BHP Billiton Petroleum (Falklands) Corporation

ENVIRONMENTAL IMPACT STATEMENT

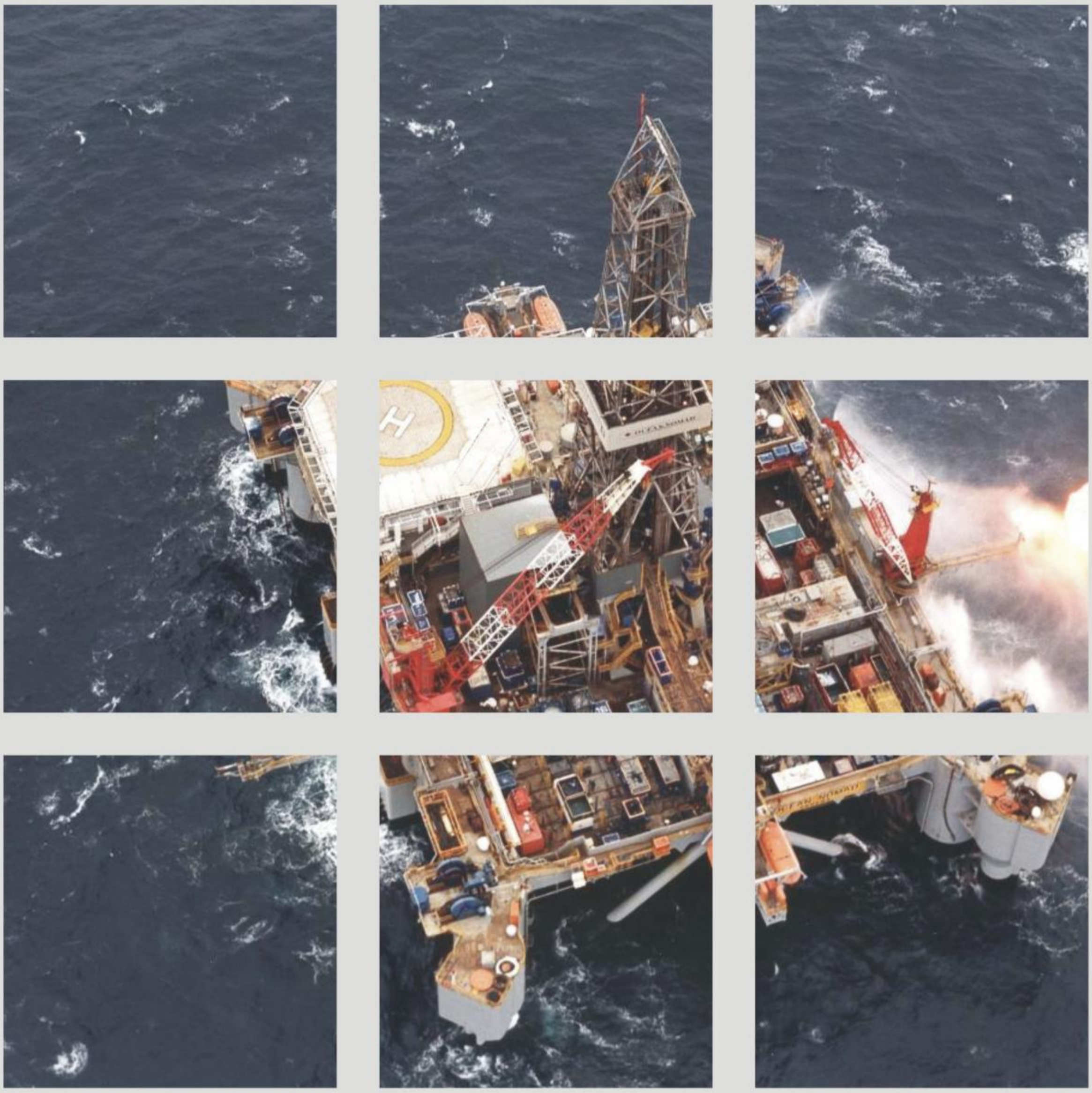
OFFSHORE

FALKLAND ISLANDS EXPLORATION DRILLING

(Licences 028 and 015)

Date: *September 2009*

Revision: *FINAL*



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September 2009

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Document Details and Issue Record

Rev No.	Details	Date	Author	Checked		Approved
				Text	Calcs.	
00	Draft for Issue to Client	14/07/2009	Shreya Shah	FD	FD	SS
01	Final Draft for Issue to Client	02/09/2009	Shreya Shah	FD	FD	SS
02	Final for Issue to Client	22/09/2009	Shreya Shah	FD	FD	SS
03	Final for issue	28/09/2009	Shreya Shah	FD	FD	SS
Document Reference:		\rpsfiles\Projects\BHP\ 1708 EIA for Falklands Exploration Drilling Operations\Report				

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Abbreviations

%	Percent
%Sat	Percentage Saturation
”	Inches
°	Degrees
°C	Degrees Celsius
µg.g-1	Micrograms per gram
2D	Two Dimensional
ACAP	Agreement on the Conservation of Albatross and Petrels
ADCP	Acoustic Doppler Current Profiler
APF	The Acoustic Doppler Current Profiler Antarctic Polar Front
ALARP	As Low As Reasonably Practicable
API	American Petroleum Industry
BHPBP(F)C	BHP Billiton Petroleum (Falklands) Corporation
boe	Barrels of oil equivalent
BOP	Blow out Preventor
CBD	Convention on Biological Diversity
CCA	Clean Caribbean Coop
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	Centimetres per second
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CO_2	Carbon Dioxide
CPI	Carbon Preference Index
DO	Dissolved Oxygen
DP	Dynamically Positioned
E	East
ED	Endocrine Disrupter
E&P	Exploration and Production
EEM’s	Environmental Emissions Monitoring System
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMP’s	Emergency Management Plan
ERP	Emergency Response Plan
FC	Falklands Conservation
FCO	Foreign and Commonwealth Office

FICZ	Falklands Interim Conservation and Management Zone
FIDA	Falklands Island Designated Area
FIFD	Falkland Islands Fisheries Department
FIC	Falkland Islands Company Ltd
FIG	Falkland Islands Government
FIPASS	Falklands Interim Port and Storage System
FOC	Fractional Organic Compound
FOCZ	Falklands Outer Conservation and Management Zone
FOGL	Falklands Oil and Gas Limited
FSLTD	Fugro Survey Limited
GMT	Greenwich Mean Time
HSEC MS	Health, Safety, Environmental and Community Management Systems
HF	Hydrofluoric Acid
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 Areas
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
LOI	Loss On Ignition
LTOBM	Low Toxicity Oil Based Mud
m	Metres
m2	Metres square
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973,
MIME	Managing Impacts on the Marine Environment
mm	Millimetres
MMO	Marine Mammal Observer
MoD	Ministry of Defence
MPC	Mount Pleasant Complex
ms-1	Metres per second
N	North
NASA	National Aeronautics and Space Administration
ng.g-1	Nanograms per gram
NNR	National Nature Reserves

NO_2	Nitrous Oxides
NO_X	Nitrogen 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
OSPARCOM	The Oslo and Paris Commissions
OSR	Oil Spill Response
OSRL	Oil Spill Response Limited
OWA	Oil Water Separator
PAH	Polycyclic Aromatic Hydrocarbons
PEC	Predicted Environmental Concentration
PLONOR	Pose Little or No Risk to the environment
PNEC	Predicted No Effect Concentration
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	Quarter 1
Q4	Quarter 4
ROV	Remotely Operated Vehicle
RQ's	Risk Assessments
S	South
SBM	Synthetic Based Mud
SMRU	Sea Mammals Research Unit
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
W	West
WBM	Water Based Mud
WOAD	World Offshore Accident Databank

Non Technical Summary

Background

BHP Billiton Petroleum (Falklands) Corporation (BHPBP(F)C) holds 14 exploration and production licences offshore the Falkland Islands in the South Atlantic after signing contracts with Falkland Oil and Gas Limited (FOGL). BHPBP(F)C holds a 51% interest in the acreage and is the designated operator. The remaining 49% is held by FOGL.

BHPBP(F)C plans to drill two exploration wells (Loligo and Toroa) in the PL028 and PL015 license areas. The proposed wells lie to the east and south-east of the Falkland Islands at a distance of 215 kilometres (Loligo) and 107 kilometres (Toroa) from the nearest landfall (Figure 1).

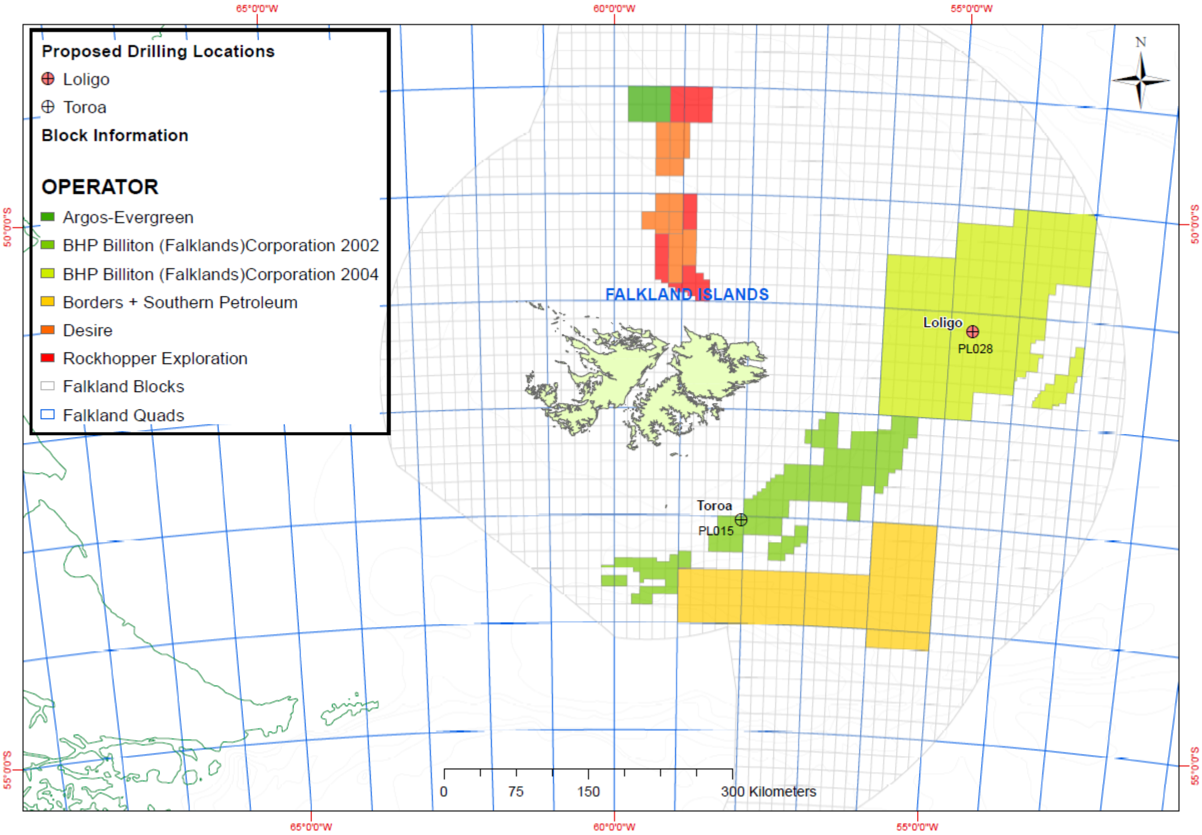

Figure 1: Loligo and Toroa Exploration Well Location Map

It is likely that the proposed exploration wells will be drilled using a semi-submersible drilling rig with anchors. Start dates for drilling the wells will be determined when a suitable rig has been secured.

Operations at the well sites are expected to last up to 75 days and. water-based muds will be used to drill the wells.

Following drilling and evaluation, the wells will be plugged and abandoned.

All 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.

Existing Environment

The Patagonian Shelf, on which the Falkland Islands sit, is of regional and global significance for marine resources. It comprises rich assemblages of seabirds, marine mammals, fish, squid and plankton populations.

There has previously been little information available on the benthic environment of this area and environmental surveys were carried out in December 2008 to January 2009 to provide current data, water column profiles, sediment analysis and identification of benthic species.

The benthic sampling that was undertaken indicated that naturally uncontaminated sediments with typical or low background concentrations of metals and hydrocarbons occur in the proposed well locations. The macrofauna data recorded were as expected, being relatively homogeneous in terms of the number species. The benthic environment was also considered to be relatively homogenous.

The main fisheries resources in the Falkland Islands are the squid species, *Illex argentinus* and *Loligo gahi*. Other types of fisheries include finfish, ray and longline. The Falkland Islands' Government annual Fisheries Statistics volume 11 (1997–2006) show that the proposed drill locations in question have no fishing interests for the key commercial target species. There are some significant fisheries interests on the landward side of the licence area, which would indicate that there is also low to medium vulnerability to disturbance from vessel movements to and from the licence area.

Marine mammal records from the seismic surveys carried out in the licence blocks PL015 and PL028 (June 2007), where a Marine Mammal Observer was stationed on board the seismic vessel, the following marine mammal species were recorded; Fin whale, Minke whale, Southern Right whale, Peale's dolphin, Dusky dolphin and Fur seal. However, fewer than 2-8 individuals of each species were observed. Due to the migratory nature of cetaceans, it is possible that other cetacean species may move through the licence areas. Overall however, the area is not considered to be of high sensitivity for cetaceans.

The Falkland Islands are an area of global importance for birdlife, particularly seabird species. The avifauna of the region is well studied and documented, and seabird distribution, breeding and foraging patterns have been studied extensively. A search of the BirdlLife International website for the International Union for Conservation of Nature Red List aves in the Falkland Islands, found 10 species as either 'Endangered' or 'Vulnerable'. Species recorded at their peak within the licence area are the King penguin (June to September), Rockhopper penguin (September to November), Magellanic penguin (November to April) and various species of albatross, petrel, fulmar, prion and shearwater. Other seabirds including shags, ducks, skuas, gulls and terns occur in the nearshore areas outside of the licence blocks.

Based on recorded distributions, the licence area to the east and south-east of the Falkland Islands is not of major significance for any of the recorded seabird species.

Impacts and Management Measures

There are no significant environmental sensitivities within the licence areas, however, seabirds and marine mammals may migrate through the area. There are no key fisheries interests within the licence blocks PL015 and PL028. The benthic (seafloor) habitat is considered to be a relatively homogenous environment with no habitats of conservation significance found during the survey in December 2008 to January 2009 of the licence blocks.

Outside of the licence areas, the near shore and coastal environments are considered to be sensitive to any forms of pollution.

The results of the environmental impact assessment of the drilling programme indicate that there are potential impacts which relate to waste management. Minimising the potential impact caused by waste issues can be achieved by implementing policies such as reuse, segregation and storage. Negative impacts will arise from onshore disposal; especially should this be at the Falklands where the capacity will be limited. Economic effects from the project are likely to be positive.

The sources of potential impacts include drill cuttings disposal, the risk of large offshore and near-shore oil spills, international transfer of solid and hazardous wastes and use of resources (i.e. fuel and potable water) should they be sourced from the Falklands. All other sources of potential impacts were deemed to be of low significance.

The potential impacts of these operations will be mitigated in a number of ways, including:

- Maintaining a spirit 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 operations, particularly in offshore chemical use and emissions reporting (Environmental Emissions Monitoring System, EEMS).
- Using water based drilling muds and low toxicity chemicals approved under the UK Offshore Chemical Notification Scheme.
- 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. BHPBP(F)C are members of Oil Spill Response Ltd which provide outside assistance in the case of a major spill.
- Implementing a detailed waste management plan to minimise the quantity of waste going to landfill, prevent unsuitable disposal of waste, maximise the re-use of materials and establish the Best Practicable Environmental Option for storage, treatment, transfer and disposal of waste materials.
- Collecting and sharing environmental data wherever possible, for example in offshore sightings, seabed surveys and meteorological and oceanographic conditions.

Conclusions

In conclusion, despite the high sensitivity and international importance of the Falkland Islands' waters, there is clear dedication to carrying out these operations to a high environmental standard. Given the current operational commitments and proposed mitigation measures, it is considered that the proposed operations can be undertaken without significant impacts to the Falkland Islands' environment.

1 Introduction

1.1 The Project

In 2007 BHP Billiton Petroleum (Falklands) Corporation (hereafter referred to as BHPBP(F)C) acquired an interest in 14 exploration and production licences offshore the Falkland Islands in the South Atlantic after signing contracts with Falkland Oil and Gas Limited (FOGL) (an AIM-listed oil and gas exploration company operating in the undrilled South and East Falklands' Basins). The licences give BHPBP(F)C the rights to explore and, if successful, eventually produce oil and gas from the East Falklands Basin located off the southern and eastern coast of the Falkland Islands (Figure 1.1).

Figure 1.1 Locality Map

BHPBP(F)C holds a 51% interest in the acreage and is the designated operator. The remaining 49% is held by Falkland Oil and Gas Limited (FOGL). The exploration and production licences cover approximately 18 million acres and are located in water depths ranging from approximately 200 to 2,000 metres (m) (Figure 1.2).

BHPBP(F)C plans to drill two exploration wells (Loligo and Toroa) in the PL028 and PL015 license areas. The proposed wells lie to the east and south-east of the Falkland Islands at a distance of 215 kilometres (Loligo) and 107 kilometres (Toroa) from the nearest landfall (Figure 1.2).

FOGL have acquired two dimensional (2D) seismic data over the licence blocks between 2005 and 2007, and BHPBP(F)C undertook geotechnical and environmental surveys in Q4 2008 / Q1 2009.

Six exploration wells were drilled within the North Falklands Basin during the 1998 drilling campaign (Figure 1.2). No commercial finds were located, but five of the six wells had oil shows and live oil was recovered at surface. Significant levels of gas were also recorded. No wells have so far been drilled within the East Falklands Basin.

Of the two wells proposed by BHPBP(F)C within the East Falklands Basin, the first well will test for oil in two target levels at the Northern Tranche Late Cretaceous Loligo Prospect. The second well will test for oil and gas in two target levels at the Southern Tranche Early Cretaceous Toroa Prospect.

It is likely that the proposed exploration wells will be drilled using a semi-submersible drilling rig, with an 8 to 12 line mooring anchor pattern. Start dates for the drilling of the wells will be determined when a suitable rig has been secured.

Operations at the well sites are expected to last up to 75 days and. water-based muds (WBM) will be used to drill the wells.

Following drilling, the wells will be logged and evaluated. Following evaluation, the wells will be plugged and abandoned regardless of the results of the evaluation.

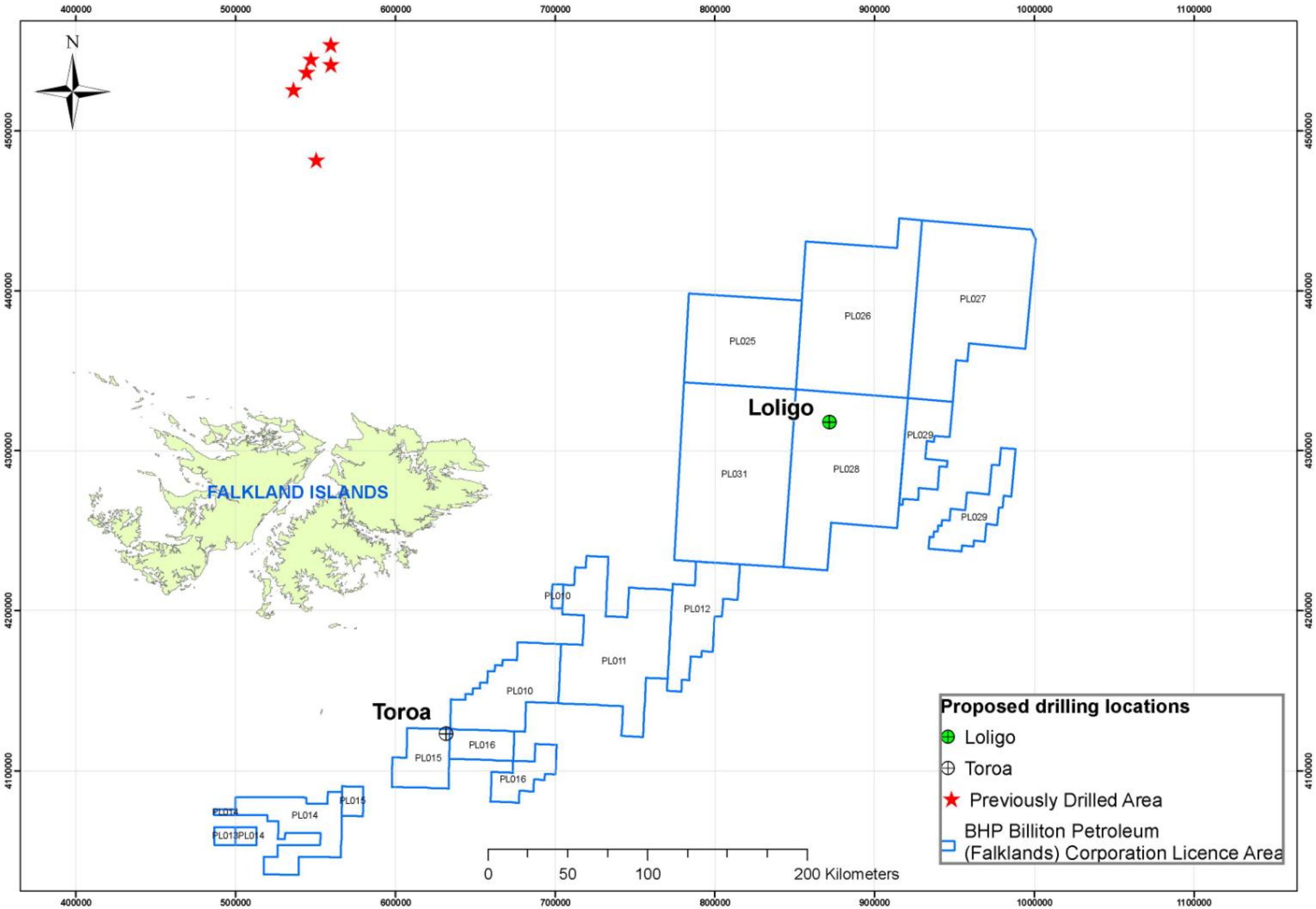

Figure 1.2 *BHPBP(F)C Licence Areas and Proposed Loligo and Toroa Exploration Well Locations*

1.2 Scope

This document constitutes an Environmental Impact Statement (EIS) as specified under the Offshore Minerals Ordinance 1994 Part VI. It has been compiled by RPS Energy at the request of BHPBP(F)C. This EIS provides an assessment of the potential impacts from proposed exploratory drilling within the PL028 and PL015 licence areas of the East Falklands Basin.

Undertaking an EIS ensures that potential environmental impacts associated with the proposed project, for both routine and non-routine operations, are correctly identified and assessed. In doing so, relevant preventative and management measures can be developed and implemented to mitigate adverse environmental impacts appropriately.

This document meets the requirements outlined in the Falkland Islands' legislation pertaining to offshore exploration and production activities – The Offshore Minerals Ordinance 1994; Amended 1997.

When a drill rig has been contracted and dates confirmed, an addendum to this EIS will be produced and submitted to the Falkland Islands' Government (FIG) for comment and approval, as per BHPBP(F)C's agreement with FIG. Impacts associated with the timing of the drilling will be included in this addendum along with proposed mitigation measures for seasonal impacts.

1.3 The Applicant

BHP Billiton Petroleum (Falklands) Corporation is a subsidiary of BHP Billiton, the world's largest diversified resources company with some 39,000 employees, working in more than 100 operations in 25 countries and with its headquarters in Melbourne, Australia. In the 12-month period ending 30 June 2007, production averaged 318,000 barrels of oil equivalent (boe) per day, or 116 million boe for the year.

BHPBP(F)C, with FOGL, currently hold 14 licences in the East Falklands Basin (Figure 1.2). BHPBP(F)C 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 BHPBP(F)C's management and oversight.

1.4 Consultations

Prior to submission of this EIS to the Falkland Islands' Government (FIG), BHPBP(F)C representatives met with a number of Falkland Islands' entities in October 2008. The issues raised during this preliminary consultation process have been considered by BHPBP(F)C 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 continue to be, consulted regularly throughout the proposed drilling programme.

Table 1.1. Summary of BHPBP(F)C Informal Consultation Responses

Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
Department of Mineral Resources	BHPBP(F)C to provide technical updates.	Technical details have been provided in this EIS, with further details to be presented in the Addendum and Basis of Design report.	Section 4
Civil Aviation and Stanley Airport	MoD is integral to all aviation issues. Charter flights to the Islands can be organised,	Details of crew transport to the Islands will be detailed in the Addendum and the MoD will be appraised of any aviation plans.	N/A
Environmental Planning Officer and Falklands Conservation	Seabirds are the main vulnerability to any offshore work (through spills).	This EIS has identified which seabirds are likely to be present in the region and within the licence blocks. Impacts to particular species will be included in the Addendum when the drilling schedule has been finalised.	Section 5.2.9, 6.6 and 6.10
Fisheries and Marine Resources	Notice to Mariners via Fisheries and Marine Resources, and minimal response capability for oil spills.	Notice to Mariners will be issued via the Fisheries and Marine Resources prior to commencing operations and an Oil Pollution Emergency Plan (OPEP) will be prepared. The OPEP will be submitted with the Addendum and will be reviewed and approved by the authorities.	Section 6 and 7
Public Works	Waste – very limited capacity for storage, management and/or onshore processing. Some recycling available.	BHPBP(F)C notes the limited waste handling capacity on the Islands and will explore waste management options with a licensed waste contractor including shipping it to another destination. The final option will be presented in the Addendum when drill rig details are known.	Section 5 and 6
Emergency Response – FI Defence Force, Fire/Rescue Service, KEMH, Police Chief	National Emergency Response Plan	BHPBP(F)C's emergency response plans and OPEP will compliment the Falkland Islands' National ER Plan. The OPEP will be submitted with the Addendum and will be reviewed and approved by the authorities.	Section 6 and 7
British Military Base at Mount Pleasant	Understanding military operations and resources, and communicating with the military on proposed activities.	BHPBP(F)C will keep the military updated on its proposed activities.	Section 5 and 6
Various service providers	Understanding service capabilities and logistics.	BHPBP(F)C has gained an early understanding of service capabilities on the Islands and will work with the drill rig provider and drilling contractor to ensure that comprehensive planning is undertaken so that no strains are placed on current capacities.	Section 6 and 7

1.5 Structure of the Report

The report is presented in six main sections.

Section 1	Introduction - provides a background to the project.
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 environmental characteristics, identifies the flora and fauna likely to be present within PL028 and PL015 and the surrounding waters, and describes other sea users within this area.
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 be implemented, to limit the impacts.
Section 7	Management Framework – provides an outline of BHP Billiton Petroleum's Health, Safety and Environment Management System.
Section 8	Conclusions of the EIS.

In addition, the report includes a non-technical summary of the environmental assessment, which highlights its main conclusions, and provides a list of references used to obtain data and information to support the assessment. Further information is also included in the appendices.

1.6 Contact Address

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

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2 Legislative 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 Councils, and in accordance with the Falkland Islands Constitution (*FCO, 2005*).

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 2011, which will place the current petroleum exploration programmes into context.

2.1 International Conventions and Agreements[1]

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

Table 2.1. International 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 2004	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	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.
CBD	Convention on Biological Diversity 1992	Not yet ratified, applies through UK extension of overseas territories	Commitment to conserve biological diversity, to use biological resources sustainably and to share equitably the benefits arising from the use of genetic resources.
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 1976	Ensures that international trade in specimens of wild animals and plants does not threaten their survival.

[1] Adapted from the FIG 'The Principal Environmental Conventions and Agreements Relevant to the Falkland Islands and Foreign and Commonwealth Office (FCO)' online database.

Known As	Full Title	Status	Summary
CMS or The Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals	Ratified* 1985	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.
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 offshore activities in the south west Atlantic.
IUCN	International Union for the Conservation of Nature	*Not a legal agreement*	The IUCN assess the conservation status of animal and plant species and assign a threat level. Lists of threatened species status (IUCN red lists) are published for different countries. The list of species identified as under threat by IUCN is given in Appendix F.
Kyoto Protocol	Kyoto Protocol to the UN Framework Convention on Climate Change	By Extension March 2007	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	Most of the subsidiary agreements ratified.	Seeks to prevent pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage from ships.
Montreal Protocol	Montreal Protocol on Substances that Deplete the Ozone layer	Ratified* December 1988	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. Both Bertha's Beach and Sea Lion Island have been accepted by the Convention of Parties and listed as having Ramsar status (Section 5.3.12). 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	By Extension March 2007	Aims to reduce greenhouse gas emissions to combat global warming.
World Heritage Convention	1972 Convention for the Protection of the World Cultural and National 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 with 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 first Environmental Charter, stating mutual responsibilities of the UK and its Overseas Territories, was signed on 26 September 2001 by Councillor Mike Summers, representing Falkland Islands Government, and Baroness Valerie Amos, 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 system of Petroleum Operations Notices (PON) are not legally binding but have been approved by the Mineral Resources Committee as best practice.

Table 2.2. Falkland Islands' Legislation relevant to Offshore Drilling and the Environment

Legislation	Key Requirements / Relevance to Proposed Operations
1) Relevance to Offshore Operations	
Environment Protection (Overseas Territories) (Amendment) Order 1997	Enables the provision of the London Dumping Convention to be implemented in the Falkland Islands' waters.
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. Production Licences (PL028 and PL015) are issued under this Ordinance.
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	Updates 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.
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

Legislation	Key Requirements / Relevance to Proposed Operations
	prior to carrying out a geophysical survey.
Petroleum Operations Notice No.4	Comprises the pro-forma and accompanying guidance notes to 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, egg collection, prohibits the introduction of new species and designates conservation areas (National Nature Reserves). Fauna specified so far for protection are two species of trout and all species of butterflies. 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 designated to area of Crown land, marine area or privately owned land with the agreement of the owner. 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 Island 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 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.

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 2.1.

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, and/or 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.

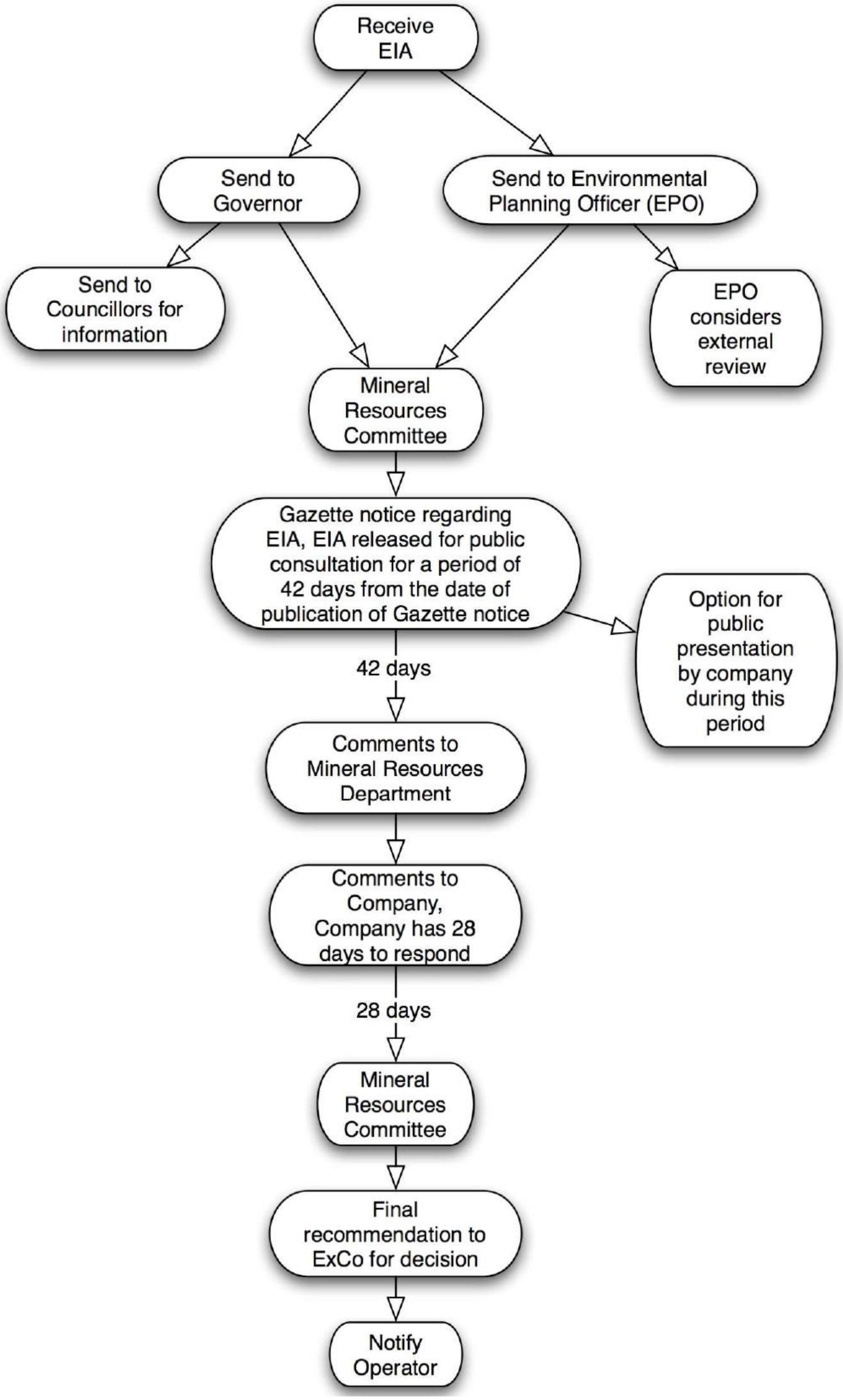

Figure 2.1. Falkland Islands' EIA/EIS Process Flowchart

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. Elements of the best practice guidelines will be utilised in developing the operations specific Environmental Management Plans for this project.

2.3.1 International Association of Oil and Gas Producers (OGP)

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 E&P Forum / United Nations Environment Programme (UNEP)

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.

2.3.3 International Association of Drilling Contractors (IADC)

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; Fall Protection;

2.3.4 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.

2.3.5 International Petroleum Industry Environmental Conservation Association (IPIECA)

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.

2.4 BHP Billiton Petroleum Health, Safety and Environmental Standards

BHP Billiton Petroleum 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 heavily influenced the design and planned execution of the drilling programme. These standards are described in Section 7 and presented in Appendix I.

3 Alternatives to the Proposed Drilling Programme

A necessary part of the impact assessment process is the consideration of alternatives to the proposed activity. Many complex factors control the situation of oil wells (geology, topography, communications, and engineering technology), meaning only a few viable alternatives can be considered environmentally. Two simple alternatives may be to drill or not drill at all.

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 BHPBP(F)C. Potential impacts from drilling activities and their management measures are discussed in subsequent chapters of this EIS.

Direct benefits to the region and country 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 (for example, improved waste disposal). These benefits could also potentially raise awareness of environmental protection in the area.

The implications of not proceeding mean that the potential environmental and social impacts (positive and negative) from the drilling operations will not occur. The environment will not necessarily maintain its current baseline condition however, as impacts from fishing and vessel activity such as waste water discharge, sedimentation, fall-out of atmospheric pollutants, and ballast water discharge will still take place.

Should the drilling programme not proceed, the potential financial and social benefits of oil and gas production cannot be realised. Ultimately, no drilling would preclude development of offshore hydrocarbon resources with missed opportunities in business and economic investment.

Alternative drilling methods and types of drill unit exist and each have their own environmental impacts. The use of a dynamically positioned (DP) drill ship or semi-submersible drilling rig would minimise seafloor disturbance as anchoring would not be required (as in a traditional semi-submersible). 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.

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. Directional drilling requires additional resources and time, is more complicated and more expensive than vertical drilling. It would only be considered where there is an exceptional reason why the well cannot be positioned over the target reservoir, which, taking full account of the baseline environmental and benthic data, is not considered to be the case in this instance.

Cuttings from the wells for this drilling campaign will be treated and disposed of to sea through the cuttings caisson (as water based muds will be used) in line with standard industry practice. Downhole injection of cuttings is not possible, as no suitable geological formation or old well exist to store the cuttings discharge.

In addition the use of water based muds, low toxicity chemicals and a solids control package on the rig will all mitigate the potential polluting impacts from cuttings disposal to sea.

Specifics of technology available onboard the rig cannot be considered at this time as the rig has not been contracted yet. However, all equipment on board the rig will have been certified and checked that it is functioning at optimum levels.

4 Drilling Programme

4.1 Overview

BHPBP(F)C is currently planning to drill two exploration wells: Loligo in licence area PL028 and Toroa in licence area PL015 (refer to Figure 1.2).

The proposed Loligo exploration well is situated approximately 225 kilometres to the east of Stanley, Falkland Islands in Falkland Islands Designated Area (FIDA) Block 42/02. The water depth at the Loligo location is approximately 1,300 metres (*FSLTD, 2009a*).

The proposed Toroa exploration well lies approximately 145 kilometres to the south-east of Stanley, Falkland Islands in FIDA Block 61/05. The water depth at the Toroa location is approximately 600 metres (*FSLTD, 2009b*).

The Loligo target reservoirs are located in the T1 Lower unit of the Slope Channel Play interval at a top depth of approximately 2,439 metres (Figure 4.1). The Toroa target reservoirs are stacked objectives in the Springhill Play interval at top depths of 2,258 and 2,310 metres (Figure 4.2). It is anticipated that hydrocarbons at Loligo, if identified, will be oil with an API of 18. At Toroa, it is anticipated that the hydrocarbons will be oil and gas at API average of 31.

Following drilling, the wells will be logged and evaluated. Regardless of the evaluation results, the wells will be plugged and abandoned in accordance with Oil & Gas UK guidelines.

