (sea fans) and scleractinians (hard corals) associated with coarse material
			21:28:40	871518	4317545			

Date	Location	File(s)	Time	Video Coordinates [m]		Transect Distance	Sediment Type	Fauna
				Easting	Northing			
15/02/09	Loligo A	20090216002757_0.mpg / 20090216004257_0.mpg / 20090216005757_0.mpg	21:28:40	871518	4317545	20	Outcropping consolidated (possibly cemented) material with coarse material and a thin veneer of muddy fine sand	Numerous gorgonians and scleractinians, occasional sponges, occasional eplilithic soft corals?, dense bryozoan / hydroid turf on exposed hard surfaces, rockling? (Gaidropsarus ensis?),
			21:35:50	871528	4317562			
30/01/09	Loligo C	200901302107.mpg	18:07:51	868589	4325446	18	Steep scarp surrounding depression, comprising cemented sediments	Very dense faunal turf - prdominantly scleractinian, but with some soft coral?. Frequent ophiuroids.
			18:14:45	868592	4325428			
30/01/09	Loligo C	200901302107.mpg / 200901302122.mpg	18:14:45	868592	4325428	31	Fragments of scarp material (at base of scarp?)	Sparser scleractinian turf with gorgonians (sea whips). Squat lobster (Munidae?)
			18:18:55	868591	4325397			
30/01/09	Loligo C	200901302122.mpg	18:18:55	868591	4325397	55	Low relief consolidated (possibly cemented) material with occasional boulders. Thin veneer of muddy fine sand.	Sparse faunal turf of scleractinians and gorgonians
			18:31:52	868553	4325357			
30/01/09	Loligo C	200901302122.mpg	18:31:52	868553	4325357	58	Fragments of scarp material (at base of scarp?)	Sparser scleractinian turf with gorgonians (sea whips). Ophiuroids
			18:33:27	868515	4325401			
30/01/09	Loligo C	200901302122.mpg	18:33:27	868515	4325401	22	Scarp surrounding depression, comprising cemented sediments	Very dense faunal turf - prdominantly scleractinian, but with some soft coral?. Frequent ophiuroids.
			18:34:59	868524	4325421			
30/01/09	Loligo C	20090130201552_0mpg / 20090130203052_0mpg / 20090130204148_0.mpg	17:15:51	868568	4325662	120	Muddy fine sand with a high proportion of coarse material	Occasional gorgonians and scleractinians, occasional sponges, bryozoan / hydroid turf on exposed hard material
			17:55:53	868570	4325542			
30/01/09	Loligo C	20090130204148_0.mpg / 20090130205649_0.mpg	17:55:53	868570	4325542	86	Consolidated (posibly cemented) material of low relief with a vener of muddy fine sand and occasional coarse material	Sparse to moderately dense faunal turf of scleractinians and gorgonians with occasional soft corals? Shrimp.
			18:05:50	868571	4325456			
30/01/09	Loligo C	20090130205649_0.mpg	18:05:50	868571	4325456	21	Steep scarp surrounding depression, comprising cemented sediments	Very dense faunal turf - prdominantly scleractinian, but with some soft coral?. Frequent ophiuroids.
			18:07:42	868588	4325444			

E. PARTICLE SIZE ANALYSIS

STATION 2



Easting: 869 735 m
Northing: 4 320 895 m

Depth: 1365 m
Sed Type: Silty sand with dark sandy patches

Easting: 869 735 m
Northing: 4 320 895 m

Depth: 1365 m
Sed Type: Silty sand with dark sandy patches

Easting: 869 708 m
Northing: 4 320 870 m

Depth: 1365 m
Sed Type: Silty sand with dark sandy patches

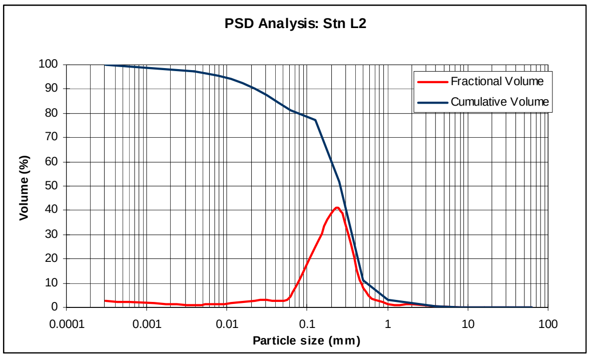
PSD – LASER AND SIEVE DATA

Aperture (mm)	Aperture (phi units)	Percentage	
		Fractional	Cumulative
63	-6.0	0.00	0.00
32	-5.0	0.00	0.00
16	-4.0	0.00	0.00
8	-3.0	0.00	0.00
4	-2.0	0.53	0.53
2	-1.0	1.25	1.78
1	0.0	1.16	2.95
0.5	1.0	8.19	11.13
0.250	2.0	40.73	51.86
0.125	3.0	25.22	77.07
0.06250	4.0	4.40	81.47
0.04420	4.5	2.88	84.36
0.03120	5.0	3.18	87.54
0.02210	5.5	2.69	90.23
0.01560	6.0	2.12	92.34
0.01108	6.5	1.68	94.02
0.00780	7.0	1.44	95.46
0.00550	7.5	1.16	96.62
0.00390	8.0	0.88	97.50
0.00031	8.5	2.50	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

SEDIMENT CHARACTERISTICS

Sorting	1.840	Poorly Sorted	
Skewness	0.484	Strongly Fine Skewed	
Kurtosis	1.681	Very Leptokurtic	
Mean (µm)	178.597	% Gravel	1.78
Median(µm)	261.412	% Sand	79.69
Mean (phi)	2.485	% Fines	18.53
Median (phi)	1.936		

CHART REPRESENTING LASER DATA



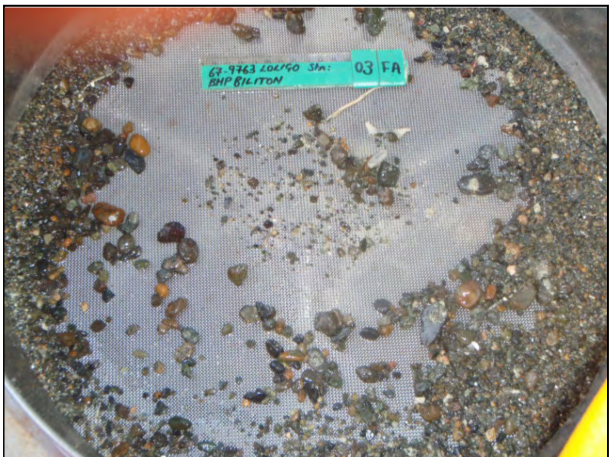
STATION 3

Easting: 868 553 m
Northing: 4 325 750 m

Depth: 1350 m
Sed Type: Silty sand with dark sandy patches

Easting: 868 553 m
Northing: 4 325 750 m

Depth: 1350 m
Sed Type: Silty sand with dark sandy patches



Easting: 868 553 m
Northing: 4 325 750 m

Depth: 1350 m
Sed Type: Silty sand with dark sandy patches

PSD – LASER AND SIEVE DATA

Data Unavailable

SEDIMENT CHARACTERISTICS

Data Unavailable

CHART REPRESENTING LASER DATA

Data Unavailable

STATION 8

Easting: 871 665 m
Northing: 4 330 072 m

Depth: 1438 m
Sed Type: SIlty sand with dark sandy patches

Easting: 871 665 m
Northing: 4 330 072 m

Depth: 1438 m
Sed Type: SIlty sand with dark sandy patches

Photograph Unavailable

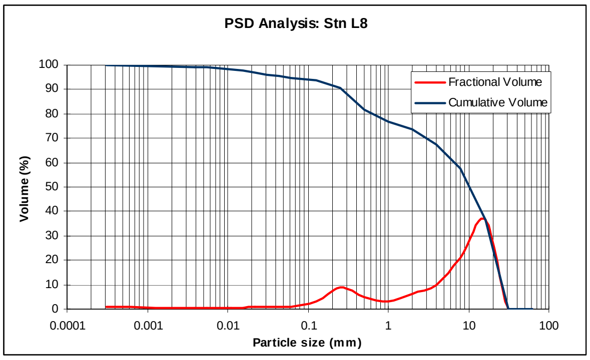
PSD – LASER AND SIEVE DATA

Aperture (mm)	Aperture (phi units)	Percentage	
		Fractional	Cumulative
63	-6.0	0.00	0.00
32	-5.0	0.00	0.00
16	-4.0	36.42	36.42
8	-3.0	21.08	57.50
4	-2.0	9.87	67.37
2	-1.0	6.10	73.48
1	0.0	3.25	76.73
0.5	1.0	5.05	81.78
0.250	2.0	8.89	90.67
0.125	3.0	3.06	93.73
0.06250	4.0	0.93	94.66
0.04420	4.5	0.75	95.41
0.03120	5.0	0.78	96.18
0.02210	5.5	0.71	96.90
0.01560	6.0	0.65	97.55
0.01108	6.5	0.56	98.11
0.00780	7.0	0.48	98.58
0.00550	7.5	0.37	98.95
0.00390	8.0	0.28	99.23
0.00031	8.5	0.77	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

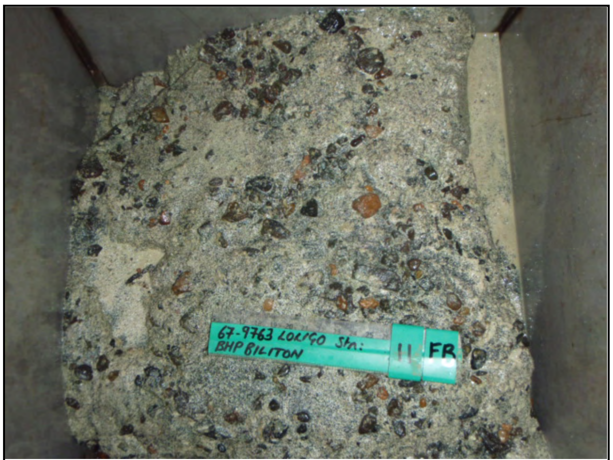
SEDIMENT CHARACTERISTICS

Sorting	2.837	Very Poorly Sorted	
Skewness	0.634	Strongly Fine Skewed	
Kurtosis	0.987	Mesokurtic	
Mean (µm)	4911.944	% Gravel	73.48
Median(µm)	10847.243	% Sand	21.18
Mean (phi)	-2.296	% Fines	5.34
Median (phi)	-3.439		

CHART REPRESENTING LASER DATA



STATION 11



Easting: 868 805 m
Northing: 4 323 434 m

Depth: 1436 m
Sed Type: Silty sand with dark sandy patches

Easting: 868 805 m
Northing: 4 323 434 m

Depth: 1436 m
Sed Type: Silty sand with dark sandy patches

Easting: 868 805 m
Northing: 4 323 434 m

Depth: 1436 m
Sed Type: Silty sand with dark sandy patches

PSD – LASER AND SIEVE DATA

Data Unavailable

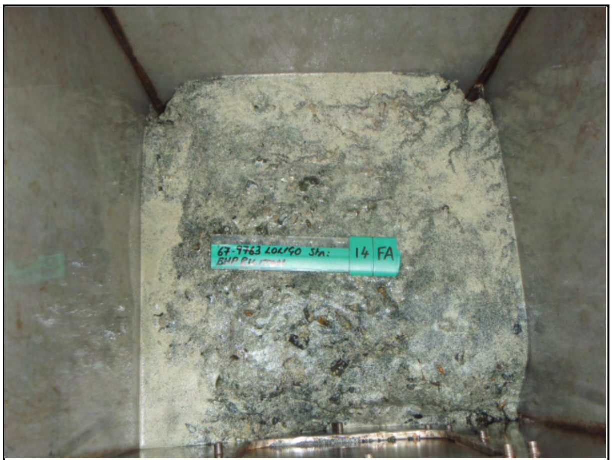
SEDIMENT CHARACTERISTICS

Data Unavailable

CHART REPRESENTING LASER DATA

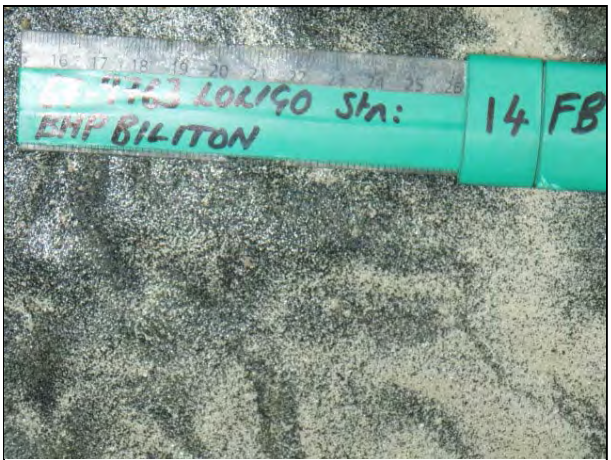
Data Unavailable

STATION 14



Easting: 869 724 m
Northing: 4 316 357 m

Depth: 1434 m
Sed Type: Fine silty (black) sand with underlying gravel



Easting: 869 671 m
Northing: 4 316 276 m

Depth: 1434 m
Sed Type: Fine silty (black) sand with underlying gravel

Easting: 869 671 m
Northing: 4 316 276 m

Depth: 1434 m
Sed Type: Fine silty (black) sand with underlying gravel

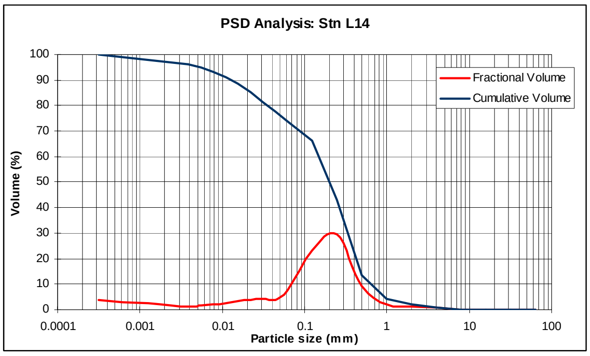
PSD – LASER AND SIEVE DATA

Aperture (mm)	Aperture (phi units)	Percentage	
		Fractional	Cumulative
63	-6.0	0.00	0.00
32	-5.0	0.00	0.00
16	-4.0	0.00	0.00
8	-3.0	0.00	0.00
4	-2.0	0.65	0.65
2	-1.0	1.34	1.99
1	0.0	2.23	4.22
0.5	1.0	9.13	13.35
0.250	2.0	29.69	43.04
0.125	3.0	23.10	66.15
0.06250	4.0	7.54	73.68
0.04420	4.5	3.78	77.46
0.03120	5.0	4.15	81.61
0.02210	5.5	3.81	85.42
0.01560	6.0	3.19	88.61
0.01108	6.5	2.52	91.13
0.00780	7.0	2.09	93.23
0.00550	7.5	1.66	94.89
0.00390	8.0	1.28	96.17
0.00031	8.5	3.83	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

SEDIMENT CHARACTERISTICS

Sorting	2.189	Very Poorly Sorted	
Skewness	0.433	Strongly Fine Skewed	
Kurtosis	1.082	Mesokurtic	
Mean (µm)	137.358	% Gravel	1.99
Median(µm)	212.354	% Sand	71.69
Mean (phi)	2.864	% Fines	26.32
Median (phi)	2.235		

CHART REPRESENTING LASER DATA

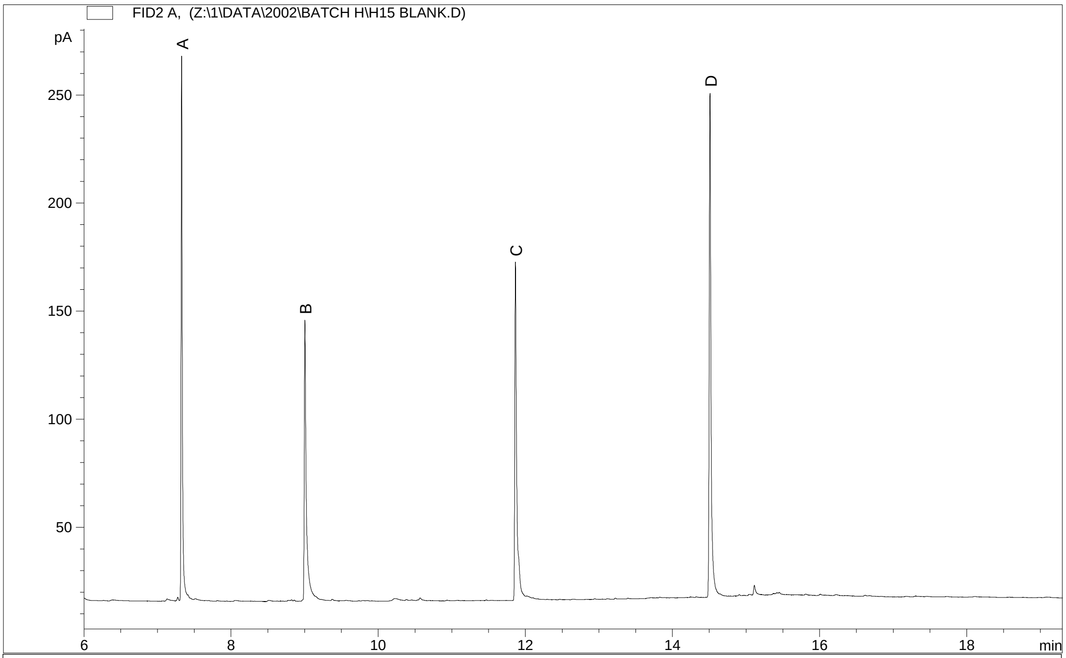


F. HYDROCARBON ANALYSIS

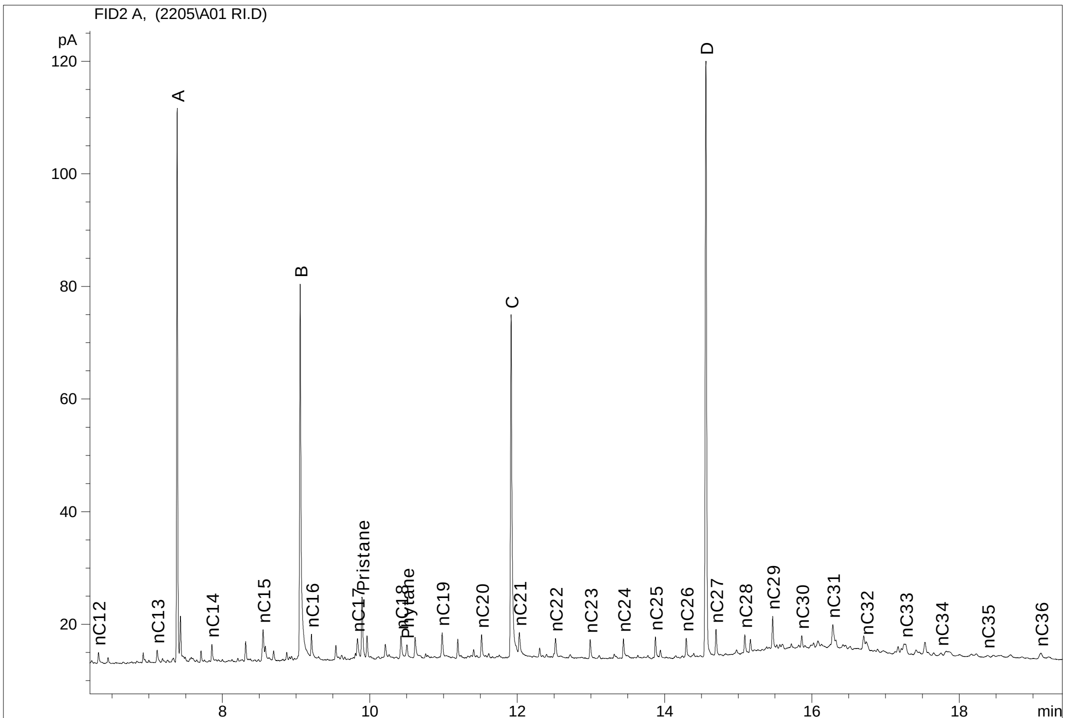
F.1 GAS CHROMATOGRAPHY TRACES

Table F.1 Internal Standard Concentrations

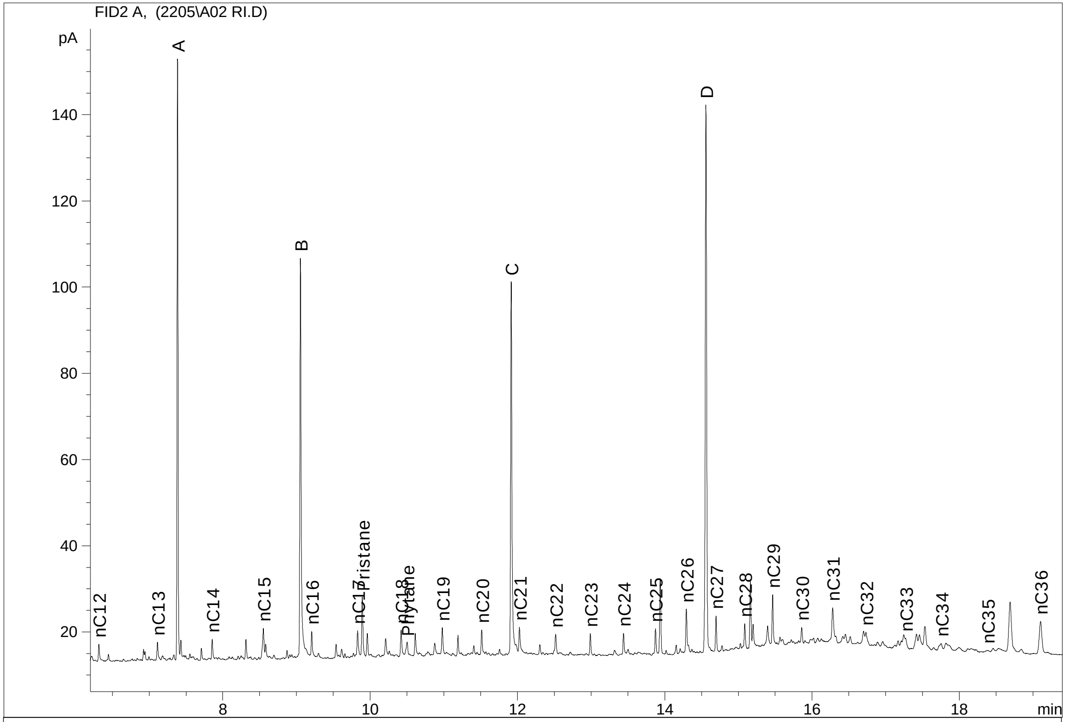
[All Concentrations Expressed as μgg^{-1}]				
Station ID	Heptamethylnonane (A)	D34 Hexadecane (B)	1-Chlorooctadecane (C)	Squalane (D)
1	0.199	0.192	0.170	0.202
2	0.172	0.166	0.147	0.174
3	0.204	0.198	0.175	0.207



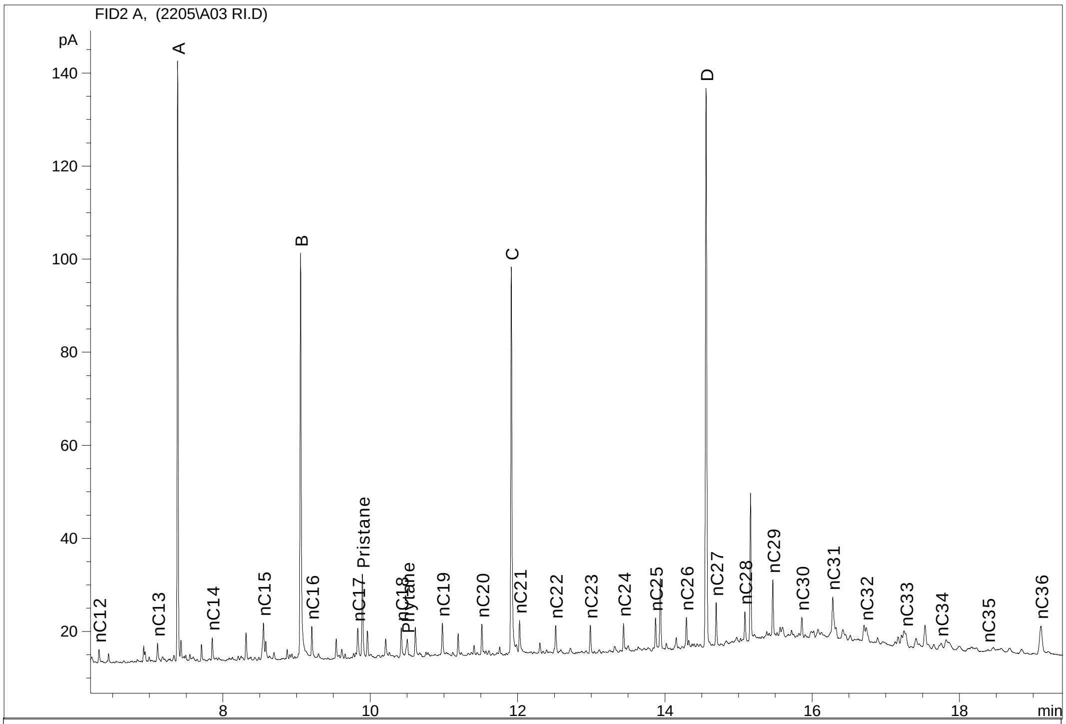
Blank GC trace with internal standards



Station 2 – Sediment GC Trace

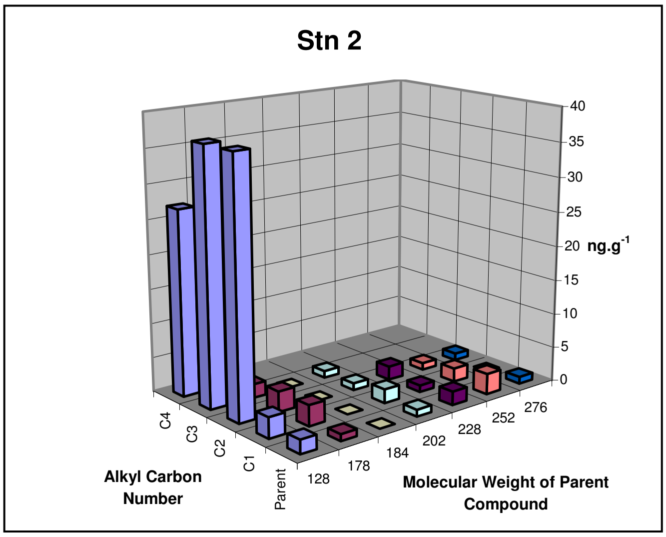


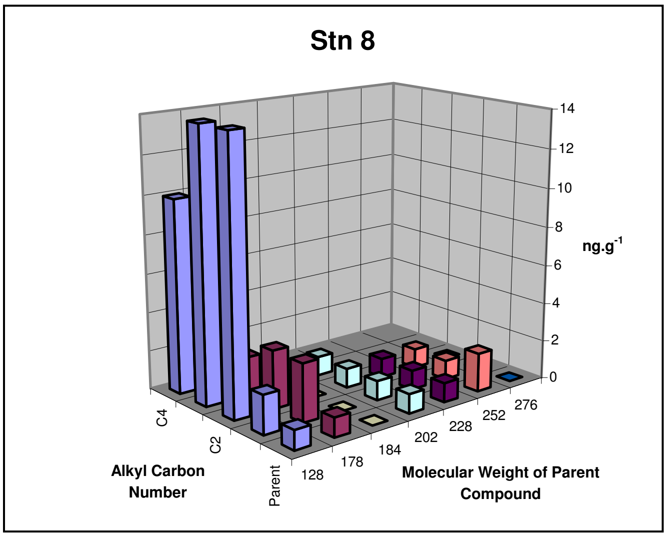
Station 8 – Sediment GC Trace

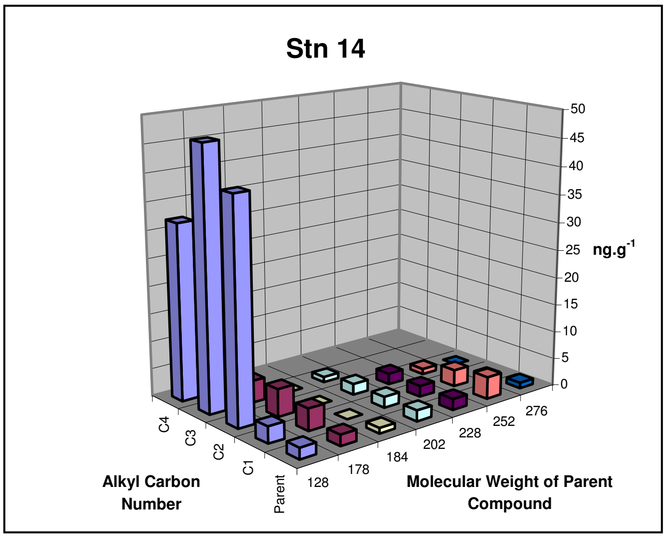


Station 14 – Sediment GC Trace

F.2 PARENT - ALKYL PAH GRAPHS


Stn 2
40
35
30
25
20
15
10
5
0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