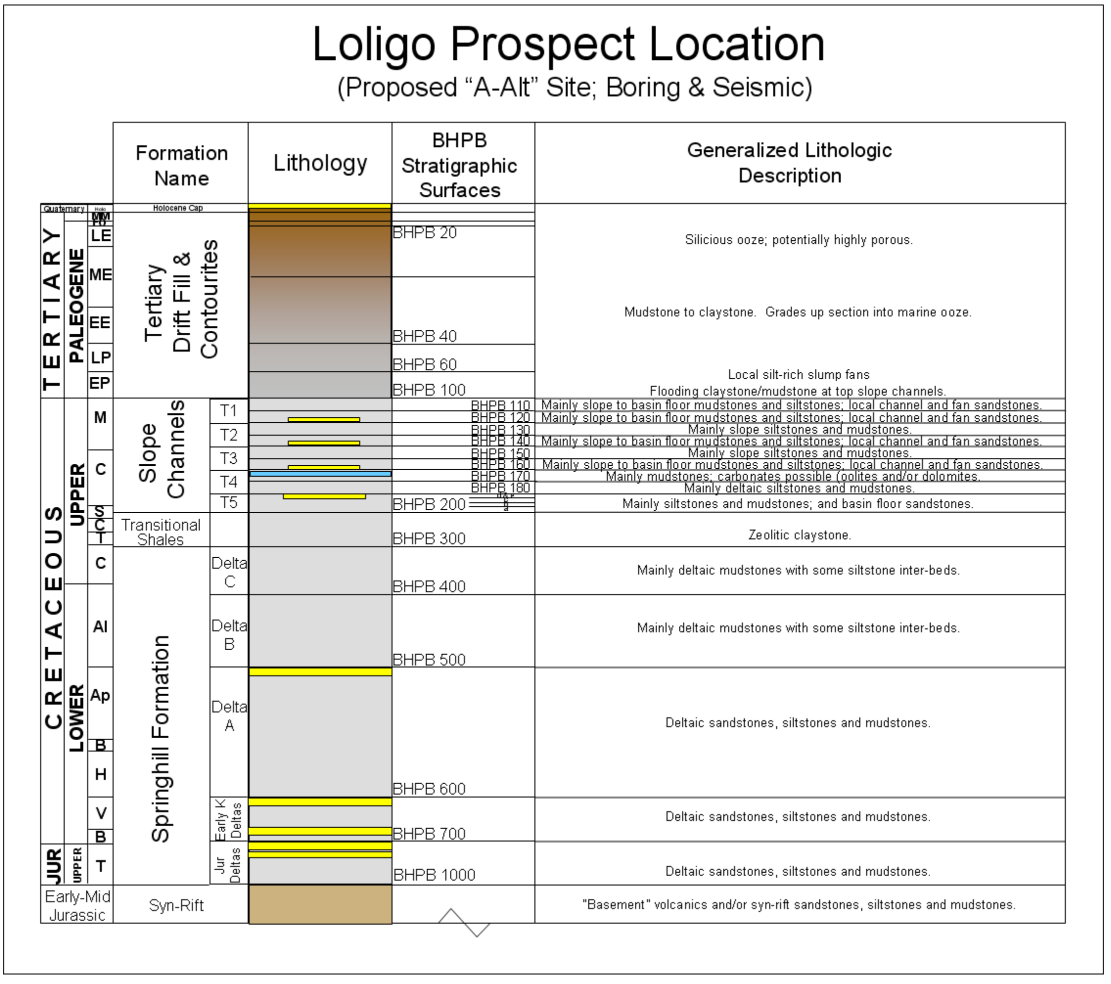

Figure 4.1 Loligo Stratigraphic Column

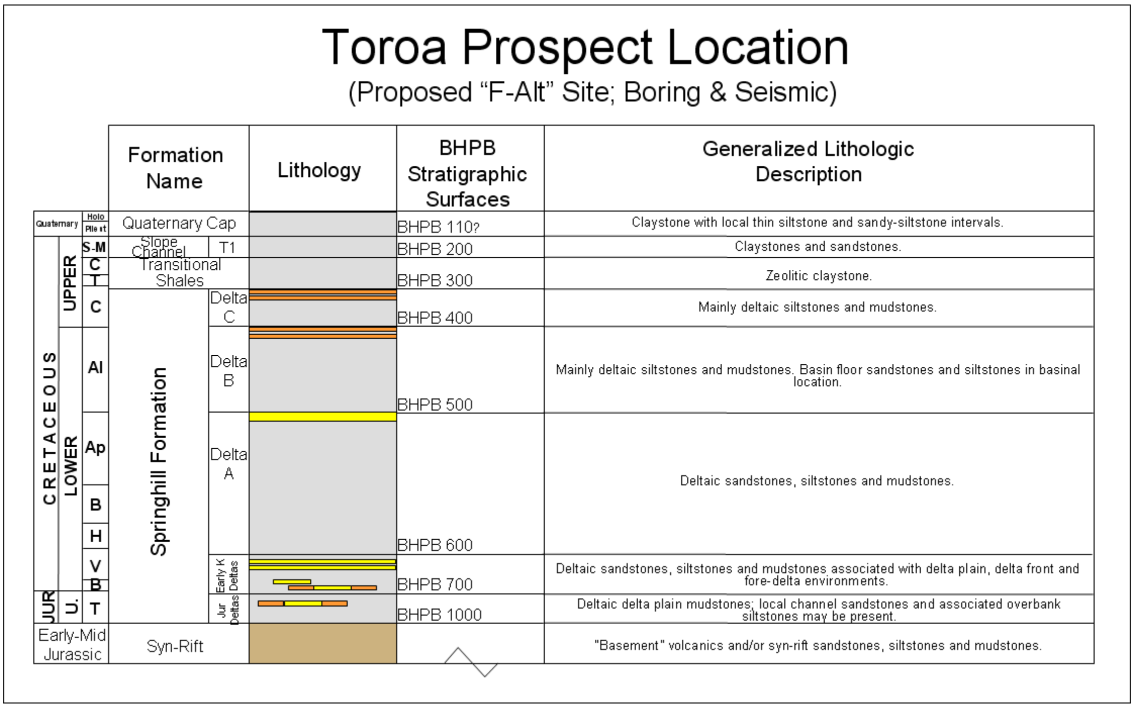

Figure 4.2 Toroa Stratigraphic Column

4.2 Exploration Well Objective and Concept

The objective of this project is to explore for recoverable hydrocarbons from the Loligo and Toroa reservoirs through the drilling and evaluation of two exploration wells.

4.3 Proposed Project Schedule

A provisional project schedule for the BHPBP(F)C drilling programme will be provided in an Addendum to this document when a drill rig and drilling contractor have been chosen.

It is anticipated that the rig will be on location for a total of up to 75 days (40 days for Loligo and 35 days for Toroa). No well testing that involves flowing well fluids to the surface is planned. All evaluations will be undertaken by wireline.

4.4 Drilling Operations

4.4.1 Key Well Information

The Loligo and Toroa well characteristics are summarised in Tables 4.1 and 4.2 respectively.

Table 4.1. Loligo Well Characteristics

Aspect	Loligo Exploration Well Detail
FIDA Block	42/02
Anticipated Drilling Location	51° 10' 23.791'' S 54° 40' 48.292" W
Anticipated Drill Rig	Semi-submersible drilling rig
Support Location	Stanley
Water Depth (m)	1,376
Depth of Well (m) (TVD)	4,271
Anticipated Spud date	Unknown
Estimated time to reach Total Depth	40 days, dry hole
Clean up and well testing	None planned
Hydrocarbons Anticipated	Oil, API 18
Anticipated Weight of Cuttings	1,157 tonnes

Table 4.2. Toroa Well Characteristics

Aspect	Toroa Exploration Well Detail
FIDA Block	61/05
Anticipated Drilling Location	53° 01' 45.236'' S 58° 02' 21.740" W
Anticipated Drill Rig	Semi-submersible drilling rig
Support Location	Stanley
Water Depth (m)	626
Depth of Well (m) (TVD)	2,700
Anticipated Spud date	Unknown
Estimated time to reach Total Depth	35 days, dry hole
Clean up and well testing	None planned
Hydrocarbons Anticipated	Oil and Gas, Av. API 31
Anticipated Weight of Cuttings	617 tonnes

4.4.2 The Drilling Rig

It is likely that the proposed exploration wells will be drilled using a semi-submersible drilling rig, with an 8 to 12 line mooring anchor pattern. Further information on semi-submersible drilling rigs is provided in Appendix A.

No unacceptable drilling risk has been identified for anchoring a rig at the proposed Loligo and Toroa exploration well sites. Results of the site survey indicated that there were no seabed obstructions in the vicinity of the proposed well sites (*FSLTD, 2009a and FSLTD, 2009b*).

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 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 therefore, the drilling fluid can be returned to the rig, in the space (or 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.

Loligo

The proposed Loligo well will be drilled to a total vertical depth of 4,271 metres (14,011 feet) or approximately 2,874 metres (9,429 feet) below mud line (Table 4.3 and Figure 4.3).

42" Hole with 36" Casing

Once the rig has been installed at the proposed location, a 42" hole will be drilled to about 95 metres (310 feet) below mud line. This section will be drilled with seawater. Occasional pills of viscosified water (using bentonite as a gelling agent) will be circulated to help cleaning the hole. A 36" casing will then be run and cemented in place.

26" Hole and 20" Casing

A 26" hole will be drilled vertically to approximately 457 metres (1,500 feet) below mud line, using seawater and gel sweeps. A 20" casing will be run and cemented in place.

17 ½" Hole and 13 $^{3}/_{8}$" Casing

A 17 $^{1}/_{2}$" hole will be drilled to approximately 1,372 metres (4,500 feet) below mud line, using WBM with density ranging from 9.0 to 9.5 ppg. A 13 $^{3}/_{8}$" casing will be run and cemented in place for 2,210 metres (7,250 feet) of this section.

12 ¼" Hole and 9 $^{5}/_{8}$" Casing

A 12 ¼" hole will be drilled to approximately 2,377 metres (7,800 feet) below mud line, using WBM with density ranging from 9.5 to11.5 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 for 3,353 metres (11,000 feet) of this section.

8 ½" Hole to TD

A 8 ½" hole will be drilled to target depth (TD) of 2,874 metres (9,429 feet) below mud line, using WBM with density ranging from 11.5 to 13.5 ppg.

Table 4.3. Proposed Loligo Well Profile

Hole Size		Casing Size		Section Length in metres (Measured Depth)	Proposed Mud Use
Millimetres	Inches	Millimetres	Inches	Metres	
1066.8	42	914.4	36	95	Seawater
660.4	26	508	20	362	Seawater + Gel Sweeps
444.5	17 $^{1}/_{2}$	339.7	13 $^{3}/_{8}$	915	WBM
311	12 ¼	244.5	9 $^{5}/_{8}$	1005	WBM
216	8 $^{1}/_{2}$	-	-	497	WBM

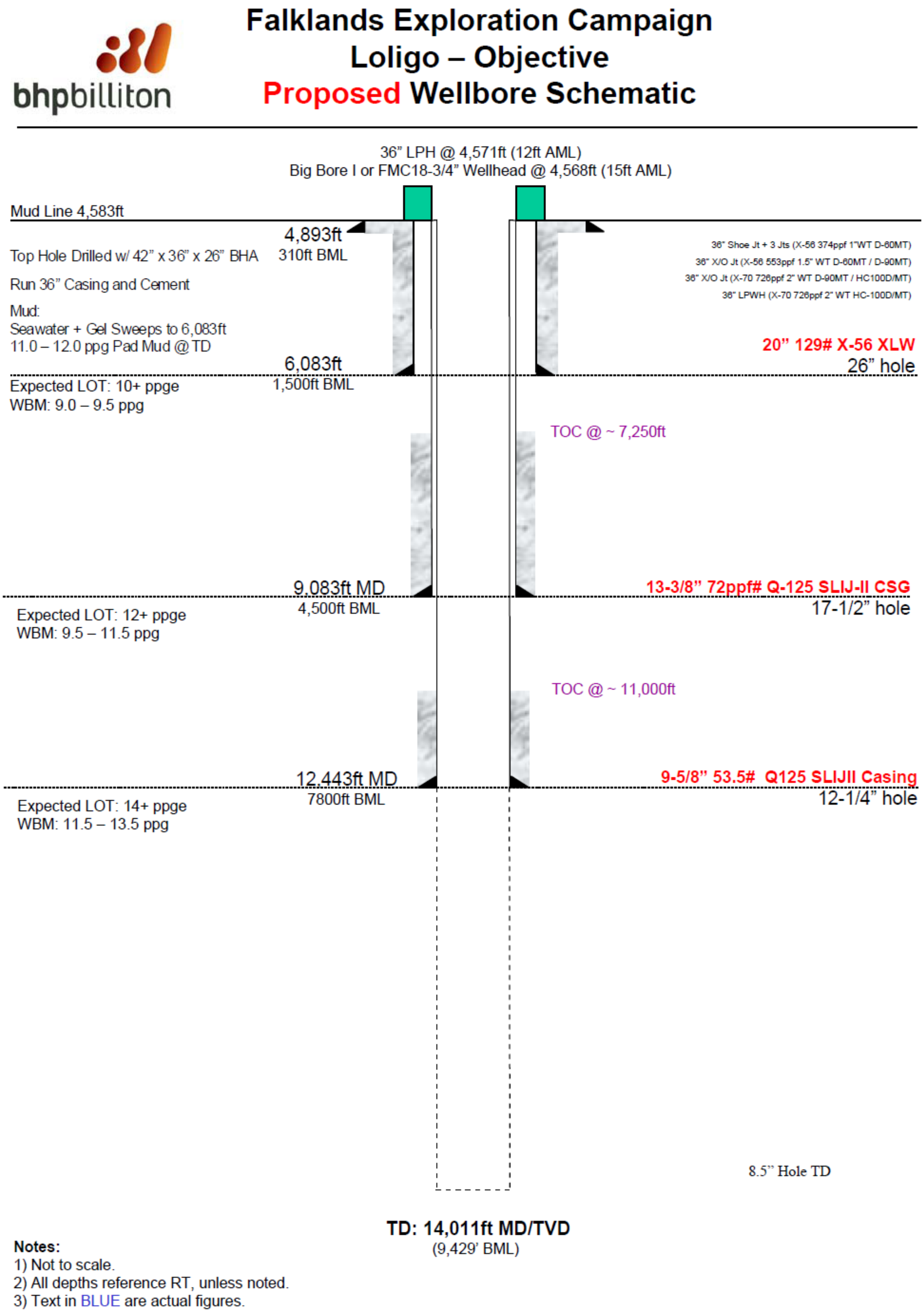

Figure 4.3 Proposed Loligo Well Schematic

Toroa

The proposed Toroa well will be drilled to a total vertical depth of 2,700 metres (8,858 feet) or 2073 metres (6802 feet) below mud line (Table 4.4 and Figure 4.4).

42" Hole with 36" Casing

Once the rig has been installed at the proposed location, a 42" hole will be drilled to about 95 metres (310 feet) below mud line. This section will be drilled with seawater. Occasional pills of viscosified water (using bentonite 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.

17 ½" Hole and 20" Casing

A 17 $^{1}/_{2}$" hole will be drilled to approximately 457 metres (1,500 feet) below mud line, using seawater and gel sweeps. A 20" casing will be run and cemented in place for this entire section.

12 ¼" Hole and 9 $^{5}/_{8}$" Casing

A 12 ¼" hole will be drilled to approximately 1,372 metres (4,500 feet) below mud line, using WBM with density ranging from 9.0–9.5 ppg. . A 9 $^{5}/_{8}$" casing will be run and cemented in place for 212 metres of this section starting from approximately 1,583 metres (5,194 feet) below mud line.

8 ½" Hole to TD

An 8 ½" hole will be drilled to target depth of 2,073 metres (6,802 feet) below mud line, using WBM with density ranging from 9.5 to 11.0 ppg. The higher density will be required to provide sufficient over-balance on the formation and prevent influx of reservoir fluids.

Table 4.4. Proposed Toroa Well Profile

Hole Size		Casing Size		Section Length in metres (Measured Depth)	Proposed Mud Use
Millimetres	Inches	Millimetres	Inches	Metres	
1066.8	42	914.4	36	95	Seawater
444.5	17 $^{1}/_{2}$	508	20	362	Seawater + Gel Sweeps
311	12 ¼	244	9 $^{5}/_{8}$	915	WBM
216	8 $^{1}/_{2}$	-	-	701	WBM

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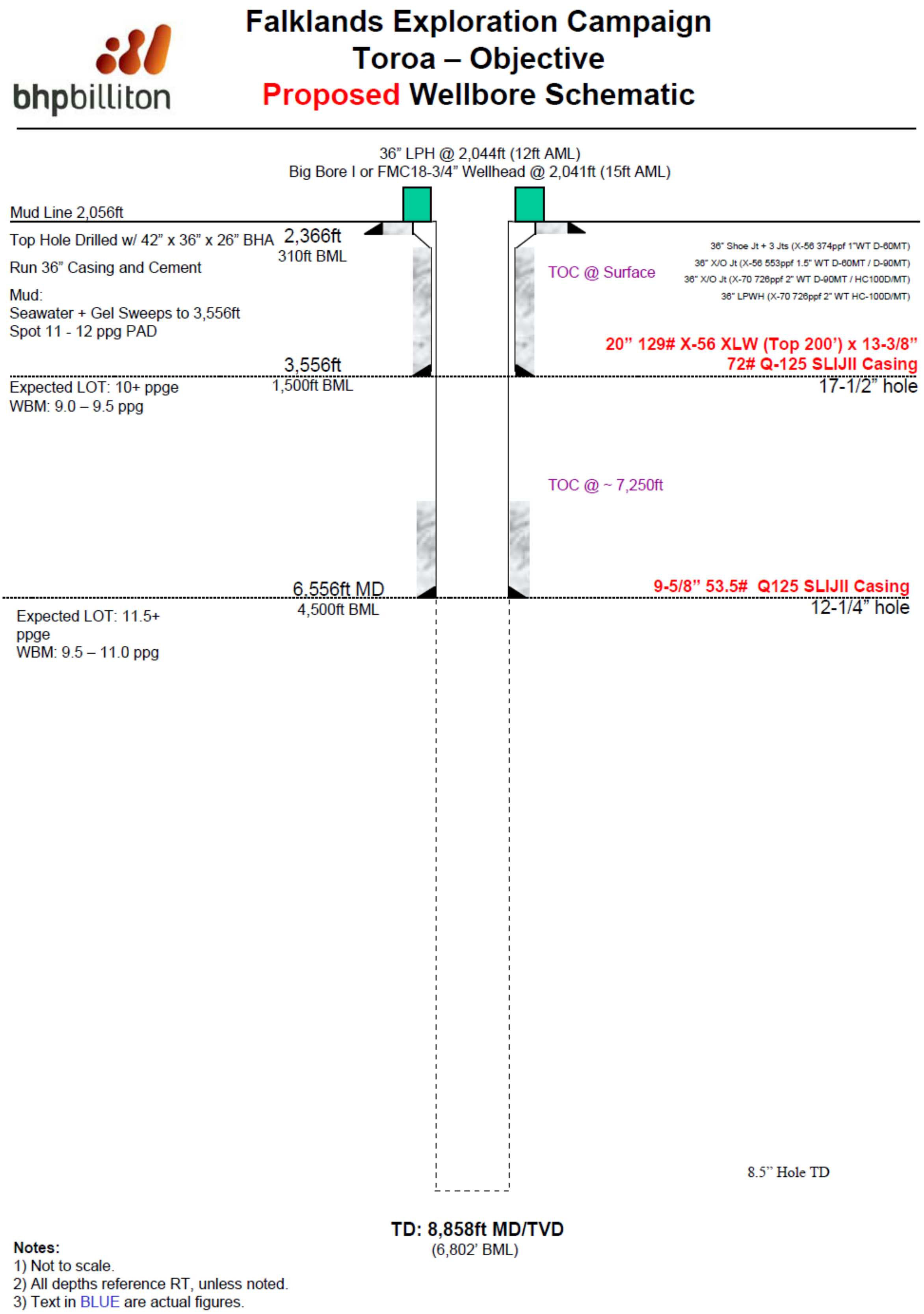

Figure 4.4 Proposed Toroa Well Schematic

4.4.4 Disposal of Drill Cuttings

The top two hole sections for the proposed Loligo well and the top-hole section for Toroa well will be drilled open to the seabed and the cuttings generated whilst doing so will be will be swept out of the hole using seawater. These will be deposited around the well bore. For subsequent 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 weight down the hole.

Whilst drilling the wells, a riser will be set between the wellhead and the rig, with a blow-out preventor fitted on the seabed near 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 10 percent. The cuttings will be cleaned to the required specification 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 and Toroa exploration wells are detailed in Tables 4.5 and 4.6.

Table 4.5. Estimate of Cuttings Generated for Proposed Loligo Well

Hole Size (in)	Hole size diameter (m)	Length (m)	Volume (cu m)	Weight (tonnes)
42	1.067	95	85	221
26	0.660	362	124	322
17 1/2	0.444	915	142	369
12 ¼	0.311	1,005	76	198
8 1/2	0.216	497	18	47
Total cuttings from Loligo well			**445**	**1157**
Discharged at Seabed			85	221
Discharged at Surface			360	936
Returned to Shore			0	0

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

Table 4.6. Estimate of Cuttings Generated for Proposed Toroa Well

Hole Size (in)	Hole size diameter (m)	Length (m)	Volume (cu m)	Weight (tonnes)
42	1.067	95	85	221
17 1/2	0.444	362	56	146
12 ¼	0.311	915	70	182
8 1/2	0.216	701	26	68
Total cuttings from Toroa well			**237**	**617**
Discharged at Seabed			85	221
Discharged at Surface			152	396
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. Both wells will be drilled using water based mud (WBM). On the rig, the cleaned mud's composition will be monitored and its contents adjusted to ensure that its properties remains as specified and it will be recycled through the well. No low toxicity oil based mud (LTOBM) will be used for the proposed wells.

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The drilling mud is specially 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 proposed mud components which BHPBP(F)C currently propose to use for the two exploration wells are listed in Tables 4.7 and 4.8.

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 4.9). 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.

Other contingency chemicals may be required if problems or emergencies are encountered during drilling or cementing operations.

4.4.6 Well Clean-up, Testing and Completion

Once drilling operations have been completed, BHPBP(F)C proposes to run electric logs to provide information on the potential type and quantities of hydrocarbons present in the target formations. Logging instruments will be attached to the bottom of a wireline and lowered to the bottom the well. They are then slowly brought back up, the devices reading different data as they pass each formation and recording it on graphs, which can be interpreted by the geologist, geophysist and drilling engineer.

In the event that hydrocarbons are encountered in sufficient quantities, as determined by the electric wireline logs, attempts to recover reservoir fluid samples may be undertaken by wireline.

After evaluation, the wells will be plugged and abandoned. The open hole will be cemented to seal off any hydrocarbon bearing formation. Further cement plugs will then be put inside the last casing string.

4.4.7 Rig Chemicals

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. The list of chemicals to be used onboard the rig will be presented in the Addendum report, when the rig has been contracted.

4.4.8 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 North-East 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), 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 practical.

All of the planned chemicals, which BHPBP(F)C currently propose to use for the Loligo and Toroa exploration wells, appear on this Ranked Lists of Products approved under the OCNS. They all have an OCNS category of 'E' or have a Gold HQ band (i.e. are least toxic, refer to Appendix B) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable. Tables 4.7 to 4.9 present the current proposed chemical products for use during the drilling programme.

Table 4.7. Planned Loligo Water-Based Drilling Mud Components

Chemical Name	Function	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
26 inch section				
Barite	Weighting chemical	227.7	227.7	E
Aquagel	Viscosifier	5.7	5.7	-
BARAZAN	Viscosifier	1.5	1.5	E
Salt	Water based drilling fluid additive	86.2	86.2	E
NaCl Brine	Weighting chemical	4.8	4.8	E
17 ½ inch section				
Barite	Weighting chemical	179.6	179.6	E
Aquagel	Viscosifier	6.6	6.6	-
Caustic Soda	Acidity control chemical	1.8	1.8	E
FILTER-CHEK	Fluid loss control chemical	3.7	3.7	E
EZ-MUD DP	Shale inhibitor/encapsulator	1.2	1.2	Gold
PAC-L	Viscosifier	3.7	3.7	E
12 ¼ inch section				
Barite	Weighting chemical	352.9	352.9	E
Aquagel	Viscosifier	22.1	22.1	-
Caustic Soda	Acidity control chemical	1.1	1.1	E
FILTER-CHEK	Fluid loss control chemical	4.4	4.4	E
EZ-MUD DP	Shale inhibitor/encapsulator	0.7	0.7	Gold
PAC-L	Viscosifier	3.3	3.3	E
8 ½ inch section				
Barite	Weighting chemical	228.9	228.9	E
Aquagel	Viscosifier	8.5	8.5	-
Caustic Soda	Acidity control chemical	0.4	0.4	E
FILTER-CHEK	Fluid loss control chemical	3.4	3.4	E
EZ-MUD DP	Shale inhibitor/encapsulator	0.3	0.3	Gold
THERMA THIN	Thinner	0.9	0.9	Gold
PAC-L	Viscosifier	1.3	1.3	E

Table 4.8. Planned Toroa Water-Based Drilling Mud Components

Chemical Name	Function	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
17 ½ inch section				
Barite	Weighting chemical	227.7	227.7	E
Aquagel	Viscosifier	5.7	5.7	-
BARAZAN	Viscosifier	1.5	1.5	E
Salt	Water based drilling fluid additive	86.2	86.2	E
NaCl Brine	Weighting chemical	4.8	4.8	E
12 ¼ inch section				
Barite	Weighting chemical	179.6	179.6	E
Aquagel	Viscosifier	6.6	6.6	-
Caustic Soda	Acidity control chemical	1.8	1.8	E
FILTER-CHEK	Fluid loss control chemical	3.7	3.7	E
EZ-MUD DP	Shale Inhabitor / Encapsulator	1.2	1.2	Gold
PAC-L	Viscosifier	3.7	3.7	E
8 ½ inch section				
Barite	Weighting chemical	119.7	119.7	E
Aquagel	Viscosifier	1.7	1.7	-
Caustic Soda	Acidity control chemical	0.8	0.8	E
FILTER-CHEK	Fluid loss control chemical	6.7	6.7	E
EZ-MUD DP	Shale Inhabitor / Encapsulator	0.5	0.5	Gold
THERMA THIN	Thinner	1.7	1.7	Gold
PAC-L	Viscosifier	2.5	2.5	E

Table 4.9. Proposed Cement Chemicals and Ratings

Chemical Name	Function	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
Loligo Exploration Well				
Antifoam Agent D175	Cement or Cement Additive	3.41	0.68	Gold
Low Temperature Dispersant D185	Cement or Cement Additive	3.41	0.68	Gold
Silicate Additive D75	Cement or Cement Additive	10.24	2.05	E
GASBLOK* LT D500	Cement or Cement Additive	44.36	8.87	Gold
Liquid Accelerator D77	Cement or Cement Additive	17.06	3.41	E
AccuSET D197 / Mid-Temp Retarder-L D801 / Cement Retarder D110 *	Cement or Cement Additive/ Cement or Cement Additive Cement or Cement Additive	3.41	0.68	Gold/ E/ Gold
Toroa Exploration Well				
Antifoam Agent D175	Cement or Cement Additive	3.41	0.68	Gold
Low Temperature Dispersant D185	Cement or Cement Additive	3.41	0.68	Gold
Silicate Additive D75	Cement or Cement Additive	10.24	2.05	E
GASBLOK* LT D500	Cement or Cement Additive	44.36	8.87	Gold
Liquid Accelerator D77	Cement or Cement Additive	17.06	3.41	E
AccuSET D197 / Mid-Temp Retarder-L D801 / Cement Retarder D110 *	Cement or Cement Additive/ Cement or Cement Additive Cement or Cement Additive	3.41	0.68	Gold/ E/ Gold

**Note: Only one out of three chemicals detailed will be chosen, dependant on the temperature.*

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 and most likely outside of the Falkland Islands.

4.5.2 Fuel

A typical semi-submersible is likely to consume 10 tonnes of fuel a day during drilling operations and a support vessel 5 tonnes of fuel a day. The Loligo and Toroa drilling campaign will use an estimated 750–1,050 tonnes of fuel. The fuel will most likely be sourced from the Falkland Islands.

4.5.3 Water

Water will be needed for operational and domestic use onboard the drill rig, and it is estimated that approximately 51,000 Litres of drilling water per day and 200 Litres of potable water per person per day is required for a typical drilling operation. As the drill rig specifications are currently unknown, water consumption figures cannot be accurately calculated; however as a typical drill rig can carry up to 100 personnel onboard it is estimated that up to 1,500,000 to 2,100,000 Litres of potable water will be required. The 40 day drilling campaign at Loligo will require approximately

2,040,000 Litres and the 35 day drilling campaign at Toroa will require approximately 1,785,000 Litres.

Potable water will either be sourced from the ocean and treated in the desalination plant, if one is available onboard the rig, or will be obtained from the Falkland Islands, or a combination of both. Drilling water will be sourced from the ocean.

4.5.4 Accommodation

During routine crew changes, the crew will need to be temporarily accommodated on the Islands as they wait for their flights. It is noted that there is limited accommodation available on the Falkland Islands, and BHPBP(F)C will work with the drilling contractor and FIG, and possibly the MOD, to look at options such as setting up a camp or using accommodation in the military base. Additional information will be provided in the Addendum.

4.6 Support Operations

The drilling rig is likely to be supported by a stand-by vessel and a supply vessel. The stand-by vessel 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 movement 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, by using a prearranged series of signals of increasing intensity, to ensure that the vessel becomes aware of the obstacle and takes action to avoid it.

The supply vessel will provide the bulk logistics, transporting material required for the drilling and well construction to the rig from port and unwanted material and material generated by the drilling operations from the rig to the port.

Rig crews will be transferred to and from the rig by helicopter. The helicopter base and number of scheduled flights that will be made to the rig per week will be determined when a rig and a drilling contractor have been contracted and be addressed in the Addendum.

All the routes used by vessels and aircraft will be pre-planned to avoid creating unnecessary disturbance to sensitive elements along their routes. Figure 5.34 illustrates the ‘no-go’ zones for areas identified to be ecologically sensitive from aircraft and helicopter activities. These areas will be avoided.

During routine crew changes, the crew will need to be temporarily accommodated on the Islands as they wait for their flights. It is noted that there is limited accommodation available on the Falkland Islands, and BHPBP(F)C will work with the drilling contractor and FIG, and possibly the MOD, to look at options such as setting up a camp or using accommodation in the military base. The impacts from increased demand will not be significant as the crew changes will not be in large numbers and as described above, a range of options exist.

4.7 Total Emissions Summary

4.7.1 Loligo Exploration Well

Figure 4.5 provides a summary of estimated totals of the main emissions and discharges directly arising from routine operations associated with the drilling of the Loligo exploration well.

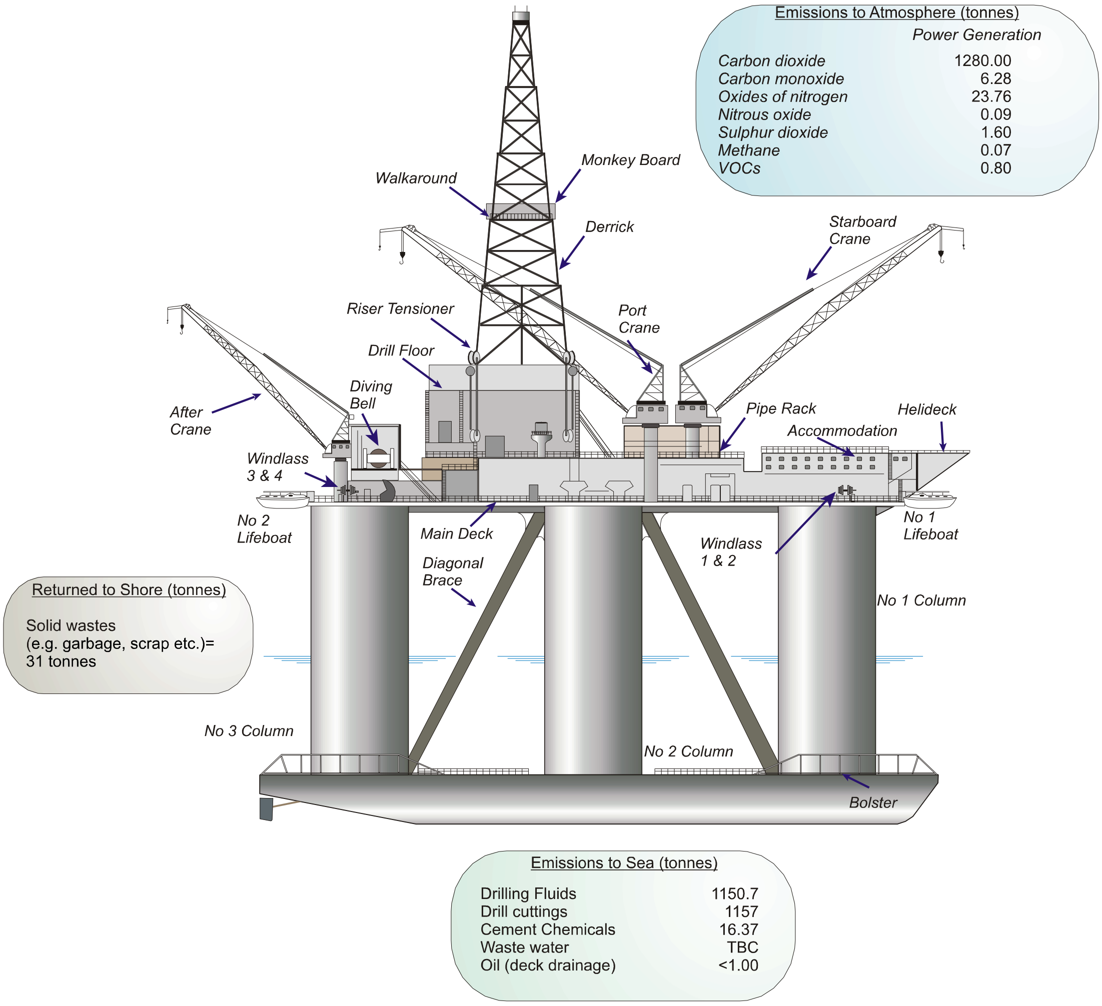

Figure 4.5 Emissions Summary for Loligo

Toroa Exploration Well

Figure 4.6 provides a summary of estimated totals of the main emissions and discharges directly arising from routine operations associated with the drilling of the Toroa exploration well.

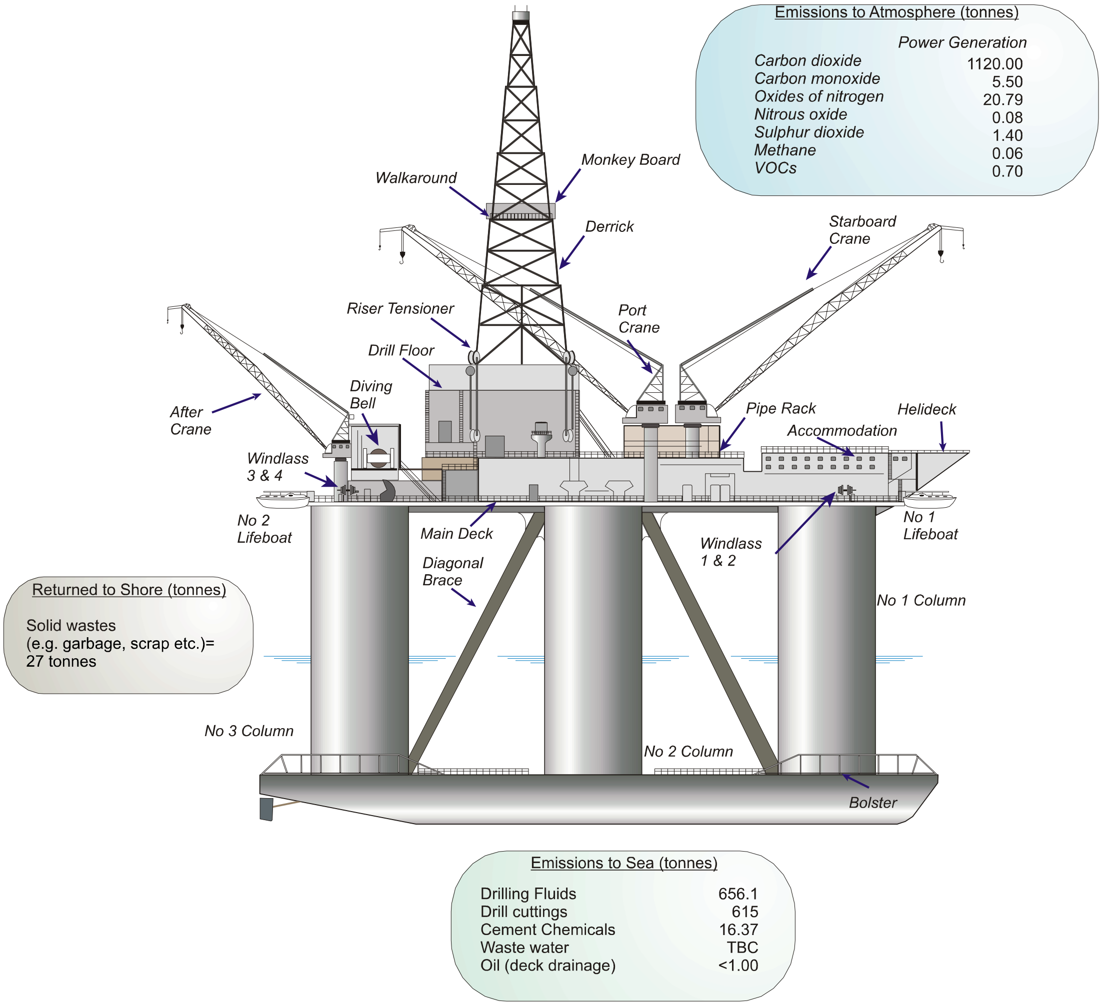

Figure 4.6 Emissions Summary for Toroa

5 Existing Environment

5.1 Introduction

This section describes the key physical, biological and socio-economic values of the marine environment within and adjacent to the proposed drilling locations. Where required, details of coastal, inter-tidal and terrestrial resources relevant to the proposed operations have also been included.

Data has primarily been sourced from:

- Desktop literature review – including publicly available material on websites and previous EIA's submitted for the region;
- Falkland Islands Environmental Baseline Surveys, 1997 and 2004;
- State of the Environment Report, 2008;
- Joint Nature Conservation Committee (JNCC) and Falklands Conservation publications;
- Consultation with relevant FIG authorities.

In addition, in order to gain more site specific information, BHPBP(F)C commissioned Fugro Survey Limited (FSLTD) to conduct a combined geophysical and environmental baseline survey at the proposed Loligo and Toroa drilling locations. Two other drilling locations were also investigated during this time: the Nimrod prospect in FIDA Block 41/29 and the Endeavour prospect in FIDA Blocks 30/17, 18, 22, 23 (refer to Figure 5.1 for block locations). The survey work was conducted from the vessel M/V Fugro Meridian during the period from the 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 well 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. The environmental baseline surveys were required to provide baseline data relating to the physicochemical and macrofaunal benthic environment and to characterise physical water column characteristics.

The survey area at Loligo encompassed a 26.2 kilometre by 15.2 kilometre survey grid orientated 339.5° / 69.5° with 15 main lines at 1,500 metres spacing and three cross lines at 7,850 metres spacing. Seabed sampling was successfully undertaken at five stations using a 0.1m^2 box corer (refer to Figure 5.1 for station locations). The survey area at Toroa encompassed an 8.7 kilometre by 7.4 kilometre survey grid with seven main lines bearing 157° / 337° and two cross lines bearing 67° / 247°. Seabed sampling was successfully undertaken at six stations using a 0.1m^2 box corer (refer to Figure 5.2 for station locations).

At all sampling stations two replicates were screened over a 0.5 mm mesh and fixed for macrofaunal analysis, and one physico-chemical sample was retained which was sub-sampled for hydrocarbon, heavy metal, organic carbon and particles size analysis. Water profiling was carried out at one location using a Valeport Midas 606+ CTD probe. 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 (*FSLTD, 2009b*).

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 reinterpreted by FSLTD to assist with the environmental baseline survey reporting.