Stn 8
14
12
10
8
6
4
2
0
ng.g-1
C4
C2
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


Stn 14
50
45
40
35
30
25
20
15
10
5
0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

G. MACROFAUNA ANALYSIS

G.1 SAMPLE DATA

The following list of taxa excludes those that were removed from the statistical analysis

Taxa	Samples								Total
	L2-FA	L2-FB	L3-FA	L3-FB	L11-FA	L11-FB	L14-FA	L14-FB	
SIPUNCULA									
Sipuncula indet.		1	2			1	2	4	10
ANNELIDA									
Acrocirridae sp. 1					1		1		2
Aglaophamus sp. 1							1		1
Ampharete sp. 1				2					2
Aphelochaeta sp. 1								4	4
Aricidea (Allia) cf. hartmani		1					2	1	4
Aricidea (Allia) sp. 1					1		1		2
Capitellidae sp. 1							1		1
Caulleriella ? sp. 1	1	1				6	3		11
Ceratocephale fauveli						1		1	2
Chone/Jasmineira sp. 1	3	1	1			1	3	1	10
Chone sp. 2								1	1
Cirrophorus cf. forticirratus	1	1					5		7
Clymenura ? sp. 1			1			3			4
Euchone sp. 1		1	3	1	1			1	7
Euchone sp. 2						2			2
Euchone indet.							2		2
Eunicidae? sp. 1						2			2
Eunoe anderssoni							1		1
Fauveliopsis sp. 1							1		1
Flabelligera sp. 1								1	1
Galathowenia scotiae	1						2		3
Kinbergonuphis oligobranchiata	3	13	7	1	6	8	23	13	74
Leaena sp. 1								1	1
Lumbrineris sp. 1								1	1
Maldanidae sp. 1					1	1			2
Melinna sp. 1	1			2	9	22	8	11	53
Myriochele riojai	1								1
Nothria anoculata		1	1	1			2	1	6
Notomastus sp. 1		1	1			1	1		4
Notoproctus sp. 1							1	3	4
Orbinia (Phylo) sp. 1	1					1		1	3
Paramphinome australis						1			1
Phyllochaetopterus sp. 1			2						2
Pista mirabilis								1	1
Polycirrus sp. 1								1	1
Rhodine intermedia					1				1
Rhodine loveni?					1	2		1	4
Samytha? sp. 1			1			3			4
Scalibregma inflatum									
Scoloplos (Leodamas) sp. 1	1	1				1	1		4
Sphaerosyllis (Sphaerosyllis) sp. 1	1						1		2
Spiochaetopterus typicus			1	2	1	1	1		6
Spiophanes cf. duplex						1			1
Tauberia cf. oligobranchiata		1					1	1	3
Tharyx sp. 1			1						1
Enchytraeidae indet.							2	1	3
CRUSTACEA									
Ampelisca sp. 1		1	2						3

Taxa	Samples								Total
	L2-FA	L2-FB	L3-FA	L3-FB	L11-FA	L11-FB	L14-FA	L14-FB	
Ampelisca sp. 2		5							5
Epimeriidae sp. 1			2						2
Harpinia sp. 1		2							2
Harpinia sp. 2						1			1
Haustoriidae sp. 1							1		1
Caprellidae sp. 1				3					3
Ischnomesus? sp. 1							1		1
Apseudes spinosus			1						1
Apseudes? sp. 1						1		5	6
Tanaidae indet.	1						1	1	3
Diastylis sp. 1			2						2
Cumacea indet.		1							1
Scalpellidae sp. 1	1								1
CHELICERATA									
Nymphon? sp. 1					1				1
MOLLUSCA									
Propeleda longicaudata						1			1
Cyclopecten cf falklandicus	1						1		2
Pectinidae (damaged)		1							1
Thyasira cf obsoleta		1						2	3
Thyasira cf transversa							1		1
Kelliella sp.								1	1
Carditopsis sp.						2			2
Lyonsiella abyssicola				1					1
Skeneidae sp	1								1
Xymenopsis sp			1						1
ECHINODERMATA									
Ophiozonella cf. falklandica	1								1
Ypsilothuriidae indet.			1						1
Number of Taxa	15	17	17	8	10	22	28	24	73
Abundance	19	34	30	13	23	63	71	59	312

The following taxa were excluded from statistical analysis

Taxa	Samples								Total
	L2-FA	L2-FB	L3-FA	L3-FB	L11-FA	L11-FB	L14-FA	L14-FB	
JUVENILE									
Cirratulid juvenile ?		1							1
Ophiuridae sp. juv.							1		1
INDETERMINATE									
Fabriciinae indet.			1					1	2
Maldanidae indet.				1					1
Sabellidae indet.					1				1
Number of Taxa		1	1	1	1		1	1	5
Abundance		1	1	1	1		1	1	6

G.2 STATION DATA

The following list of taxa excludes those that were removed from the statistical analysis

Taxa	Samples				Total
	L2	L3	L11	L14	
SIPUNCULA					
Sipuncula indet.	1	2	1	6	10
ANNELIDA					
Acrocirridae sp. 1			1	1	2
Aglaophamus sp. 1				1	1
Ampharete sp. 1		2			2
Aphelochaeta sp. 1				4	4
Aricidea (Allia) cf. hartmani	1			3	4
Aricidea (Allia) sp. 1			1	1	2
Capitellidae sp. 1				1	1
Caulleriella ? sp. 1	2		6	3	11
Ceratocephale fauveli			1	1	2
Chone/Jasmineira sp. 1	4	1	1	4	10
Chone sp. 2				1	1
Cirrophorus cf. forticirratus	2			5	7
Clymenura ? sp. 1		1	3		4
Euchone sp. 1	1	4	1	1	7
Euchone sp. 2			2		2
Euchone indet.				2	2
Eunicidae? sp. 1			2		2
Eunoe anderssoni				1	1
Fauveliopsis sp. 1				1	1
Flabelligera sp. 1				1	1
Galathowenia scotiae	1			2	3
Kinbergonuphis oligobranchiata	16	8	14	36	74
Leaena sp. 1				1	1
Lumbrineris sp. 1				1	1
Maldanidae sp. 1			2		2
Melinna sp. 1	1	2	31	19	53
Myriochele riojai	1				1
Nothria anoculata	1	2		3	6
Notomastus sp. 1	1	1	1	1	4
Notoproctus sp. 1				4	4
Orbinia (Phylo) sp. 1	1		1	1	3
Paramphinome australis			1		1
Phyllochaetopterus sp. 1		2			2
Pista mirabilis				1	1
Polycirrus sp. 1				1	1
Rhodine intermedia			1		1
Rhodine loveni?			3	1	4
Samytha? sp. 1		1	3		4
Scalibregma inflatum					
Scoloplos (Leodamas) sp. 1	2		1	1	4
Sphaerosyllis (Sphaerosyllis) sp. 1	1			1	2
Spiochaetopterus typicus		3	2	1	6
Spiophanes cf. duplex			1		1
Tauberia cf. oligobranchiata	1			2	3
Tharyx sp. 1		1			1
Enchytraeidae indet.				3	3
CRUSTACEA					
Ampelisca sp. 1	1	2			3

Taxa	Samples				Total
	L2	L3	L11	L14	
Ampelisca sp. 2	5				5
Epimeriidae sp. 1		2			2
Harpinia sp. 1	2				2
Harpinia sp. 2			1		1
Haustoriidae sp. 1				1	1
Caprellidae sp. 1		3			3
Ischnomesus? sp. 1				1	1
Apseudes spinosus		1			1
Apseudes? sp. 1			1	5	6
Tanaidae indet.	1			2	3
Diastylis sp. 1		2			2
Cumacea indet.	1				1
Scalpellidae sp. 1	1				1
CHELICERATA					
Nymphon? sp. 1			1		1
MOLLUSCA					
Propeleda longicaudata			1		1
Cyclopecten cf falklandicus	1			1	2
Pectinidae (damaged)	1				1
Thyasira cf obsoleta	1			2	3
Thyasira cf transversa				1	1
Kelliella sp.				1	1
Carditopsis sp.			2		2
Lyonsiella abyssicola		1			1
Skeneidae sp	1				1
Xymenopsis sp		1			1
ECHINODERMATA					
Ophiozonella cf. falklandica	1				1
Ypsilothuriidae indet.		1			1

Number of Taxa	27	21	27	42	73
Abundance	19	30	23	71	312

The following taxa were excluded from statistical analysis

Taxa	Samples				Total
	L2	L3	L11	L14	
JUVENILE					
Cirratulid juvenile ?	1				1
Ophiuridae sp. juv.				1	1
INDETERMINATE					
Fabriciinae indet.		1		1	2
Maldanidae indet.		1			1
Sabellidae indet.			1		1

Number of Taxa	1	2	1	2	5
Abundance	1	2	1	2	6

H. CORRELATIONS

H.1 ALL SITES

Variable	Depth	Sorting	Mean (phi)	% Gravel	% Sand	% Fines	F.O.C. %	^LOI % @ 450C	THC	UCM	n-alk nC12-20	n-alk nC21-36	n-alk nC12-36	cpi nC12-20	cpi nC21-36
Depth															
Sorting	0.786														
Mean (phi)	-0.780	-0.785													
% Gravel	0.309	0.565	-0.814												
% Sand	0.837	0.488	-0.395	-0.207											
% Fines	-0.967	-0.793	0.855	-0.403	-0.812										
F.O.C. %	-0.951	-0.775	0.784	-0.319	-0.837	0.973									
^LOI % @ 450C	-0.096	-0.134	-0.001	-0.067	0.095	-0.049	-0.086								
THC	-0.869	-0.659	0.790	-0.364	-0.760	0.929	0.929	-0.204							
UCM	-0.894	-0.685	0.809	-0.374	-0.772	0.946	0.936	-0.159	0.987						
n-alk nC12-20	-0.944	-0.730	0.779	-0.303	-0.839	0.966	0.952	-0.129	0.932	0.949					
n-alk nC21-36	-0.767	-0.518	0.684	-0.312	-0.665	0.808	0.829	-0.244	0.947	0.901	0.831				
n-alk nC12-36	-0.870	-0.623	0.748	-0.320	-0.761	0.903	0.911	-0.198	0.978	0.954	0.932	0.976			
cpi nC12-20	-0.825	-0.674	0.676	-0.260	-0.748	0.856	0.841	-0.141	0.815	0.837	0.833	0.676	0.762		
cpi nC21-36	-0.216	-0.299	0.255	-0.166	-0.159	0.247	0.252	-0.055	0.025	0.049	0.181	-0.130	-0.023	0.150	
cpi nC12-36	-0.479	-0.474	0.471	-0.240	-0.409	0.525	0.512	-0.113	0.323	0.344	0.462	0.144	0.266	0.496	0.923
Pristane	-0.947	-0.722	0.773	-0.294	-0.844	0.965	0.945	-0.100	0.923	0.940	0.994	0.819	0.922	0.827	0.194
Phytane	-0.901	-0.649	0.697	-0.223	-0.813	0.894	0.862	-0.008	0.845	0.888	0.941	0.743	0.852	0.806	0.119
Pr:Ph ratio	-0.205	-0.287	0.361	-0.349	-0.101	0.302	0.338	-0.329	0.385	0.317	0.233	0.388	0.339	0.250	0.079
Total 2-6 ring PAH	-0.872	-0.725	0.739	-0.290	-0.789	0.911	0.886	-0.169	0.806	0.853	0.928	0.643	0.777	0.821	0.402
NPD	-0.819	-0.698	0.707	-0.282	-0.746	0.866	0.836	-0.203	0.747	0.799	0.883	0.573	0.713	0.791	0.458
4-6 ring PAH	-0.960	-0.750	0.776	-0.292	-0.852	0.971	0.962	-0.065	0.911	0.941	0.987	0.791	0.900	0.846	0.225
NPD / 4-6 ring ratio	0.563	0.329	-0.426	0.191	0.425	-0.512	-0.509	-0.269	-0.583	-0.561	-0.515	-0.623	-0.615	-0.339	0.353
Aluminium AR	-0.746	-0.459	0.462	-0.057	-0.676	0.666	0.611	0.086	0.555	0.614	0.720	0.481	0.599	0.641	-0.003
Arsenic AR	0.765	0.609	-0.450	-0.017	0.807	-0.745	-0.774	0.129	-0.626	-0.667	-0.771	-0.491	-0.618	-0.764	-0.370
Barium AR	0.547	0.705	-0.448	0.236	0.438	-0.551	-0.602	0.144	-0.562	-0.523	-0.552	-0.569	-0.584	-0.391	-0.301
Chromium AR	0.704	0.520	-0.406	-0.050	0.773	-0.693	-0.724	0.196	-0.602	-0.640	-0.751	-0.478	-0.604	-0.728	-0.321
Copper AR	0.034	-0.095	0.020	-0.041	-0.014	0.037	0.109	-0.115	0.119	0.018	-0.062	0.204	0.110	-0.025	-0.042
Iron AR	0.531	0.496	-0.582	0.327	0.479	-0.643	-0.678	0.344	-0.667	-0.634	-0.595	-0.584	-0.605	-0.577	-0.380
Lead AR	0.545	0.459	-0.506	0.321	0.361	-0.530	-0.501	-0.152	-0.477	-0.542	-0.511	-0.404	-0.463	-0.410	-0.024
Nickel AR	-0.603	-0.502	0.398	-0.050	-0.606	0.597	0.609	-0.023	0.400	0.446	0.552	0.248	0.366	0.497	0.677
Vanadium AR	0.624	0.576	-0.357	-0.016	0.650	-0.599	-0.635	0.120	-0.472	-0.517	-0.648	-0.341	-0.474	-0.615	-0.432
Zinc AR	0.502	0.454	-0.266	-0.047	0.530	-0.468	-0.501	0.056	-0.327	-0.392	-0.539	-0.188	-0.332	-0.432	-0.449
Aluminium HF	-0.904	-0.623	0.675	-0.205	-0.808	0.878	0.842	-0.038	0.776	0.820	0.912	0.671	0.795	0.833	0.183
Arsenic HF	0.748	0.594	-0.408	-0.061	0.798	-0.710	-0.710	0.030	-0.554	-0.601	-0.737	-0.407	-0.552	-0.721	-0.387
Barium HF	-0.451	-0.090	0.279	0.036	-0.492	0.439	0.409	-0.016	0.357	0.431	0.483	0.217	0.331	0.576	0.025
Cadmium HF	-0.112	-0.200	0.198	-0.083	-0.240	0.274	0.363	-0.724	0.438	0.377	0.278	0.446	0.391	0.294	0.059
Chromium HF	0.886	0.605	-0.704	0.205	0.858	-0.926	-0.921	0.169	-0.888	-0.899	-0.932	-0.778	-0.869	-0.858	-0.193
Copper HF	-0.477	-0.483	0.213	0.096	-0.533	0.441	0.489	-0.032	0.287	0.317	0.446	0.181	0.291	0.431	0.440
Iron HF	0.754	0.571	-0.724	0.345	0.679	-0.841	-0.859	0.224	-0.850	-0.849	-0.836	-0.764	-0.822	-0.731	-0.091
Lead HF	0.166	0.211	-0.088	0.021	0.143	-0.147	-0.148	-0.300	-0.096	-0.140	-0.121	-0.013	-0.055	-0.047	-0.099
Nickel HF	0.054	0.077	-0.198	0.140	0.143	-0.218	-0.270	0.477	-0.394	-0.335	-0.181	-0.418	-0.336	-0.203	0.092
Tin HF	0.343	0.306	-0.092	-0.090	0.310	-0.237	-0.218	-0.350	-0.055	-0.153	-0.271	0.037	-0.091	-0.159	-0.091
Vanadium HF	-0.077	0.057	0.062	-0.152	0.175	-0.073	-0.183	0.690	-0.174	-0.137	-0.087	-0.156	-0.125	-0.142	-0.195
Zinc HF	0.508	0.492	-0.458	0.173	0.517	-0.587	-0.622	0.359	-0.575	-0.593	-0.570	-0.478	-0.525	-0.547	-0.376

Variable	cpi nC12-36	Pristane	Phytane	Pr:Ph ratio	Total 2-6 ring PAH	NPD	4-6 ring PAH	NPD / 4-6 ring ratio	Aluminium AR	Arsenic AR	Barium AR	Chromium AR	Copper AR	Iron AR	Lead AR
Depth															
Sorting															
Mean (phi)															
% Gravel															
% Sand															
% Fines															
F.O.C. %															
^LOI % @ 450C															
THC															
UCM															
n-alk nC12-20															
n-alk nC21-36															
n-alk nC12-36															
cpi nC12-20															
cpi nC21-36															
cpi nC12-36															
Pristane	0.470														
Phytane	0.399	0.928													
Pr:Ph ratio	0.157	0.267	-0.078												
Total 2-6 ring PAH	0.634	0.927	0.890	0.167											
NPD	0.670	0.882	0.849	0.147	0.993										
4-6 ring PAH	0.491	0.986	0.942	0.209	0.951	0.909									
NPD / 4-6 ring ratio	0.167	-0.518	-0.466	-0.211	-0.204	-0.100	-0.474								
Aluminium AR	0.225	0.721	0.778	-0.116	0.658	0.617	0.724	-0.495							
Arsenic AR	-0.559	-0.763	-0.775	0.004	-0.879	-0.880	-0.818	0.041	-0.593						
Barium AR	-0.384	-0.549	-0.449	-0.305	-0.526	-0.503	-0.552	0.185	-0.142	0.480					
Chromium AR	-0.511	-0.732	-0.774	0.108	-0.846	-0.846	-0.789	0.053	-0.592	0.952	0.435				
Copper AR	-0.047	-0.064	-0.205	0.445	-0.165	-0.189	-0.086	-0.060	-0.334	0.109	-0.182	0.244			
Iron AR	-0.541	-0.581	-0.482	-0.362	-0.605	-0.593	-0.597	0.124	-0.013	0.496	0.580	0.532	-0.234		
Lead AR	-0.168	-0.529	-0.505	-0.206	-0.471	-0.442	-0.517	0.396	-0.342	0.271	0.286	0.194	0.306	0.241	
Nickel AR	0.750	0.573	0.480	0.180	0.675	0.689	0.590	-0.063	0.487	-0.667	-0.397	-0.556	-0.057	-0.342	-0.332
Vanadium AR	-0.552	-0.637	-0.666	0.106	-0.806	-0.824	-0.703	-0.119	-0.465	0.944	0.532	0.944	0.250	0.441	0.193
Zinc AR	-0.503	-0.524	-0.608	0.296	-0.705	-0.728	-0.597	-0.157	-0.381	0.812	0.441	0.869	0.460	0.401	0.253
Aluminium HF	0.455	0.913	0.930	0.009	0.887	0.852	0.923	-0.431	0.869	-0.809	-0.371	-0.817	-0.237	-0.461	-0.424
Arsenic HF	-0.568	-0.729	-0.794	0.171	-0.839	-0.839	-0.782	0.059	-0.669	0.960	0.422	0.918	0.147	0.395	0.194
Barium HF	0.224	0.485	0.553	-0.177	0.512	0.502	0.504	-0.187	0.630	-0.521	0.313	-0.597	-0.382	-0.198	-0.197
Cadmium HF	0.145	0.268	0.065	0.666	0.280	0.285	0.247	0.102	-0.191	-0.213	-0.415	-0.199	0.490	-0.574	-0.057
Chromium HF	-0.491	-0.915	-0.891	-0.157	-0.859	-0.815	-0.921	0.513	-0.702	0.753	0.397	0.779	0.046	0.633	0.403
Copper HF	0.479	0.434	0.497	-0.217	0.600	0.618	0.513	0.217	0.365	-0.833	-0.399	-0.770	0.061	-0.297	0.090
Iron HF	-0.354	-0.805	-0.734	-0.299	-0.731	-0.685	-0.805	0.527	-0.516	0.573	0.328	0.616	-0.081	0.628	0.382
Lead HF	-0.117	-0.143	-0.113	-0.151	-0.105	-0.096	-0.124	0.186	0.063	-0.026	0.152	-0.158	0.088	-0.005	0.758
Nickel HF	-0.019	-0.185	0.009	-0.697	-0.102	-0.086	-0.139	0.164	0.254	-0.102	0.259	-0.118	-0.418	0.481	0.328
Tin HF	-0.100	-0.300	-0.408	0.349	-0.353	-0.352	-0.332	0.041	-0.376	0.411	0.150	0.356	0.480	-0.134	0.597
Vanadium HF	-0.190	-0.072	0.047	-0.399	-0.213	-0.253	-0.091	-0.420	0.290	0.280	0.306	0.254	-0.424	0.433	-0.089
Zinc HF	-0.483	-0.593	-0.509	-0.357	-0.703	-0.713	-0.626	-0.111	-0.218	0.644	0.566	0.544	-0.126	0.610	0.389

Variable	Nickel AR	Vanadium AR	Zinc AR	Aluminium HF	Arsenic HF	Barium HF	Cadmium HF	Chromium HF	Copper HF	Iron HF	Lead HF	Nickel HF	Tin HF	Vanadium HF
Depth														
Sorting														
Mean (phi)														
% Gravel														
% Sand														
% Fines														
F.O.C. %														
^LOI % @ 450C														
THC														
UCM														
n-alk nC12-20														
n-alk nC21-36														
n-alk nC12-36														
cpi nC12-20														
cpi nC21-36														
cpi nC12-36														
Pristane														
Phytane														
Pr:Ph ratio														
Total 2-6 ring PAH														
NPD														
4-6 ring PAH														
NPD / 4-6 ring ratio														
Aluminium AR														
Arsenic AR														
Barium AR														
Chromium AR														
Copper AR														
Iron AR									P < 0.01					
Lead AR									P < 0.05					
Nickel AR														
Vanadium AR	-0.585													
Zinc AR	-0.489	0.922												
Aluminium HF	0.587	-0.688	-0.601											
Arsenic HF	-0.649	0.901	0.800	-0.819										
Barium HF	0.321	-0.400	-0.399	0.695	-0.519									
Cadmium HF	0.113	-0.169	-0.020	0.043	-0.038	-0.100								
Chromium HF	-0.574	0.606	0.506	-0.898	0.731	-0.617	-0.267							
Copper HF	0.525	-0.841	-0.758	0.525	-0.869	0.278	0.086	-0.434						
Iron HF	-0.452	0.445	0.345	-0.723	0.495	-0.519	-0.413	0.918	-0.259					
Lead HF	-0.180	-0.069	0.009	0.065	-0.059	0.189	0.010	0.002	0.231	-0.001				
Nickel HF	-0.028	-0.196	-0.279	0.080	-0.264	0.176	-0.806	0.199	0.367	0.382	0.333			
Tin HF	-0.292	0.461	0.594	-0.368	0.448	-0.240	0.316	0.159	-0.392	0.010	0.461	-0.311		
Vanadium HF	-0.182	0.288	0.183	0.078	0.140	0.129	-0.883	0.106	-0.298	0.209	-0.027	0.622	-0.177	
Zinc HF	-0.504	0.581	0.506	-0.490	0.556	-0.153	-0.584	0.464	-0.542	0.351	0.162	0.382	0.289	0.607

H.2 COMPARABLY DEEP SITES (NIMROD, LOLIGO AND ENDEAVOUR)

Variables	Depth	Sorting	Mean (phi)	% Gravel	% Sand	% Fines	F.O.C. %	^LOI % @ 450C	THC	UCM	n-alk nC12-20	n-alk nC21-36	n-alk nC12-36	cpi nC12-20	cpi nC21-36
Depth															
Sorting	0.119														
Mean (phi)	-0.362	-0.474													
% Gravel	0.379	0.608	-0.978												
% Sand	-0.438	-0.699	0.871	-0.948											
% Fines	-0.118	-0.198	0.849	-0.747	0.497										
F.O.C. %	0.338	-0.111	0.382	-0.338	0.161	0.586									
^LOI % @ 450C	-0.689	-0.254	0.014	-0.079	0.194	-0.190	-0.536								
THC	0.188	0.147	0.456	-0.352	0.113	0.726	0.711	-0.538							
UCM	0.186	0.139	0.515	-0.404	0.177	0.735	0.595	-0.447	0.934						
n-alk nC12-20	0.173	0.201	0.317	-0.243	0.124	0.405	0.401	-0.507	0.650	0.692					
n-alk nC21-36	0.057	0.259	0.296	-0.223	0.054	0.496	0.563	-0.512	0.871	0.703	0.563				
n-alk nC12-36	0.059	0.273	0.321	-0.244	0.078	0.503	0.560	-0.534	0.874	0.737	0.687	0.986			
cpi nC12-20	0.223	-0.011	0.106	-0.086	-0.002	0.238	0.145	-0.245	0.263	0.283	0.078	0.021	0.013		
cpi nC21-36	0.097	-0.260	0.161	-0.155	0.159	0.089	0.140	-0.164	-0.213	-0.241	-0.018	-0.306	-0.281	0.010	
cpi nC12-36	0.111	-0.188	0.208	-0.175	0.126	0.215	0.188	-0.240	-0.048	-0.092	0.062	-0.193	-0.172	0.329	0.931
Pristane	0.095	0.265	0.285	-0.213	0.104	0.365	0.260	-0.418	0.627	0.705	0.942	0.548	0.663	0.096	-0.095
Phytane	-0.045	0.297	0.054	0.030	-0.086	0.098	-0.272	-0.007	0.063	0.238	0.599	-0.016	0.112	0.057	0.061
Pr:Ph ratio	0.145	-0.188	0.302	-0.330	0.261	0.354	0.603	-0.375	0.562	0.428	0.056	0.531	0.460	0.200	-0.167
Total 2-6 ring PAH	0.497	-0.006	0.182	-0.150	0.128	0.144	0.059	-0.437	0.070	0.241	0.434	-0.142	-0.059	0.232	0.508
NPD	0.512	-0.033	0.157	-0.133	0.121	0.109	0.032	-0.426	0.016	0.176	0.363	-0.186	-0.112	0.241	0.537
4-6 ring PAH	0.273	0.171	0.302	-0.230	0.139	0.337	0.220	-0.391	0.416	0.611	0.791	0.182	0.306	0.111	0.183
NPD / 4-6 ring ratio	0.526	-0.109	-0.098	0.080	-0.023	-0.171	-0.084	-0.318	-0.312	-0.265	-0.164	-0.390	-0.395	0.213	0.623
Aluminium AR	-0.272	0.270	-0.191	0.198	-0.121	-0.288	-0.641	0.162	-0.305	-0.189	0.142	-0.209	-0.133	0.020	-0.337
Arsenic AR	-0.506	-0.097	0.447	-0.410	0.314	0.463	0.174	0.226	0.432	0.391	0.137	0.454	0.436	-0.238	-0.402
Barium AR	-0.225	0.517	-0.026	0.116	-0.186	0.073	-0.166	0.227	-0.084	0.067	0.018	-0.202	-0.164	0.221	-0.324
Chromium AR	-0.518	-0.207	0.408	-0.397	0.325	0.405	0.118	0.301	0.335	0.286	-0.041	0.367	0.318	-0.220	-0.390
Copper AR	0.127	-0.192	0.056	-0.051	-0.066	0.277	0.532	-0.177	0.314	0.103	-0.186	0.358	0.264	-0.006	-0.005
Iron AR	-0.339	0.078	-0.268	0.227	-0.087	-0.437	-0.648	0.451	-0.462	-0.354	-0.177	-0.319	-0.292	-0.211	-0.399
Lead AR	0.178	0.079	-0.214	0.253	-0.293	-0.078	0.059	-0.215	-0.056	-0.178	-0.015	-0.070	-0.078	0.126	0.335
Nickel AR	0.555	-0.029	-0.439	0.414	-0.356	-0.387	-0.296	-0.250	-0.392	-0.361	-0.020	-0.399	-0.368	0.087	0.318
Vanadium AR	-0.469	0.082	0.338	-0.273	0.131	0.471	0.186	0.168	0.472	0.411	0.097	0.482	0.447	-0.098	-0.513
Zinc AR	-0.368	0.034	0.284	-0.237	0.102	0.436	0.224	0.081	0.515	0.405	0.001	0.555	0.486	0.089	-0.535
Aluminium HF	-0.114	0.360	-0.038	0.071	-0.040	-0.110	-0.442	-0.056	-0.166	-0.036	0.355	-0.142	-0.039	0.252	-0.059
Arsenic HF	-0.303	-0.065	0.458	-0.442	0.361	0.452	0.394	0.030	0.575	0.526	0.161	0.603	0.567	-0.158	-0.462
Barium HF	0.017	0.501	-0.120	0.181	-0.202	-0.072	-0.174	-0.003	-0.116	0.058	0.178	-0.254	-0.179	0.412	-0.177
Cadmium HF	0.733	-0.041	0.042	-0.028	-0.085	0.252	0.726	-0.785	0.558	0.449	0.218	0.482	0.444	0.226	0.076
Chromium HF	-0.253	-0.450	-0.055	-0.075	0.280	-0.383	-0.401	0.419	-0.470	-0.442	-0.514	-0.344	-0.404	-0.383	0.086
Copper HF	0.349	-0.155	-0.328	0.286	-0.196	-0.373	-0.186	-0.067	-0.581	-0.563	-0.251	-0.595	-0.578	-0.014	0.598
Iron HF	-0.274	-0.132	-0.317	0.240	-0.060	-0.532	-0.708	0.369	-0.610	-0.581	-0.502	-0.483	-0.525	-0.182	0.230
Lead HF	0.098	0.149	0.067	-0.028	0.000	0.078	0.001	-0.333	0.029	-0.025	0.182	0.063	0.091	0.200	0.184
Nickel HF	-0.482	-0.045	-0.154	0.112	0.059	-0.429	-0.689	0.542	-0.739	-0.639	-0.229	-0.659	-0.605	-0.191	0.250
Tin HF	0.059	0.069	0.265	-0.194	0.027	0.474	0.539	-0.405	0.648	0.460	0.252	0.592	0.548	0.274	-0.015
Vanadium HF	-0.901	0.013	0.166	-0.174	0.256	-0.060	-0.567	0.751	-0.307	-0.233	-0.125	-0.216	-0.189	-0.187	-0.226
Zinc HF	-0.602	0.080	-0.040	0.033	0.016	-0.122	-0.219	0.562	-0.152	-0.203	-0.092	-0.015	-0.006	-0.160	-0.392