The results from the Loligo and Toroa combined geophysical and environmental baseline surveys have been incorporated, where relevant, throughout this section of the EIS. A copy of the full survey reports has also been provided for reference in Appendix C (Loligo) and Appendix D (Toroa).

The data obtained from all four site surveys has been used to draw comparisons. While Loligo, Nimrod and Endeavour were all of broadly comparable sediment type, seabed topography and depth, 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 conducted in the North Falklands Basin during 1998 were undertaken in much shallower water depths and were therefore considered unsuitable for comparison to the current survey data (*FSLTD, 2009a*).

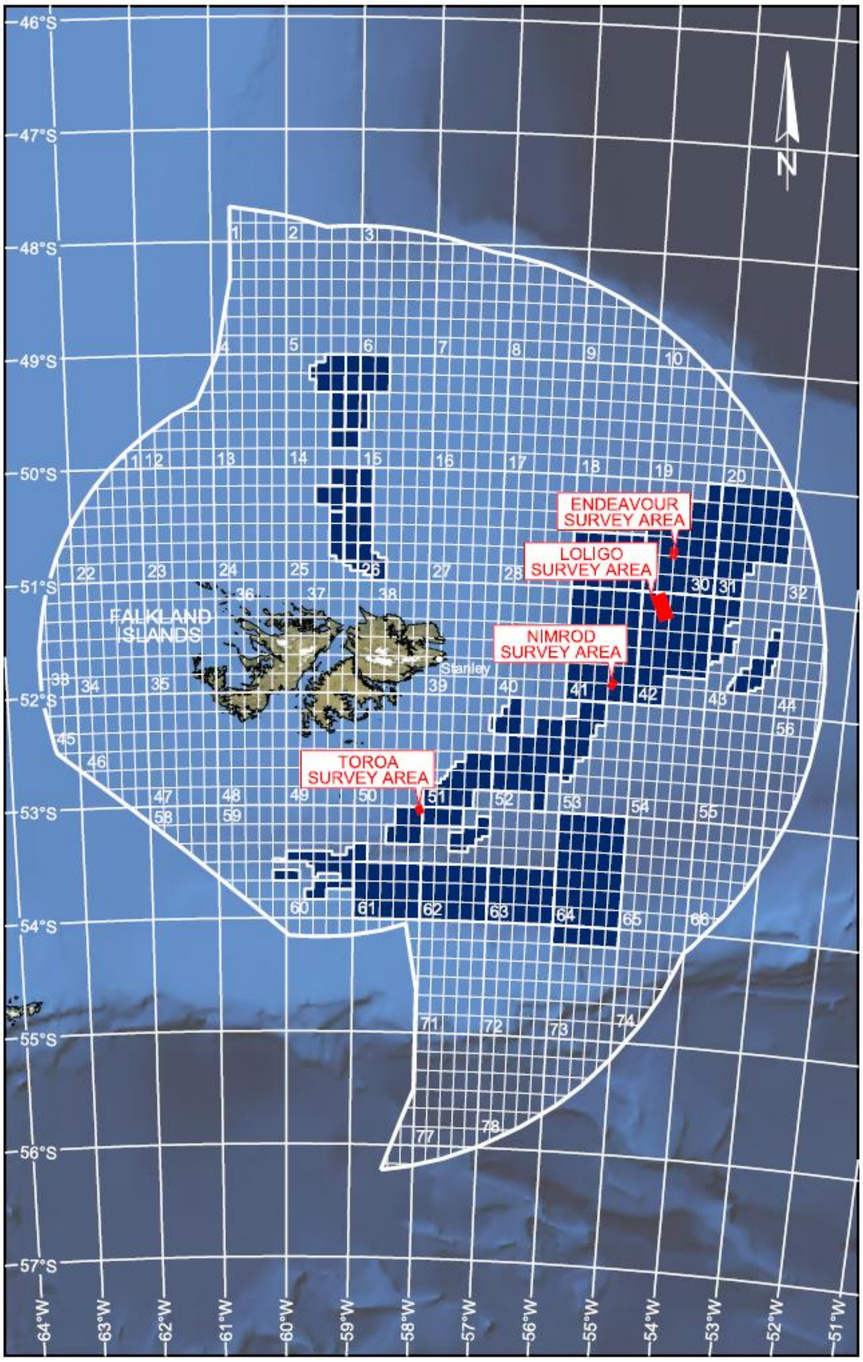

Figure 5.1 Location Map Showing the Loligo, Toroa, Nimrod and Endeavour Site Survey Areas (FSLTD, 2009a)

5.2 Physical Environment

5.2.1 Geography

The proposed Loligo and Toroa exploration wells are situated in the South Atlantic Ocean approximately 225 kilometres to the east and approximately 145 kilometres to the south-east, respectively, of Stanley on the Falkland Islands (refer to Figure 1.2).

The Falkland Islands are an archipelago of approximately 700 islands in the South Atlantic, the largest of which are East Falklands and West Falklands. Situated some 770 kilometres north-east 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, situated on the Falklands Plateau, are separated to the north from the Argentine Basin by the Falklands Escarpment. Two distinct regions of bathymetry affect large-scale water mass movements in the area. The first is the Patagonian Shelf, extending over 300 kilometres from the South American coastline, with the Falklands situated on an eastward extension at the southern extent of the shelf. The second is the Falklands Basin, comprising of a steep sided shelf break to the east and south of the Falklands, with steep sided troughs, transient mud waves and seabed scouring.

Loligo Site Survey Results

Water depths in the Loligo survey area ranged from approximately 1,305 metres in the north-western corner to approximately 1,488 metres at the base of a prominent escarpment in the central portion of area. Within the vicinity of the proposed Loligo exploration well water depths are approximately 1,488 metres LAT (Figure 5.2) (*FSLTD, 2009a*).

The study area can be divided into two distinct zones based on general seafloor morphology and character. The two areas are 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 (1,435 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 (refer to Appendix C for further information) (*FSLTD, 2009a*).

Toroa Site Survey Results

Water depths in the Toroa survey area ranged from approximately 552 metres in the northern corner to approximately 728 metres in the south. Within the vicinity of the proposed Toroa exploration well water depths are approximately 606 metres LAT (Figure 5.3) (*FSLTD, 2009b*).

The seafloor dipped regionally down to the south-east with slopes ranging from approximately 0.6 degrees in the north-western portion of the survey area, and increasing gradually to about 1.8 degrees in the south-east. There is no indication of past or incipient seafloor slope instability within the study area (*FSLTD, 2009b*).

The only seafloor topographic or geologic features identified within the survey area were a series of west-south-west to east-north-east trending curvilinear features in the extreme north-west of the site and one similar south-west to north-east trending feature in the central part of the study area. These features were characterised either by a slight local flattening of the seafloor or a shallow seafloor trough and are probably the result of differential erosion of variable seafloor sediments by marine currents. It is possible that the erosional processes responsible for generating these features are active (refer to Appendix D for further information) (*FSLTD, 2009b*).

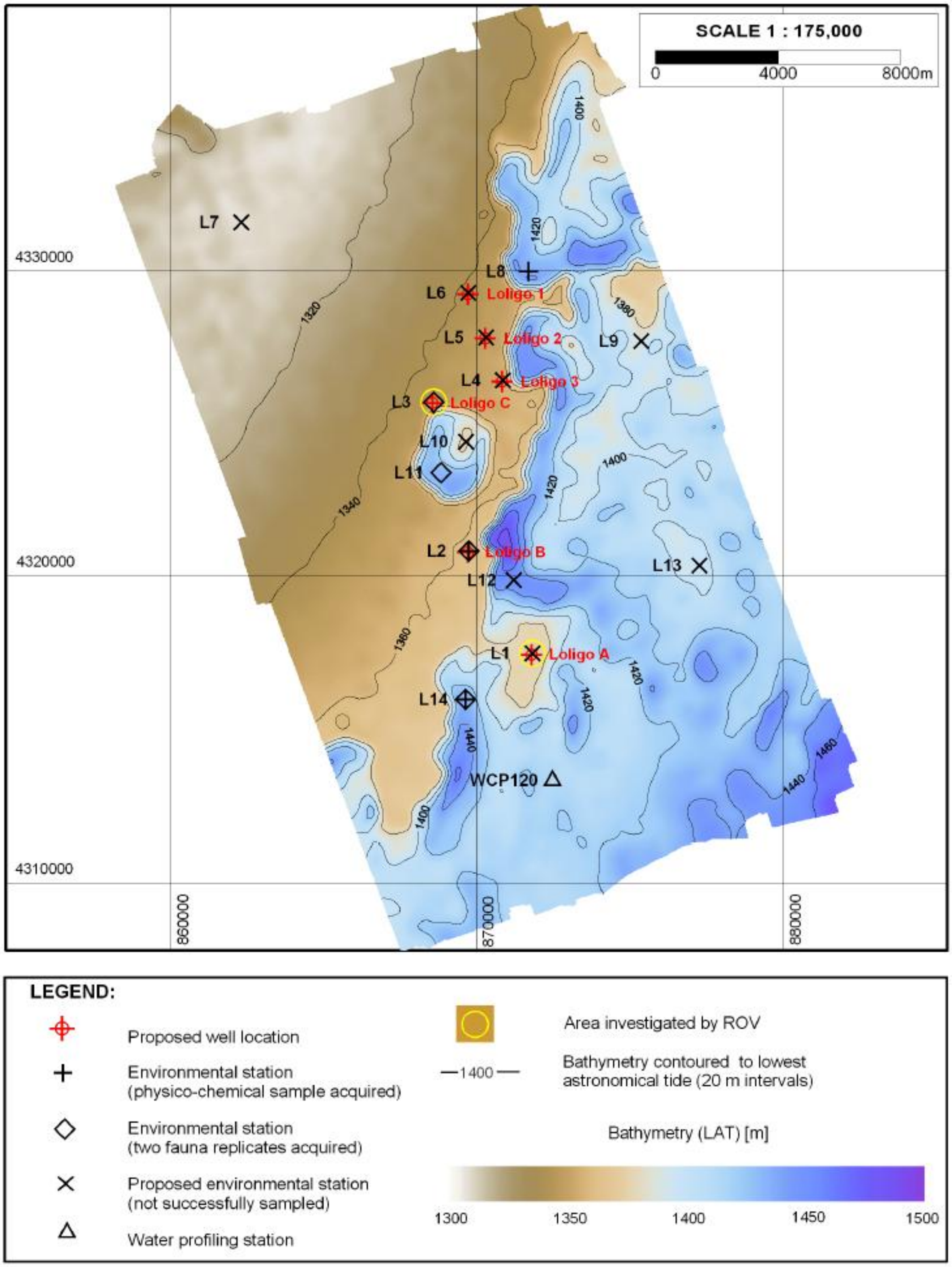

Figure 5.2 Survey Bathymetry within the Vicinity of the Proposed Loligo Exploration Well (labelled 'Loligo A' on the above chart) (FSLTD, 2009a)

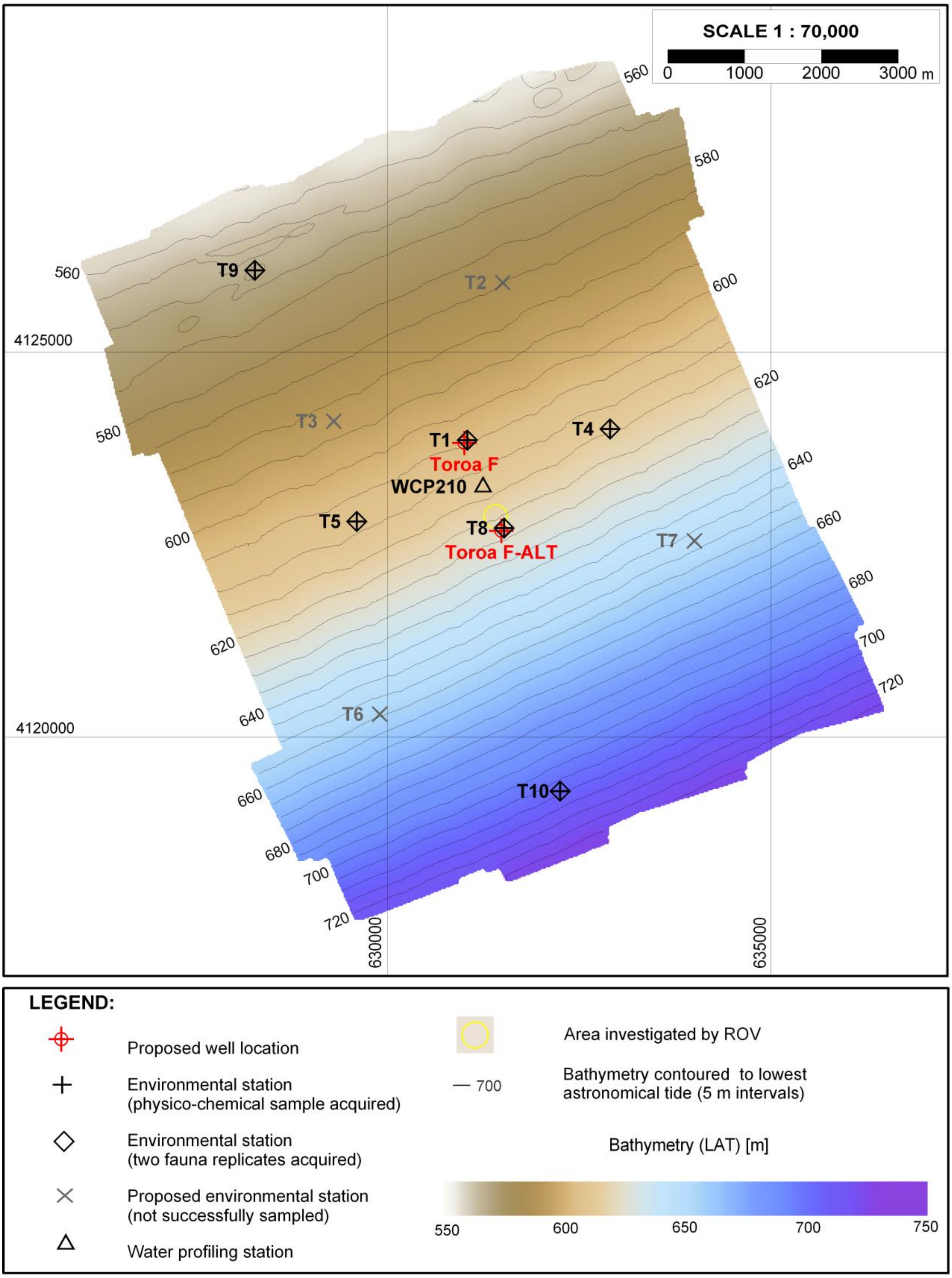

Figure 5.3 Survey Bathymetry within the Vicinity of the Proposed Toroa Exploration Well (labelled 'Toroa F-ALT' on the above chart) (FSLTD, 2009b)

5.2.3 Seabed Sediments

Loligo 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 site survey area (Figure 5.4). 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 (refer to Appendix C for further information) (*FSLTD, 2009a*).

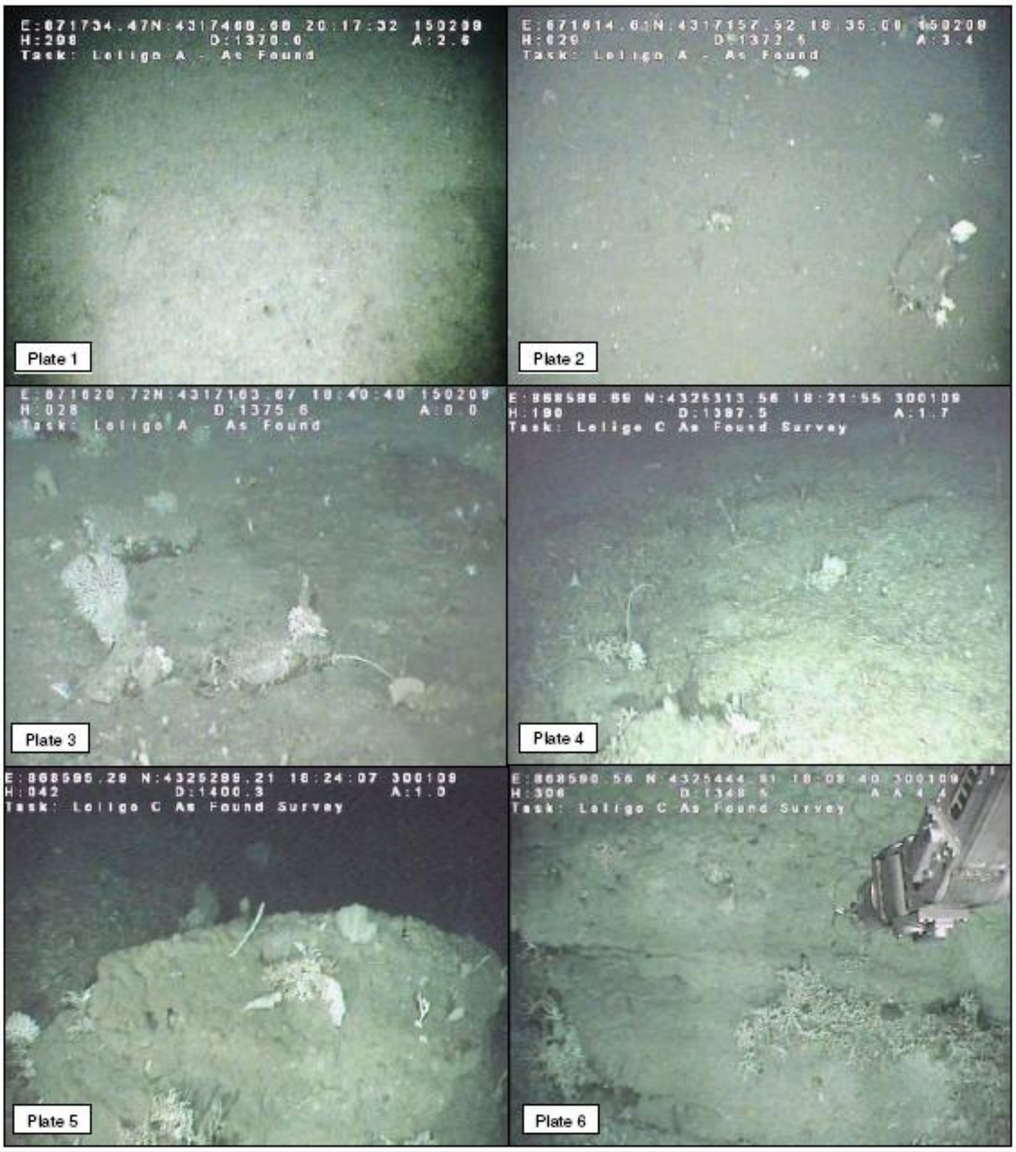

Plate 1: Homogeneous muddy fine sand in the vicinity of the proposed Loligo A location

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

Figure 5.4 Screen Grabs of ROV Footage, Showing Notable Seabed Features within the Loligo Site Survey Area (FSLTD, 2009a)

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Toroa Site Survey Results

The geophysical data collected during the Toroa site survey suggested that surficial sediments were extremely homogeneous and this was supported by the evidence of the box corer and gravity corer sampling, drilling and ROV programs, all of which showed that seafloor materials consisted of silt / clay throughout the site (refer to Figure 5.5 and Appendix D for further information) (*FSLTD, 2009b*).

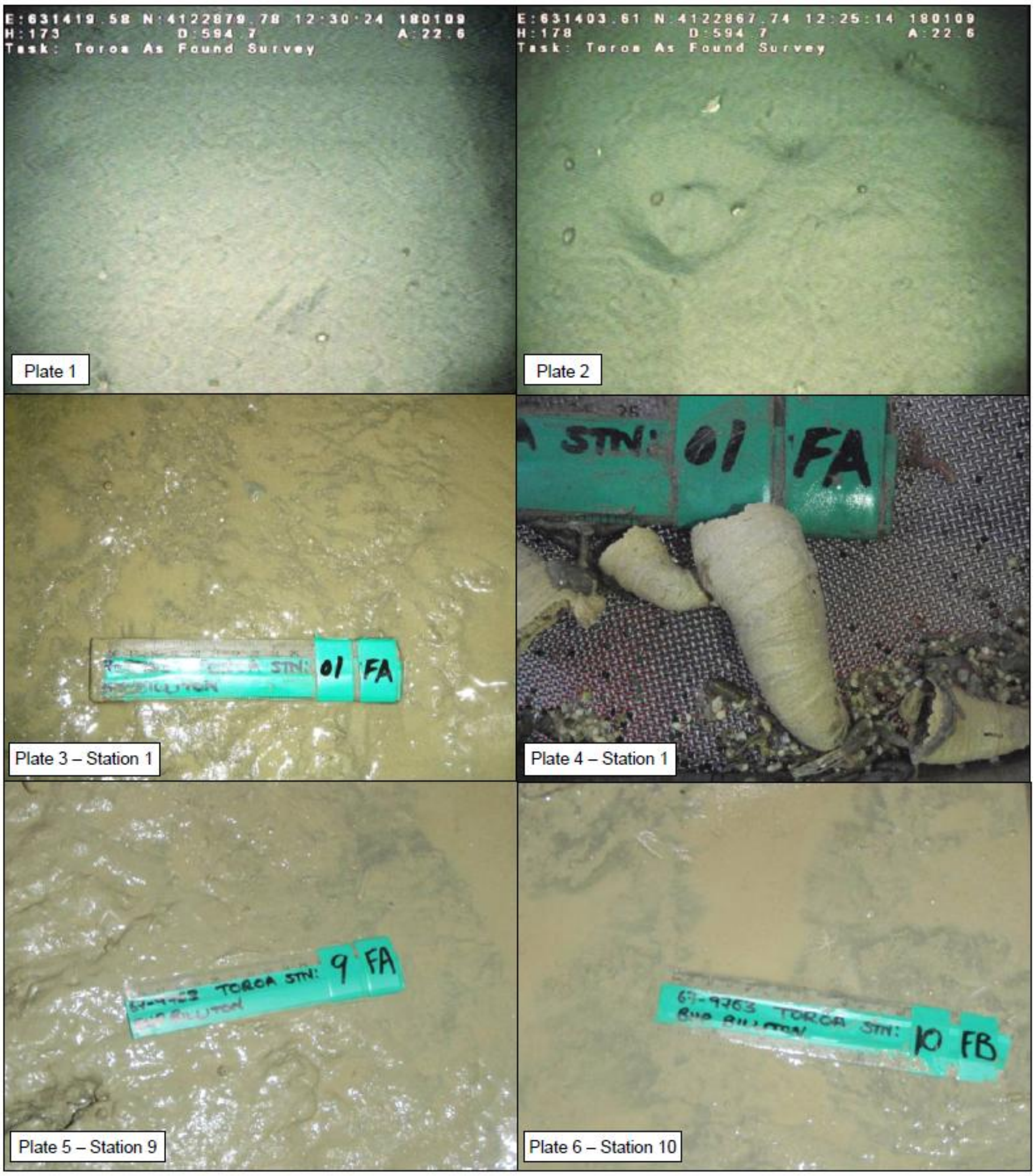


Plate 1: Homogeneous silt / clay sediment in the vicinity of the Toroa A borehole

Plate 2: Silt / clay sediment with some coarse material and conspicuous bioturbation in the vicinity of the Toroa A borehole

Plate 3: Sample 1FA, showing silt / clay sediment near the centre of the site (the proposed Toroa F location)

Plate 4: Sample 1FA after sieving, showing coral and shell fragments and some sand

Plates 5 and 6: Samples 9FA and 10FB demonstrate the homogeneity of the site's sediment, having been taken at its shallowest and deepest extremes, respectively

Figure 5.5 Screen Grabs of ROV Footage and Sample Photographs Demonstrating Sediment Type within the Toroa Site Survey Area (FSLTD, 2009b)

5.2.4 Granulometry

Particle size analysis (PSA) was performed using wet sieving techniques and laser diffraction.

Loligo Site Survey Results

The Loligo 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 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
L14		1434.0	137.4	2.86	2.19	2.0	71.7	26.3	Very poorly sorted fine
Comparison of Results									
Loligo	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. SD: Standard deviation

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 (*FSLTD, 2009a*).

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 (Endeavor and Nimrod), whose sediments also comprised muddy medium and fine sands (*FSLTD, 2009a*).

Toroa Site Survey Results

The Toroa PSA results are summarised in Table 5.2, with a description of the sediment type of each sample also given based on the Wentworth Classification (*Buchanan, 1984*).

Particle size analysis of the data also suggested that sediments across the Toroa survey area were extremely homogeneous, the graphical means of the samples' distributions ranging from 4.87 phi units (34.1 µm) to 5.08 phi units (29.5 µm). The Wentworth classification of the graphical means categorise the sediments in two separate classes (poorly sorted medium silt or poorly sorted coarse silt), however all graphical means fall only marginally above or below the threshold between the two classes (5 phi units) (*FSLTD, 2009b*).

Both sand and fines content of the samples are consistent across the stations, the former ranging between approximately 20% and 25% and the latter between approximately 75% and 80%. No coarse material was identified from the analysis, although occasional shell and coral fragments were seen from the ROV footage and in the sieved fauna samples (refer to Figure 5.5).

The sediment identified from Toroa was distinctly different from that identified from the deeper sites surveyed (Loligo, Endeavour and Nimrod), all of which were shown to have much coarser sand dominated sediments (*FSLTD, 2009b*).

Table 5.2. Toroa Summary of Particle Size Analysis (FSLTD, 2009b)

Station		Depth (m)	Mean (µm)	Mean Phi	Sorting	Coarse %	Sand %	Fines %	Graphical Mean/ Wentworth
T1		600	29.5	5.08	1.54	0.0	20.3	79.7	Poorly sorted medium silt
T4		615	30.7	5.03	1.53	0.0	21.1	78.9	Poorly sorted medium silt
T5		610	29.9	5.06	1.54	0.0	20.6	79.4	Poorly sorted medium silt
T8		622	31.3	5.00	1.54	0.0	22.3	77.7	Poorly sorted medium silt
T9		571	34.1	4.87	1.54	0.0	25.1	74.9	Poorly sorted medium silt
T10		702	32.6	4.94	1.53	0.0	23.7	76.3	Poorly sorted medium silt
Comparison of Results									
Toroa	Mean	620	31.4	5.00	1.54	0.0	22.2	77.8	Poorly sorted course silt
	SD	44	1.7	0.08	0.01	0.0	1.9	1.9	
Loligo	Mean	1412	1742.6	1.02	2.29	25.7	57.5	16.7	Very poorly sorted medium silt
	SD	41	2744.8	2.88	0.51	41.3	31.7	10.6	
Endeavour	Mean	1372	156.5	2.71	2.34	4.3	69.1	26.5	Very poorly sorted fine sand
	SD	23	35.9	0.36	0.24	4.7	4.7	4.6	
Nimrod	Mean	1284	179.3	2.51	2.31	6.2	71.3	22.6	Very poorly sorted fine sand
	SD	14	37.3	0.30	0.32	4.0	5.4	3.9	

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

Organic Carbon, Hydrocarbon and Heavy/Trace Metal Analysis

Loligo Site Survey Results

Both fractionated organic carbon (FOC) and total organic matter by loss on ignition (TOM by LOI) concentrations appeared relatively consistent across the Loligo 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 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 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 UKOOA values, indicating typical background levels for an unimpacted environment (*FSLTD, 2009a*).

Toroa Site Survey Results

Both FOC and TOM were consistent across the sampling stations, the former ranging from 0.62% to 0.77% (stations T10 and T9, respectively) and the latter from 4.7% to 6.8% (stations T10 and T4, respectively). The lowest proportions of both FOC and TOM were identified from the deepest of the station samples (station T10). The higher values for TOM may be due to carbonates present in the samples.

Total hydrocarbon concentrations (THC) were low compared to North Sea UKOOA data, though considered moderate for the remote nature of the survey area,, ranging from 7.0 $\mu g.g^{-1}$ to 10.1 $\mu g.g^{-1}$ (stations T8 and T5, respectively). These concentrations are presumed to originate from local natural oil seeps and are considered to be typical background concentrations for the area.

Total n-alkane concentration was low, ranging from 0.505 $\mu g.g^{-1}$ to 0.749 $\mu g.g^{-1}$ (stations T8 and T5, respectively), this trend (and those seen in concentrations of individual aliphatics) generally reflected that seen in THC. The lack of odd or even-carbon number preference in the n-alkanes, the carbon preference index (CPI) being close to unity, may have been the result of diffuse inputs from natural seeps to the survey area.

Total PAH concentrations were low, but higher than expected for this region, again suggesting a local presence of natural oil seeps. They showed little correspondence with the patterns identified in other hydrocarbon concentrations and instead appeared to show a spatial (or depth-related) trend, being measured at their lowest (195 $ng.g^{-1}$) at the shallowest station (station T9) and at their highest (243 $ng.g^{-1}$) at the deepest station (station T10). No clear causal mechanism for this trend (e.g. sedimentary gradient) was apparent.

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. The former technique is the less stringent of the two measures and provides a partial estimate of metals, indicative of bioavailable concentrations, while the more stringent HF digestion releases matrix locked metals to provide a 'near total' estimate of both bioavailable and unavailable concentrations. As would be expected given the differing stringency of the two extraction procedures, the concentrations measured by aqua regia digestion were generally much lower than those measured by HF digestion. The concentrations of heavy and trace metals appeared consistent across the site, being found at levels typical for unimpacted silt / clay sediments (*FSLTD, 2009b*).

Comparison of Site Survey Data

Toroa survey area was substantially shallower and was distinctly different in terms of both sediment type and seabed topography. Comparison with the data collected from the other survey sites showed that fractionated organic carbon (FOC) concentrations at Loligo 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 total organic matter (TOM) concentration across the wider survey area, suggesting that variable amounts of inorganic carbon were present, biasing the results of TOM analyses (*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 Falklands are surrounded by four major sedimentary basins: the Falklands Plateau Basin to the east, the South Falklands Basin to the south, the Malvinas Basin to the west, and the North Falklands Basin to the north (refer to Figure 5.6). Petroleum exploration in the region is in its infancy and the North Falklands Basin is currently the only one of the four basins drilled to date. The proposed Toroa exploration well is located within the South Falklands Basin, while the proposed Loligo exploration well lies within the Falklands Plateau 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 Weddel 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 Gondwanan 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 Weddel 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.

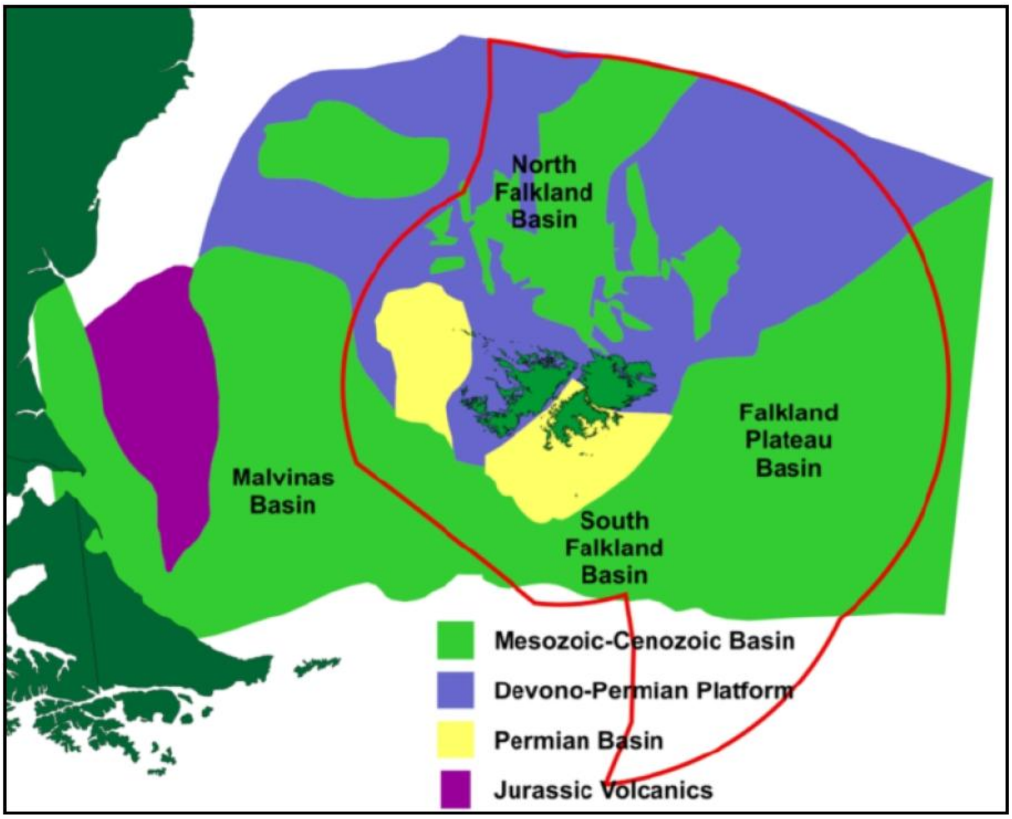


Figure 5.6 Petroleum Basins of the Falklands Plateau (BGS, 2006)

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 south-easterly prograding deltaic complexes with associated basin floor fans. These units are analogous with the scale of the linked delta/fan 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. This is reflected in the development of the fringing clastic systems where low accommodation strandplains source hyperpycnally generated turbidite systems.

Ultimately, the oceanic thermal subsidence associated with the expanding oceanic Scotian plate, drowns these systems in the middle Eocene. This results in the establishment of the present, ooze dominated system.

5.2.6 Oceanography

Water Circulation and Tidal Currents

The Falklands lie to the north of the Antarctic Polar Front or Antarctic Convergence, where cool surface waters to 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 intensifies and deviates northwards as it flows around Cape Horn, and splits to either side of the Falkland Islands (Figure 5.7). 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 km wide band towards the warm south flowing Brazil Current (*Munro, 2004; Glorioso & Flather, 1995*).

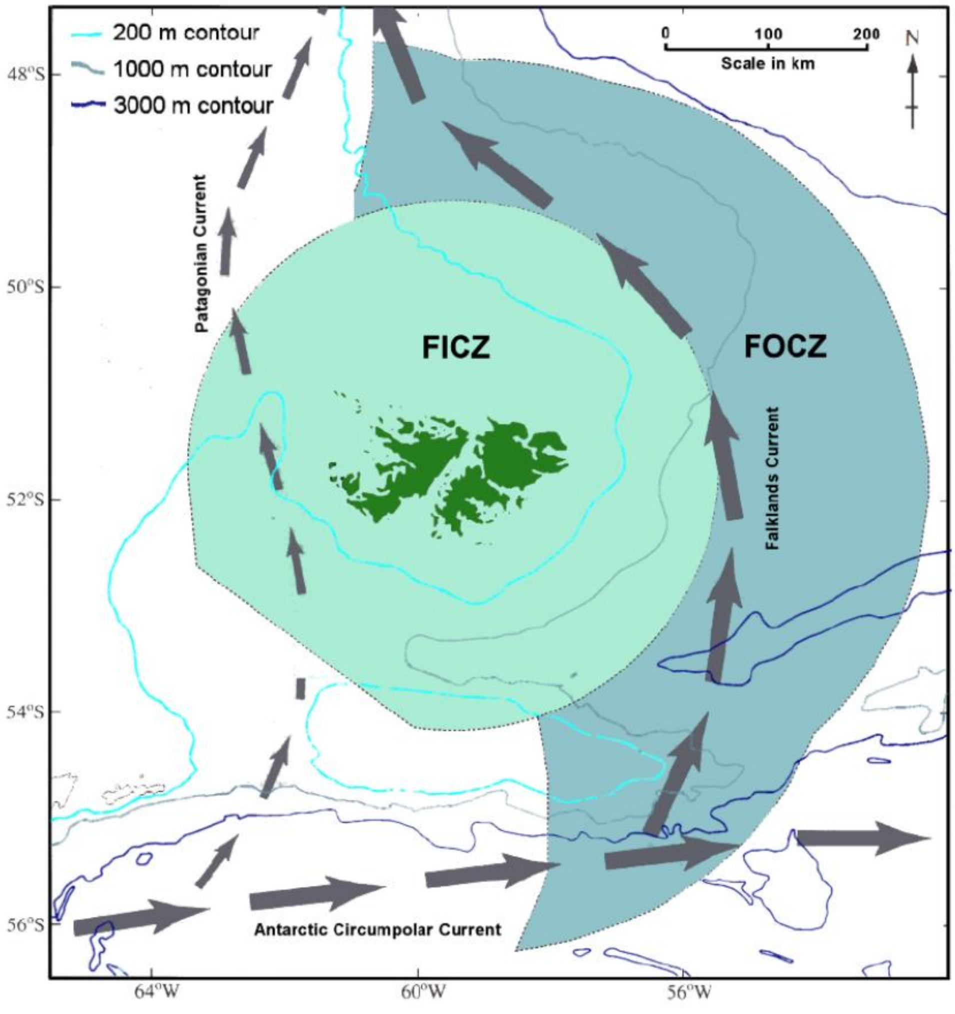


Figure 5.7 Falkland Islands' Conservation Zones (Inner and Outer) Plus Major Currents and Water Depths

Average diverging current speeds are less than 25 cm/s (0.5 knots) to the west and 25–50 cm/s (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 & Root, 1997*).

From 6th December 2008 to the 26th April 2009, two metocean buoys were deployed at both the proposed Loligo and Toroa well locations by Fugro Survey Limited on behalf of BHPBP(F)C. The aim of the deployments was to gather data on current speed and direction throughout the water profile between these times. The Loligo 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 5.8). The Toroa metocean buoy, deployed in a water depth of 692 metres, was also equipped with a Long Ranger RDI 75kHz ADCP and two RCM7's (Figure 5.9). However, unfortunately, the ADCP unit at Toroa became flooded shortly after deployment due to failure of the unit casing and as such, current profile data was not recorded from this unit.