Variables	cpi nC12-36	Pristane	Phytane	Pr:Ph ratio	Total 2-6 ring PAH	NPD	4-6 ring PAH	NPD / 4-6 ring ratio	Aluminium AR	Arsenic AR	Barium AR	Chromium AR	Copper AR	Iron AR	Lead AR
Depth															
Sorting															
Mean (phi)															
% Gravel															
% Sand															
% Fines															
F.O.C. %															
^LOI % @ 450C															
THC															
UCM															
n-alk nC12-20															
n-alk nC21-36															
n-alk nC12-36															
cpi nC12-20															
cpi nC21-36															
cpi nC12-36															
Pristane	-0.009														
Phytane	0.126	0.608													
Pr:Ph ratio	-0.107	0.109	-0.690												
Total 2-6 ring PAH	0.497	0.409	0.475	-0.186											
NPD	0.525	0.334	0.432	-0.194	0.995										
4-6 ring PAH	0.188	0.801	0.638	-0.088	0.773	0.709									
NPD / 4-6 ring ratio	0.592	-0.205	0.020	-0.158	0.721	0.781	0.133								
Aluminium AR	-0.306	0.195	0.437	-0.418	-0.027	-0.047	0.113	-0.234							
Arsenic AR	-0.362	0.207	-0.169	0.383	-0.596	-0.638	-0.162	-0.748	0.000						
Barium AR	-0.230	0.060	0.242	-0.214	-0.041	-0.063	0.114	-0.183	0.491	0.012					
Chromium AR	-0.367	0.078	-0.293	0.473	-0.604	-0.625	-0.311	-0.610	-0.079	0.890	-0.008				
Copper AR	-0.003	-0.245	-0.529	0.490	-0.361	-0.335	-0.440	-0.046	-0.483	0.159	-0.219	0.366			
Iron AR	-0.449	-0.102	0.145	-0.298	-0.229	-0.227	-0.185	-0.235	0.737	0.039	0.373	0.170	-0.317		
Lead AR	0.346	-0.212	-0.021	-0.204	0.127	0.150	-0.059	0.264	0.097	-0.406	-0.003	-0.442	0.297	-0.125	
Nickel AR	0.269	-0.070	0.282	-0.402	0.547	0.588	0.134	0.667	0.212	-0.780	-0.121	-0.611	-0.040	0.194	0.381
Vanadium AR	-0.424	0.190	-0.183	0.422	-0.644	-0.682	-0.227	-0.743	0.056	0.917	0.230	0.901	0.336	0.068	-0.311
Zinc AR	-0.406	0.080	-0.338	0.564	-0.627	-0.646	-0.334	-0.616	0.032	0.749	0.175	0.835	0.553	0.112	-0.099
Aluminium HF	0.023	0.381	0.685	-0.533	0.357	0.333	0.422	0.064	0.731	-0.285	0.453	-0.456	-0.569	0.194	0.136
Arsenic HF	-0.422	0.225	-0.349	0.631	-0.498	-0.538	-0.104	-0.629	-0.231	0.894	-0.059	0.799	0.213	-0.125	-0.496
Barium HF	-0.059	0.190	0.432	-0.362	0.242	0.219	0.331	0.039	0.492	-0.281	0.808	-0.430	-0.424	0.099	0.087
Cadmium HF	0.119	0.165	-0.405	0.681	0.211	0.216	0.126	0.272	-0.524	-0.051	-0.358	-0.037	0.530	-0.564	0.066
Chromium HF	-0.107	-0.360	-0.398	0.142	-0.121	-0.082	-0.349	0.182	-0.138	0.019	-0.396	0.304	0.057	0.307	-0.305
Copper HF	0.472	-0.361	0.120	-0.479	0.480	0.534	0.004	0.726	-0.013	-0.862	-0.102	-0.711	0.035	0.007	0.501
Iron HF	0.122	-0.308	-0.066	-0.209	-0.014	0.026	-0.279	0.269	0.141	-0.214	-0.256	0.027	-0.172	0.338	-0.100
Lead HF	0.221	0.008	0.156	-0.211	0.292	0.298	0.173	0.241	0.321	-0.355	0.142	-0.526	-0.007	-0.166	0.773
Nickel HF	0.147	-0.263	0.373	-0.757	0.091	0.110	-0.059	0.141	0.525	-0.375	0.250	-0.346	-0.460	0.505	0.296
Tin HF	0.119	0.127	-0.295	0.500	-0.118	-0.132	-0.001	-0.158	-0.204	0.248	-0.060	0.159	0.517	-0.433	0.587
Vanadium HF	-0.219	-0.055	0.274	-0.417	-0.416	-0.437	-0.169	-0.530	0.492	0.401	0.338	0.327	-0.440	0.488	-0.171
Zinc HF	-0.355	-0.196	0.039	-0.294	-0.625	-0.640	-0.363	-0.630	0.370	0.367	0.320	0.209	-0.137	0.420	0.163

Variables	Nickel AR	Vanadium AR	Zinc AR	Aluminium HF	Arsenic HF	Barium HF	Cadmium HF	Chromium HF	Copper HF	Iron HF	Lead HF	Nickel HF	Tin HF	Vanadium HF
Depth														
Sorting														
Mean (phi)														
% Gravel														
% Sand														
% Fines														
F.O.C. %														
^LOI % @ 450C														
THC														
UCM														
n-alk nC12-20														
n-alk nC21-36														
n-alk nC12-36														
cpi nC12-20														
cpi nC21-36														
cpi nC12-36														
Pristane														
Phytane														
Pr:Ph ratio														
Total 2-6 ring PAH														
NPD														
4-6 ring PAH														
NPD / 4-6 ring ratio														
Aluminium AR														
Arsenic AR														
Barium AR														
Chromium AR														
Copper AR														
Iron AR														
Lead AR														
Nickel AR									P < 0.01					
Vanadium AR	-0.691								P < 0.05					
Zinc AR	-0.552	0.897												
Aluminium HF	0.239	-0.224	-0.294											
Arsenic HF	-0.853	0.806	0.710	-0.410										
Barium HF	0.034	-0.129	-0.194	0.758	-0.283									
Cadmium HF	0.063	-0.014	0.136	-0.398	0.233	-0.237								
Chromium HF	0.058	-0.071	-0.011	-0.413	0.045	-0.543	-0.158							
Copper HF	0.828	-0.809	-0.693	0.147	-0.911	0.069	-0.045	0.109						
Iron HF	0.295	-0.219	-0.187	-0.021	-0.338	-0.283	-0.399	0.785	0.292					
Lead HF	0.236	-0.302	-0.159	0.558	-0.379	0.387	0.028	-0.475	0.330	-0.272				
Nickel HF	0.309	-0.402	-0.441	0.483	-0.610	0.280	-0.832	0.193	0.507	0.462	0.293			
Tin HF	-0.288	0.335	0.520	-0.156	0.313	-0.100	0.433	-0.394	-0.280	-0.448	0.517	-0.386		
Vanadium HF	-0.427	0.338	0.177	0.322	0.149	0.180	-0.907	0.123	-0.323	0.263	-0.059	0.625	-0.211	
Zinc HF	-0.427	0.317	0.273	0.110	0.210	0.153	-0.603	-0.202	-0.317	-0.218	0.134	0.401	0.126	0.721

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SERVICE WARRANTY

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Appendix D

Appendix D: Protected Species - Aves

International Union for Conservation of Nature (IUCN) Red List Species Relevant to Falkland Islands

Table D.1. IUCN Red List Categories

Category Code	
EX	Extinct
EW	Extinct in the wild
CR	Critically Endangered
EN	Endangered
VU	Vulnerable
NT	Near-threatened
LC	Least Concerned
DD	Data Deficient
NE	Not Evaluated

Table D.2. IUCN Red List bird species relevant to the Falkland Islands

Species	Category
Coscoroba Swan *Coscoroba coscoroba*	LC
Falkland Steamerduck *Tachyeres brachypterus*	LC
Flying Steamerduck *Tachyeres patachonicus*	LC
Upland Goose *Chloephaga picta*	LC
Kelp Goose *Chloephaga hybrida*	LC
Ruddy-headed Goose *Chloephaga rubidiceps*	LC
Crested Duck *Lophonetta specularioides*	LC
Chiloe Wigeon *Anas sibilatrix*	LC
Cinnamon Teal *Anas cyanoptera*	LC
Speckled Teal *Anas flavirostris*	LC
Yellow-billed Pintail *Anas georgica*	LC
Silver Teal *Anas versicolor*	LC
King Penguin *Aptenodytes patagonicus*	LC
Gentoo Penguin *Pygoscelis papua*	NT
Chinstrap Penguin *Pygoscelis antarcticus*	LC
Southern Rockhopper Penguin *Eudyptes chrysocome*	VU
Macaroni Penguin *Eudyptes chrysolophus*	VU
Magellanic Penguin *Spheniscus magellanicus*	NT
Wandering Albatross *Diomedea exulans*	VU
Northern Royal Albatross *Diomedea sanfordi*	EN
Southern Royal Albatross *Diomedea epomophora*	VU
Light-mantled Sooty Albatross *Phoebetria palpebrata*	NT
Black-browed Albatross *Thalassarche melanophrys*	EN
Grey-headed Albatross *Thalassarche chrysostoma*	VU

Southern Giant-petrel *Macronectes giganteus*	LC
Northern Giant-petrel *Macronectes halli*	LC
Southern Fulmar *Fulmarus glacialoides*	LC
Antarctic Petrel *Thalassoica antarctica*	LC
Cape Petrel *Daption capense*	LC
Blue Petrel *Halobaena caerulea*	LC
Broad-billed Prion *Pachyptila vittata*	LC
Fairy Prion *Pachyptila turtur*	LC
Kerguelen Petrel *Lugensa brevirostris*	LC
Soft-plumaged Petrel *Pterodroma mollis*	LC
Atlantic Petrel *Pterodroma incerta*	EN
White-chinned Petrel *Procellaria aequinoctialis*	VU
Grey Petrel *Procellaria cinerea*	NT
Cory's Shearwater *Calonectris diomedea*	LC
Great Shearwater *Puffinus gravis*	LC
Sooty Shearwater *Puffinus griseus*	NT
Manx Shearwater *Puffinus puffinus*	LC
Little Shearwater *Puffinus assimilis*	LC
Wilson's Storm-petrel *Oceanites oceanicus*	LC
Grey-backed Storm-petrel *Garrodia nereis*	LC
Black-bellied Storm-petrel *Fregetta tropica*	LC
Common Diving-petrel *Pelecanoides urinatrix*	LC
White-tufted Grebe *Rollandia rolland*	LC
Silvery Grebe *Podiceps occipitalis*	LC
Black-crowned Night-heron *Nycticorax nycticorax*	LC
Imperial Shag *Phalacrocorax atriceps*	LC
Rock Shag *Phalacrocorax magellanicus*	LC
Crested Caracara *Caracara cheriway*	LC
Striated Caracara *Phalcoboenus australis*	NT
Peregrine Falcon *Falco peregrinus*	LC
Magellanic Oystercatcher *Haematopus leucopodus*	LC
Two-banded Plover *Charadrius falklandicus*	LC
White-rumped Sandpiper *Calidris fuscicollis*	LC
Dolphin Gull *Leucophaeus scoresbii*	LC
Kelp Gull *Larus dominicanus*	LC
Brown-hooded Gull *Larus maculipennis*	LC
Arctic Tern *Sterna paradisaea*	LC
South Polar Skua *Catharacta maccormicki*	LC
Short-eared Owl *Asio flammeus*	LC
Dark-faced Ground-tyrant *Muscisaxicola maclovianus*	LC
Cobb's Wren *Troglodytes cobbi*	VU
Long-tailed Meadowlark *Sturnella loyca*	LC
Sooty Albatross *Phoebetria fusca,*	EN
Yellow Nosed Albatross *Thalassarche chlororhynchos*	EN
Buller’s Albatross *Thalassarche bulleri*	NT
Shy Albatross *Thalassarche cauta,*	LC
Antarctic Fulmar *Fulmarus glacialoides*	LC