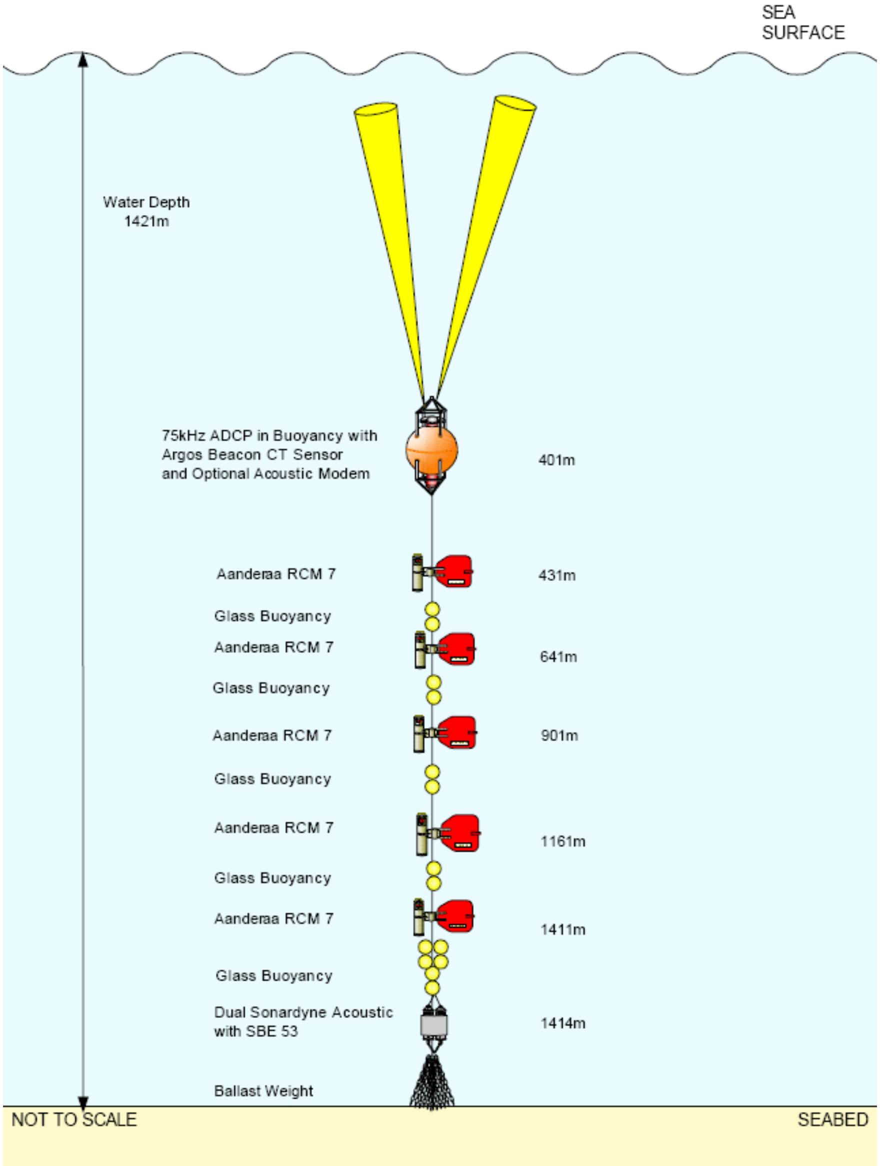


Figure 5.8. Metocean buoy deployed at the proposed Loligo well location (FSLTD, 2009c)

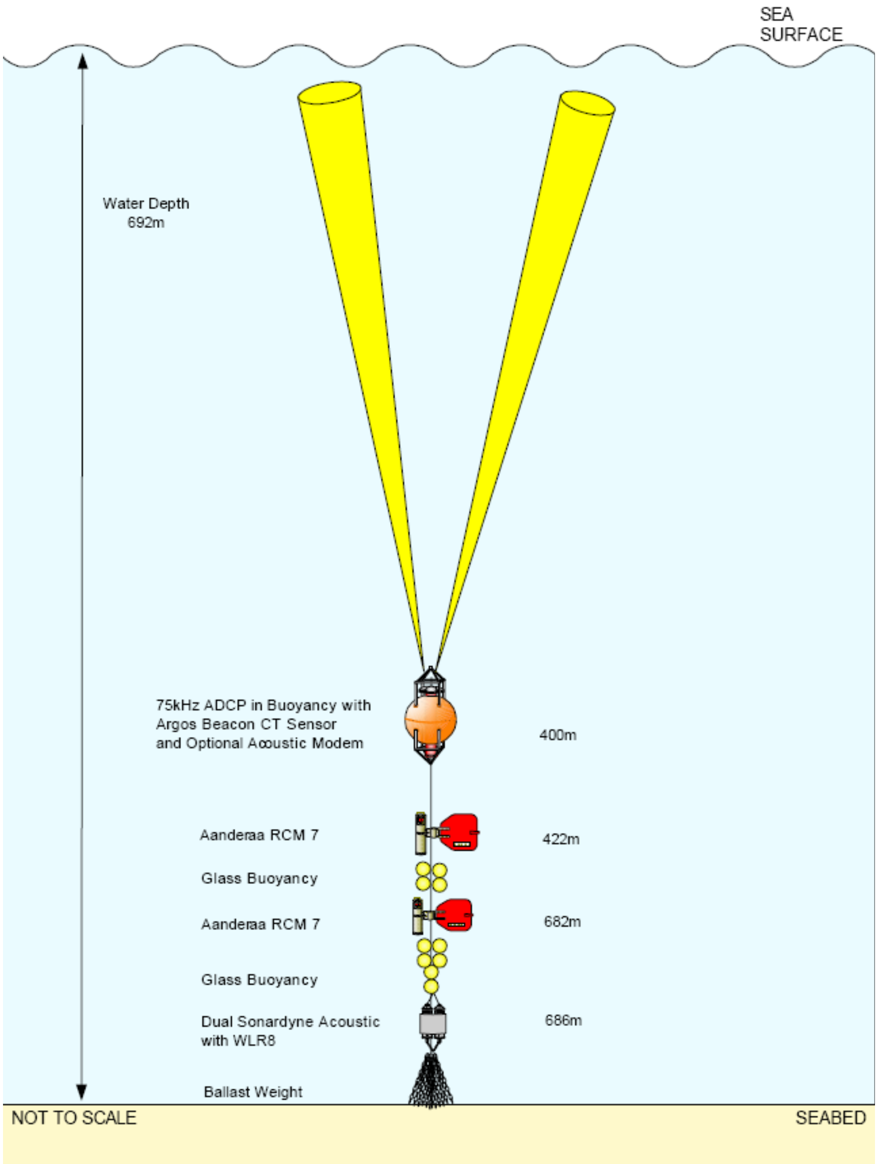


Figure 5.9. Metocean buoy deployed at the proposed Toroa well location (FSLTD, 2009c)

Table 5.3 lists the maximum observed current speeds at each of the metocean buoys. The maximum observed current speed was 0.75 ms^{-1}, measured at Loligo 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). Moderate current speeds were observed all along the mooring profile. 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) were also moderate, reaching speeds above 0.5 ms^{-1}. The maximum current speed observed at Toroa was 0.39 ms^{-1} at 682 metres below the sea surface (10 metres above the seabed) with a corresponding direction of 233^{o} (true).

Table 5.3. Maximum observed current speeds and directions from the instruments at both metocean buoys (FSLTD, 2009c)

Data Bin No.	Depth Below MSL	Current Speed (ms^{-1})		Direction of Current Maximum	Date and Time of Maximum
	metres	Maximum	Mean	(° True)	GMT
Loligo Bin 25	41	0.75	0.22	257	26-JAN-2009 0300
Loligo Bin 12	249	0.63	0.19	266	26-JAN-2009 0740
Loligo RCM1	431	0.59	0.19	282	15-JAN-2009 1410
Loligo RCM2	641	0.64	0.19	001	17-JAN-2009 1020
Loligo RCM3	901	0.58	0.15	006	17-JAN-2009 0820
Loligo RCM4	1161	0.51	0.16	034	31-JAN-2009 1110
Toroa RCM1	422	0.32	0.10	012	13-APR-2009 0700
Toroa RCM2	682	0.39	0.11	233	13-APR-2009 1640

For 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 041°. This is broadly consistent with the general current pattern observed in the area. The same residual current speed and direction analysis could not be done for the Toroa location, due to the failure of the ADCP device.

Current patterns and bathymetry influence nutrient circulation and marine productivity levels. The proposed Loligo and Toroa drilling locations are removed from the area of upwelling on the continental shelf north of the Falklands, which demonstrates high biological productivity, and therefore high concentrations of birds and marine mammals.

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.

Waves

Winds can generate rough sea conditions with waves of variable direction and height. Maximum wave heights in the vicinity of the proposed drilling locations are in the region of 2 to 3 metres (Figure 5.10). 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 south-west.

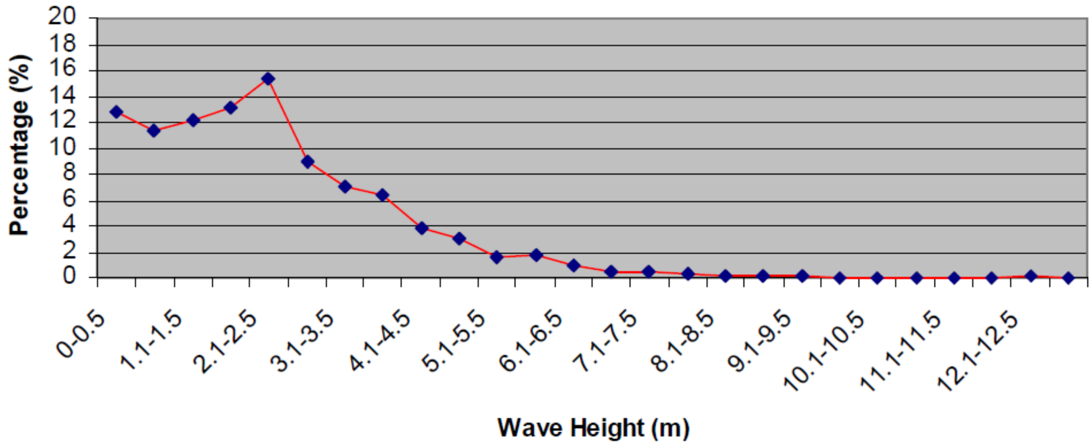


Figure 5.10 Annual Wave Exceedance

Water Column Characteristics

Loligo Site Survey Results

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 surface temperature at the time of data collection (December 2008 to February 2009) 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 showed a general trend of decreasing to the seabed (where the minimum temperature of 2.9°C was recorded) (*FSLTD, 2009a*).

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.) (*FSLTD, 2009a*).

Toroa Site Survey Results

Two water profiling attempts were made at location Toroa WCP210. The first deployment returned erroneous data so a second attempt was made using a different water profiler which acquired good data for all parameters except pH (as no functioning sensor was available).

The surface temperature was approximately 9.7°C and this remained relatively constant in the upper layers of the water column to approximately 14 metres depth. Below this there was a distinct thermocline over which the water temperature descended fairly rapidly to 5.3°C at approximately 140 metres depth before declining gradually to a temperature of 4.4°C at the seabed (*FSLTD, 2009b*).

Although salinity showed minimal variation throughout the water column, ranging from a minimum of 34.1 ppt at the surface to 34.2 ppt at the seabed, it appeared to have a strong negative relationship with temperature (*FSLTD, 2009b*).

DO declined rapidly from a surface concentration of approximately 85%sat. to 72%sat. at around 130 m depth. DO then decreased steadily to the seabed (minimum concentration of 66%sat.) (*FSLTD, 2009b*).

Comparison of Results

The temperature, salinity and turbidity measured appeared broadly consistent between the four survey locations (Loligo, Toroa, Endeavour and Nimrod) although unsurprisingly, given the shallower water depth at Toroa, seabed temperatures were substantially higher. The profiles obtained from Toroa also lacked the fluctuation in certain parameters seen in depth at Loligo and Endeavour, which were though to relate to inflow of a separate water body. DO was lower than at all of the other sites and this may have related to the Toroa data being the only data acquired during darkness, when phytoplankton will deplete rather than produce oxygen. Gradually decreasing trends were apparent in DO saturation at all sites except Loligo, which showed marked super-saturation in the upper layers of the water-column, thought possibly to relate to day time oxygen production by phytoplankton (*FSLTD, 2009b*).

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) or 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 troughs that move across the area (*Hydrographer of the Navy, 1993*).

Temperature

The Falklands have a narrow terrestrial temperature range with mean annual maximum temperatures of approximately 10°C, mean annual minimum temperatures of approximately 3°C, and mean monthly ranges of between –5°C to 20°C (Figure 5.11). Temperatures over the open sea are less variable than on land.

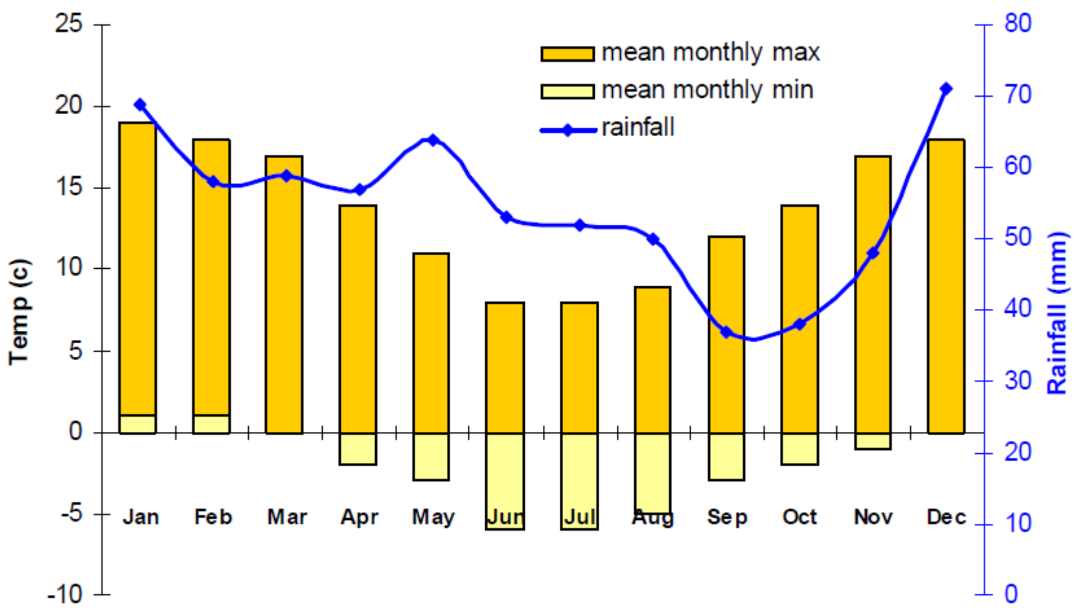


Figure 5.11 Climate Averages for Stanley Harbour

Precipitation

Figure 5.11 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 low, but consistent. Due to their location in the lee of the South American continent the ‘rain shadow’ effect of the Andean cordillera is still prevalent (*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

The prevailing wind direction is an annual broad arc spanning south-west to north-west constantly (Figure 5.12). 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 or from a westerly direction.

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 and annual wave exceedance for the area encompassing the licence blocks.

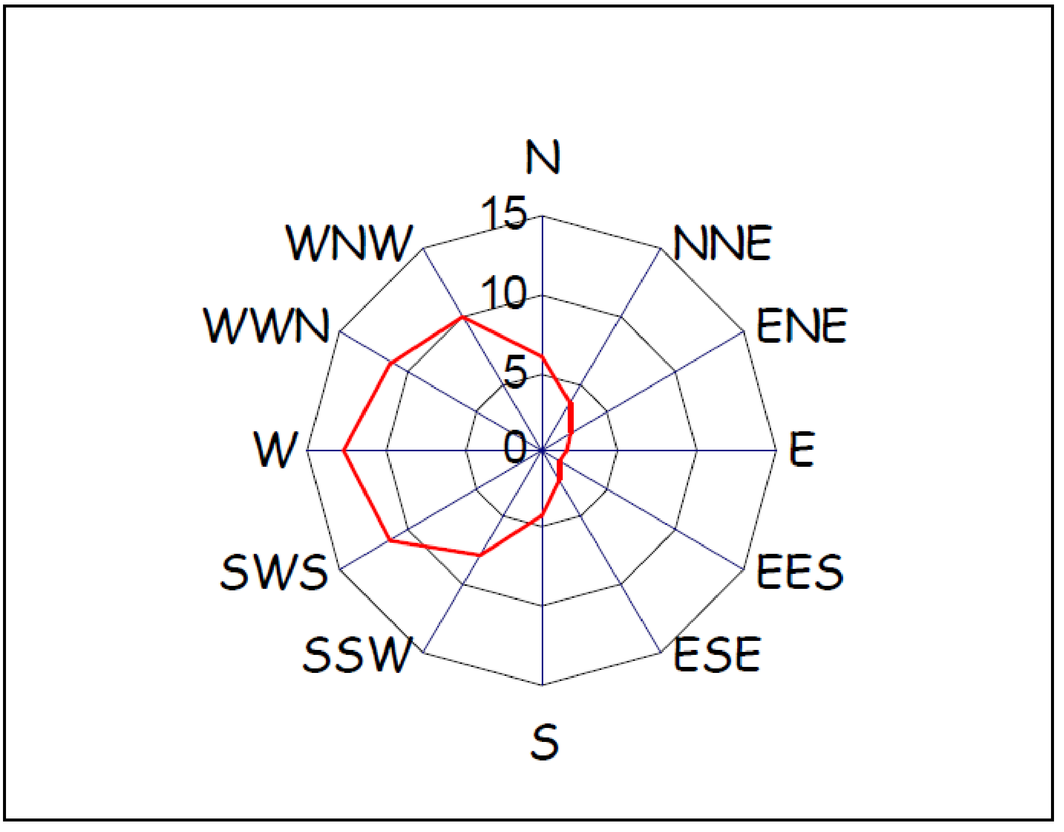


Figure 5.12 Annual Wind Direction

5.2.8 Icebergs

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 5.13).

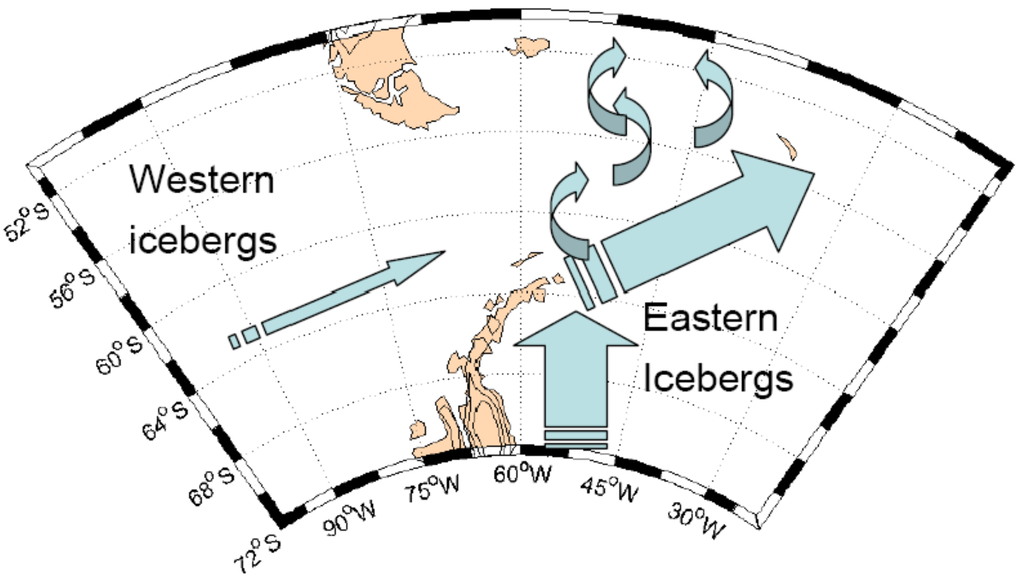


Figure 5.13 Sources and Movements of Icebergs in the Falklands Region

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) 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 well 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 number of icebergs approaching the Falkland Islands is strongly influenced by the oceanographic conditions east of the Drake Passage, which in turn is likely to be influenced by the strength of the Antarctic Circumpolar Current and the positions of the oceanographic fronts converging in the Falklands region. The total number of icebergs being exported from Antarctica is believed to have less influence than the oceanographic conditions on the number of icebergs approaching the Falkland Islands (*Partington, 2006*).

The secondary source is the 'western' icebergs that are advected north, 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 south-west. In comparison, the secondary source is rare, with only one instance recorded in the large iceberg database out of 70. 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 icebergs is in the eastern portion of the licence area as it is nearer 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. Because of the strong eddy activity in the Drake Passage, the presence of icebergs in any of the licence areas cannot be ruled out.

Little evidence exists for any seasonal behaviour in iceberg drifts or populations. There are fewer recordings of large iceberg calvings during winter (summer welt plays a role in calving), but as icebergs take months or even years to reach the Falklands region, any seasonal pattern in iceberg numbers no longer remains by the time they arrive.

There is no evidence that the 2002 peak in icebergs exiting the Weddell Sea was followed by an iceberg outbreak in the Falklands Islands shortly afterwards. 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, suggesting an oceanographic rather than source population control on the icebergs found in the lease areas.

5.3 Biological Environment

The Patagonian Shelf, on which the Falkland Islands sit, is of regional and global significance for marine resources (*Croxall & Wood, 2002*). It comprises rich assemblages of seabirds, marine mammals, fish, squid and plankton populations. The following sub-sections outline the existing biological resources known to occur around the Falklands and area to the south and east of the Islands.

5.3.1 Marine and Intertidal Vegetation

Seaweeds are an important resource in the Falkland Islands for extraction and use in commercial products, such as fertiliser, and as an integral part of the health and biodiversity of the natural ecosystem. The giant and tree kelp are the most common macroalgae species in offshore zones of the Falkland Islands, extending from the 4 to 30 metres water depths.

Giant Kelp

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

Kelp species prefer depths of less than 40 metres, temperatures less than 20ºC and hard substrate, such as rocky bottoms, for attachment. The high nutrient rich waters of the Falklands are particularly conducive for kelp development. Studies suggest kelp fronds may grow at rates of 1–2 feet 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.

Macrocystis pyrifera 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 Falklands (*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. Little is known of the lifecycle of the species in the Falklands. It has been suggested that the Falkland Islands *Macrocystis* population is more stable than most other giant kelp beds at high latitudes, due to absence of winter storms.

Tree Kelp

Tree kelps (*Lessonia* sp.) are 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 Falklands. *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 and other marine creatures as feeding grounds and spawning/nursery areas (*Munro, 2004*).

Given the range of water depths at the proposed drilling locations (approx. 550 to 1,490 metres), kelp species are only likely to be found as free-floating patches. Distribution of free-floating kelp patches in Falkland Islands waters was reported from the at-sea surveys carried out between February 1998 and January 2001 (*White et al., 2002*). These areas are important for the 22 seabird species recorded as associating with free-floating patches of kelp.

5.3.2 Plankton

Plankton are marine and freshwater organisms with limited swimming capability that drift with the prevailing currents. They represent an integral part of the marine ecosystem as they provide the basis of all food for higher levels of the marine food chain. Plankton are generally divided into broad functional groups – Phytoplankton (autotrophic) and Zooplankton (heterotrophic).

Due to a lack of knowledge on the distribution and ecology of plankton species in Falklands' waters, current information is based on the 'Discovery' research expeditions undertaken during the early part of the twentieth century between the Falkland Islands and South America, compiled from 1926–1986.

Phytoplankton

Phytoplankton is reliant on the availability of sunlight and nutrients for their photosynthetic processes. As such, it exists in the photic-zone of the ocean and in higher concentrations in summer at the 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 44ºS there were relatively few species and a marked increase in diatoms, in comparison to the dominance of dinoflagellates, ciliates and crustaceans further north. This confirms known trends that diatoms comprise a significant component of the plankton population in higher latitudes, compared to tropical waters (*Barnes & Hughes, 1988*).

Research on the zooplankton of the south-west Atlantic Ocean, focusing on cephalopod larvae in relation to the major oceanographic features (*Rodhouse et al., 1992*) indicate that the lowest zooplankton concentrations occur in the shelf seas around the Falklands.

NASA photographed a large phytoplankton bloom in December 2002 surrounding the Falkland Islands (Figure 5.14), 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 winds buffering the Falklands from the east may generate waves which bring the nutrient rich waters to the surface. When sunlight penetrates, phytoplankton blooms may occur. Although large areas of the southern oceans are characterised by low productivity, inshore shelf waters where shelter, coupled with the nutrient up-welling, can increase numbers significantly.

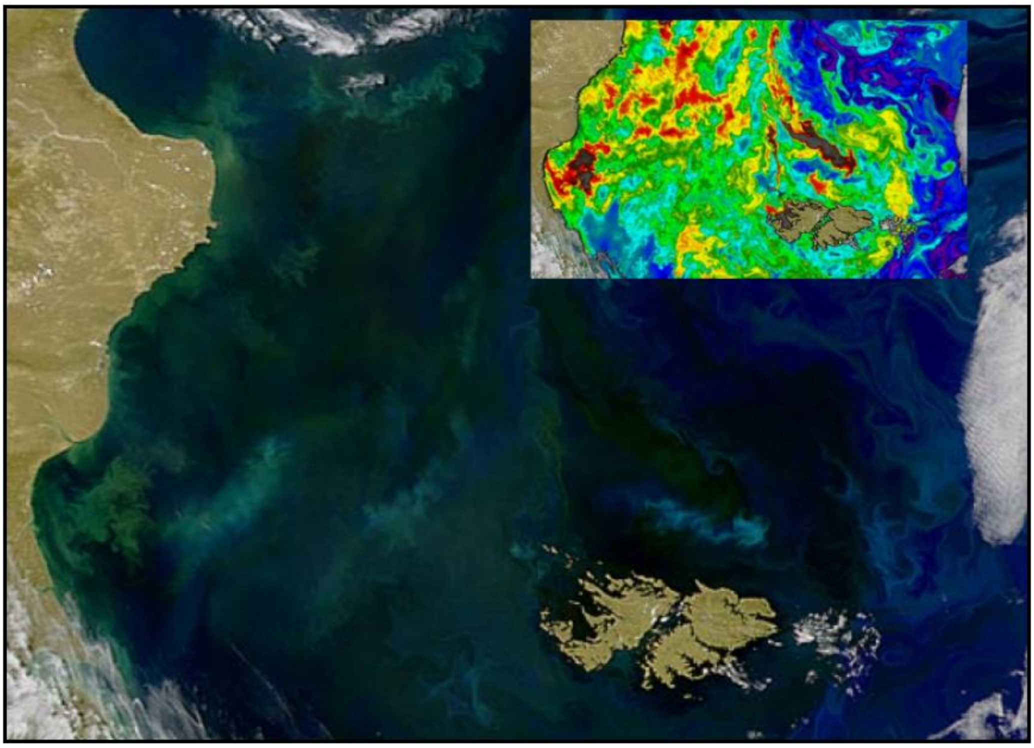


Figure 5.14 Phytoplankton Bloom (Areas of Light Blue / Green) near the Falkland Islands (NASA SeaWiFS, 2002)

Zooplankton

Zooplankton, a heterotrophic species, can range in size from microscopic bacteria to larger organisms, such as jellyfish.

The complex current patterns around the Falklands, with the rising bathymetry and the extensive shelf area, create stable areas to the north and to a lesser extent in the south-west, where high salinity and loaded water wells up, to produce phytoplankton activity supporting high levels of zooplankton (*Agnew, 2002*).

As with phytoplankton, numbers appear to rise sharply leading into the 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. Species identified in Falklands' waters are presented in Table 5.4.

Table 5.4. Zooplankton Species in Falkland Islands' Waters

	Species
Euphasids	*Sagitta gazellae*
	Euphausis lucens
	Euphausia vallentini
	Thysanoess gregaria
Amphipod	*Thermisto gaudichaudii*
Decpod	*Munida gregaria*

Zooplankton also consists of a number of juvenile fish species and cephalopods (*Agnew, 2001*), such as Lobster Krill (*Munida gregaria*) (Figure 5.15), which is regarded as the most important of the zooplankton species in Falklands' waters. Krill, a key species in the food chain, is consumed by squid, fish, seals, baleen whales and seabirds (particularly the black-browed albatross and penguins) in the Falklands.

Figure 5.15 Lobster Krill (Munida gregoria)

5.3.3 Benthic Fauna

Epifauna / Pelagic Fauna

Loligo Site Survey

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.

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 5.16 - Plates 3 and 4) and on outcrops of consolidated sediment (Figure 5.16 - 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 5.16 - 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 C (Figure 5.16 - Plate 1) (refer to Appendix C for further details) (*FSLTD, 2009a*).

Although more sparsely distributed than the cnidarian taxa, sponges (*phylum Porifera*) were prominent in some areas (Figure 5.16 - Plates 3 and 5).

Of the free-living taxa recorded the most abundant were brittle stars (class Ophiuroidea), which sometimes formed dense aggregations on consolidated sediment outcrops (Figure 5.16 - Plate 1). Shrimps (presumably members of the Caridea) were occasionally seen throughout the ROV footage as were small fish (*FSLTD, 2009a*).

Toroa Site Survey

ROV obtained video footage, taken during bore hole operations at the Toroa A location, were reviewed and reinterpreted to assess the epifaunal communities of these two locations.

The most dramatic footage obtained from the Toroa site was of a porbeagle shark (*Lamna nasas*) which was briefly observed at a depth of approximately 590 metres (Figure 5.17 - Plate 1) (refer to Appendix D for further details).

The most frequently occurring epifaunal taxa encountered were tubicolous (tube-dwelling) onuphid worms, at least the majority of which were probably *Onuphis pseudoirirescens*, a dominant component of the community sampled (Figure 5.17 - Plates 3 and 4). Brittle-stars, which appeared from their gross morphology to largely comprise members of the family Amphiuridae (three species of which were recorded from the sample data) were frequently seen (Figure 5.17 - Plates 3 and 4). A prominent, if sparsely distributed, member of the epifaunal community that was tentatively identified as a seapen (order Pennatulacea) was also occasionally observed (Figure 5.17 - Plate 2).

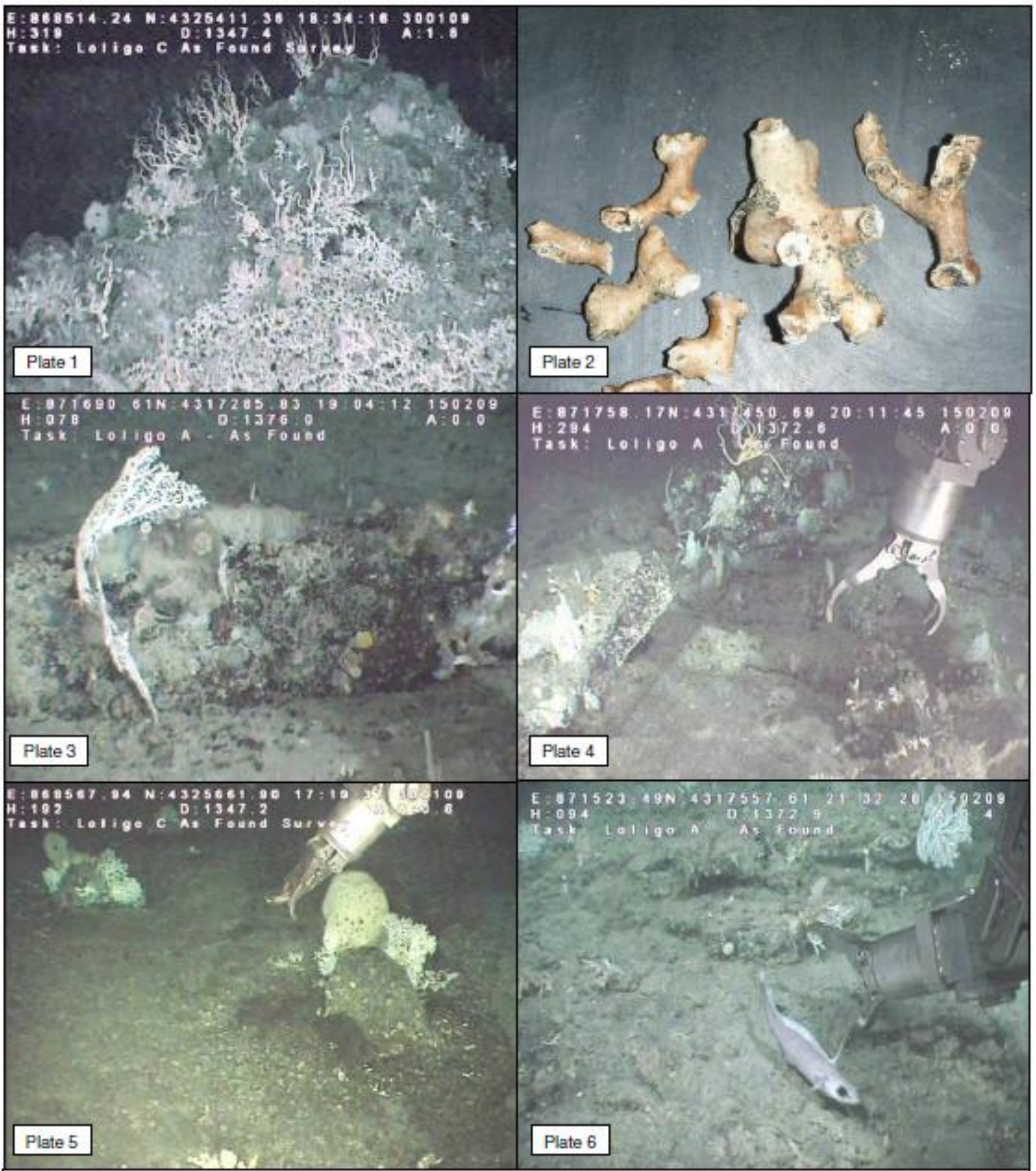


Plate 1: Dense coverage of a hard coral (possibly *Lophelia pertusa*) with filter-feeding brittle-stars (Ophiuroidea) on a consolidated sediment outcrop in the depression near Loligo C

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 5.16 Screen Grabs of ROV Footage, Showing Examples of Epifaunal Taxa (FSLTD, 2009a)

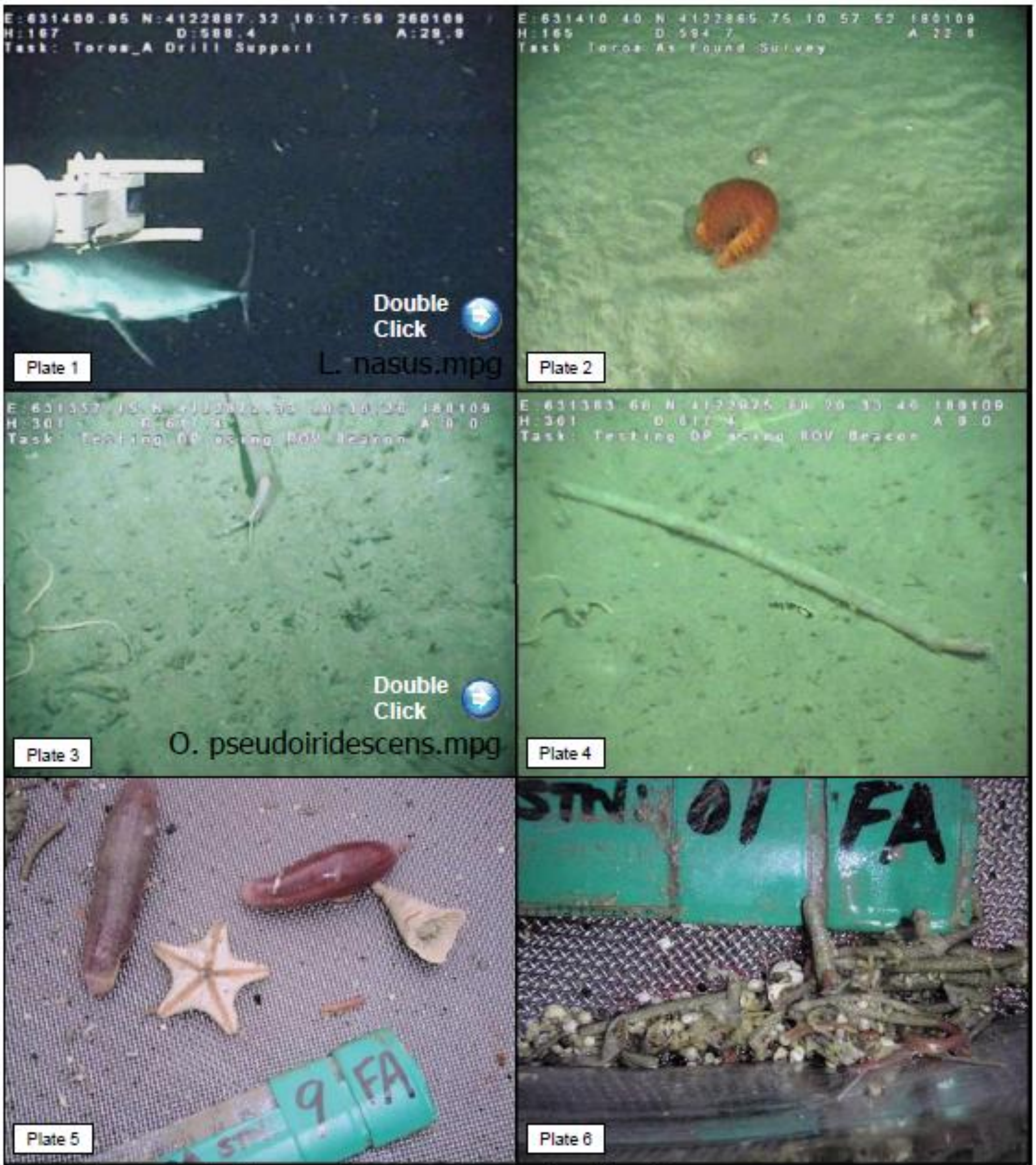


Plate 1: The porbeagle shark (*Lamna nasus*) seen during drilling operations at Toroa A

Plate 2: A seapen? (Pennatulacea?)

Plate 3: An onuphid polychaete (*Onuphis pseudoiridescens*) and brittle-stars (probably *Amphiura* sp.)

Plate 4: A close up of the same onuphid (*Onuphis pseudoiridescens*)

Plate 5: The sea cucumbers *Molpadia* cf. *musculus* and starfish *Ctenodiscus australis* in grab sample T9-FA after sieving

Plate 6: Tubes of the onuphid polychaete *Onuphis pseudoiridescens* in grab sample T1-FA after sieving

Figure 5.17 Screen Grabs of ROV Footage and Grab Sample Photographs, Showing Notable Fauna (FSLTD, 2009b)

Infauna

Loligo Site Survey

Two 0.1 m^2 macrofaunal grab 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).

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 5.18). In terms of abundance the Annelida were overwhelmingly dominant, representing 81.1% of the 312 individuals recorded in total from the samples (*FSLTD, 2009a*).

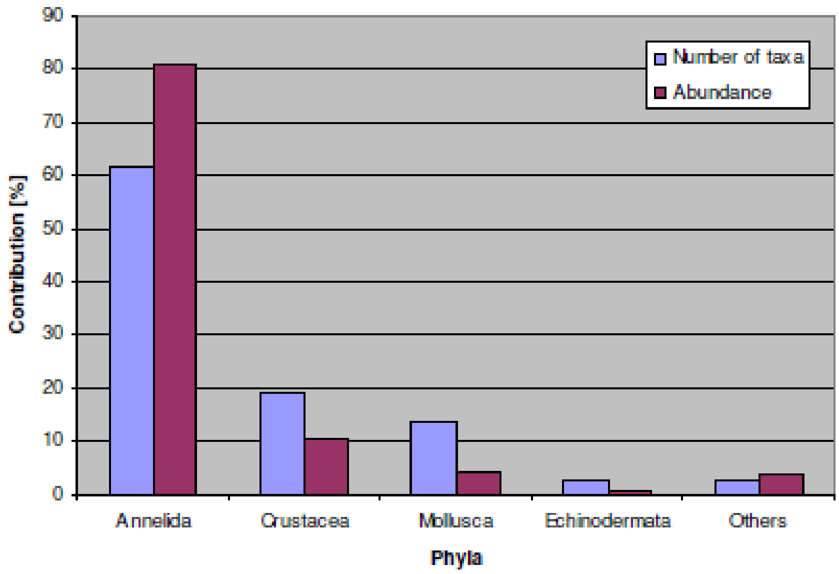


Figure 5.18 Abundance of Taxonomic Groups (FSLTD, 2009a)

The dominant taxa recorded from the survey area are shown in Table 5.5. 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.