White Bellied Storm Petrel *Fregetta grallaria*	LC
Black Necked Swan *Cygnus melancoryphus*	LC
Ashy- headed Goose *Chloephaga poliocephala*	LC
Feral Goose	LC
Yellow – billed teal *Anas flavirostris*	LC
Falklands Skua *Stercorarius antarcticus*	LC
Arctic Skua *Stercorarius parasiticus*	LC
Long – tailed skua *Stercorarius longicaudus*	LC
Chilean Skua *Stercorarius chilensis*	LC
South American Tern *Sterna hirundinacea*	LC
Great Winged Petrel *Pterodroma macroptera*	LC
Spectacled Petrel *Procellaria conspicillata*	VU
Ceyenne tern *Thalasseus sandvicensis*	LC
Grass Wren *Cistothorus platensis*	LC
Black Throated Finch *Poephila cincta*	NT
Falkland Thrush *Turdus falcklandii*	LC
Falkland Pipit *Anthus correndera grayi*	LC
Rufous – Chested Dotterel *Charadrius modestus*	LC
Grey – backed storm petrel *Garrodia nereis*	LC

Agreement on the Conservation of Albatrosses and Petrels (ACAP)

Table D.3. ACAP Listed Species (2009)

Common Name	Scientific Name	IUCN Status (2010)*
Northern Royal Albatross	*Diomedia sanfordi*	EN
Southern Royal Albatross	*Diomedia epomophora*	VU
Wandering Albatross	*Diomedia exulans*	VU
Antipodean Albatross	*Diomedia antipoddensis*	VU
Amsterdam Albatross	*Diomedia amsterdamensis*	CR
Tristan Albatross	*Diomedia dabbenena*	CR
Sooty Albatross	*Phoebetria fusca*	EN
Light-mantled Sooty Albatross	*Phoebetria palpebrata*	NT
Waved Albatross	*Phoebastria irrorata*	CR
Short-tailed Albatross	*Phoebastria albatrus*	VU
Black-footed Albatross	*Phoebastria nigripes*	EN
Laysan Albatross	*Phoebastria*	NT
Atlantic Yellow-nosed Albatross	*Thalassarche chlorohynchos*	EN
Indian Yellow-nosed Albatross	*Thalassarche carteri*	EN
Grey-headed Albatross	*Thalassarche chrysostoma*	VU
Black-browed Albatross	*Thalassarche melanophris*	EN
Campbell Albatross	*Thalassarche impavida*	VU
Buller's Albatross	*Thalassarche bulleri*	NT
Shy Albatross	*Thalassarche cauta*	NT
White-capped Albatross	*Thalassarche steadi*	NT
Chatham Albatross	*Thalassarche eremite*	VU
Salvin's Albatross	*Thalassarche salvini*	VU
Southern Giant Petrel	*Macronectes giganteus*	LC
White-chinned Petrel	*Procellaria aequinoctialis*	VU
Spectacled Petrel	*Procellaria cosnpicillata*	VU
Black Petrel	*Procellaria parkinsoni*	VU
Westland Petrel	*Procellaria westlandica*	VU
Grey Petrel	*Procellaria cinerea*	NT

* Refer to Table D.1 for IUCN Red List categories

Table D.4. ACAP breeding sites in the Falkland Islands (Species codes: BBA – Black-browed Albatross, SGP – Southern Giant Petrel, WCP – White-chinned Petrel, NNR – National Nature Reserve

Island/Breeding Site	Island Size (ha)*	Protection Status	ACAP Species	Ownership	Remarks
Barren Island	1,150		SGP	Private	
Beauchêne Island	170	NNR	BBA, SGP	Government	
Beaver Island Group: Governor Island	220		SGP	Private	

Island/Breeding Site	Island Size (ha)*	Protection Status	ACAP Species	Ownership	Remarks
Beaver Island Group: Penn Island	155		SGP	Private	
Bird Island	120	NNR	BBA	Government	
Bleaker Island	2,070	NNR	SGP	Private	
Bottom island (Port William)	8		WCP	Government	
Burnt Islet	4		SGP	Private	
Carcass Island	1,894		SGP	Private	
Dyke Island	1,500		SGP	Private	
East Falkland, Black Rincon	< 1		SGP	Private	Berkeley Sound
East Falkland, Cape Dolphin	< 1	NNR	SGP	Private	
East Falkland, Driftwood Point	< 1		SGP	Quasi-government#	North Arm
East Falkland, False Bull Point	< 1		SGP	Quasi-government#	North Arm
East Falkland, Fanny Point	< 1		SGP	Quasi-government#	North Arm
East Falkland, Motley Point	< 1		SGP	Quasi-government#	Walker Creek
East Falkland, Rincon Grande	< 1		SGP	Private	
Elephant Cays: Golden Knob Island	1.5		SGP	Private	
Elephant Cays: Sandy Cay	80		SGP	Private	
George Island	2,400		SGP	Private	
Jason Island Group: Elephant Jason	260	NNR	BBA	Government	
Jason Island Group: Grand Jason	1,380		BBA, SGP	Private Conservation Organisation	
Jason Island Group: Jason West Kay	22	NNR	SGP	Government	
Jason Island Group: South Jason	375	NNR	BBA	Government	
Jason Island Group: Steeple Jason	790		BBA, SGP	Private Conservation Organisation	
Keppel Island	3,626		BBA	Private	
Kidney Island	15	NNR	WCP	Government	
Lively Island	5,585		SGP	Private	
Low Island (Byron Sound)	75		SGP	Private	
New Island Group: New Island	2,363	NNR	BBA, WCP	Conservation Trust	
New Island Group: North Island	75		BBA	Private Conservation Organisation	
Pebble Island	10,336		SGP	Private	
Saunders Island	8,500		BBA	Private	

Island/Breeding Site	Island Size (ha)*	Protection Status	ACAP Species	Ownership	Remarks
Sea Lion Island	905		SGP	Quasi-government#	
Speedwell Island	5,150		SGP	Private	
Swan Island	1,375		SGP	Private	
Third Passage Island	80		SGP	Private	King George Bay
West Falkland, Hope Point	< 1		SGP	Private	Dunbar Farm
West Falkland, Rookery Point	< 1		SGP	Private	Albamarle
West Falkland, Grave Cove	< 1		BBA	Private	Dunbar Farm
West Island	110		SGP	Private	Cape Orford
West Point Island	1,255		BBA	Private	

* Island size for whole island, except for the main islands of East and West Falklands, where the size provided is for the actual breeding site.

Sites managed by quasi-government organisations primarily for purposes other than conservation (mainly agriculture and tourism) are treated separately from FIG owned land that is managed for conservation.

Appendix E

Appendix E – IUCN Red List Cetaceans and Fish

Table E.1. IUCN Red List marine mammals and fish species relevant to the Falkland Islands

Common Name	Scientific Name	IUCN Categorry
Cetaceans		
Sei whale	*Balaenoptera borealis*	EN
Blue whale	*Balaenoptera musculus*	EN
Commerson's dolphin	*Cephalorhynchus commersonii*	DD
Southern right whale	*Eubalaena australis*	LC
Southern bottlenose whale	*Hyperoodon planifrons*	LC
Peale's dolphin	*Lagenorhynchus australis*	DD
Killer whale	*Orcinus orca*	DD
Spectacled porpoise	*Phocoena dioptrica*	DD
Sperm whale	*Physeter macrocephalus*	VU
Fin Whale	*Balaenoptera physalus*	DD
Antarctic Minke Whale	*Balaenoptera acutorostrata*	DD
Long – finned Pilot Whale	*Globicephala melas*	DD
Hourglass dolphins	*Lagenorhynchus cruciger*	LC
Pinnipeds		
South American Sea Lion	*Otaria flavescens*	LC
Southern Elephant Seal	*Mirounga leoina*	LC
South American Fur Seal	*Arctocephalus australis*	LC
Leopard Seal	*Hydrurga leptonyx*	LC
Fish		
Graytail Skate	*Bathyraja griseocauda*	EN
Whitedotted Skate	*Bathyraja albomaculata*	VU

Table E.2. IUCN Red List Categories

Category Code			
EX	Extinct	NT	Near-threatened
EW	Extinct in the wild	LC	Least Concerned
CR	Critically Endangered	DD	Data Deficient
EN	Endangered	NE	Not Evaluated
VU	Vulnerable		

Appendix F

Appendix F: Cuttings Modelling – The BMT PROTEUS Model

F.1 Introduction

The Pollution Risk Offshore Technical Evaluation System (PROTEUS) has been developed by BMT to predict the fate and impact of discharged drilling mud, cuttings and produced waters in the marine environment. It is based on a discrete particle representation concept which considers the physical, geochemical and biological mechanisms from which the fate and impact of drilling discharges can be predicted.

Development of PROTEUS has been sponsored by a consortium of oil companies and the UK Government under the 'Managing Impacts on the Marine Environment' (MIME) programme. The model is based on research conducted at world-leading institutions in the fields of dispersion physics, geochemistry and ecotoxicology.

F.2 Theory

The drilling mud and cuttings model uses a particle-tracking approach. The discharge is represented by the release of a discrete number of particles during each time step of the model simulation. Each particle has an individual size and density, determined by the model from input density distribution data. The model is provided with hydrodynamic data which is used in the simulation of particle advection and dispersion in three dimensions. The particles' size and density are used to determine the settling characteristics of the mud and cuttings.

F.3 Particle advection

The model can consider advection of particles by tidal and wind-induced currents. As well as advecting the particles, current shear through the water column acts to disperse particles. Current shear is calculated by the model using well-established equations described by van Veen, and as quoted in Bowden (1965) (see also van Dam and Louwersheir (1992)).

F.4 Particle diffusion

Turbulent diffusion processes (in this case, dispersion processes other than current shearing) are simulated using a random walk technique. At each time step, $\delta\tau$, individual particles are subject to a three dimensional random displacement, $\delta\vec{r}$. The scale of displacement in each dimension at each time step is determined by the following equation:

$$\delta r = \sqrt{2E\delta\tau}$$

where E is the diffusivity coefficient.

The direction in which particles move is determined using a random number generator subroutine based on Schrage's algorithm (Bratley et al., 1983). The random seeds used in Schrage's algorithm are altered at each time step.

F.5 Particle settling

In theory, particle settling is a function of a few quantifiable parameters, such as particle density, particle size and water density. The rate at which particles settle is termed the settling velocity. The distribution of particle sizes and densities within the discharged mud and cuttings is used to determine the distribution of particle settling velocities within the discharged material. At each model time step when discharge is occurring, the model releases a set of particles with a range of settling velocities in proportion to this distribution.

However, the settling of material in seawater is more complex than this theoretical approach. Experimental observations suggest that the mud dispersion is actually subject to very complicated flow phenomena which can make calculation of settling velocities more difficult. For instance, as discharge particle concentration increases, inter-particle collisions occur more frequently and cause enhanced flocculation and aggregation. This enhanced aggregation of particles may accelerate the descent of mud and cuttings discharges. Therefore, the settling speed is often multiplied by an acceleration factor, F, which is given by the following empirical formula:

$$F = 0.013.C^{\varepsilon}$$

where C is the local concentration of the fine particles. ε takes an empirical value of approximately 1.3. The factor is restricted to values between 1 and 100 according to Bowers and Goldenblatt (1978) and Brandsma et al. (1992).

Where water-based muds (WBM) are discharged, it is assumed that separation of the mud from the cuttings will occur fairly readily upon contact with the sea-water, and aggregation will be minimal. In this case the acceleration factor F, is not included. If synthetic oil-based muds (SOBM) are discharged, it is assumed that the mud will not disaggregate, and will therefore remain attached to the cuttings particles, settling at the same velocity as the cuttings to which they are attached.

F.6 Boundary conditions

Mud and cuttings particles are assumed stationary once they reach the seabed. Re-suspension can be considered only when information on erosion and sedimentation mechanisms at the seabed including critical hydrodynamic shear stresses around the discharge area is known. Thus, particle re-suspension is not considered in the model.

A symmetric reflection boundary condition is applied to particles which reach the sea surface. This boundary condition usually applies to fine particles which reach the surface through the random walk process.

F.7 Model

The model predicts the deposition pattern of particles on the seabed. The number of particles per unit area is calculated and particle volume information is then used to determine the seabed thickness of drilling discharge.

F.8 Input parameters

The parameters input into the PROTEUS model for the Loligo A exploration well were as follows:

Table F.1. Loligo A well input parameters

Hole Size (in)	Hole size (m)	Length (m)	Volume (m3)	Weight (tonnes)
42	1.07	79	70.6	183.6
26	0.66	640	219.2	569.9
17 $^{1}/_{2}$	0.44	800	124.1	322.7
12 ¼	0.31	1192	90.6	235.6
Total cuttings from Loligo A well			**504.5**	**1311.8**
Discharged at Seabed			**289.8**	**753.5**
Discharged at Surface			**214.7**	**558.3**
Returned to Shore			**0**	**0**

In the absence of any site-specific particle size distributions (PSD), generic PSDs have been used for the modelling study (Figures F.1 and F.2). These size distributions have been compiled from a range of sampling programs undertaken for various projects in the North Sea. The particle settling velocities were derived analytically from the size distribution and densities, using the well established theories developed by Dyer (1986) and Sleath (1984), which have subsequently been analysed and are detailed by Bryden & Charles (1998).

The current speed and direction data used for the model run was from the same hydrodynamic dataset that was used for oil spill modelling (see Appendix G)

Figure F.1. Particle Size Distributions (PSD) for drill cuttings from a toothed drill bit used in the modelling. Plot shows the cumulative distribution of solids (by diameter) within the drill cuttings.

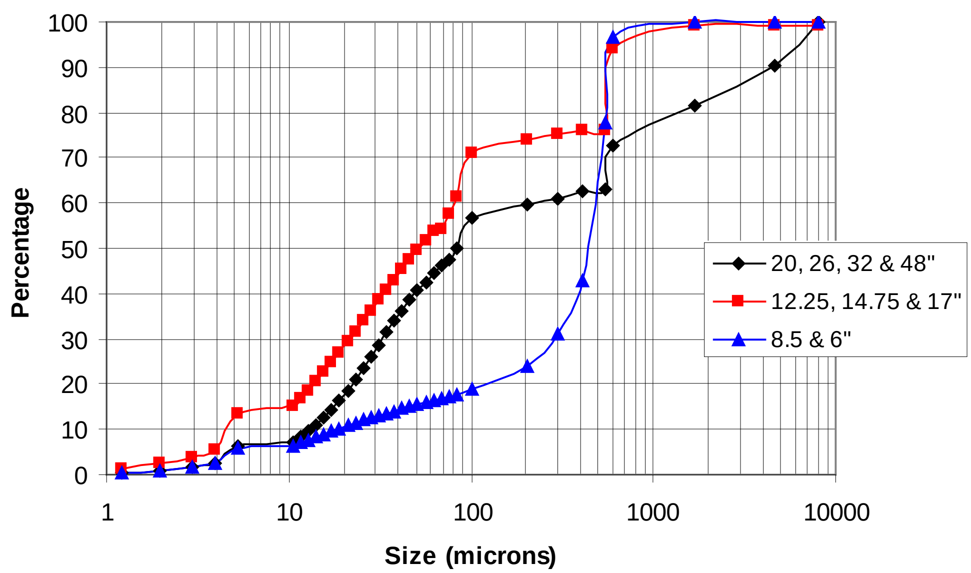
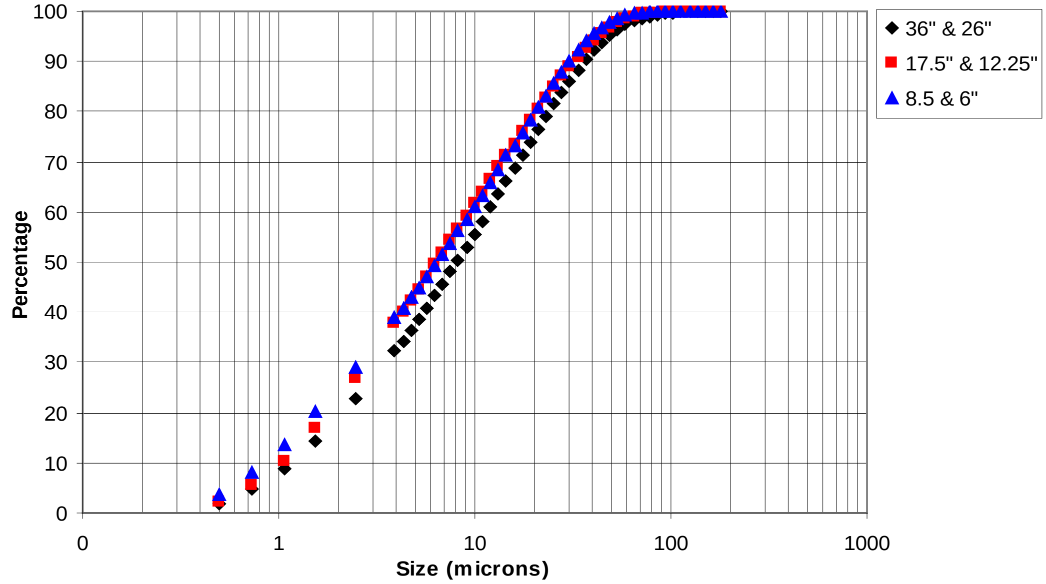


Figure F.2. Particle Size Distribution (PSD) for solid particles within drilling muds used in the modelling. Plot shows the cumulative distribution of solids by diameter.



Appendix G

Appendix G: Oil Spill Modelling – The BMT OSIS Model

G.1 Introduction

The Oil Spill Information System (OSIS) is a state-of-the-art oil spill modelling system for the prediction of the trajectory, spreading, shoreline impact and weathering of marine oil spills. The system provides a total capability to predict the movement, spreading, weathering and coastal impact of oil spilt in the marine environment. Most importantly, the model has been extensively validated during scientific sea trials (through a licence exclusively held in the UK by AEA Technology) and real incidents (e.g. Braer, Sea Empress). The system has been the primary oil spill modelling system in the UK for many years and is used by the Maritime and Coastguard Agency, Oil Spill Response Ltd., Briggs Environmental Services, and most of the UK-based oil companies. It is also used internationally in areas such as SE Asia, Pacific Asia and the Caspian by many of the world's largest oil companies

G.2 Databases

OSIS relies on five primary database types to provide its model predictions. Four of these databases are pre-configured and stored in the system to provide maps, oceanographic information, bathymetric data and oil properties information. The fifth database is the weather database which is set-up by the user for the prevailing weather conditions at the time of the spill.

G.3 Mapping

The OSIS v 4.2.2 map databases contain information for display using the Geographical Information System (GIS) in OSIS. These maps may contain information on the coastline, bathymetry, coastal features, areas sensitive to oil spills, response information etc. Data can be imported from external applications using digital inter-change formats.

G.3.1 Oceanographic information

OSIS derives information on water movement from a sophisticated current data server which allows multiple data sources to be combined and integrated to provide water flows information on tidal and seasonal cycles. BMT Cordah's Digital Tidal Atlas can be then be used to visualise and manipulate this information.

Outside continental shelf, tidal influences are negligible and water movement is predominantly defined by currents. Currents in the vicinity of the Falkland Islands may vary considerably depending on the prevailing weather and variations in temperature and density. In depths of less than 200 metres, a considerable part of the water movement is tidal and the proportion increases as the depths decrease.

A hydrodynamic hindcast database for the Falkland Islands has been obtained and built into OSIS modelling programme. The system is configured for the global ocean with HYCOM as the dynamical model. It comprises of the following;

- Daily surface current velocity fields derived from the ocean circulation model hindcast data (at 1/12 degree resolution).
- Bathymetry, derived from a quality controlled NRL DBDB2 dataset.
- Surface forcing, derived from Navy Operational Global Atmospheric Prediction System (NOGAPS). This includes wind stress, wind speed, heat flux (using bulk formula), and precipitation.

The HYCOM system is a hybrid isopycnal model, which has fixed layer thicknesses in the upper mixed layer, and constant density layers through most of the water column. Archived analysis field data have been extracted for the Falkland region of interest for the model surface layer, which is representative of the upper 1 metre of the water column. Further details of the modelling system can be found at www.hycom.org.

Tidal currents are derived from BMT ARGOSS' in-house tidal database. This has been generated from global analysis of satellite altimeter observations, combined with tidal elevation measurements from around 5000 coastal stations. The model computes depth averaged barotropic tidal current velocities; these have then been extended through the water column using an empirical logarithmic velocity profile, to estimate equivalent tidal current velocities in the top 1 metre.

G.3.2 Bathymetric Database

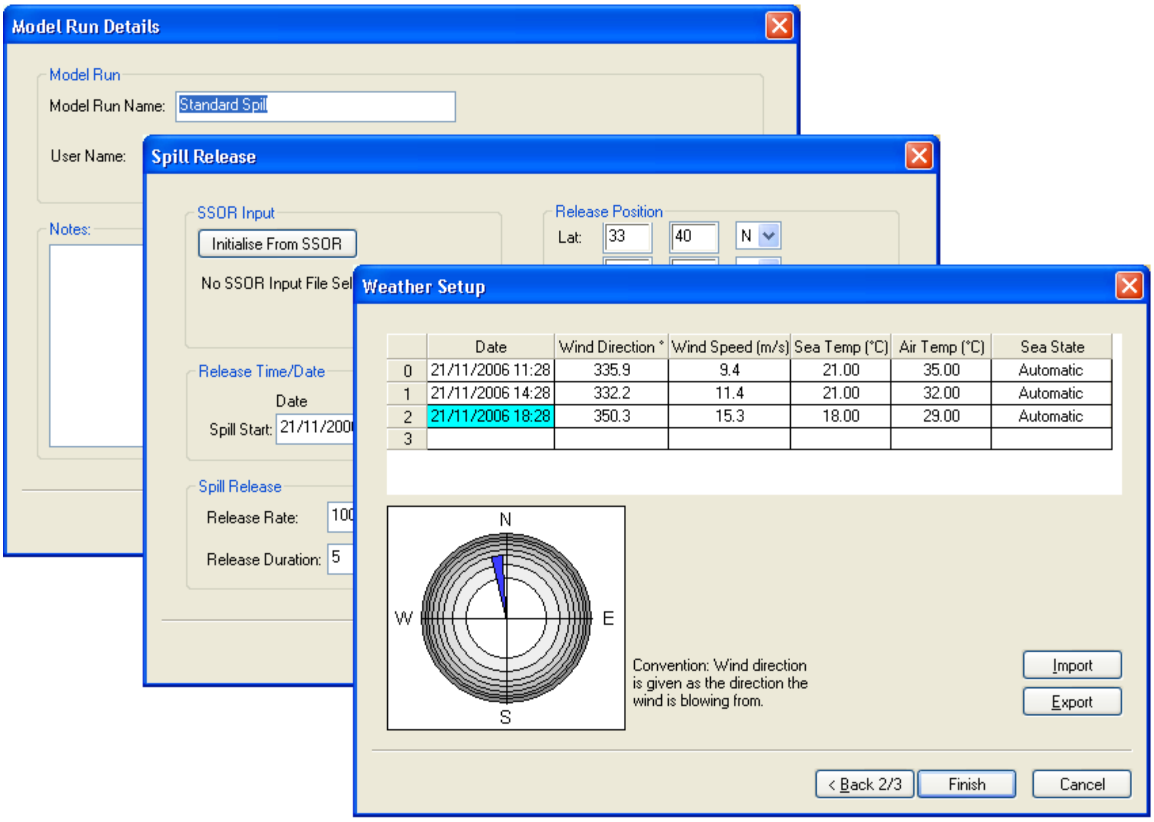
The requirement for bathymetric data within OSIS is satisfied by the bathymetric database which takes random bathymetric data input and stores it in a digital bathymetry model format.

G.3.3 Weather database

Prevailing wind data is a requisite feature of the OSIS model and along with prevailing currents contributes to the actual spill movements. OSIS models oil weathering based on the properties of the fresh oil. This information is entered via the model run manager which contains linked spreadsheets. These spreadsheets allow the user to setup multiple spills and associated weather data for running in a batch mode ideal for the multiple spill runs required during contingency planning.

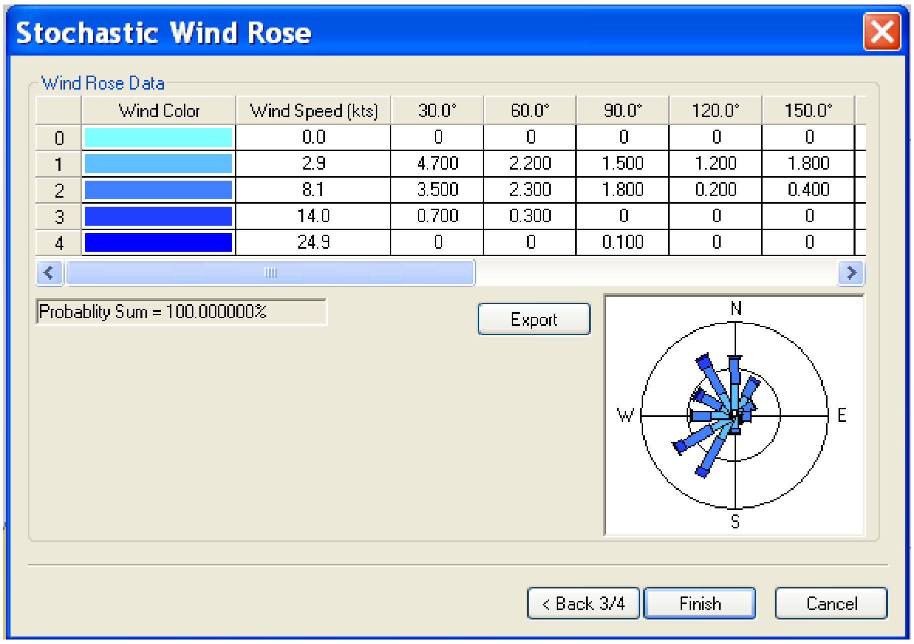
The wind input data required differs depending on the type of modelling simulation that will be undertaken. If the modelling simulation is a trajectory run, then only the prevailing direction (s) and force (s) of the expected or worst case wind is required. Typical wind input format is demonstrated in Figure G1.

Figure G.1. Trajectory wind data set up



If the modelling simulation undertaken is a stochastic run then actual wind rose data representative of the location where the spill simulation is being run will be required. The wind data required should detail, direction, force and percentage of occurrence for wind activity in the modelling location. Typical data requirements can be seen in Figure G2.

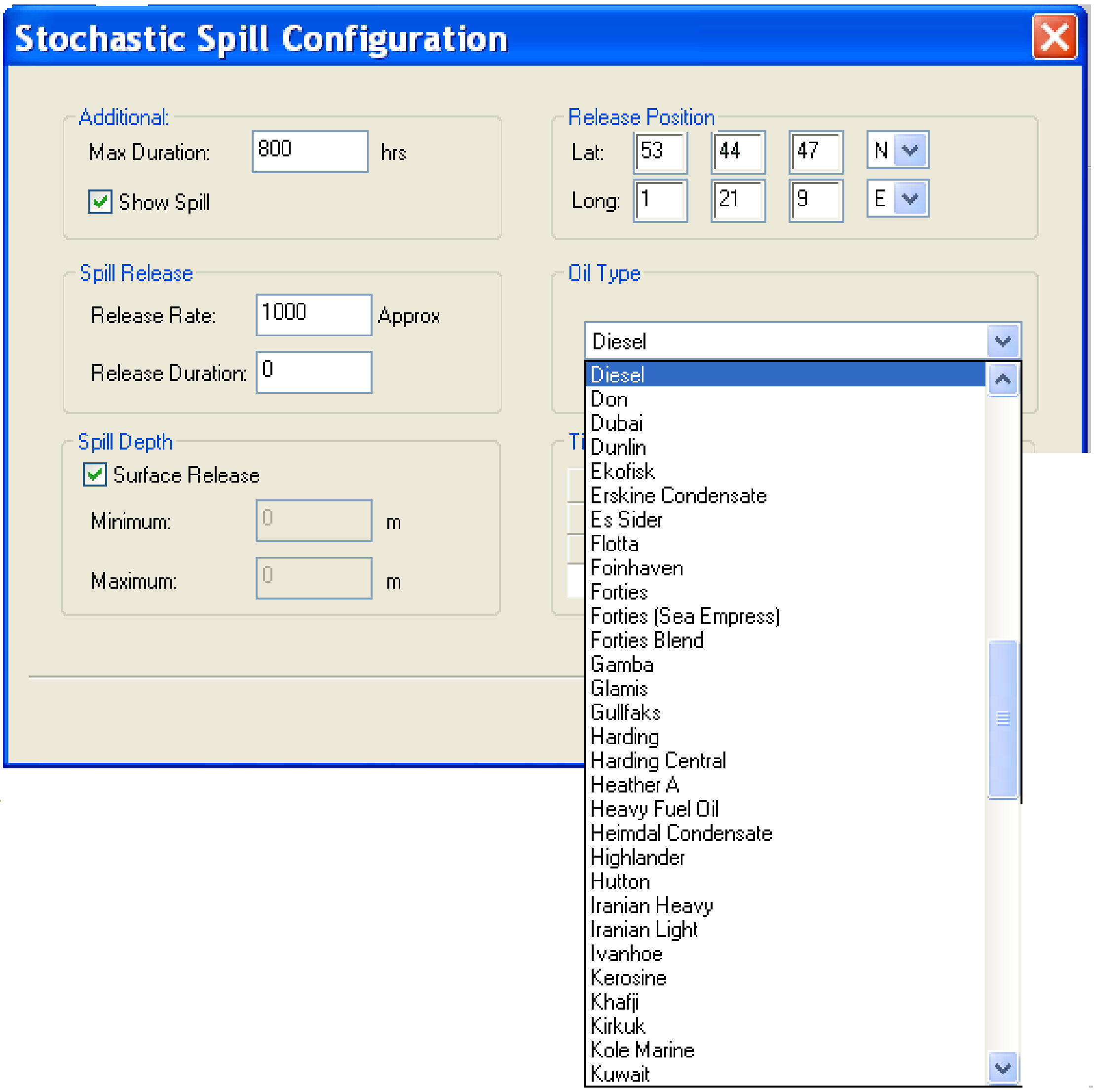
Figure G.2. Trajectory wind data set up



G.3.4 Oil Properties Database

OSIS models oil weathering based on the properties of the fresh oil. The oil properties database contains over 100 international oils and new oils may be added as required provided that the necessary oil analyses have been carried out. Information on the spill scenario is input using the Spill Data menu which allows definition of the volume, duration, diameter and depth of the spill as well as the oil type, tidal data to be used and the model run conditions; weather forecast is then added to the spill scenario based on the best available data including wind speed and direction, sea and air temperature, and sea state Typical spill data inputs are illustrated in Figure G3.