Table 5.5. 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

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*).

Toroa Site Survey

Two 0.1 m^2 macrofaunal grab samples were analysed from each of the six stations sampled, giving a total of twelve 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).

A total of 103 discrete macrofaunal taxa were found during the course of the Toroa survey, excluding the six juvenile and three indeterminate taxa, records which were not included in the analysis.

Of the taxa recorded 53.4% were annelid, 20.4% were crustacean, 17.5% were molluscan and 6.8% were echinoderm (Figure 5.19). In terms of abundance the Annelida were dominant, representing 54.5% of the 488 individuals recorded in total from the samples.

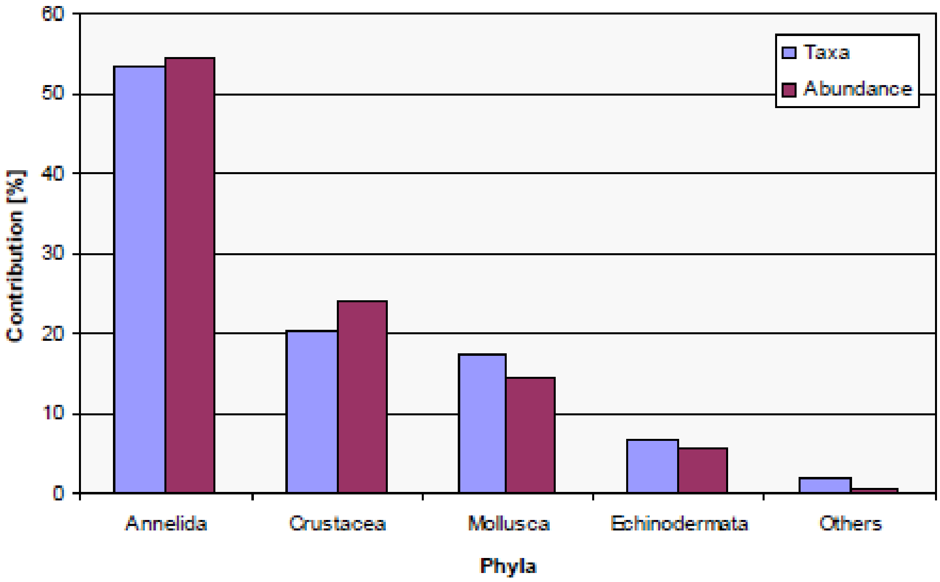


Figure 5.19 Abundance of Taxonomic Groups (FSLTD, 2009b)

The dominant taxa recorded from the survey area are shown in Table 5.6. Of the dominant infaunal taxa identified the majority were polychaetous annelids, although the most abundant species overall was the amphipod crustacean Haustoriidae 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 station data could be grouped within a single statistically undifferentiated cluster. This cluster was shown to be characterised by the amphipod Haustoriidae sp. 1 and polychaete O. pseudoirirescens, species that were consistently abundant at all stations (*FSLTD, 2009b*).

Table 5.6. Dominant Taxa by Abundance and Dominance Rank for Samples [0.1m²] (FSLTD, 2009b)

Taxon	Rank Abundance	Mean Abundance	Frequency (%)	Rank Dominance
Haustoriidae sp. 1	1	5.6	83.3	1
Onuphis pseudoiridescens	2	5.3	100.0	2
Ampharete sp. 1	3	2.7	75.0	3
Stemaspis sp. 1	4	1.7	50.0	4
Ctenodiscus australis	5	1.1	50.0	6
Nucula falklandica	6	0.9	66.7	8
Thyasira subovata	6	0.9	41.7	9
Axinulus of croulinensis	6	0.9	41.7	6
Harpinia sp. 2	9	0.8	41.7	11
Chaetozone ander	10	0.8	50.0	13
Pulsellum falklandicum	11	0.7	25.0	5
Myriochele riojai	14	0.6	25.0	10

Comparison of Site Survey Data

The community at the Toroa site was similarly rich and exhibited a similar (non-dominated) abundance structure to the community of the deeper Loligo site. There also appeared to be some overlap in species distributions between the two sites, with 24 of the taxa co-occurring at the two survey areas (out of those taxa differentiated at species level). Despite this similarity the two different communities were clearly distinct from each other, with none of the shared species assuming equal prominence at both sites. Out of the taxa recorded from both sites only a small number were dominant components of the Toroa community (Haustoriidae sp. 1, *Ampharete sp*. 1 and *Harpinia sp.* 2) and they were all recorded at low abundance at Loligo. Only two prominent members of the Loligo community were apparent at Toroa (*Kinbergonuphis oligobranchiata* and *Melinna sp. 1*), neither being recorded at particularly high abundance (*FSLTD, 2009b*).

5.3.4 Fish, Squid and Shellfish

Much of the information sourced for these sub-sections is based on work undertaken by the Falkland Islands Fisheries Department (FIFD) as commercial fishing is a significant part of the local economy. Additional information has been sourced from the 2008 State of the Environment Report (*Otley et al, 2008*).

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*). Commercial fishing is described from a socio-economic perspective in Section 5.4.1.

The Falklands Interim Conservation and Management Zone (FICZ) was introduced in February 1987 to reduce uncontrolled fishing. 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 main fisheries resources are the squid species, *Illex argentinus* and *Loligo gahi*. The existing finfish fishery targets predominantly hake, hoki, red cod and blue whiting. Blue whiting provides the highest finfish catches with 80% of the catch targeted seasonally by large surimi trawlers. A specialised small ray fishery exists, and a small longline fishery operates targeting Patagonian toothfish.

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 antarcticus*). A small-scale scallop (*Zygochlamys patagonica*) fishery is also being developed (Munro, 2004) in the Falkland Islands Conservation Zone. Approximately 920 tonnes (green weight) of scallops was taken in 2003 and 2004, constituting the total allowable catch from the known scallop banks, situated mainly to the northeast of Stanley.

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 (The International Collective in Support of Fishworkers (ICSF); www.icsf.net.

5.3.5 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*).

Cephalopod paralarvae and juveniles sampled in the south-west Atlantic Ocean 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 an Octopus sp. (*Rodhouse et al., 1992*).

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

Argentine Shortfin Squid (*Illex Argentinus*)

Illex argentinus, one of the most abundant cephalopods in the Southwest Atlantic, is distributed from approximately 30ºS to 54ºS over the Patagonian shelf, slope and around the Falkland Islands. *I.argentinus* is a demersal and schooling species.

Illex argentinus is caught in the FICZ between late February and June, at depths of 80–800 m (*FIFD, 2001; Rodhouse & Hatfield, 1990*). Fishing catch peaks between April and May with principal catch areas to the north and north-west of the Falklands, although they can vary annually.

The migration and dispersal of *Illex argentinus* is highly dependant upon the major oceanic currents and resultant water temperature, therefore abundance in the Falklands is highly variable. The species is predominantly a warmer water species and variations in current strength and flow, that modify sea temperatures and temperature gradients, can influence major changes in migration and aggregation of the species (*FIFD, 2001*).

Pantagonian Squid (*Loligo gahi*)

Loligo gahi is a demersal, schooling species found in shallower water around the coast to a depth of about 400 metres (*Boyle, 1983*). They have two main spawning periods; the spring (September-October) spawning group is larger than the autumn (March-April) group.

This fishing industry is focused to the south of East Falklands, mainly around Beauchene Island from February to June, later moving northwards to north-east of East Falklands around August–October. The trawling fleet targets *Loligo gahi* during its feeding phase, in depths of 120–250 metres, corresponding to the optimum commercial size

Squid eggs have been recorded in shallow marine areas (less than 30 metres depth) during dive surveys carried out in 1996 *(FIG, 1996*) and by the FIFD (*FIFD, 2000*). Eggs were found in inshore waters of all islands sampled, except the offshore islands to the south. In 1999 (*FIFD, 2000*) egg masses were encountered around the entire coast of East Falklands with the exception of the central part of Falklands Sound. All egg masses found were associated with and attached to kelp, although there was considerable local variation in egg mass density.

A third squid species, red squid (*Martialia hyadesi*) is not widely fished. It is larger in size than *Illex argentinus* or *Loligo gahi* and is thought to be abundant in the waters of the Antarctic Convergence Zone, near South Georgia. This species forms at least 90% of the squid intake of the grey-headed albatross population during the chick rearing period resulting in approximately 1400 tonnes of squid consumed each breeding season (*Brunetti & Ivanovic, 1992*).

5.3.6 Finfish

Some 11 species of finfish are caught in significant quantities. Southern blue whiting catch is found to the south-west and north-east of the Falklands. Hoki, rays, red cod and Patagonian toothfish are caught widely around the Falklands in the FICZ, except in the south-east. Within the FOCZ all are caught to the north of the Falklands. Patagonian toothfish and rays are also caught to the south-east within the FOCZ (*Munro, 2004*).

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.

Hake (*Merluccius* sp.)

Hake are widespread throughout the FICZ and two species are caught commercially; Patagonian hake (*Merluccius hubbsi*) and common hake (*Merluccius australis*), which are similar species and often counted together in catch statistics. The common hake is distributed mainly in the offshore waters to the north of the Falklands as opposed to the Patagonian hake, which is found to the south of the Falklands. 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*), and around Beauchene Island to the south (*Lisovenko et al., 1982; Tingley et al., 1995*). *Merluccius hubbsi* is thought to spawn in September and October, and *M.australis* in June and August. 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.

Southern Blue Whiting (*Micromesistius australis*)

Southern blue whiting are a food source for the Patagonian hake and consequently showing a similar distribution. Southern blue whiting migrate to the Falklands outer shelf and aggregate in dense schools to spawn. Specialised surimi vessels target feeding concentrations of southern blue whiting until the following March. Acoustic surveys of the southern blue whiting stock are conducted annually through a joint Argentine/Falklands project.

The Falklands' sub-species are found at depths between 180 to 780 metres and appear to be most abundant at depths of 200 metres around the Falklands (*Inada and Nakamura, 1975*). Spawning occurs in August and September around the south of the Falklands and both eggs and larvae are pelagic. Pre-spawning fish congregate south of West Falklands during July (*Patterson, 1986*) and subsequent to spawning migrate into deeper water dispersing south and west where they are thinly distributed over the Patagonian Shelf.

Whiptail Hake / Hoki (Macruronus magellanicus)

Whiptail hake, or hoki, is the second most important commercial species in terms of annual catch. A pelagic and near-bottom fish, the species is present in Falklands' waters year round and is generally associated with warmer waters up to 200 metres deep in the north and west of the FICZ (*Middleton et al., 2001*). Falklands' waters are primarily a feeding ground. 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.

Cod (*Notothenia* spp.)

Antarctic cod are one of the most common fish in Antarctic and subantarctic waters, and 16 species have been recorded in Falklands' waters. Of these the predominant species are *Notothenia ramsayii* and yellow belly (*Notothenia macrocephala*); common in nearshore waters in summer, but migrating to deeper waters during the winter (*ERT, 1997*).

5.3.7 Shellfish

Data on shellfish found in the shallow and offshore waters of the Falklands are scarce. Lobster krill is abundant in Falklands' 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* sp.).

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 south east of the Falklands. Juveniles and adults are found at the edges of kelp beds (*Hoggarth, 1993*).

Patagonian scallop (*Zygochlamys patagonica*)

A small commercial fishery exists for the Patagonian scallop in the northeast of the FICZ at depths of 130 and 142 metres. Stock assessment estimates a standing biomass in these beds of 18,000–27,000 MT (Metric Tonnes). Distribution is mainly along the north eastern, eastern and southern edge of the Falklands shelf. Distribution is thought to be determined by three main factors: the Falklands Current, 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*).

5.3.8 Marine Mammals

Little is known about the populations, distribution and habits of marine mammals in the waters surrounding the Falkland Islands, particularly in the deeper waters to the south and east. There may be more than 20 species which occur in Falkland Islands' waters but probably with only 2 to 3 resident species (*Munro, 2004*).

After the award of the initial round of hydrocarbon exploration licences in 1996, six wells were subsequently drilled. The threat to seabird and marine mammal populations was recognised and the Joint Nature Conservation Committee (JNCC) and Falklands Conservation (FC) conducted a 'Seabirds at Sea Survey' between 1998 and 2000. Post the initial round of drilling, additional funding was allocated to FC to continue a further two years of at-sea surveys. To date, the findings from these surveys are still the major body of work regarding the frequency and distribution of marine mammals, particularly cetaceans, in the region. Previous knowledge of whales and dolphins around the shores of the Falkland Islands had been based on occasional random sightings, strandings and a few records from commercial whaling (*Munro, 2004*).

The at-sea surveys encompassed an area defined by a box extending north and east from 56º S 64º W. Additional marine mammal data has now been compiled based on the reports provided by Marine Mammal Observers on seismic vessels during acquisition programmes. This includes surveys undertaken in BHPBP(F)C's licence area when it was under the Operatorship of FOGL. Although not currently a legal requirement in the Falkland Islands, Marine Mammal Observers have recently been stationed on seismic vessels as a voluntary measure by several of the Falklands operating companies.

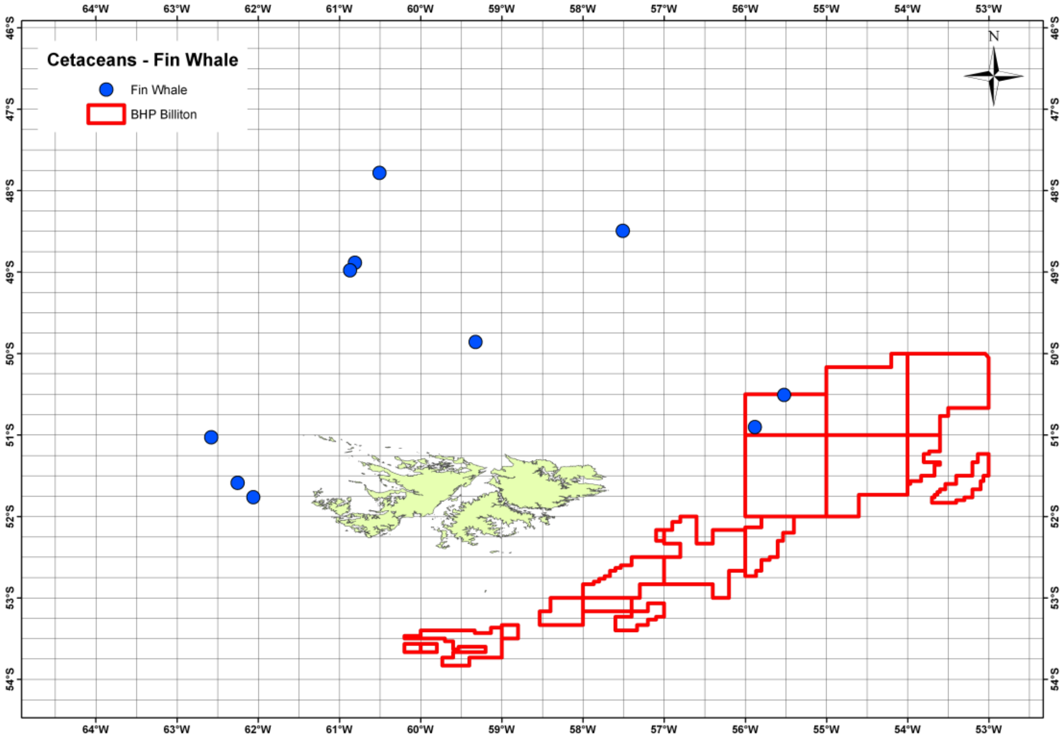
Cetaceans

Cetaceans in Falkland Islands' waters may either occur as a consequence of their passage on migration or when they enter sheltered waters to give birth or to mate.

The following results, unless stated otherwise, have been extracted from the Distribution of Seabirds and Marine Mammals in Falkland Islands' Waters, 2002 and represent the findings of those surveys between 1998 and 2001. Seventeen species of marine mammals were recorded over the period including 14 species of cetacean and three pinniped species. In total, 6,550 individual marine mammals were seen during the survey period.

Figure 5.20, below, depicts the distribution and species of cetaceans sightings recorded during all the surveys months.

Cetacean Species Distribution in the North Falklands Basin (1998-2001)



<u>Fin whale - (*Balaenoptera physalus*)</u>

Majority of fin whales were recorded between November and January, with 57 recorded in total on 27 separate occasions over the survey area. Sightings were generally in water depths >200 m.

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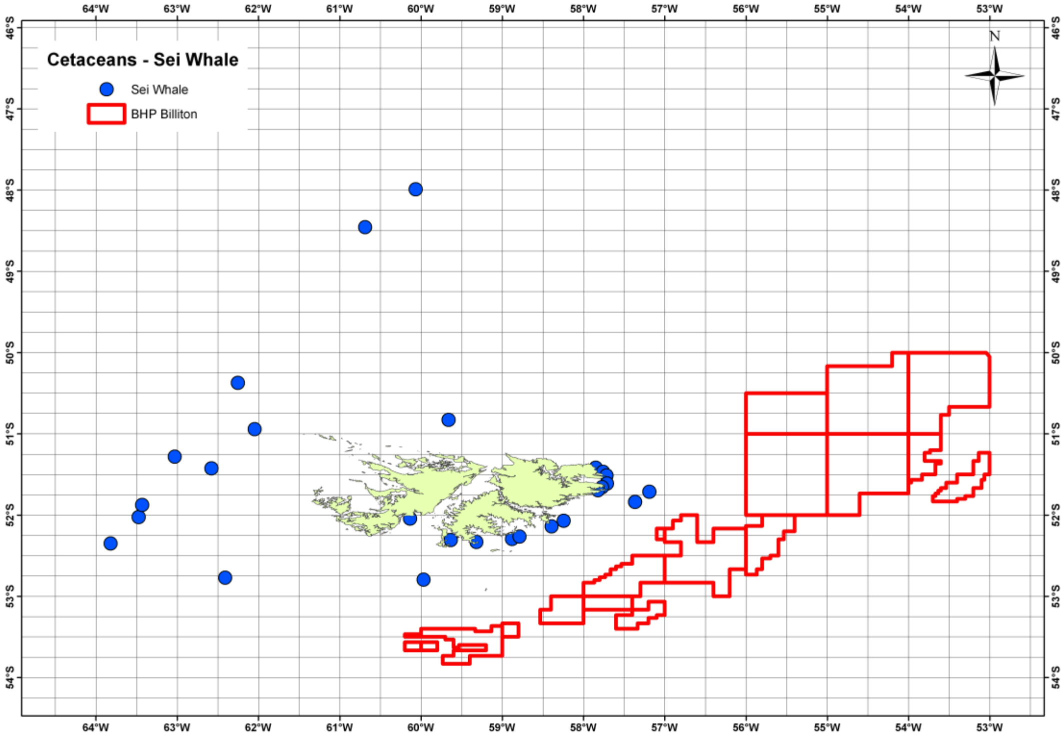
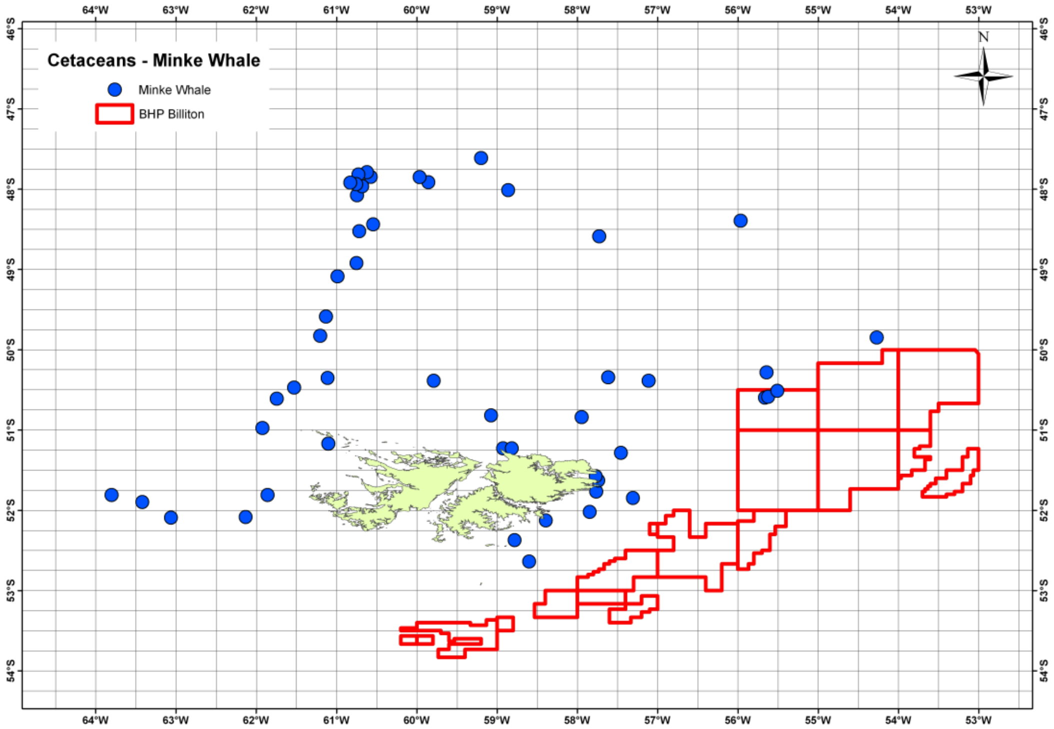
Cetacean Species Distribution in the North Falklands Basin (1998-2001)



Sei whale (*Balaenoptera borealis*)

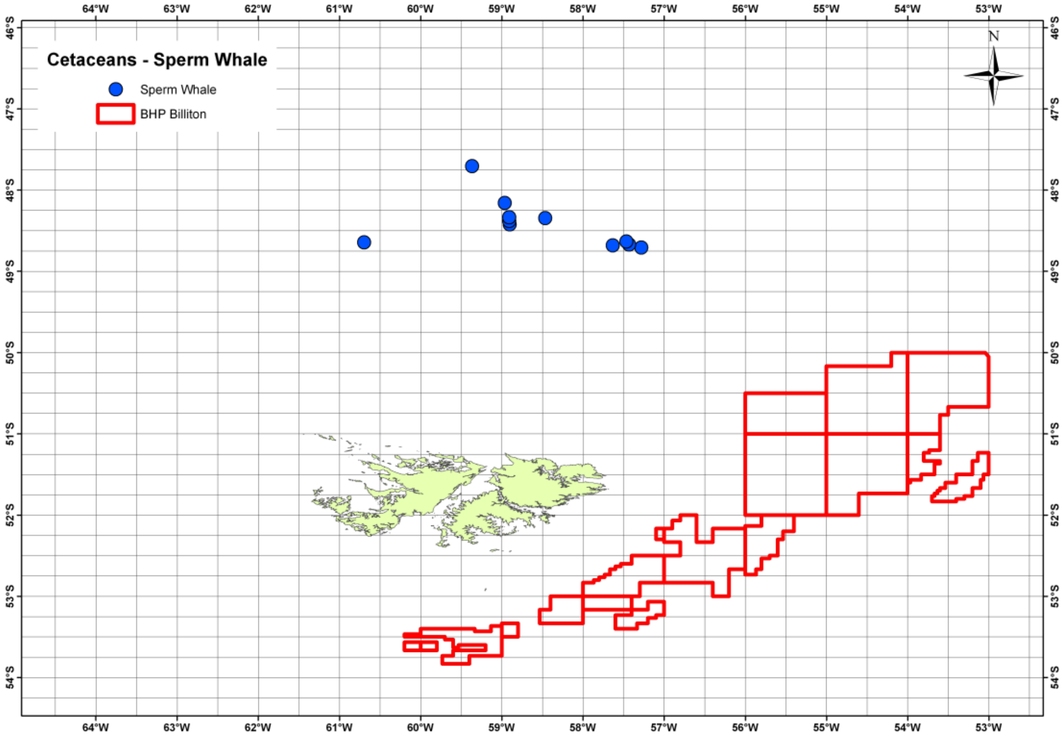
Most sei whale sightings were between November and April, with 45 individuals recorded on 31 occasions. Most records were from Patagonian Shelf waters, with others in relatively shallow waters.



Minke whale (*Balaenoptera acutorostrata*)

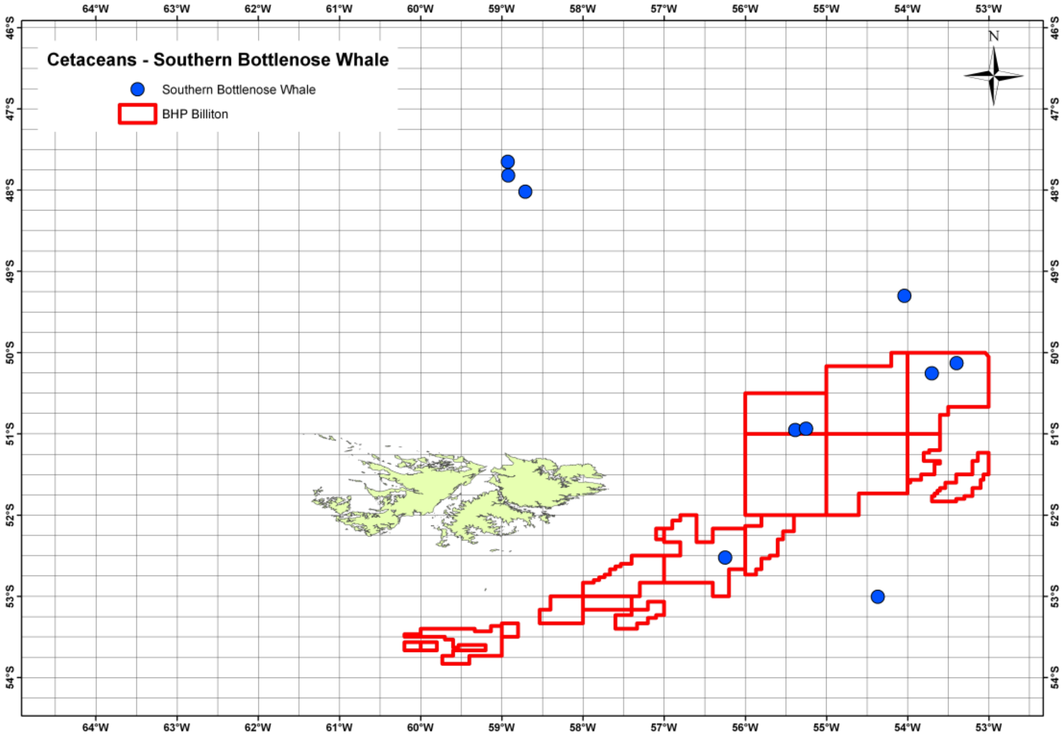
Minke whale sightings peaked in April and December, with a total of 68 whales recorded on 60 occasions. The majority of records were from Patagonian Shelf waters around East Falklands and in the north-west of the survey area.

Cetacean Species Distribution in the North Falklands Basin (1998-2001)



Sperm whale (*Physeter macrocephalus)*

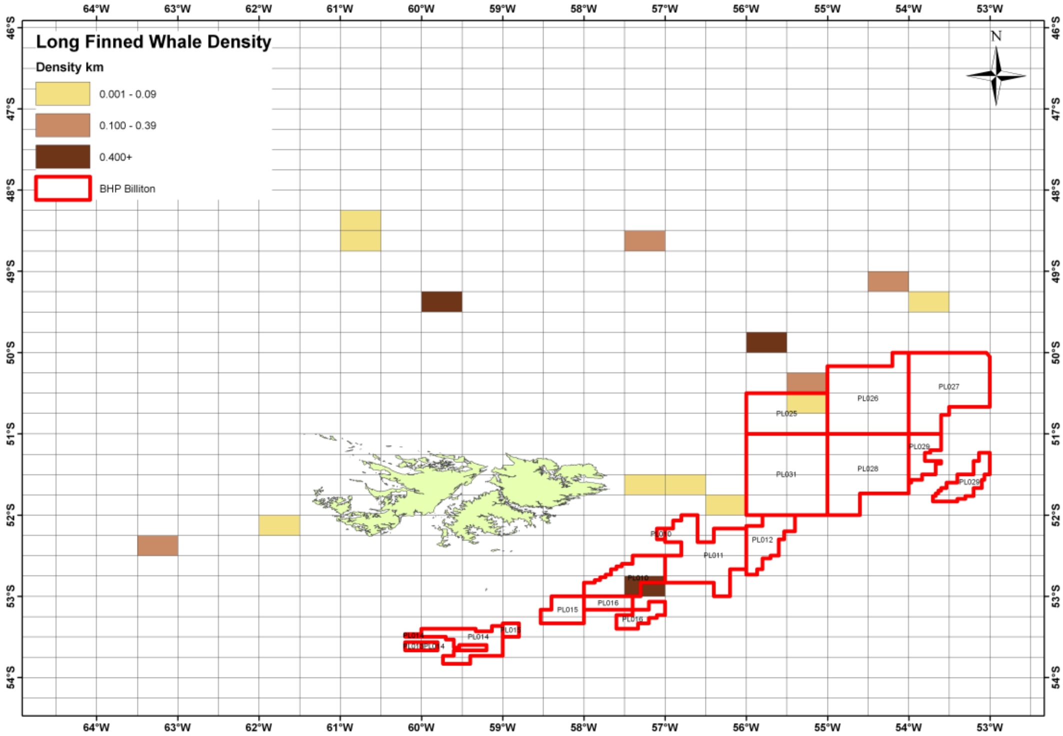
A total of 28 sperm whales were recorded on 21 occasions, mainly in July, October and December, but also throughout most months. All sperm whale sightings occurred in deeper waters (>200 m), with records clustered to primarily to the north of the Falkland Islands.



Southern bottlenose whale (*Hyperoodon planifrons)*

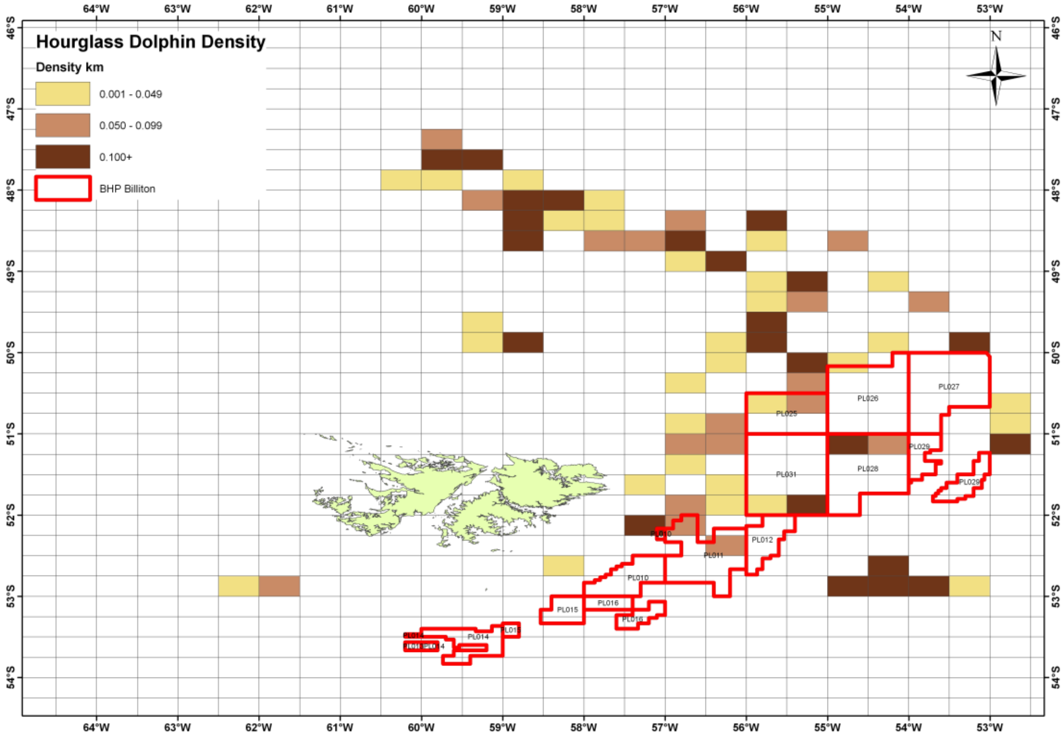
Southern bottlenose whales were recorded between September and February, with a total of 34 records on 18 occasions. All sightings were made in waters >1000 metres, generally to the north, east and south.

Cetacean Species Distribution in the North Falklands Basin (1998-2001)



Long-finned pilot whale (*Globicephala melas*)

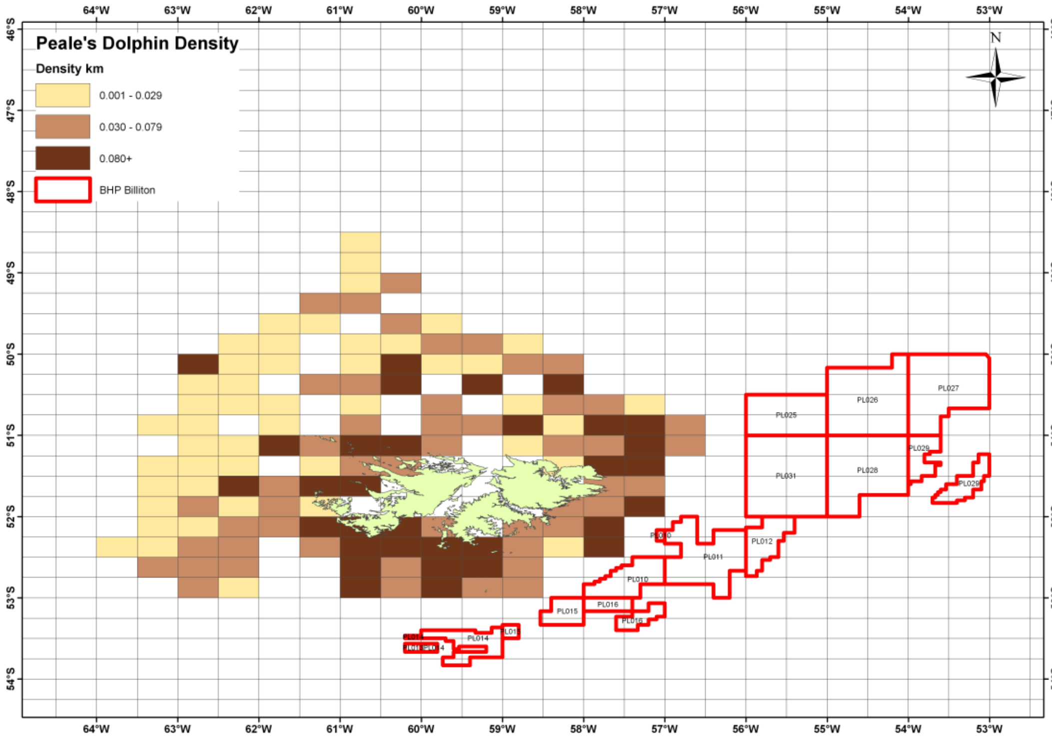
Large numbers of long-finned pilot whale were recorded (872 over 27 occasions), with group sizes of up to 200. Although these whales were recorded in all months except January, they were predominantly recorded between April and September in waters deeper than 200 metres.



Hourglass dolphin (*Lagenorhynchus cruciger*)

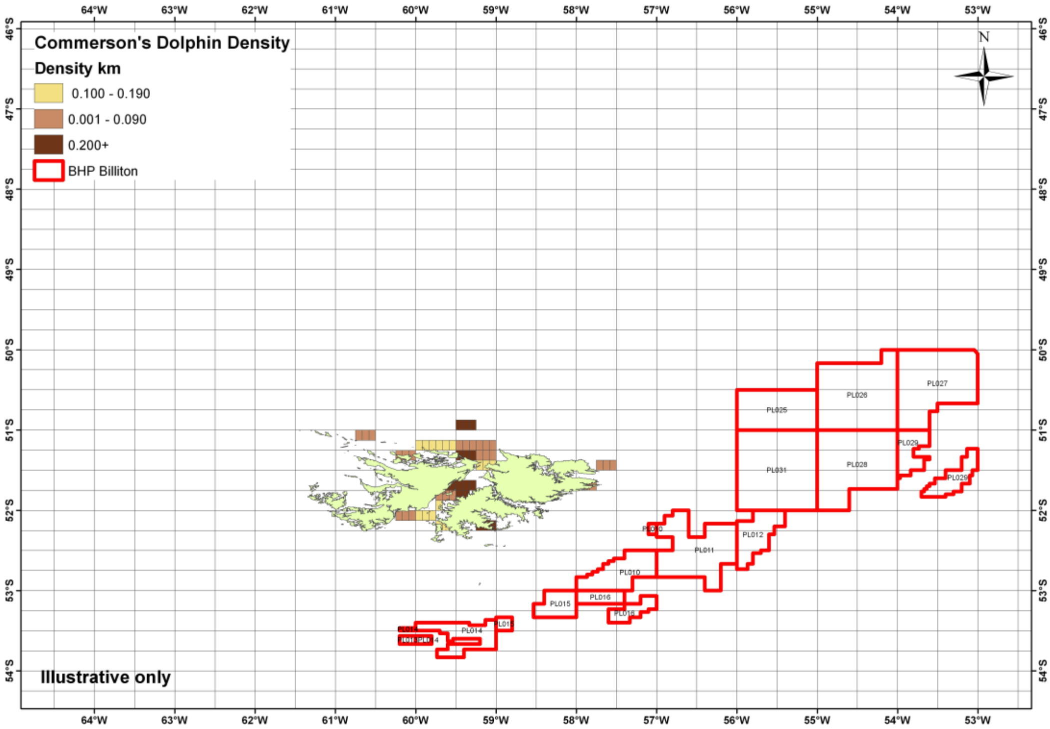
Hourglass dolphins were recorded in large numbers, with 866 Sightings over 177 occasions, mainly between September and March and in water depths of greater than 200 metres.

Cetacean Species Distribution in the North Falklands Basin (1998-2001)



Peale's dolphin (*Lagenorhynchus australis*)

Peale's dolphins were the most numerous and frequently recorded cetacean with a total of 2617 animals recorded on 864 occasions. They were recorded in all months with a maximum of 358 animals in August. They were generally found in waters less than 200 metres deep.



Commerson's dolphin (*Cephalorhynchus commersonii)*

A total of 336 Commerson's dolphin was recorded on 100 occasions, covering all months except May. Dip in records over May and June may be due to variation in the level of survey effort rather than seasonal variations. No observations were made over 25 kilometres offshore.

Figure 5.20 Cetacean Species Distribution in the North Falklands Basin (1998-2001)

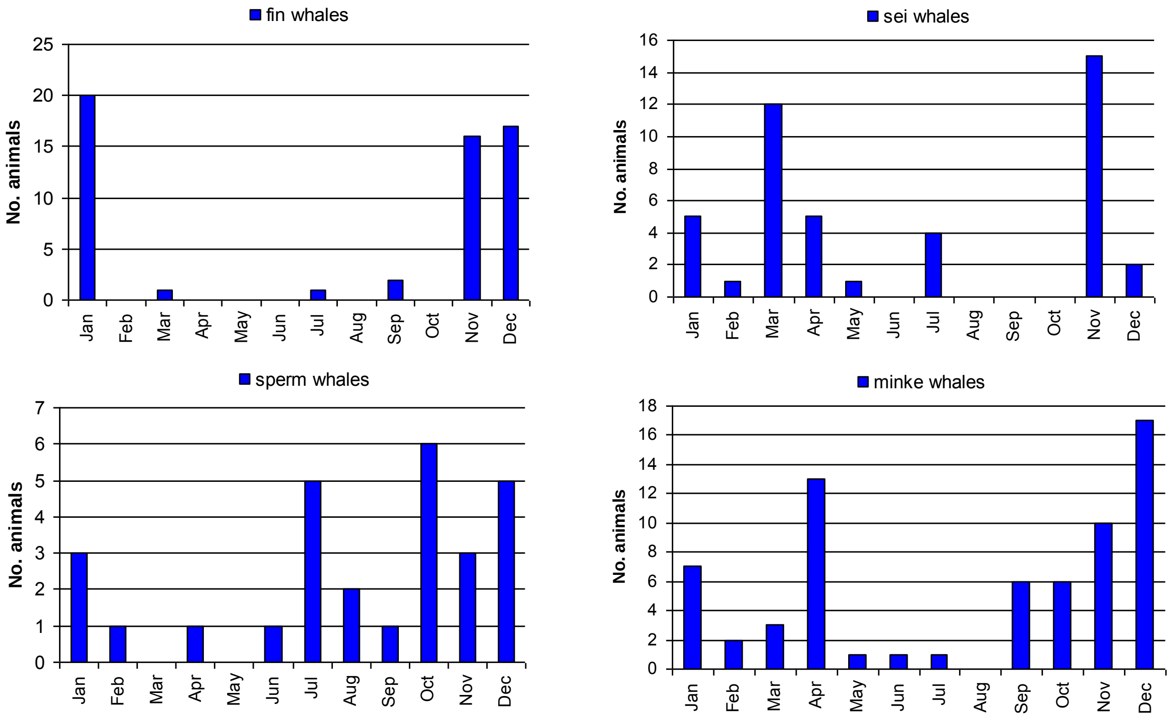
In addition to the sightings described above, several species of marine mammals were recorded on fewer than 10 occasions and are therefore described as rare in *White et al. (2002)*. Descriptions of these sightings are provided below.

Southern right whale (*Eubalaena australis)*	Two records, of two separate individuals, were recorded in 1998. A further record was made in June 2000 and two additional records of single animals in January 2001. Although the majority of sightings were to the north of the Falkland Islands, the low number sightings make geographic or seasonal modelling inaccurate.
Humpback whale (*Megaptera novaeangliae)*	Seven records were made over five occasions, all between October and March in Patagonian Shelf waters. Most records were made to the north-west of the Falklands.
Unidentified beaked whale species (*Mesoplodon spp.*)	There were 15 animals sighted in seven occasions, none were specifically identified. All records were in waters deeper than 1000 metres to the east of the Falklands.
Killer whale (*Orcinus orca)*	A total of 18 animals were recorded in seven occasions, mainly in coastal and Patagonian Shelf waters. These sightings took place throughout the year in groups of between one and four animals. Longline fishing vessels have also reported interaction with killer whales in deep waters to the north and east, where they remove fish from the lines (*Munro, 2004*).
Southern right whale dolphin (*Lissodelphis peronii*)	Southern right whale dolphins were recorded on five occasions totalling 231 animals, all in deep waters to the east of the Falkland Islands.

Munro (2004) states that records of sightings in Falkland Islands waters of dusky dolphins (*Lagenorhynchus obscurus*), bottlenose dolphin (*Tursiops truncatus*) and spectacled porpoise (*Phococena dioptica*) have also been made. The lack of any sighting over the three year survey period, however, indicates that these animals are unlikely to be present in the licence area in significant numbers.

Based on the 1998 to 2001 survey results (Figure 5.21), the following species of cetacean were recorded within the vicinity of the proposed Loligo and Toroa drilling locations: fin whale, minke whale, southern bottlenose whale, long-finned pilot whale and hourglass dolphin, although only the southern bottlenose whale, long-finned pilot whale and hourglass dolphin were recorded in significant numbers. Due to the migratory nature of cetaceans however, it is probable that other cetacean species present may move close to the proposed exploration wells.

Overall, the area in the vicinity of the proposed drilling activity is not considered to be an area of particularly high sensitivity for cetaceans.



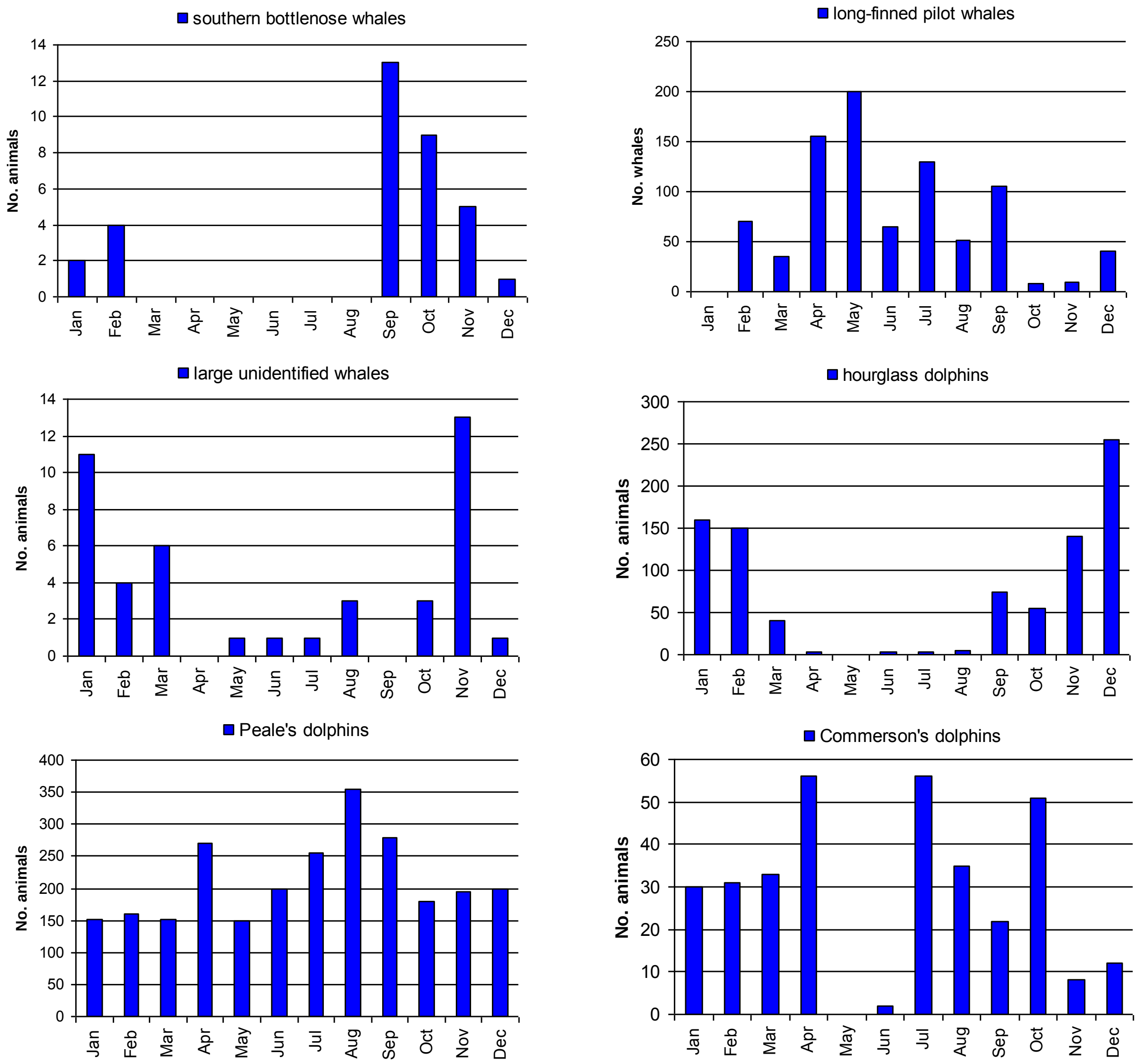


Figure 5.21 Cetacean Numbers Recorded per Month (JNCC, 2002)

Figure 5.22 and Figure 5.23 provide updated marine mammal records from the seismic surveys carried out in the licence area (June 2007), where a Marine Mammal Observer (MMO) was stationed on board the seismic vessel. Marine mammal observations and mitigation measures were employed in accordance with guidance published by the JNCC and accepted as best practice in UK waters and elsewhere. This data indicates that the southern right whale are likely to be present within the immediate vicinity of the proposed Loligo exploration well, while southern right whale, dusky dolphin and Peale's dolphin are likely to be present within the immediate vicinity of the proposed Toroa drilling location.

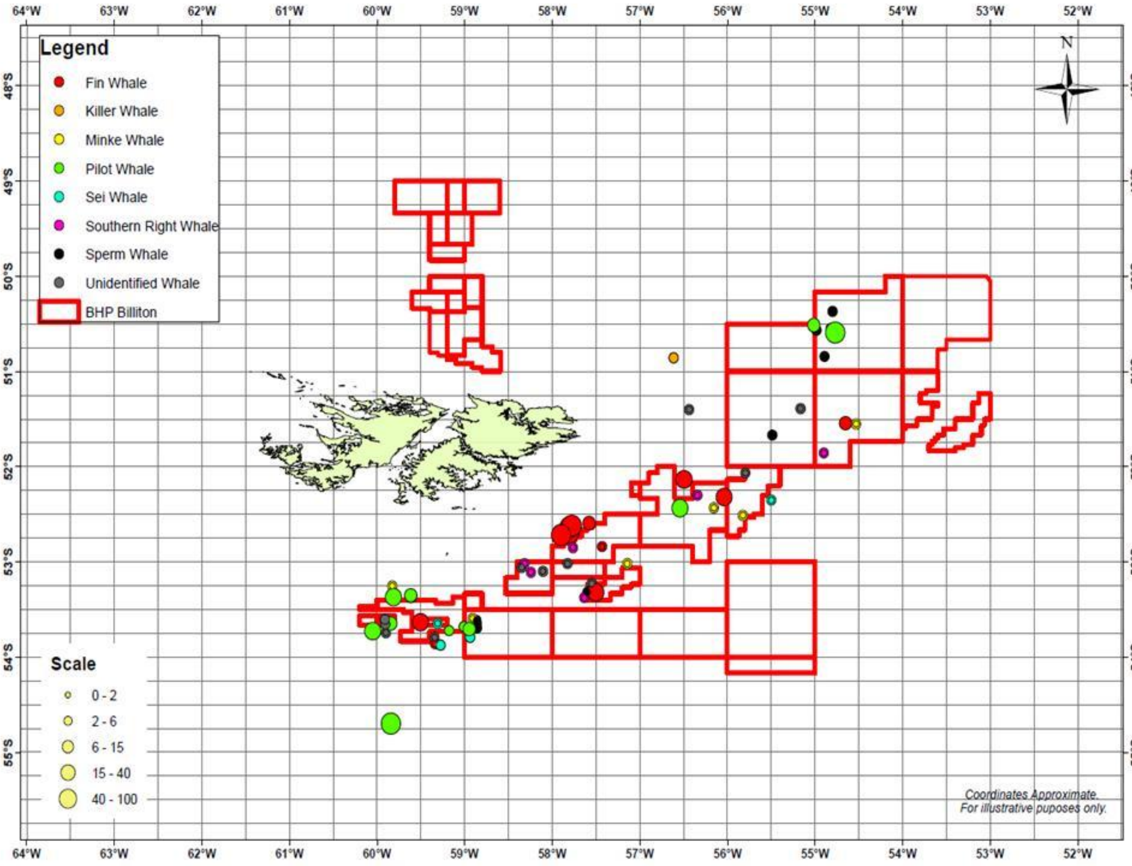


Figure 5.22 Whale Numbers Recorded per Month

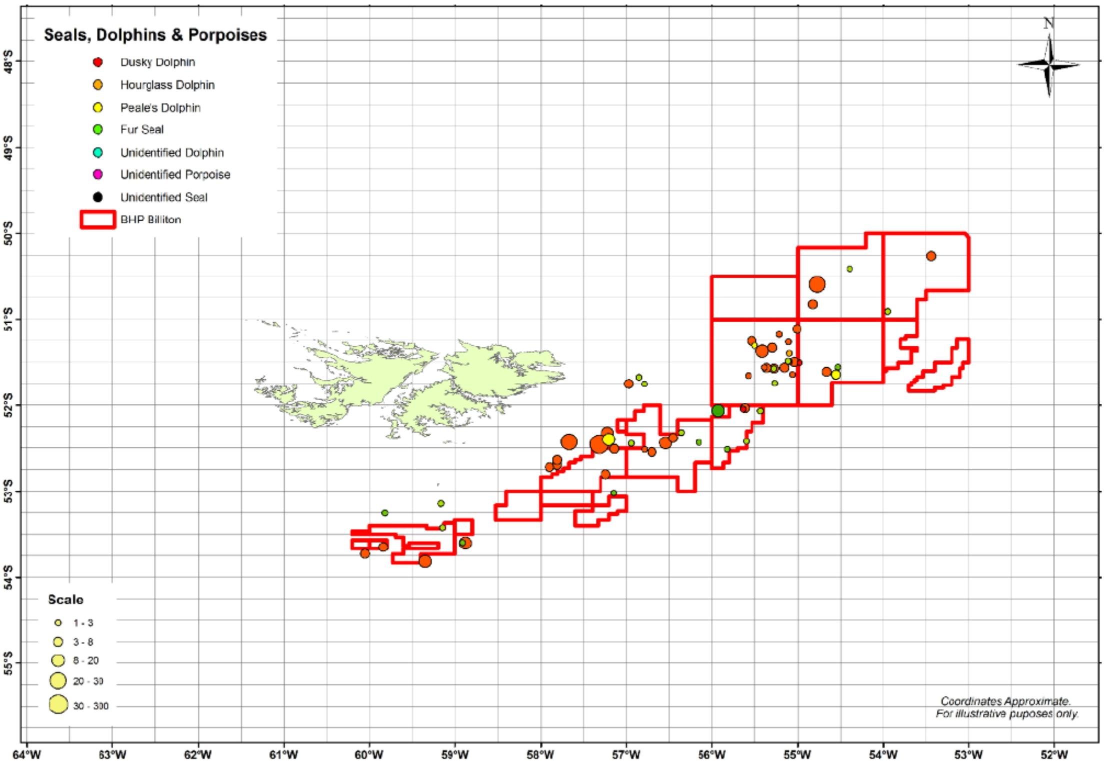


Figure 5.23 Seal, Dolphin and Porpoise Numbers Recorded per Month

Pinnipeds

Four seal species occur in the Falklands – three species breeding and one occurring as a vagrant. Seal species include the predominant *Otaridae* (eared seals) group comprising fur seal and sea lion species, and the *Phocidae* (true seals) group comprising southern elephant seal and leopard seal.

South American sea lion Otaria flavescens (formally Otaria byronia)

The southern sea lion (*Otario flavescens*) is widely distributed along the coast of South America as far north as Peru and Brazil. Within the Falklands, sea lions breed in small colonies at around one hundred sites, mainly on remote sandy beaches with adjacent tussac grass.

Both males and females are an orange-colour with upturned snouts. The manes on males are lighter than females, but female fur on the head and neck is lighter than that of males. Size varies with males having an average length of 2.6 metres and an average weight of about 300 kg. Females are slightly smaller, having an average length of 1.8 to 2 metres and usually weighing approximately half the weight of the males, around 150 kg. Breeding begins in December when bulls establish territories, with the females arriving during late December and January to pup. Females mate shortly after pupping, but continue to rear the pups for up to 12 months or more (*Munro, 2004*)

The UK Sea Mammals Research Unit (SMRU) conducted the most complete census of southern sea lions on the Falkland Islands in 1995 and repeated it in 2003 to monitor population trends. The two censuses update partial surveys conducted between 1934 and 1937 by Hamilton and aerial surveys conducted by Strange in 1990 (*Strange, 1992*). Population estimates have varied with the JNCC at-sea surveys estimating a Falklands resident population of 3,385. Thompson (2003) estimates a current Falklands population of approximately 7047 animals, with an estimated 2,744 pups born annually. The census trends concluded that while the overall population is increasing, it is still well below the peak populations recorded in the 1930's, due to heavy exploitation during the twentieth century.

South American fur seal (Arctocephalus australis)

The South American fur seal is the smallest of the pinnipeds to breed in the Falklands. It breeds at 15 known sites within the Falklands, where it tends to concentrate in fairly large numbers on elevated rocky shores. Fur seals appear to prefer to inhabit rocky coastal strips above the reach of storms (*Laws, 1981*) and undercut cliff edges, with access to both offshore reefs or kelp beds and coastal tussac grass habitat (*Bonner, 1968*).

Males of the species have a dark grey coat of fur with the females and sub-adults having lighter grey or tan colouring on the chest and muzzle. On average, adult males measure up to 2 metres long and weigh 150–200 kg and females measure up to 1.5 metres long and weigh 30–60 kg. Mating commences in early November with the establishment of territories by the dominant bulls. Cubs are generally born around 6–8 weeks later in mid-December

It is estimated that the current Falklands population stands at over 10,000 adults, however no dedicated population census has been conducted in recent years. It is probable that there may have been a steady increase this century following its near extermination by the fur trade during the last century (*Munro, 2004*).

It can be seen from Figure 5.23 that fur seals have been observed within the vicinity of the Toroa drilling location.

Southern elephant seal (Mirounga leonine)

The southern elephant seal is the largest of all the pinniped species. Found in most sub-Antarctic waters, the Falklands hold only a very small percentage of the world population. Only one major breeding colony exists on Sea Lion Island and it is estimated to represent around 90% or more of the breeding population of the Falklands.

The elephant seal gets its name from both its massive size and from the large proboscis which males have. Males are much bigger than the females with bulls weighing around 2000—3000 kg and 3 metres in length compared to about 600–800 kg for females. Southern elephant seals breed from August to November with the bulls arriving weeks before the females to claim territories. Pups are born 0–10 days after the females come to shore.

Falkland Islands' elephant seals were almost hunted to extinction by sealers in the past. A population peak of around 3500 was recorded in the 1950's, but there are indications that the Falklands population has declined over the last few years. Elephant seals feed on fish and squid and impacts to the food source and environmental changes are key factors in population decline.

Leopard Seal (Hydrurga leptonyx)

The leopard seal is a winter visitor to the Falkland Islands, with only occasional sightings reported to Falklands Conservation. They are known to breed on sub-Antarctic pack ice and are highly unlikely to be impacted by normal offshore operations.

Leopard seals have dark grey backs and light grey stomachs. They get their name from their spotted throats. Females are generally larger than the males. The males are usually about 2.8 meters long and weigh up to 320 kg, while females are around 3 to 3.5 metres in length and weigh up to 370–400 kg.

Only the South American fur seal is likely to be spotted in the licence area to the south and east of the Falkland Islands and no species of pinniped is found in significant numbers in the Blocks.

5.3.9 Seabirds

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 region is well studied and documented, and seabird distribution, breeding and foraging patterns have been studied extensively. A number of publications outlining survey efforts by those such as Croxall et al. (1984), Woods (1988; 1997), Strange (1992) have recently been supplemented by ongoing seabird monitoring and survey programmes conducted by FC/JNCC such as the:

- Falkland Islands State of the Environment Report (*Otley et al., 2008*). This report documents the current knowledge of the Falkland Islands' environment.
- Origin, age, sex and breeding status of wandering albatrosses (*Diomedea exulans*), northern (*Macronectes halli*) and southern giant petrels (*Macronectes giganteus*) attending demersal longliners in Falkland Islands and Scotia Ridge waters, 2001 –2005 (*Otley et al., 2006*). The report summarises three years of survey work undertaken in Falkland Islands' waters between 2001 and 2005.
- Patterns of seabird attendance at Patagonian toothfish longliners in the oceanic waters of the Falkland Islands, 2001–2004 (*Otley, 2005*). The report summarises the surveys of seabirds attending Patagonian toothfish longliners during line setting and hauling activities in deepwater to the east of the Falkland Islands made between July 2001 and June 2004.
- The distribution of seabirds and marine mammals in Falkland Islands' waters (*White, 2002*). The report summarises three years of survey work undertaken in Falkland Islands' waters between February 1998 and January 2001.
- Vulnerable concentrations of seabirds (*White et al., 2001*). The report summarises two years of survey work in the form of a vulnerability atlas, with the aim of highlighting the locations of seabird concentrations that would be the most vulnerable to the effects of surface pollution.

These reports have been used extensively to provide a synopsis of seabird species, numbers, locations and sensitivities, and the information presented below and in the following sections has been based on these sources.

Between 1998 and 2001 a total of 218 species were recorded along with some unconfirmed sightings and have been included within this list. There were 21 resident landbirds, 18 waterbirds, 22 breeding seabirds, 18 annual non-breeding migrants and at least 139 occasional visitors (*Woods et al., 2004*). 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, 2005*).

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

A search of the BirdlLife International website for the IUCN Red List aves in the Falkland Islands, found 10 species as either ‘Endangered’ or ‘Vulnerable’, and a further seven as ‘Near Threatened’ species’ (Appendix E).

Penguins

Nine penguin species have been recorded in the Falkland Islands with the following six species identified during the at-sea survey period (1998–2001) (Figure 5.24). Of these, only the Chinstrap penguin (p. *Antarctica*) is not considered to be a locally breeding species.

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

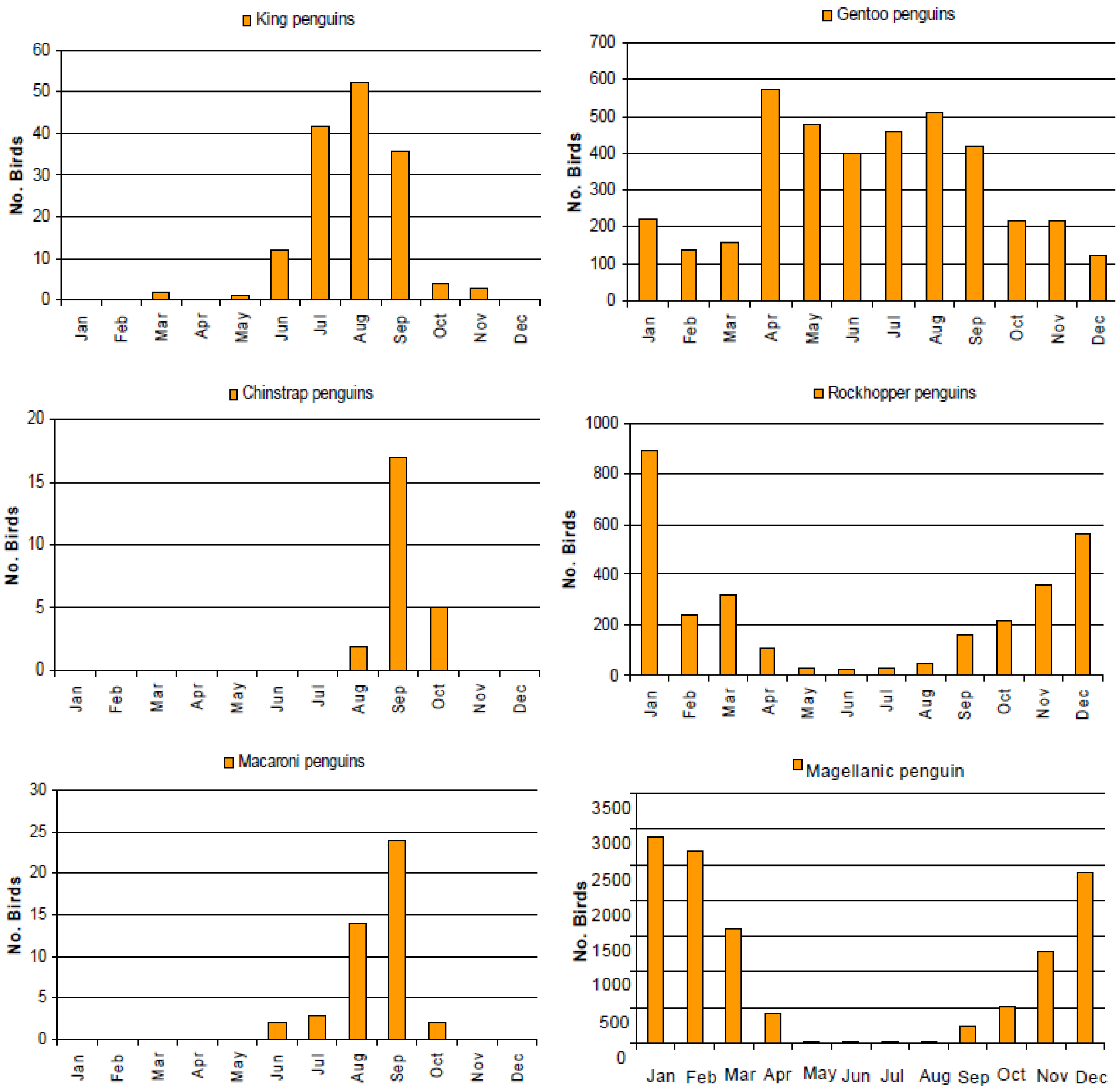


Figure 5.24 Penguin Numbers Recorded per Month (JNCC, 2002)

King Penguin (Aptenodytes patagonicus)

The Falkland Islands population of king penguin is almost entirely concentrated at Volunteer Point, although a few individuals can be found nesting amongst gentoo penguins at four to six locations within the Falklands (*Huin, 2007*). The 2005/2006 Penguin Consensus observed 260 chicks at Volunteer Beach (*Huin, 2007*). From the 1980s to 2001, the Volunteer Beach breeding population was estimated at between 344–516 breeding pairs increasing at additional 12–15 chicks per year. This increase has somewhat slowed over the past three years (*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, particularly to a polluting event.

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

The majority of king penguin records occur to the north of the Falkland Islands between June and September (Figure 5.24). Distribution maps also show scattered sightings to the south and east of the Falkland Islands, including within the licence area, primarily between June and September with a very small number of sightings between October and May.

Gentoo penguin (Pygoscelis papua)

The gentoo penguin is numerous and widely distributed throughout the Falkland Islands, although most are found around West Falklands 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 and represents, of the 12 major breeding regions, the second largest gentoo population in the world after South Georgia (*Huin, 2007*). 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 show that the birds remain in predominantly inshore waters, preferring low coastal plains close to a sand or shingle beach and an open ocean free of kelp, although in winter foraging trips may be undertaken up to 300 km from the coast.

A total of 3,896 gentoo penguins were recorded during 1998 to 2001, covering all months but with an increase between April and September (Figure 5.24). They are only likely to be found outside coastal waters between April and November, with densities in offshore areas generally low.

There were no records of gentoo penguins within the licence area and the predominance in near-shore areas makes it unlikely this species would be encountered in the vicinity of the proposed drilling operations.

Rockhopper penguin (Eudyptes chrysocome)

The rockhopper penguin *Eudyptes chrysocome* 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.

Rockhopper penguins are found in greatest numbers in the outer islands of West Falklands. There are around 52 breeding sites on the Falklands, with a population estimated at 211,000 breeding pairs in 2005/2006 (*Huin, 2007*). Three colonies of importance in the Falklands are on Beauchêne Island (31%), Steeple Jason (28%) and Grand Jason (5%). Forty-eight percent of the world's southern rockhopper population is found on islands in southern Chile, 29% on the Falklands and 24% in southern Argentina. The decline of the rockhopper population has lead to the IUCN classifying it as 'Threatened' (*BI, 2004*).

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. Tracking of rockhopper penguins has shown that they may enter the licence area on foraging trips.

Rockhopper penguins have been observed at significant distance from the Falkland Islands. Between December and March the majority of recorded sightings are from near-shore areas and to the west of the Falkland Islands, with very few scattered sightings within the vicinity of the proposed drilling operations. From September to November distribution is more widely spread across Falkland Islands' waters and scattered sightings are likely throughout BHPBP(F)C's licence area. Between April and August there are fewer sightings and these are primarily to the north and west of the Falkland Islands, with only occasional records within the vicinity of the proposed drilling operations (refer to Figure 5.24).

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 and suggests hybridisation may occur between the species (*White & Clausen, 2002*).

The macaroni penguin, however, 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 distribution of macaroni penguin is mainly to the north of the Islands, although there is a possibility of occurrence within the vicinity of the proposed exploration wells.

Magellanic penguin (Speniscus magellanicus)

The Magellanic penguin is less colonial than the other penguin species on the Falkland Islands and an estimated 200,000 breeding pairs over 90 locations on the Islands are thought to comprise one third of the world's population (*Thomas, 1993*). As a significant proportion of the world population, the Falkland Islands are internationally important for the Magellanic penguins.

In excess of 12,000 Magellanic penguins were recorded during the 1998–2001 at-sea surveys, the majority between November and April. Few were recorded between May and August, with the highest densities recorded between December and February, primarily in inshore waters. Some locally high densities were recorded over Patagonian Shelf waters and continental shelf slope waters to the north of the Falklands.

Penguin tracking has shown that they may travel through BHPBP(F)C's licence area during long foraging trips into deeper waters, although majority of sightings were recorded to the north of the Falkland Islands and in near-shore waters. Distribution offshore peaks between November and April, with fewer records between September and October and hardly any between May and August (refer to Figure 5.24). Occurrence within the licence area is possible between November and April, but not in significant numbers.

Chinstrap penguin (P. antarctica)

Chinstrap penguins do not breed in the Falkland Islands, however a total of 24 individuals were recorded on 10 occasions (1998–2001). All records occurred between August and October to the south east of the Falkland Islands. Occurrence in the vicinity of the proposed drilling activity is therefore possible over these months, but unlikely given the frequency of sightings.

Albatrosses

Albatross species are globally declining with populations in the Falkland Islands reported to have dropped by 28% in the last 20 years (Woods, 1988). Eleven species of albatross have been recorded in the Falkland Islands, although only the black-browed albatross is a resident breeding species.

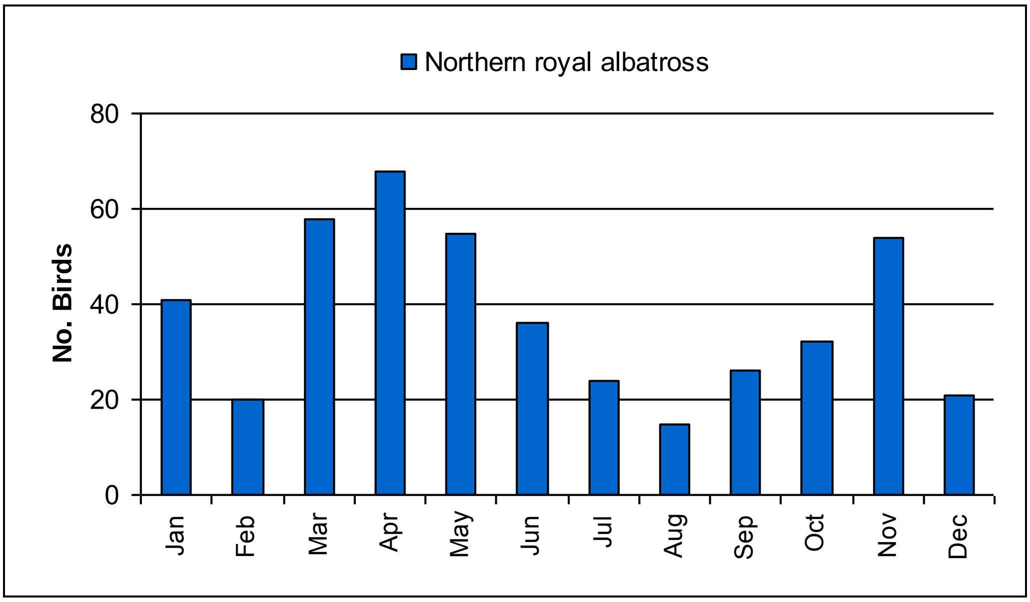
Ten of the 11 species of albatross recorded in the Falkland Islands are afforded conservation status, and include:

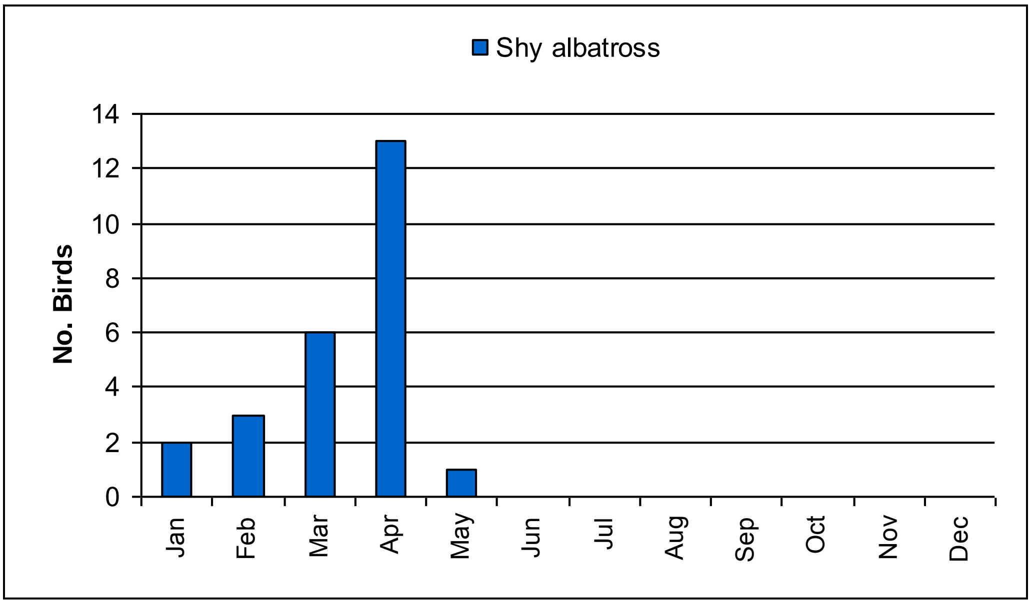
- Black-browed albatross (*Thalassarche melanophris*) – Endangered
- Buller's albatross (*Thalassarche bulleri*) – Vulnerable
- Grey-headed albatross (*Thalassarche chrysostoma*) – Vulnerable
- Light-mantled sooty albatross (*Phoebetricia palpebrata*) – Near Threatened
- Northern royal albatross (*Diomedea 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

The numbers of individuals of each species observed during the at-sea survey period (1998–2001) per month are shown in Figure 5.25, and are described in detail below.

Albatross Numbers Recorded per Month (*JNCC, 2002*)





Albatross Numbers Recorded per Month (*JNCC, 2002*)

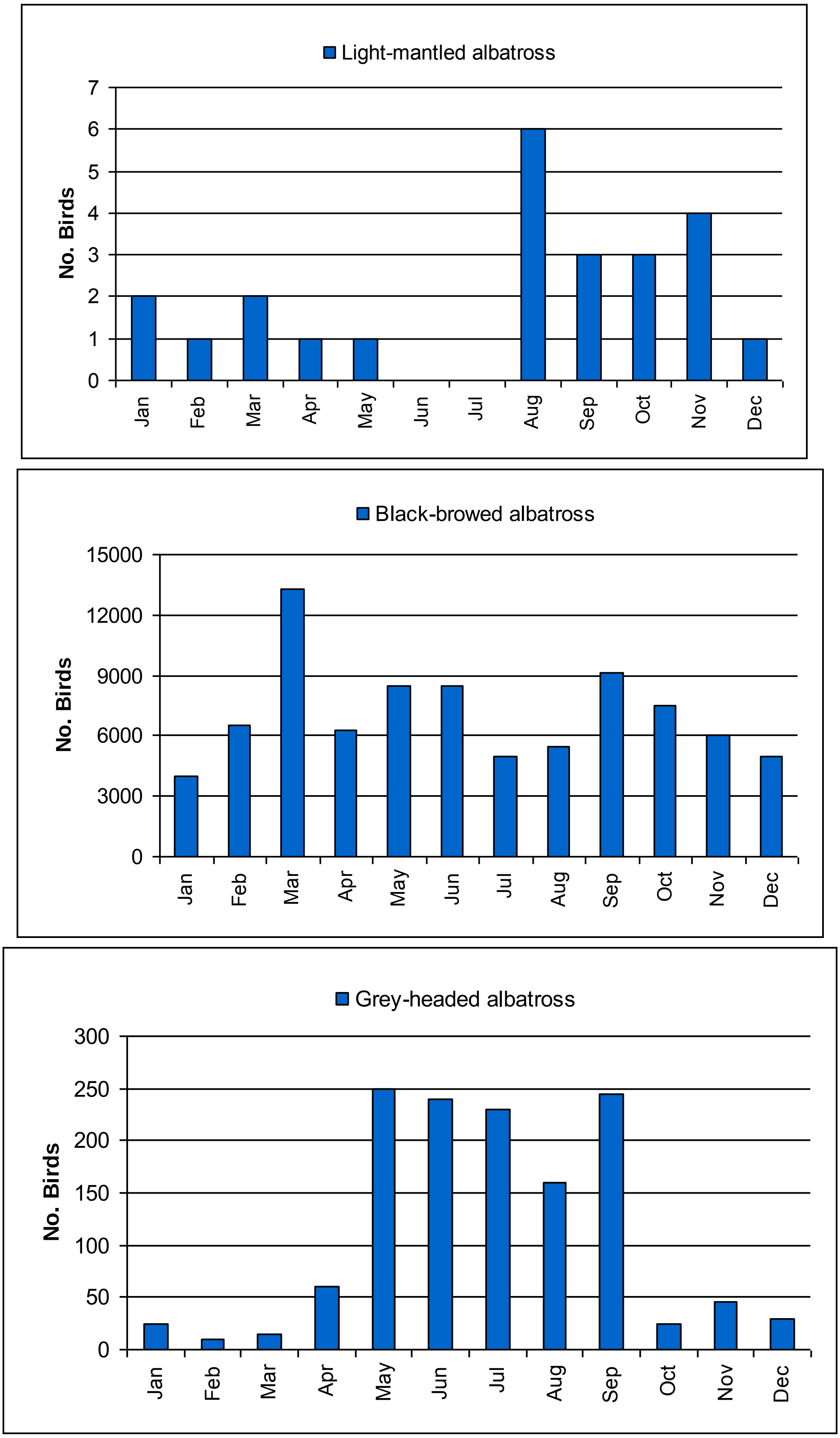


Figure 5.25 Albatross Numbers Recorded per Month (JNCC, 2002)

Black-browed albatross (Thalassarche melanophris)

The population 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 represents 70% of the world population, and makes the islands of critical importance for the conservation of this species. Black-browed albatross is now classified as ‘Endangered’ by Birdlife International and the IUCN Red List.

Black-browed albatross were recorded in all months (1998–2001), with a total of 84,614 birds recorded, reaching a peak in March. Between November and January the highest densities occurred in inshore waters to the west of the Falklands. Between February and June high densities occurred throughout Patagonian Shelf waters to the north-west of the Falklands and between July and October high densities shifted to the west and south-west of the Falklands (refer to Figure 5.25).

There is very low recorded distribution in the vicinity of the proposed drilling areas, although occasional sightings are likely, primarily between November and January but also at other times of the year.