Figure G.3. Spill model inputs



During the spill run the user may utilise a number of options allowing the onscreen data to be analysed or adding supporting data. An example of this is the ability to visualise the current flow field and wind data under which the oil spill is being influenced. The user may also use the Spill Move option to reposition a spill on the basis of visual or remotely sensed observations.

G.4 Validation

Validation has been fundamental in the development of OSIS. It is one of the few models which have been validated against licensed oil spill sea trials. Its weathering algorithms have been developed through empirical work, not based on theoretical equations. Most of the oils in the OSIS database have been specifically laboratory-characterised to allow them to use the unique OSIS weathering model.

Qualitatively and quantitatively assess the nature, significance and probability of impacts on OSIS has been validated at sea against:

- 18 oil spill trials, up to three days in duration
- 10 different oil types
- Meteorological conditions from Beaufort scale 1-6

G.5 Metocean Data input

G.5.1 Introduction

This report provides a high level overview of the environmental resources that could potentially be impacted from possible spill scenarios associated with the proposed FOGL drilling activities, south /east of the Falkland Islands in the South Atlantic.

The modelling data presented in this report has been was derived using BMT's Oil Spill Information System (OSIS) 4.0 model and recent met-ocean data.

Both trajectory (conservative, absolute and worst case) and stochastic (under typical weather conditions) modelling scenarios were run to detail the possible and likely behaviour of the spills from the Loligo A, Vinson West and Scotia East D well locations.

G.5.2 Currents

Outside continental shelf, tidal influences are negligible and water movement is predominantly defined by currents. Currents in the vicinity of the Falkland Islands may vary considerably depending on the prevailing weather and variations in temperature and density. In depths of less than 200 metres, a considerable part of the water movement is tidal and the proportion increases as the depths decrease.

A hydrodynamic hindcast database for the Falkland Islands has been obtained from BMT (*BMT, 2011*). This current data is built into the OSIS modelling programme and comprises of the following:

- Daily surface current velocity fields derived from the ocean circulation model hindcast data (at 1/12 degree resolution). These are combined with surface tidal current velocities from BMT ARGOSS' tidal database;
- Resultant data, representative of the total surface current velocity, at 1/12 degree resolution.
- Bathymetry, derived from a quality controlled NRL DBDB2 dataset.
- Surface forcing, derived from Navy Operational Global Atmospheric Prediction System (NOGAPS). This includes wind stress, wind speed, heat flux (using bulk formula), and precipitation

The HYCOM system is a hybrid isopycnal model, which has fixed layer thicknesses in the upper mixed layer, and constant density layers through most of the water column. Archived analysis field data have been extracted for the Falkland region of interest for the model surface layer, which is representative of the upper 1 metre of the water column. Further details of the modelling system can be found at www.hycom.org.

Tidal currents are derived from BMT ARGOSS' in-house tidal database. This has been generated from global analysis of satellite altimeter observations, combined with tidal elevation measurements from around 5000 coastal stations. The model computes depth averaged barotropic tidal current velocities; these have then been extended through the water column using an empirical logarithmic velocity profile, to estimate equivalent tidal current velocities in the top 1 metre.

G.5.3 Wave Movements

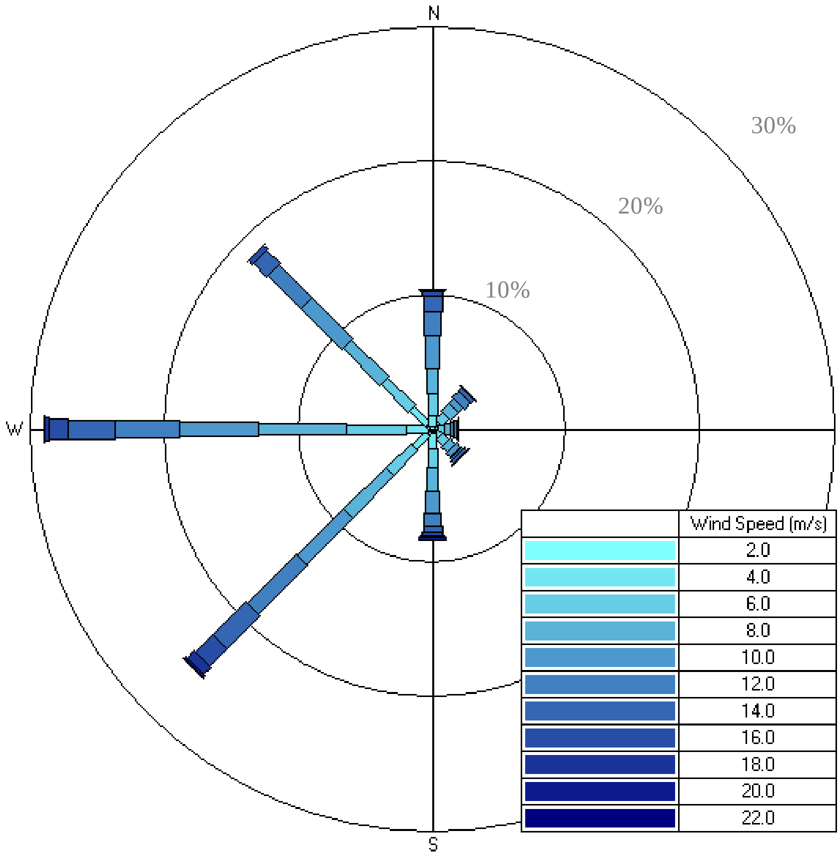
The prevailing direction of wave movements varies throughout the year. However, in January wave swells tend to be most common and strongest from the south-westerly through westerly to northern directions. Whereas in July, wave swells tend to be predominantly from the southern to north-western directions.

G.5.4 Wind

A 30 knot onshore wind towards the nearest landmass is stipulated for use in worst case wind conditions oil spill modelling for the UKCS. As this OSCP is following the example of the UK, a 30 knot onshore wind was also used for the worst case onshore wind scenarios in the modelled scenarios.

For the purposes of the stochastic (typical wind conditions) oil spill modelling, wind roses were obtained for the proposed drilling period (April, May and June) from the wind data presented in the metocean report compiled by Fugro GEOS (2005), which summarises the metocean conditions observed in the FOGL licence areas. A combined wind rose was compiled. (Figure G.1) and used for input into the model where typical wind conditions were to be modelled.

Figure G.1. Averaged Wind Rose for April-June used for Input into the OSIS Oil Spill Modelling under Typical Wind Conditions (compiled from derived data obtained from Fugro GEOS 2005)



G.5.5 Sea Temperature

Mean sea surface temperature varies throughout the year. In February, sea surface temperature in the region of the proposed drilling locations is approximately 6 to 10°C while in August it is relatively lower, ranging between 4 to 6 °C. The temperature of 6°C was used for modelling.

Appendix H

Appendix H: Oiled wildlife preparedness and response

H.1 Overview of Sea Alarm's services to Oil Spill Response Members

Under the Service Level Agreement, a Member of Oil Spill Response has access to an emergency oiled wildlife response and preparedness service, coordinated by the Sea Alarm Foundation. This is made possible under a contract signed in 2005 between Oil Spill Response and Sea Alarm. Sea Alarm is a non-governmental organisation which works to improve global preparedness for and response to oiled wildlife incidents. An Oil Spill Response Member can contact Sea Alarm via the Oil Spill Response Duty manager or directly via the contact details below.

H.2 Sea Alarm Capabilities

If mobilised, Sea Alarm will:

- Work closely with the client to determine the appropriate level of wildlife response and resource needs.
- Depending on the severity of the incident, Sea Alarm can provide distant expert advice and coach local responders remotely (via phone/email – Level 1 response), mobilise an assessment team of 2-4 people to visit the site to determine which assistance is needed and at what scale (Level 2 response) and/or mobilise an appropriate team of responders that works on site to assist the local response (Level 3 response).
- On the basis of information available Sea Alarm would identify available wildlife response organisations and experts and propose a response team and a plan to the client, and if agreed,
- Sign contracts, both with the Client and back-to-back with its team of wildlife responders (latter via subcontracts). All responders would have Professional Indemnity and travel insurance, via their own organisations or Sea Alarm.
- After contract signature, coordinate the mobilisation of the international wildlife response team.
- Together with Oil Spill Response, co-ordinate mobilisation of stocks of oiled wildlife response equipment from Oil Spill Response bases, plus 1 Oil Spill Response Specialist to be responsible for use and maintenance on site.
- Co-ordinate activities of the international wildlife response team on site and ensure the optimal integration of these activities into the overall oil spill response.
- Coordinate downscaling, demobilisation and debriefing towards the end of the response assistance, and completing documentation, reporting and financial administration.

H.3 International wildlife response team

The principle aim of oiled wildlife response is to mitigate the effects of oil on wildlife (seabirds, marine mammals and sea turtles). Sea Alarm works in conjunction with its international network to lead or support all elements of an oiled wildlife response in cooperation with local authorities, experts and response groups. This may include:

- Initial wildlife response assessment and response planning.
- Mobilisation of oiled wildlife response equipment (from Oil Spill Response or other).
- Hazing operations (techniques to deter wildlife away from oiled areas).
- Search and collection of oiled wildlife (alive and dead) on the beach or coastline.

- Setup of temporary rehabilitation facilities and/or transformation of existing rescue centres to handle large numbers of oiled animals.
- Transport of oiled wildlife to a forward holding centre or rehabilitation facility.
- Triage of animals for either long term rehabilitation or euthanasia.
- Cleaning and rehabilitation.
- Euthanasia of wildlife as appropriate and authorised by regulators.
- Monitoring and release
- Scientific wildlife impact assessment
- Liaising and working with key representatives of the international compensation regimes (e.g. ITOPF, P&I Clubs, IOPC Fund) to maximise the probability of cost reimbursement.

Rather than having a team of international experts on its payroll, Sea Alarm currently maintains close contacts with a pool of approximately 20 experts from 10 leading response groups worldwide who collaborate and work according to the same professional standards (see Figure 1). In selecting a team, emphasis will be given to responders nearest to the incident location as a first wave, but bringing in the best available expertise from the global pool so that the response is not dependent on availability of only one organisation. These experts are experienced in different aspects of dealing with oiled wildlife, including managers/staff of permanent wildlife rescue centres (many routinely deal with oiled wildlife), specialists in search and collection of oiled wildlife, wildlife veterinarians, and scientists trained in impact assessment. Most members of the international team have previous experience of large oiled wildlife incidents.

Figure H.1. Network of international wildlife response organisations

Sea Alarm develops and publishes Country Wildlife Response Profiles which summarise information to support a wildlife response in each coastal country. Through this process, Sea Alarm tries to identify any local wildlife responders or scientists who could play a role in an oiled wildlife incident. This includes key persons from scientific groups, institutes or NGOs with local up to date knowledge on the species and habitats at risk from an oil spill. Sea Alarm would routinely try to contact these persons in the initial stages of an incident. Profiles are published at http://www.sea-alarm.org/?page_id=2612.

As for an Oil Spill Response Mobilisation, Sea Alarm and its international wildlife response team will function better with certain administrative, logistics and financial support from the client to assist smooth running of oiled wildlife operations on site. This could include personnel/animal transportation, sourcing rehabilitation facilities (buildings of opportunity), equipment and consumables etc, and will be arranged as part of the contract

H.4 Wildlife response planning

The best guarantee for a fast and effective wildlife response mobilisation is provided by a pre-spill developed wildlife response plan. Such a plan is best integrated with the overall oil spill response plan that the client has to have in place for its oil exploration, production or transportation activities in a country or area. The wildlife response plan specifies the alerting and mobilisation procedure and indicates which local and international resources have been identified for a tiered response. A wildlife response plan has both generic and specific elements and is best based on internationally agreed principles and guidelines (e.g. the IPIECA Guide to oiled wildlife response planning, see www.ipieca.org). Sea Alarm can assist a client with developing an integrated oiled wildlife response plan and procedures that enable timely and swift mobilisation and optimal use of local and international resources based on tiered response and best practices.

H.5 Training and exercises

Oil spill response managers who have to manage the integration of an oiled wildlife response into the various operations of an oil spill incident require at least a basic knowledge of what an oiled wildlife response is and which kind of support and management it requires from an incident command system. Together with its expert organisations, Sea Alarm offers various training courses. Courses can be offered for HSE managers including theoretical modules and table top exercises that provide an introduction to oiled wildlife response and the key issues of mobilisation and setting up a response system and facilities. Other courses can be offered to hands-on responders (e.g. local wildlife groups, scientists or personnel that have been identified to play a role in the tiered response) including various theoretical and practical modules. These courses are tailor-made with regards to the specific requirements of the region and/or the agreed response plan and could last from 0.5 to several days, depending on the level of knowledge of the participants and the level of training additionally required.

Sea Alarm also offers assistance with the design of oil spill exercises in which a wildlife component needs to be integrated and can also be invited as a participant, to coordinate and oversee wildlife response activities.

For further information, contact:

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