Grey-headed albatross (Thalassarche chrysostoma)

Grey-headed albatross visit the Falkland Islands from breeding grounds in South Georgia and Diego Ramirez. The grey-headed albatross is classified as ‘Vulnerable’.

A total of 1321 grey-headed albatross were recorded, covering all months (1998–2001) with a peak between May and September. Distribution varied throughout the year, with records over the licence area occurring throughout the year but primarily between July and September (refer to Figure 5.25). Greatest numbers of grey-headed albatross occur to the south and west of the Falkland Islands and occurrence within the licence area to the east is not considered significant.

Light-mantled sooty albatross (Phoebetricia palpebrata)

The light-mantled albatross is also a non-breeding visitor from the South Georgia region where there are an estimated 5000–7000 breeding pairs.

In total 24 were recorded during the 1998–2001 at-sea survey, mainly between August and November and in waters deeper than 200 metres to the east of the Falklands. Occurrence within the vicinity of the proposed drilling activity is therefore probable, although due to the low numbers of sightings and widely scattered distribution, occurrence within close proximity to Loligo is not considered significant.

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

The royal albatrosses are also visiting species, breeding in New Zealand and using South Pacific and Patagonian feeding grounds. The southern royal albatross is classified as ‘Vulnerable’ where as the Northern is ‘Endangered’.

Of the 4,114 royal albatrosses recorded (1998–2001), 3252 were identified as southern and 447 as northern (with 415 not determined). Highest numbers of southern royal albatross were seen between March and June, particularly to the north-west of the Falklands. Highest numbers of northern royal albatross were seen between March and July (Figure 5.25).

Although occasional sightings of northern and southern royal albatross are probable within the vicinity of the proposed exploration wells to the south and east of the Falkland Islands, the predominance of sightings to the north-west indicates that occurrence within the licence area to the east is not significant.

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’.

Few shy albatross have been recorded in the Falkland Islands previously. A total of 25 were recorded during the 1998–2001 at-sea survey, all between January and May. The majority of records were from the north and west of the Falklands. A single recorded sighting was made within BHPBP(F)C's licence area and occasional sightings are possible between January and May, however this is unlikely and occurrence within the licence area is not considered significant.

Wandering albatross (Diomedea exulans)

The wandering albatross is a non-breeding visitor to the Falkland Islands, predominantly from breeding colonies in the South Georgia Islands around 1,300 kilometres to the east. The wandering albatross is classified as 'Vulnerable', as the population continues to decline with only 1,553 breeding pairs recorded in 2003–2004.

Wandering albatross were recorded by the at-sea surveys for all months, with a peak in November and highs between January and April (Figure 5.25). They were locally abundant in all deep waters surveyed, particularly to the east of the Falklands and are therefore likely to occur within the licence area.

Petrels and Shearwater

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 with nine species breeding on the Islands:

- Northern giant petrel (*Macronectes halli*)
- Southern giant petrel (*Macronectes giganteus*)
- Antarctic petrel (Thalassoica Antarctica)
- Cape petrel (Daption capense)
- Antarctic fulmar (Fulmarus glacialoides)
- Blue petrel (Halobaena caerulea)
- Kerguelen petrel (Pterodroma brevirostris)
- Soft-plumaged petrel (*Pterodroma mollis*)
- Atlantic petrel (Pterodroma incerta)
- Prion spp (Pachyptila spp)
- Grey petrel (Procellaria cinerea)
- White-chinned petrel (Procellaria aequinoctialis)
- Great shearwater (*Puffins gravis*)
- Sooty shearwater (*Puffins griseus*)
- Little shearwater (*Puffins assimilis*)
- Wilson's storm-petrel (*Oceanites oceanicus*)
- Grey backed storm-petrel (*Garrodia nereis*)
- Black-bellied storm-petrel (*Fregetta tropica*)
- White-bellied storm-petrel (*Fregetta grallaria*)
- White-bellied storm-petrel (*Fregetta grallaria*)
- Northern giant petrel (*Macronectes halli*)
- 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 at-sea distribution 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' (*BI, 2000*).

Giant petrels are divided between the northern and the southern, with only the southern giant petrel breeding regularly in the Falklands (population estimated at between 5,000 and 10,000 pairs (*Woods & Woods, 1997*)). In total 6,672 giant petrels were recorded in the at-sea survey (1998–2001), accounting for 3,535 southern and 751 northern giant petrel, with 2,386 recorded as unidentified giant petrel.

Southern giant petrels were recorded in all months during the at-sea survey, peaking in June and with highest densities between March and June over Patagonian Shelf waters to the west and 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 & Huin, 2005*). Most colonies concentrate around the south of South Falklands and to the west of West Falklands. Nearly 20,000 breeding pairs were counted in 2004/2005, which account for 40% of the global population (*Reid & Huin, 2005*). Although sightings within the licence blocks are possible, distribution is concentrated away from this area and occurrence within the BHPBP(F)C acreage is not considered significant.

Northern giant petrels were recorded throughout the year. Between March and August densities were highest to the north and west of the Falklands. From September to February sightings were less concentrated and more widely scattered. Northern giant petrels were less likely to be recorded in coastal or inshore waters. Although scattered sightings have occurred over the licence area, the principal distribution of northern giant petrel is to the north-west of the Falkland Islands between March and August. Due to the low distribution over the Blocks, occurrence is not considered significant.

A total of 56 Antarctic petrels were recorded, all between July and September in waters to the south and east of the Falklands. Antarctic petrels are winter visitors to the Falkland Islands. The distribution of Antarctic petrel sightings indicates that occurrence within the licence area is likely, although in low numbers and only during the austral winter when operations are less likely to be carried out.

Cape petrels were recorded every month, with a total of 15,199 records made over the survey. Highest numbers were recorded between May and September with very few records occurring between December and April. Distribution is primarily to the west of the Falkland Islands, although it becomes more widespread during October and November. There is a reasonable likelihood of occurrence within the licence area, although only in small numbers and the concentration to the west of the Islands indicates that this would not be of high significance.

A total of 18,061 Antarctic fulmars were recorded, all between April and December. Highest densities were recorded between April and June, dropping between July and October with only occasional sightings for the rest of the year. Only occasional records were made within the licence area and occurrence of this species is not considered significant.

Blue petrels, another non-breeding visitor to the Falkland Islands, were recorded in the period May to October. A total of 573 blue petrels were recorded, the majority in deep waters to the east and south-east of the Falklands. Occurrence within the licence area is considered likely, although only between May and November.

A total of 152 Kerguelen petrels were recorded, almost wholly between May and November and mainly in the deep waters to the north, east and south of the Falklands. Peak numbers were recorded in August. Distribution of Kerguelen petrel sightings was widespread and an occasional sighting within the licence area is likely, although the lack of any concentration of sightings makes this species less vulnerable to impacts.

Soft-plumaged petrels are non-breeding late summer visitors to the Falklands, with records occurring between November and April, peaking in January. In total, 861 soft-plumaged petrels were recorded, mainly in deep waters to the north-east of the Falkland Islands. There is a high chance of some occurrence to the east of the Falkland Islands and within the licence area, although with the main distribution to the north this is not considered to be significant.

A total of 252 Atlantic petrels were recorded, primarily between October and March but with records in all months. Most sightings were to the north-east and south-east of the Falklands in deep waters and occurrence of this species within the licence area is likely. The wide distribution of sightings decreases the potential impacts to this species from operations in any one area.

Due to the difficulty in identifying prions (small petrels) to species level at sea, most records from the survey were for ‘prion species’. A total of 119,610 records make prions the most numerous seabirds encountered during the survey, with the highest numbers recorded between September and January. Highest densities were recorded to the west, north and south of the Falklands. Although occasional sightings within the licence area are likely, due to the concentration of prion sightings outside of this area occurrence is not considered to be significant.

The fairy prion was identifiable at sea and has been recorded separately. In total 228 fairy prions were recorded, in all months except February, with peaks in April, August and October. This species was recorded primarily in continental shelf slope and oceanic waters. Distribution of the fairy prion is widely scattered and sensitivity in the licence area is not considered to be significant.

Grey petrels were recorded mainly between December and March, with peak numbers in February. A total of 45 grey petrels were recorded, all in deep waters to the north and east of the Falklands. Although widely distributed, grey petrels are more likely to be sighted to the east and south-east of the Falkland Islands and occurrence in the licence area is therefore significant over the austral summer.

The white-chinned petrel breed on the Falkland Islands and survey work from summers of 2004/2005 and 2005/2006 indicate that this accounts for less than 1% of the global population. A total of 8044 white-chinned petrel were recorded from the at-sea survey (1998–2001), encompassing all months but with the highest numbers between January and May. Most records were to the north and west of the Falklands. There were limited sightings to the east of the Islands and occurrence in the licence area is not considered to be significant.

Great shearwaters were recorded primarily between December and April during the at-sea survey, with almost none recorded between June and October. Total number of records was 6,468, mainly over shelf slope and oceanic waters to the north and east of the Falkland Islands. Although of importance at a local level, the population is not globally significant as an estimated five million breeding pairs are found on the Tristan da Cunha and Gough Island group. Distribution is widely scattered, primarily towards the north-east, and occurrence in the licence area is not considered to be significant.

Sooty shearwaters breed on the Falkland Islands, with a population estimated at 10,000 to 20,000 pairs (*Woods & Woods, 1997*). A total of 37,109 sooty shearwaters were recorded, mainly between September and March, peaking in October. Most records occurred throughout inshore waters of the Falklands and shelf to the east and south. Although some sightings are likely in the licence area over the austral summer, distribution is mainly concentrated in shallower waters and is not significant in the Blocks to the east. The population is not considered to be globally significant as the world population is estimated to be in the millions.

A total of 24 little shearwaters were recorded, all between December and April with a peak in March. All records came from waters to the north and east of the Falklands. Probability of sightings within the licence areas is small and abundance in the Blocks is not considered significant.

Of the six species of storm petrels previously recorded during the at-sea survey within Falkland Islands' waters, four species were recorded during at-sea surveys. Wilson's storm-petrel breeds on the Falklands with an estimated population in excess of 5000 pairs (*Woods & Woods, 1997*). A total of 21,019 Wilson's storm-petrels were recorded, mainly between October and June. Most records were to the west and north-west of the Falklands, although high densities also occurred to the north-east between November and February. New colonies were recently found at Steeple Jason in 2004 and South Jason in 2006 (*Otley et al., 2008*). Offshore abundance is concentrated away from the licence area and not considered significant in this area.

The Falkland Islands support between 1000 and 5000 breeding pairs of grey-backed storm-petrels (*Woods & Woods, 1997*). A total of 2758 grey-backed storm-petrels were recorded, mainly between September and March. Records occurred on all sides of the Falklands, with high densities recorded to the north of the Falklands from November to March. A few recordings were made within the licence area to the south-east, however occurrence is not considered to be significant.

Black bellied and white bellied storm-petrels were both recorded, primarily between December and February and in the deep waters to the north-east of the Falklands, outside of the licence areas. There were 205 records of black bellied storm-petrels and 23 of white bellied storm-petrels. Numbers of both species peaked in January. Occasional sightings of black bellied storm-petrels are likely to the east and south of the Islands, although the number of sightings is not considered significant.

A total of 6078 diving petrels were recorded during the at-sea survey, incorporating both the Magellan (133 confirmed) and common (753 confirmed) diving-petrel. The remainder were not specifically identified, but have been combined with common diving-petrel numbers for the purposes of the report. Most diving petrels were recorded between September and February, with greatest densities to the west and south of the Falklands. Occasional sightings of the common diving petrel are possible in the licence area throughout all months of the year, particularly between March and August, although the number is not considered to be significant.

Shags

Three species of shags 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*)) and the other (red-legged shag) is a vagrant (and was not recorded during the at-sea survey).

The population of rock shags is estimated at between 32,000 and 59,000 pairs (*Woods & Woods, 1997*). They are only found in the Falkland Islands and South America. A total of 796 rock shags were recorded during the at-sea survey, peaking in July and mainly within enclosed or partially enclosed waters. All rock shags were recorded within 27 kilometres of the coast, with evidence of birds remaining closest to the coast during summer. Occurrence of rock shags within the offshore licence area is therefore not considered to be significant.

The population of imperial shag in the Falkland Islands is estimated at 45,000 to 84,000 breeding pairs (*Woods & Woods, 1997*). A total of 39,264 imperial shags were recorded during surveys, 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 within the offshore licence area is therefore not considered to be significant.

Swans, Geese and Ducks

Twenty-one species of swans, geese and ducks have been recorded in the Falkland Islands including fourteen native and one introduced species breeding in the wild: black-necked swan, coscoroba swan, ashy-headed goose, ruddy-headed goose, upland goose, kelp goose, feral goose, crested duck, Falkland Islands flightless streamer duck, flying steamer duck, yellow-billed teal, Chiloe wigeon, yellow-billed pintail, silver teal and cinnamon teal (*Woods & Woods, 1997*). Most species are likely to be found in coastal areas, and are migratory.

Only one species of duck was recorded during the at-sea survey off the Falkland Islands; the Falkland Steamer duck (*Tachyeres brachydactyla*).

The Falkland Steamer duck is endemic to the Falklands with an estimated of between 9,000 and 16,000 pairs (*Woods & Woods, 1997*). A total of 699 Falkland Steamer ducks were recorded during the at-sea survey, however all records were made in coastal waters with peak numbers recorded in April, tailing off to nil in December. Occurrence within the offshore licence area is therefore not considered to be significant.

Skuas Stercorariidae

Five species of skua have been recorded in the waters of the Falkland Islands, of which one species breeds on the Falklands and four species were observed during the at-sea surveys:

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

The Falkland Islands support a population of between 5,000 and 9,000 pairs of Falkland skua, the majority of the world population of this subspecies. Of the 737 Catharacta skuas recorded during the at-sea survey, 573 were recorded as Falkland 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. A few birds were sighted May to October offshore to the north of the Falkland Islands.

Arctic skuas are summer visitors to the Falkland Islands and only 35 were recorded over the at-sea survey period between January and April in inshore waters and deeper waters to the north of the Falklands.

Long-tailed skuas were recorded in the waters off the Falkland Islands between November and April. A total of 239 long-tailed skuas were recorded, mainly in deep waters to the north and north-east of the Falklands, outside of the licence areas.

Distribution of skuas is concentrated away from the licence area and occurrence of skuas in the offshore Blocks to the south and east of the Falkland Islands is expected to be rare. Occurrence within the vicinity of the proposed drilling activity is therefore not considered to be significant.

Gulls Laridae

Seven species of gull have been recorded in the Falkland Islands, of which the following three species are known to breed in the Falklands (listed above) and were recorded during the at-sea surveys:

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

The Falkland Islands population of dolphin gulls is estimated at between 3,000 and 6,000 pairs (*Woods & Woods, 1997*). Accounting for 85% of the world population, the Falkland Islands' population is of global importance. A total of 114 dolphin gulls were recorded during the at-sea survey on 60 occasions for all months except March and peaking in July. Distribution was concentrated in coastal waters and no gulls were recorded more than 20 kilometres from the coast.

The Falkland Islands kelp gull population is estimated at between 24,000 and 44,000 pairs (*Woods & Woods, 1997*). A total of 2,288 were recorded during the at-sea survey, covering all months and peaking June to September. Records between November and April were primarily close to shore, whereas records from May to October were more widespread over Patagonian Shelf and continental shelf slope waters, although very rarely in deep waters.

The Falkland Islands brown-hooded gull population is estimated at between 1,400 and 2,600 pairs (*Woods & Woods, 1997*), compared to a global population of approximately 50,000 pairs. A total of 134 brown-hooded gulls were recorded during the at-sea survey over 69 occasions, covering all months with the highest recorded number in January. The majority of records were made within 10 km of the coast, with a recorded maximum of 53 kilometres from the coast.

The distribution of all gull species is concentrated on the coastal zone and near-shore area. Occurrence of gulls within the vicinity of the proposed drilling activity is therefore not considered to be significant.

Terns Sternidae

Three species of tern were recorded during the at-sea survey (listed below), although eight species have been previously recorded in Falkland Islands' waters (*Otley et al., 2008*) of which only one species is known to breed in the Falklands:

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

A total of 1894 South American terns were recorded during the at-sea survey for all months and peaking March to April. The South American tern is the only species known to breed in the Falkland Islands. Distribution was mainly in coastal waters.

Arctic terns are a summer visitor to the Falklands. A total of 21 Arctic terns was recorded during the at-sea survey, all between October and March. They were observed widely distributed throughout the at-sea survey area, mostly in offshore areas. A number of unidentified sterna terns were also recorded during the at-sea survey. Of the 160 unidentified terns recorded in offshore waters, the majority were between April and November. Distribution was widely scattered although very few sightings were made to the south-east of the Falkland Islands. No tern species have significant abundance or distribution within the licence area, although occasional sightings are possible.

Rare Seabirds

Less than ten sightings of the below listed seabird species were recorded during the at-sea surveys. Due to the low numbers observations, modelling of spatial or monthly distribution is not considered meaningful.

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

5.3.10 Seabird 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 Falkland Islands' waters, negative impacts on seabird productivity through competition for food with commercial fisheries have not yet been identified (*White, 2001*). Death from entanglement and snagging with longline hooks is considered to be of low risk due to a well managed fishery and a relatively low amount of longlining.

To date, reports of adverse effects to seabirds from surface pollution such as oil is low in the Falkland Islands. Hence, the increasing oil and gas exploration activities in the area are a potential threat to seabird populations.

The following information has been sourced from '*Vulnerable Concentrations of Seabirds in Falkland Islands Waters' (1998–2000)*, a report produced by the JNCC under contract to Falklands Conservation, with funding support from the FIG.

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 and well documented (*White et al., 2001*) and are not expanded upon further here.

A summary of the seabird vulnerability survey results for each month of the year, focusing on the BHPBP(F)C licence area is given below with monthly vulnerability of seabird concentrations to surface pollution illustrated in Figure 5.26.

Seabird vulnerability in January is highest in coastal and Patagonian Shelf waters. Small petrels (prions, storm-petrels, diving-petrels and shearwaters) are the main species.

Vulnerability in the vicinity of the proposed Loligo and Toroa exploration wells is low to medium over January and February with coverage decreasing between March and May before showing renewed patches of low to medium vulnerability from June through to the end of the year. There is a small patch of high vulnerability visible within the licence area in September, although overall the area to the south and east of the Falkland Islands is removed from areas of high sensitivity and are some of the least sensitive areas within the Falklands Conservation Zone.

Based on the findings of this survey and the conclusions presented in the publication (*White et al, 2001*), the Austral summer months of December through to February have the highest overall vulnerability for the seabird species in the waters surrounding the Falklands. July and the winter months are the period of lowest overall vulnerability. Highest vulnerability coincides with the breeding season for most seabird species on the Falklands.

Concentrations of seabirds in coastal waters are more vulnerable to the effects of surface pollution than in all other areas. Although this summary concentrates on the proposed operational locations, the Falkland Islands' coastline has been included on the adapted maps of seabird vulnerability (Figure 5.22) to account for the potential spread of oil spills towards the coastline, particularly smaller spills from near-shore activities or during bunkering operations in port.

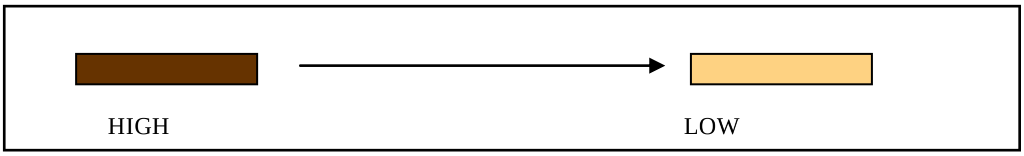
The vulnerability atlases show inshore waters to be particularly important for all months of the year, largely due to the presence of resident species with a predominantly coastal distribution such as the endemic Falklands Steamer duck, imperial shag and gentoo penguin.

Other areas of importance to seabirds are the Patagonian Shelf waters to the north and west of the Falklands, which support high densities of black-browed albatrosses and royal albatrosses year-round. Low densities of seabirds encountered in deep waters areas generally result in low to moderate vulnerability for all months (*White et al., 2002*).

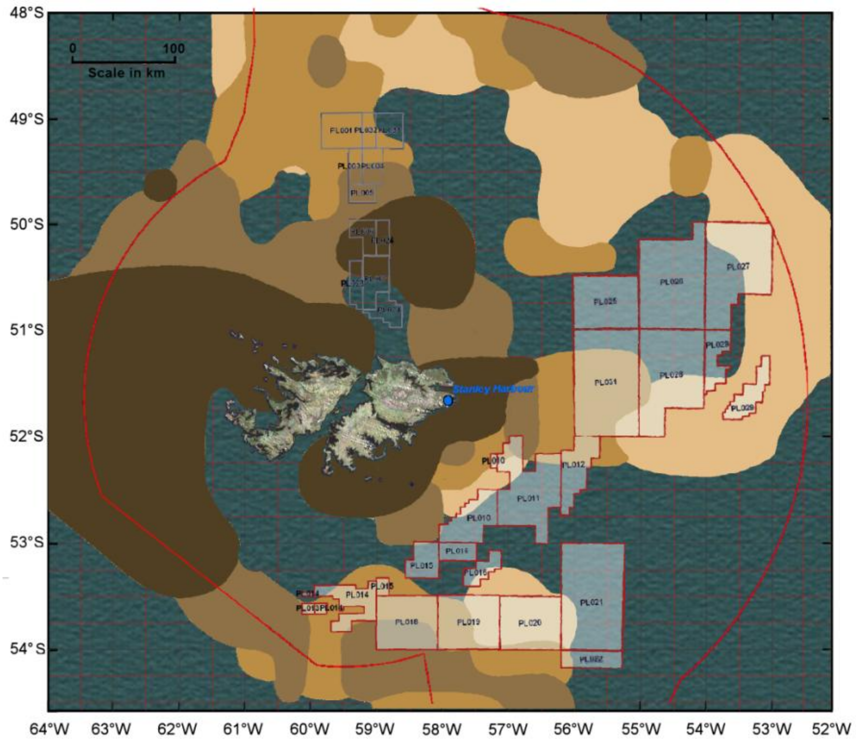
Oiled seabirds were recorded for all three survey years, peaking between March and October, and coinciding with the period of highest shipping activity. Many seabirds migrate through the Patagonian Shelf waters, so surface pollution in other areas may also have an impact on Falkland Islands' populations. An estimated 40,000 penguins die from oil pollution on the coast of Argentina each year due to chronic oil pollution such as the discharge of oily waste from ballast tanks.

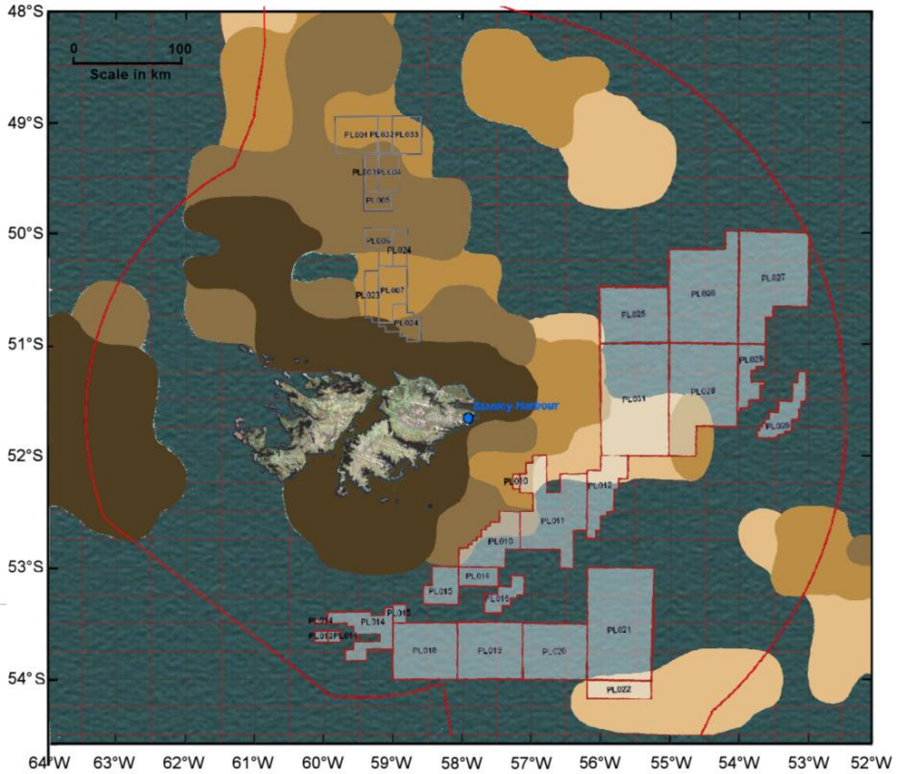
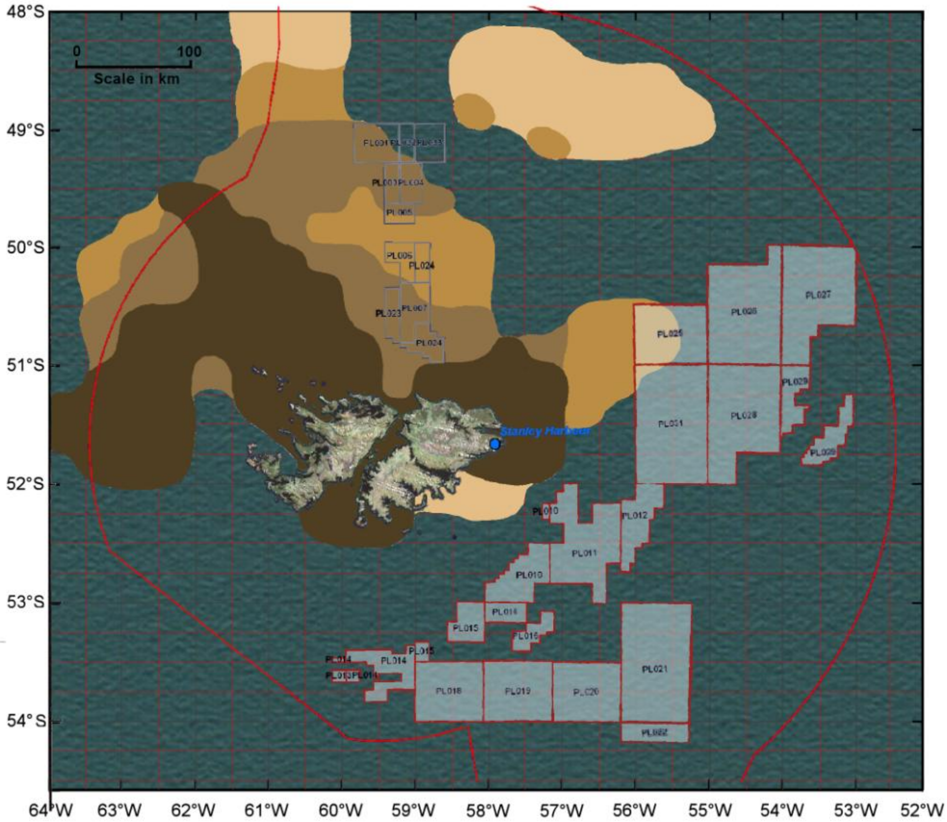
In White et al. (2002) hydrocarbon exploration is only one of the threats facing seabird populations at sea and awareness of problems for the albatross and petrel populations from interactions with fisheries in the Southern Oceans is growing.

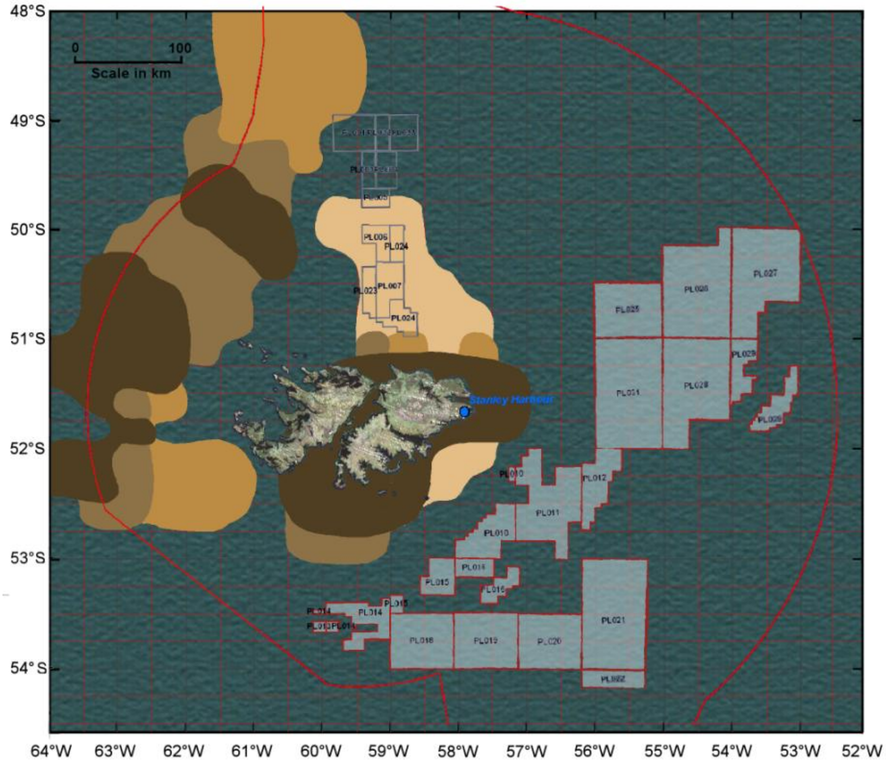
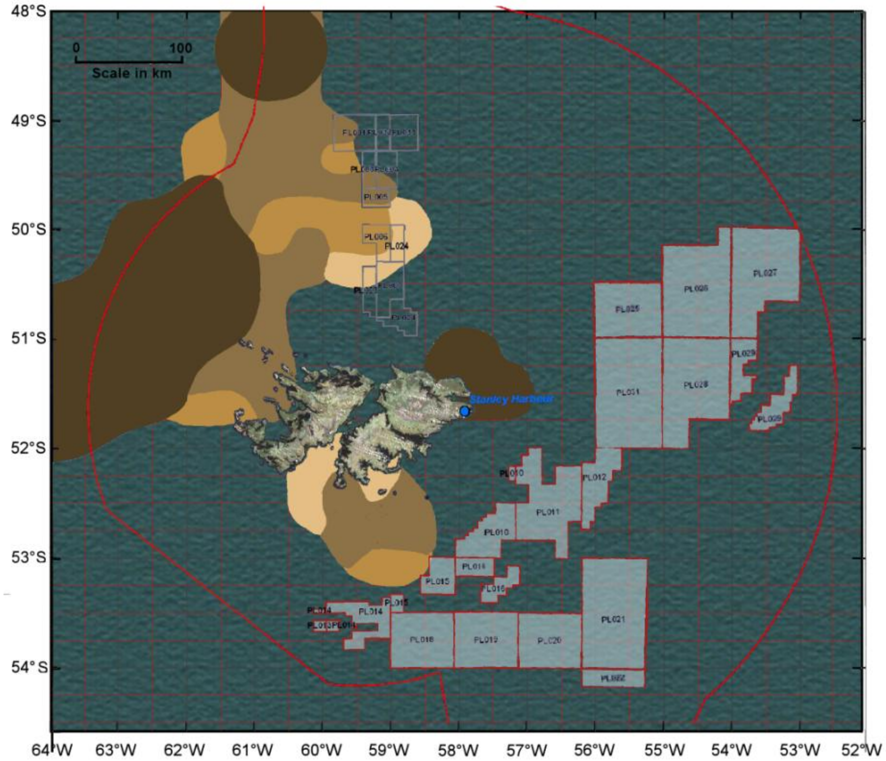
Seabird Vulnerability Mapping: Key

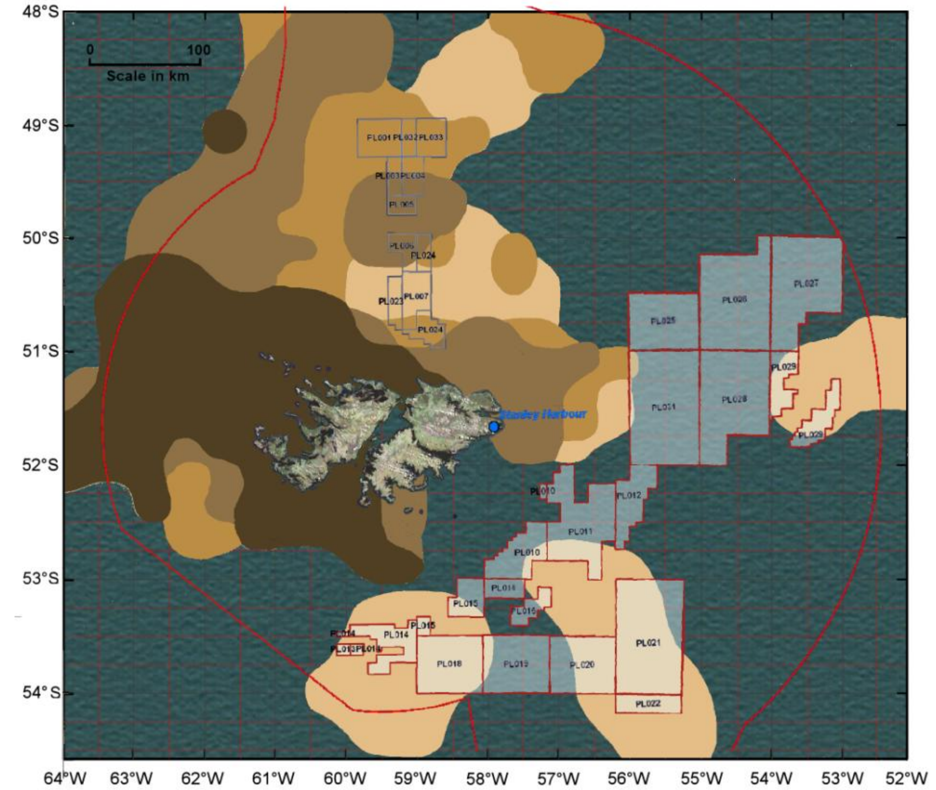
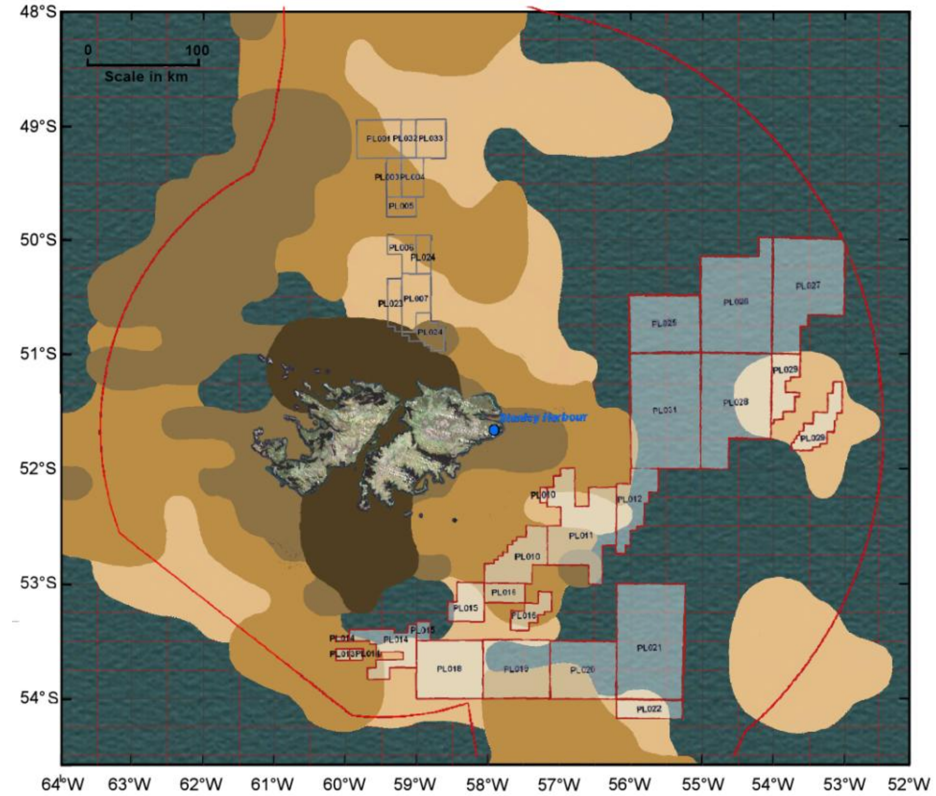


Vulnerability of seabirds to surface pollution is depicted in four shades ranging from pale (lowest vulnerability) to dark (highest vulnerability) as shown in the key above.

January	

February	
March	

April	Scale in km 0 100 48°S 49°S 50°S 51°S 52°S 53°S 54°S 64°W 63°W 62°W 61°W 60°W 59°W 58°W 57°W 56°W 55°W 54°W 53°W 52°W Stanley Harbour
May	Scale in km 0 100 48°S 49°S 50°S 51°S 52°S 53°S 54°S 64°W 63°W 62°W 61°W 60°W 59°W 58°W 57°W 56°W 55°W 54°W 53°W 52°W Stanley Harbour

June	
July	

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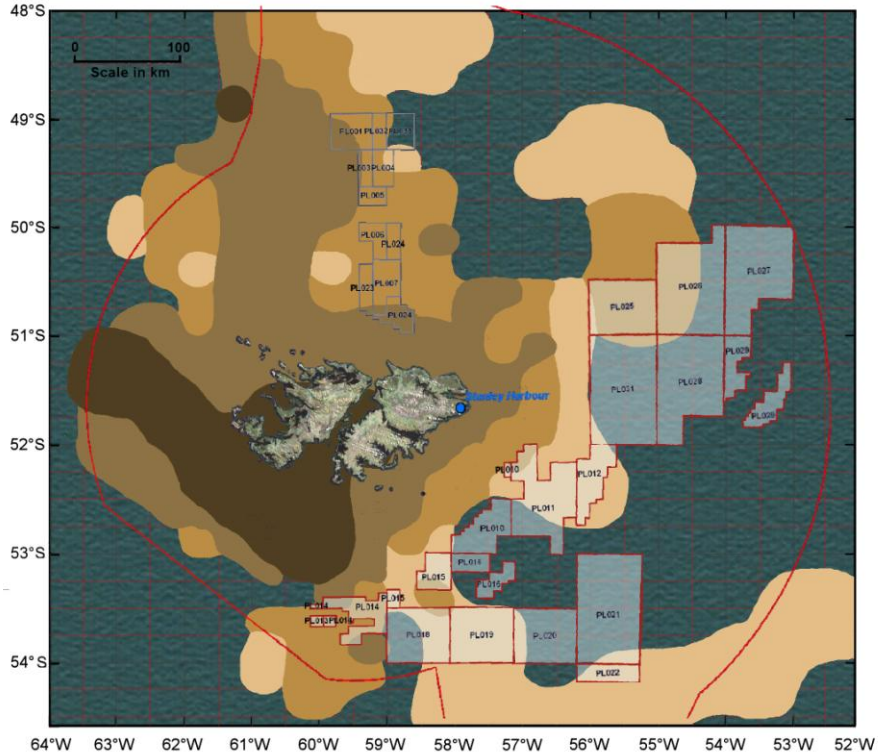
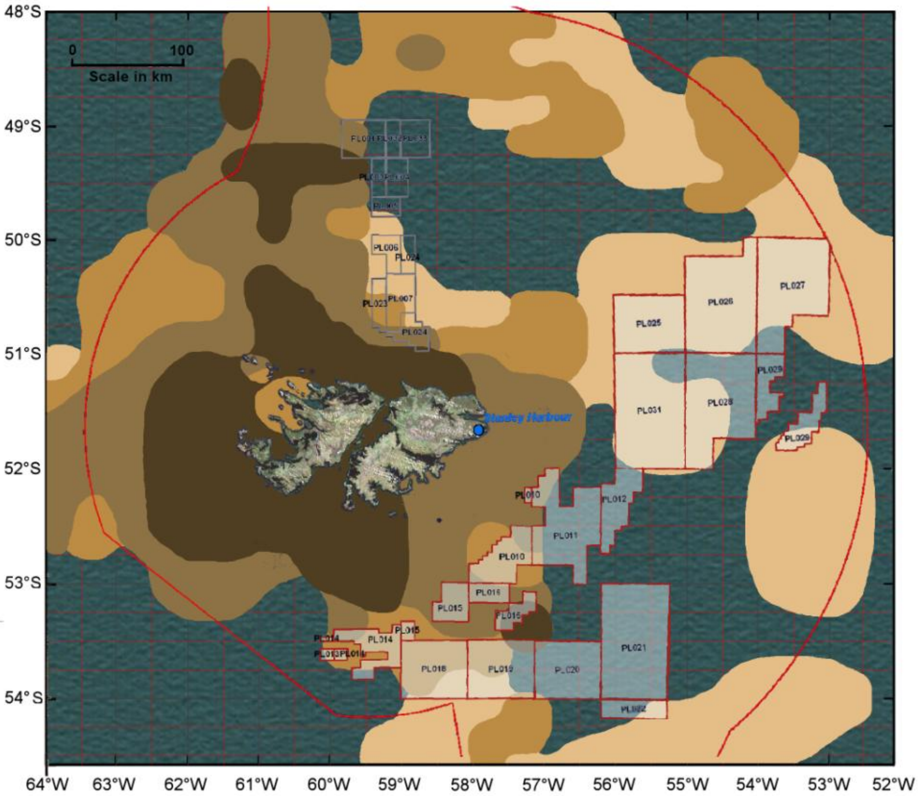
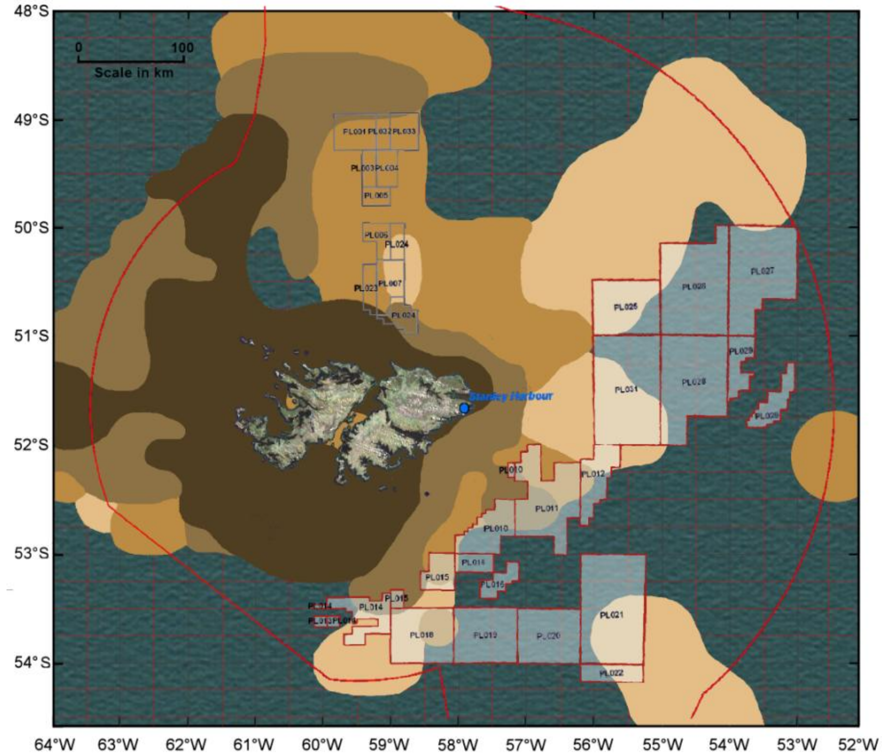
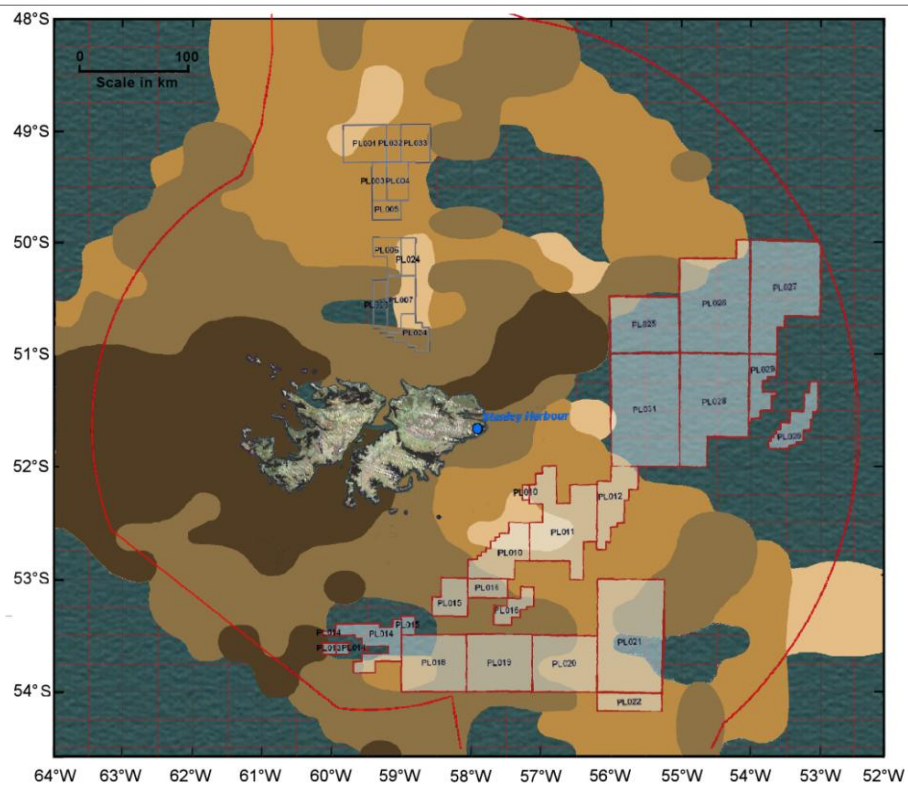
August	
September	

October



November



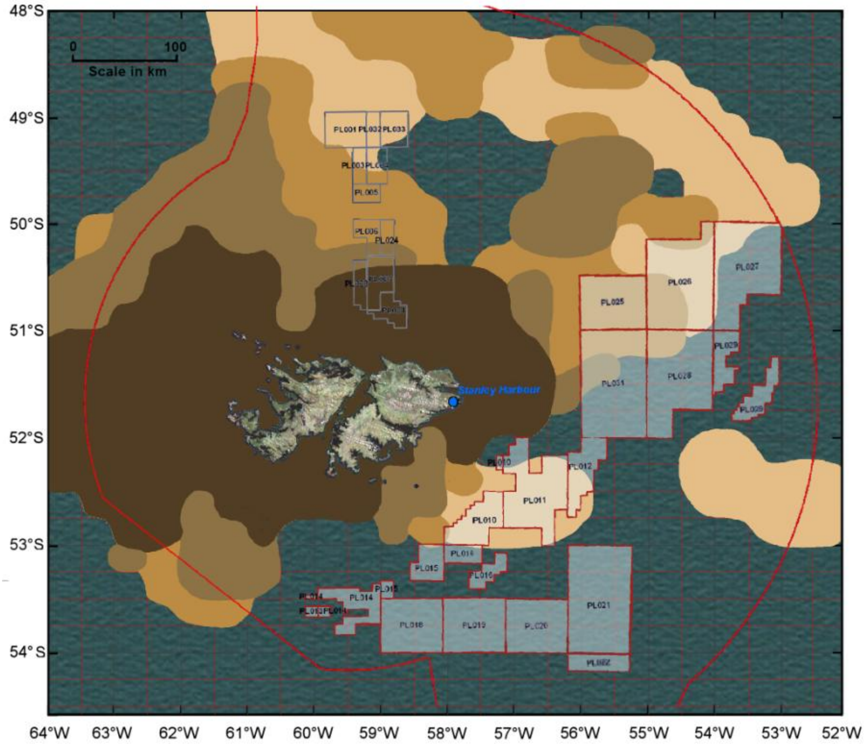
December	

Figure 5.26 Monthly Vulnerability of Seabird Concentrations to Surface Pollution (1998-2000)

5.3.11 Threatened Species

The IUCN Red List is a comprehensive listing of all species within the Falklands marine environment which are characterised as 'endangered', 'threatened' or 'vulnerable' to 'extinction'.

A search of the Red List found 43 species recorded as threatened, and 31 classified as 'Least Concern'[1]. Most pinnipeds are of the latter category. There were seven species (two cetaceans and five birds) listed as endangered – the highest level of conservation status.

Overall the Red List results included:

- 17 species of cetaceans;
- 2 species of fish;
- 24 species of birds.

The list of species identified as under threat by IUCN is given in Appendix F.

5.3.12 Protected Habitats and Areas

Three types of formal designation operate in the Falkland Islands:

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

Although the FIG can designate marine reserves, to-date no marine NNR has been created in the Falkland Islands. The proposed well locations are within the designated petroleum exploration and

[1] A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

production licence blocks held by BHPBP(F)C and FOGL, and the area is unlikely to be designated a marine NNR in the future.

Existing Nature Reserves were designated under the Nature Reserves Ordinance 1964 and Sanctuaries designated under the Wild Animals and Birds Protection Ordinance 1964 are now designated as NNR and Nature Reserves respectively (Table 5.7).

Table 5.7. Protected Areas

Date		Order	Designated Area
Nature Reserve Orders (now National Nature Reserves)	1964	Nature Reserves (Kidney & Cochon Islands) Order 1964 (1/64)	Cochon Island 51° 36'S 57° 47'W Kidney Island 51° 38'S 57° 45'W
	1966	Nature Reserves (Flat Jason Island) Order 1966 (2/66)	Flat Jason 51° 06'S 60° 53'W
	1969	Nature Reserves (Bird Island) Order 1969 (4/69)	Bird Island 52° 10'S 60° 54'W
	1973	Nature Reserves (Crown Jason Islands) Order 1973 (10/73)	Elephant Jason 51° 09'S 60° 51'W South Jason 51° 12'S 60° 53'W North Fur Is. 51° 08'S 60° 44'W South Fur Is. 51° 15'S 60° 51'W Jason East Cay 51° 00'S 61° 18'W Jason West Cay 50° 58'S 61° 25'W The Fridays 51° 03'S 60° 58'W White Rock 51° 17'S 60° 53'W Seal Rocks 51° 07'S 60° 48'W
	1978	Nature Reserves (Sea Dog & Arch Islands) Order 1978 (2/78)	Sea Dog Island 52 00'S 61 06'W Arch Islands 52 13'S 60 27'W (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, 51° 15'S 60° 38'W Adjacent to Carcass Island, West Falklands
	1964	Wild Animals & Birds Protection (Sanctuaries) (Low Island) Order 1964 (3/64)	Low Island, 51° 19'S 60° 27'W Adjacent to Carcass Island, West Falklands
	1964	Wild Animals & Birds Protection (Sanctuaries) (Beauchene Island) Order 1964 (4/64)	Beauchene Island, 52° 54'S 59° 11'W
	1966	Wild Animals and Birds Protection (Sanctuaries) (Middle Island) Order 1966 (4/66)	Middle Island, 51° 38'S 60° 20'W 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. 51° 29'S 57° 50'W
	1968	Wild Animals and Birds Protection (Cape Dolphin Sanctuary) Order 1968 (12/68)	Extreme end of Cape Dolphin. 51° 15'S 58° 51'W
	1970	Wild Animals & Birds Protection (Bleaker Island Sanctuary) Order 1970 (3/70)	Bleaker Island north of Long Gulch. 52° 18'S 58° 51'W
	1973	Wild Animals & Birds Protection (Stanley Common and Cape Pembroke Peninsula Sanctuary) Order 1973 (1/73)	Stanley Common & Cape Pembroke. 51° 43'S 57° 49'W
	1993	New island South Sanctuary Order 1993 (14/93)	New Island South 51° 43'S 61° 18'W
	1996	Moss Side Sanctuary Order 1996 (26/96)	Pond and sand-grass flats behind Elephant Beach (Top Sandgrass Camp & Sorrel Pond Camp). 51° 23'S 58° 49'W
	1998	Narrows Sanctuary Order 1998 (53/98)	Narrows Farm, West Falklands. 51° 41'S 60° 19'W
	1998	East Bay Sanctuary Order 1998 (54/98)	East Bay Farm, West Falklands 51° 48'S 60° 13'W

Date		Order	Designated Area
	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 57°50'W 51°44'S
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

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 IBA's 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. Of the 22 identified sites 17 consist of islands and island groups and four are situated on the main islands of East or West Falklands. There is currently no extension of IBA's to marine areas. The 22 IBA sites are:

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

5.4 Social and Economic Environment

The information for the following sub-sections is based on the last census undertaken in 2006, sourced from the Foreign and Commonwealth Office (FCO). The population of the Falklands was recorded as 2955[2] with the majority living in the capital, Stanley. An additional 2,478 military personnel are located at the Mount Pleasant Complex (MPC). Christianity is the major religion on the Falklands.

5.4.1 Economy

The general economic characteristics of the Falkland Islands are summarised below:

Gross Domestic Product:	£70 million (2001)
Gross Domestic Product per Head:	£24,030 (2001)
Annual Growth:	2% (estimated)
Inflation:	3.5% (estimated)
Major Industries:	Fisheries, tourism and agriculture
Major Trading Partners:	United Kingdom, Spain and Chile
Exchange Rate:	UK£1 = FI£1

The economy of the Falklands 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 fisheries. The Falklands have received no aid from Britain since 1992 and are now self-sufficient in all areas except defence (*FCO, 2007*).

The three largest industries are agriculture, tourism and commercial fisheries, which are discussed in the below sections. Statistics for 2005/2006 indicate that £16.1 million revenue was bought in by the Fisheries industry, followed by £14.6 million from retail sales.

A workforce of approximately 2,492 exists in the Falklands, with the FIG the largest employer, employing around 500 people. The fisheries, tourism, infrastructure development and retail industries are quickly growing and employing more people.

Agriculture

Agriculture remains a large industry on the Falklands, and the FIG funded modern abattoir meets EU standards and hopes to capitalise on the Falklands' certification as an organic country (*FCO, 2007*).

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 Falklands' unique environment and wildlife.

Passenger numbers in recent years on cruises to the Falklands have increased significantly, and are predicted to continue to increase. In the 2006/2007 tourist season 51,000 cruise ship passengers visited the Falkland Islands, rising to 62,000 in the 2008/09 season. 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 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 Falklands. In Stanley, there is only one hotel (the Malvina House) and a choice of guest house and bed & 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

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[2] This figure includes persons present in the Falkland Islands in connection with the military garrison, but exclude all military personnel and their families (*Census 2006*)

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.

Fisheries and Aquaculture

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 FIG. The fisheries generate over £21 million per annum in licence fees, roughly half the government revenue. Since 1990 Britain and Argentina have worked together to conserve fish stocks under the auspices of a UK/Argentine South Atlantic Fisheries Commission (*FCO, 2005*). Approximately £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 the Falkland Islands 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*)
- Red cod (*Salilota australis*)
- Skates & rays (*Rajidae*)

The key catches are the squid species: *Illex argentinus* and *Loligo gahi*, followed by the southern blue whiting (Figure 5.27). Approximately 2.4 MT of Illex, 1.2 MT of Loligo, and 20,500 tonnes of southern blue whiting were caught in 2006.

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 had been in decline since 2002, but resurged in 2006 after oceanographic conditions returned to normal following years of warm anomalies. Seasonal jigging fishery for the Illex takes place between February and June and is concentrated over the Patagonian Shelf to the north and west of the Falklands. The trawl fishery for Loligo squid operates between February and May and between August and November off the east coast of the Falklands.

The FIG annual Fisheries Statistics volume 11 (1997–2006) indicate that the offshore licence areas are not within any large catch (by volume) locations for the key species (Figure 5.28 to Figure 5.32). No key target species are caught in the licence areas.

In 2006, 194 fishing licences were issued predominantly for the squid and finfish species. Previous licence allocations varied from 372 in 1989 to 205 in 2005. The majority in 2006 were issued to fleets from the Falkland Islands, Spain and Korea.

To protect against poachers, the waters are patrolled by FIG aircraft and a fishery protection vessel.

Aquaculture in the Falkland Islands is relatively new with salmon fish-farming trialled in the early 1990s. Although commercial growth rates could be achieved, no external market for Falkland Islands grown salmon was found. Mytilus edulis chilensis, native blue mussel, is farmed in the Falklands over an area covering 22 ha and approximately 20 tonnes of mussels are on ropes at any one time (Otley et al., 2008). Pacific oysters (Crassostrea gigas) are farmed over approximately 200 ha at Darwin in the Falkland Islands for the local market (*Otley et al., 2008*).

The mussel and oyster farming is currently small-scale, although the aquaculture industry has been identified as a potential economic diversification sector (*Otley et al., 2008*).

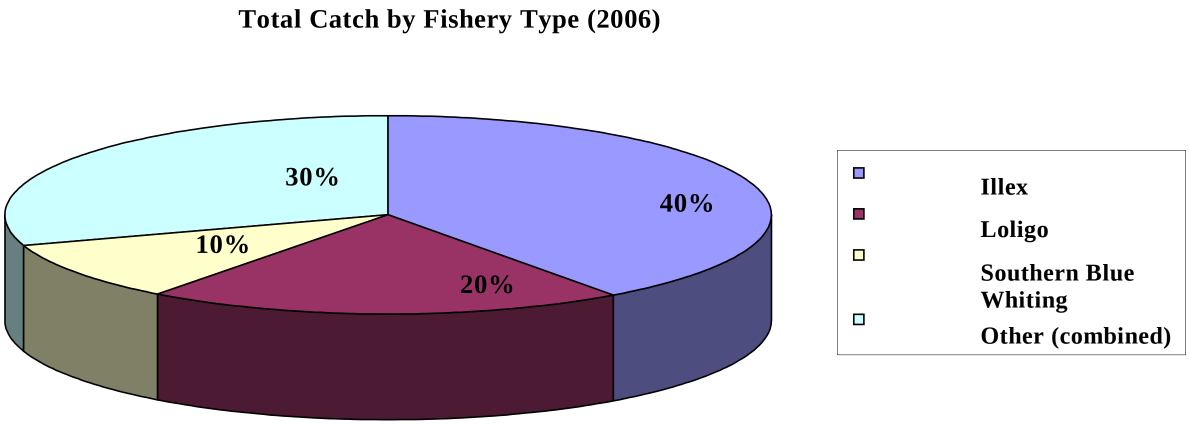

Figure 5.27 Total Catch by % and Fishery Type in the Falkland Islands for 2006

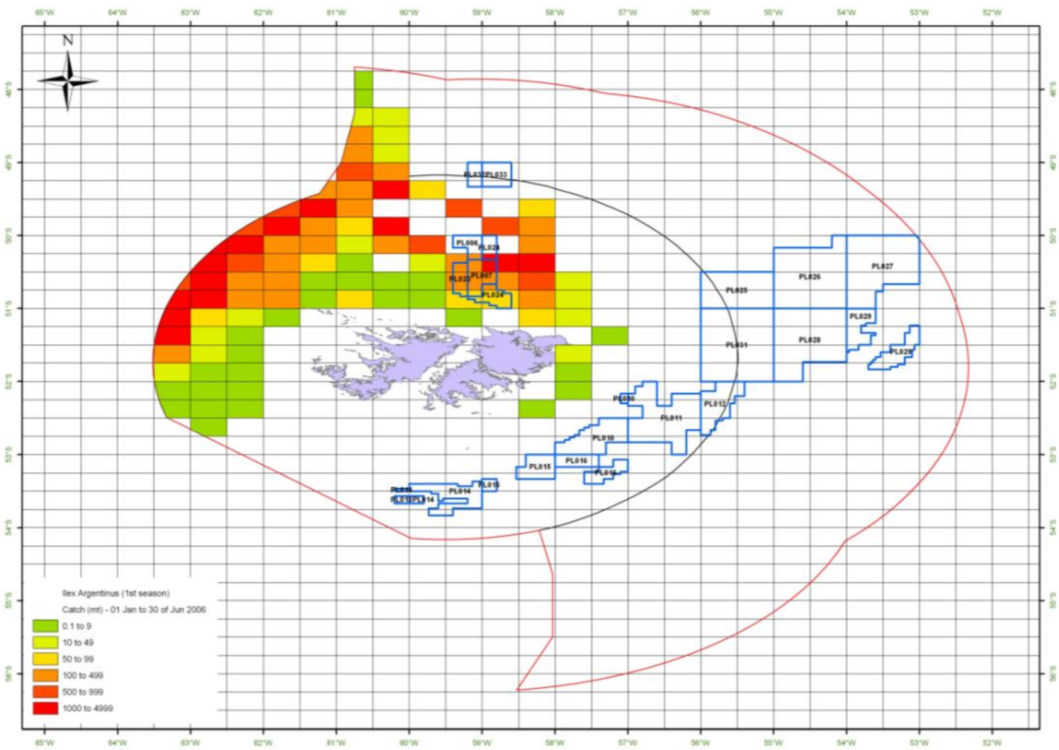

Figure 5.28 Illex argentinus catches (tonnes) by grid for Season 1 (Jan–Jun 2006)

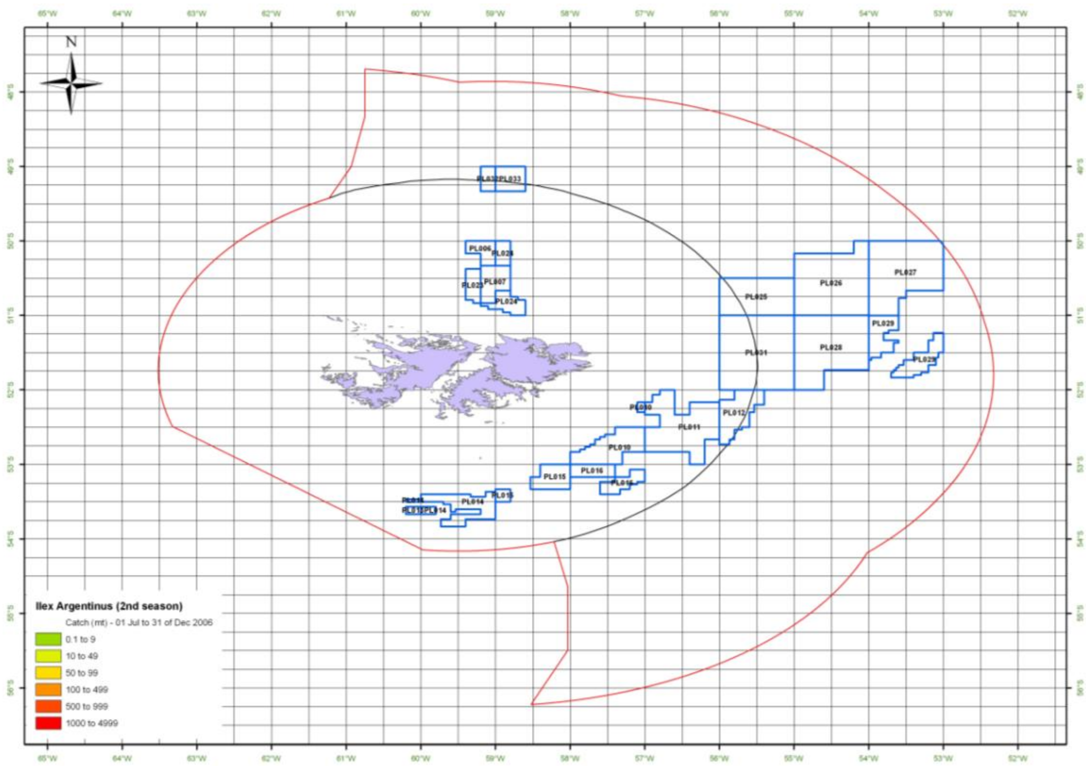

Figure 5.29 Illex argentinus catches (tonnes) by grid for Season 2 (Jul–Jun 2006)

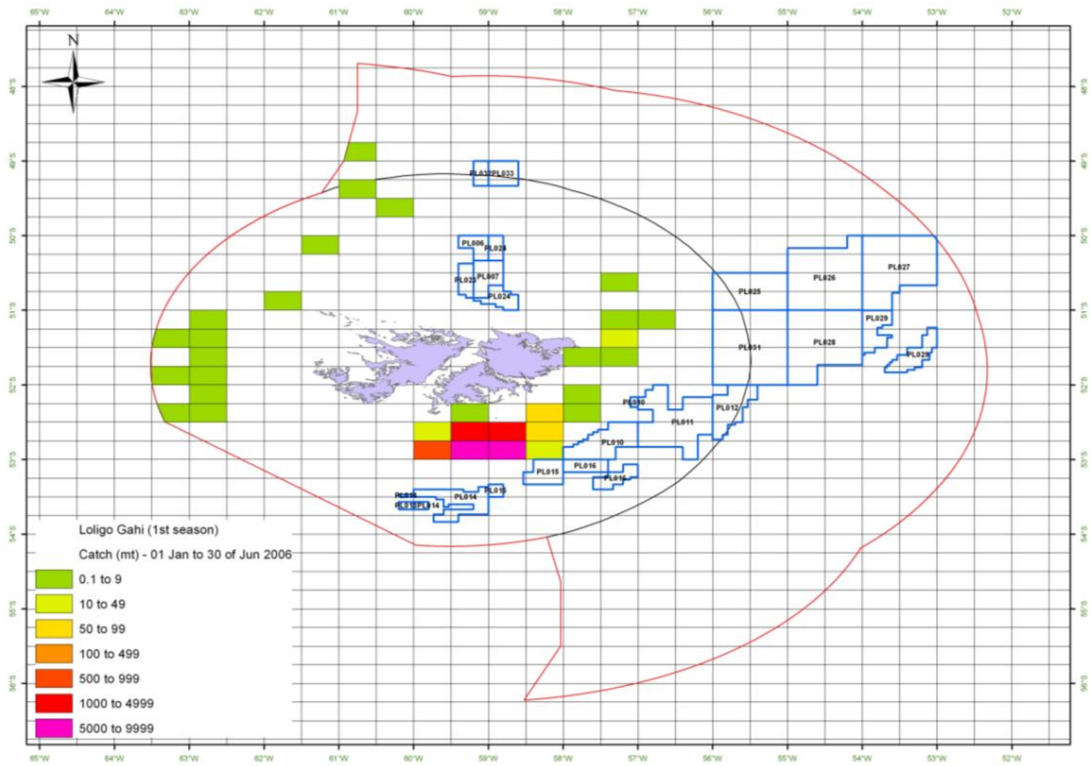

Figure 5.30 Loligo gahi catches (tonnes) by grid square for Season 1 (Jan–Jun 2006)

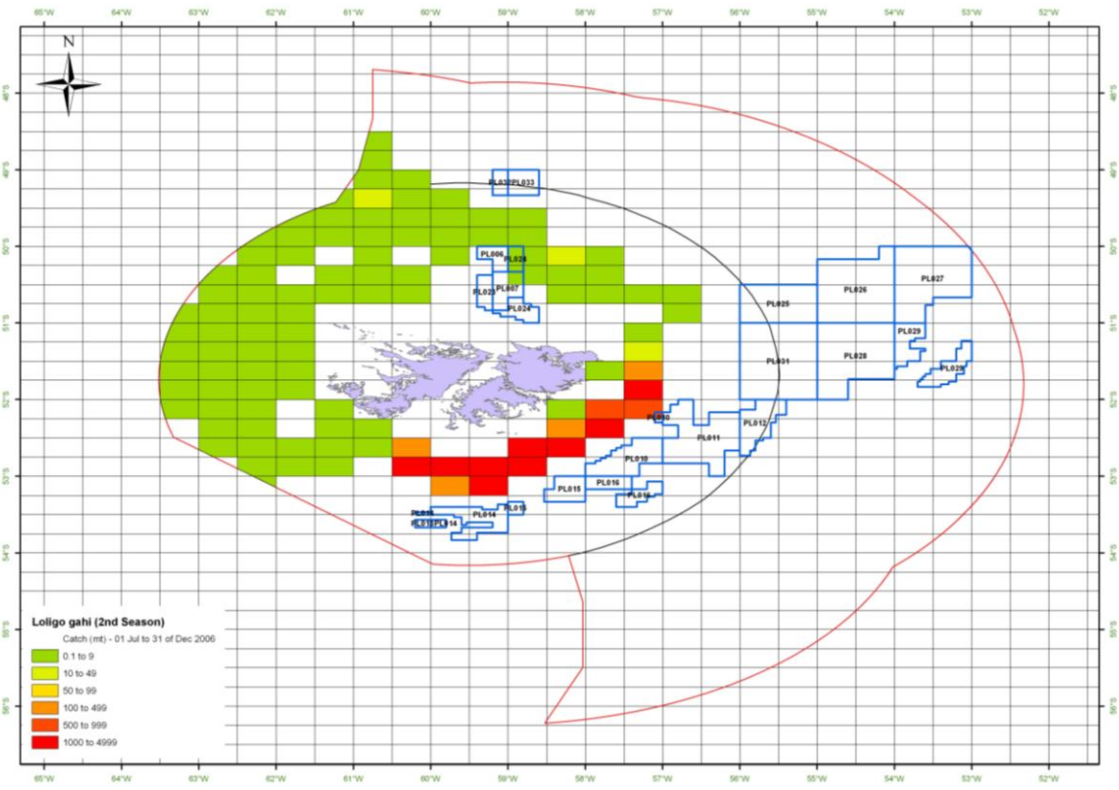

Figure 5.31 Loligo gahi catches (tonnes) by grid square for Season 2 (Jul–Dec 2006)

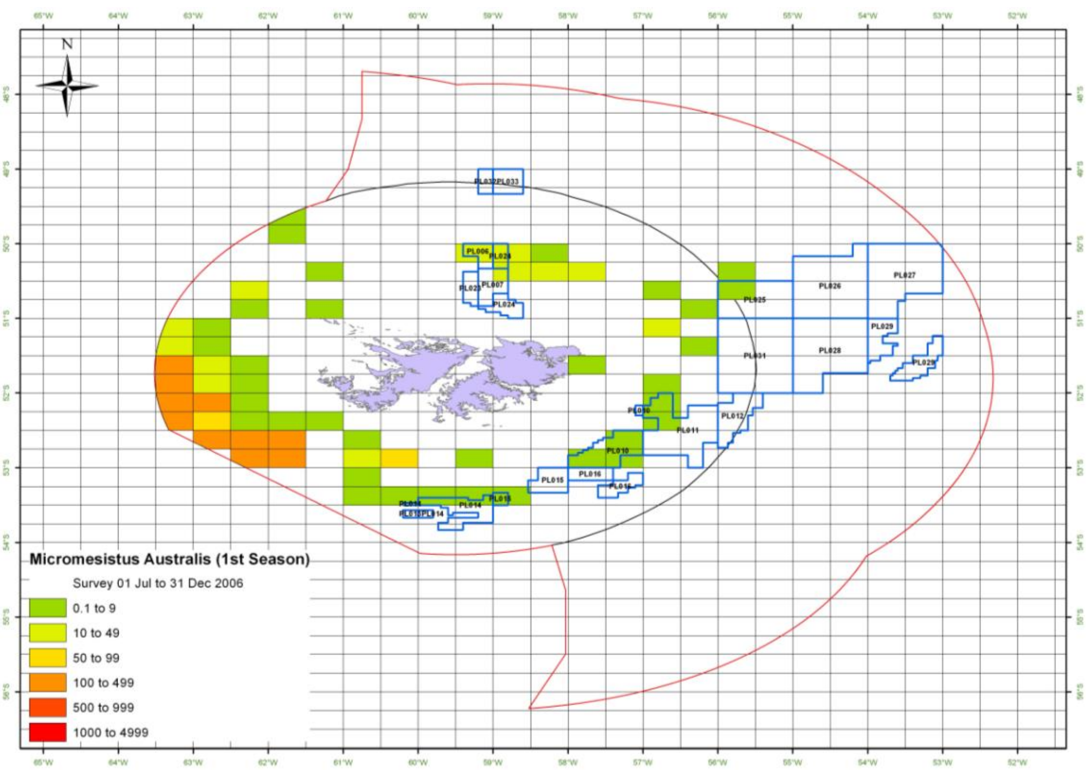

Figure 5.32 Micromesistius australis catches (tonnes) by grid square for Season 1 (Jan–Jun 2006)

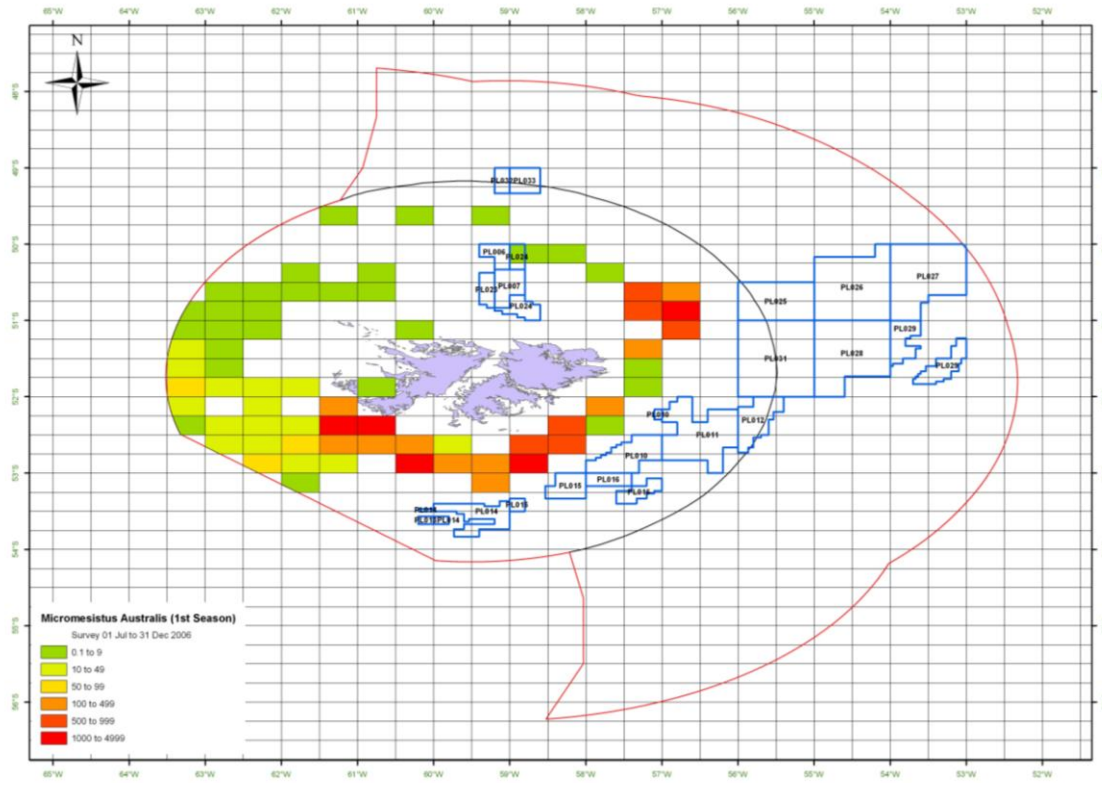

Figure 5.32 Micromesistius australis catches (tonnes) by grid square for Season 2 (Jul–Dec 2006)

The above figures demonstrate that the licence area to the south and east of the Falklands has no recorded Illex catch throughout the year. There is a low level of catch on the landward side of the Blocks close to the eastern shore of East Falklands which may have minor significance for vessel movements to and from the proposed operations in the first half of the year.

There is also no recorded Loligo catch within the licence area throughout the year, although there is again fishing activity on the landward side of the Blocks close to the southern and eastern coasts of East Falklands which may be impacted by vessel movements to and from the licence area. Near shore Loligo fishery to the east of the Falklands is most intense in the second half of the year between July and December.

There is a low recorded catch of southern blue whiting in near-shore parts of the licence area between January and July. Although there is no reported catch in the licence area for season 2 (July to December), the southern blue whiting fishery intensifies in the stretch of water between the Blocks and the Falkland Islands over this period. There is therefore greater vulnerability to disturbance from vessel movements to and from the licence area over this period.

5.4.2 Marine Archaeology

Numerous ships wrecks lie in the Falklands' waters including 19 registered shipwrecks (six from the World War One battle of the Falkland Islands) and other designated war graves which cannot be disturbed (Figure 5.33).

Stanley harbour contains wrecks of wooden ships constructed in the 19^{th} century, including the Lady Elizabeth and the Jhelum, which are considered important examples of ship construction of this period.

There are five listed wrecks within the licence area, although no identified wrecks or significant marine artefacts are currently specified within the proposed survey locations. There risk of encountering shipwrecks at the proposed operational locations is extremely small due to the considerable water depth and low level of seabed disturbance. The Hydrographic Office identification number / name, co-ordinates and depths of the wrecks are (*ERT, 1997; FIG, 2008*) presented in Table 5.8.

Table 5.8. Marine Wreck Locations

Wreck	Location	
	Latitude	Longitude
Within the BHPBP(F)C **Licence Areas**		
9	-50 44 7.6692	-54 28 49.5420
Scharnhorst	-52 27 53.6516	-56 07 3.4636
Gneisenau	-52 33 9.9049	-56 11 32.2810
SMS Leipzig	-53 38 34.3781	-56 31 2.6080
SMS Nurenburg	-53 14 47.4865	-55 37 11.6317
Adjoining the BHPBP(F)C **Licence Areas**		
11	-52 03 30.1614	-56 59 33.1460
Baden	-52 17 15.7440	-57 20 14.8323
Santa Isabel	-52 23 46.2691	-57 14 55.7152
Outside of the BHPBP(F)C **Licence Areas**		
HMS Antelope	-52 02 3.6451	-59 43 41.2890
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
HMS Ardent	-51 33 33.5224	-59 04 9.1386
HMS Coventry	-51 07 55.6134	-59 43 11.1419
10	-52 13 31.4690	-53 54 14.1888
12	-52 02 13.5400	-57 35 48.2348
13	-52 18 13.2903	-58 32 27.3286

5.4.3 Communications

There are no recorded pipelines or cables in the vicinity of the licence areas.

Mobile phone reception is now available within the Falkland Islands and is provided by Cable & Wireless.

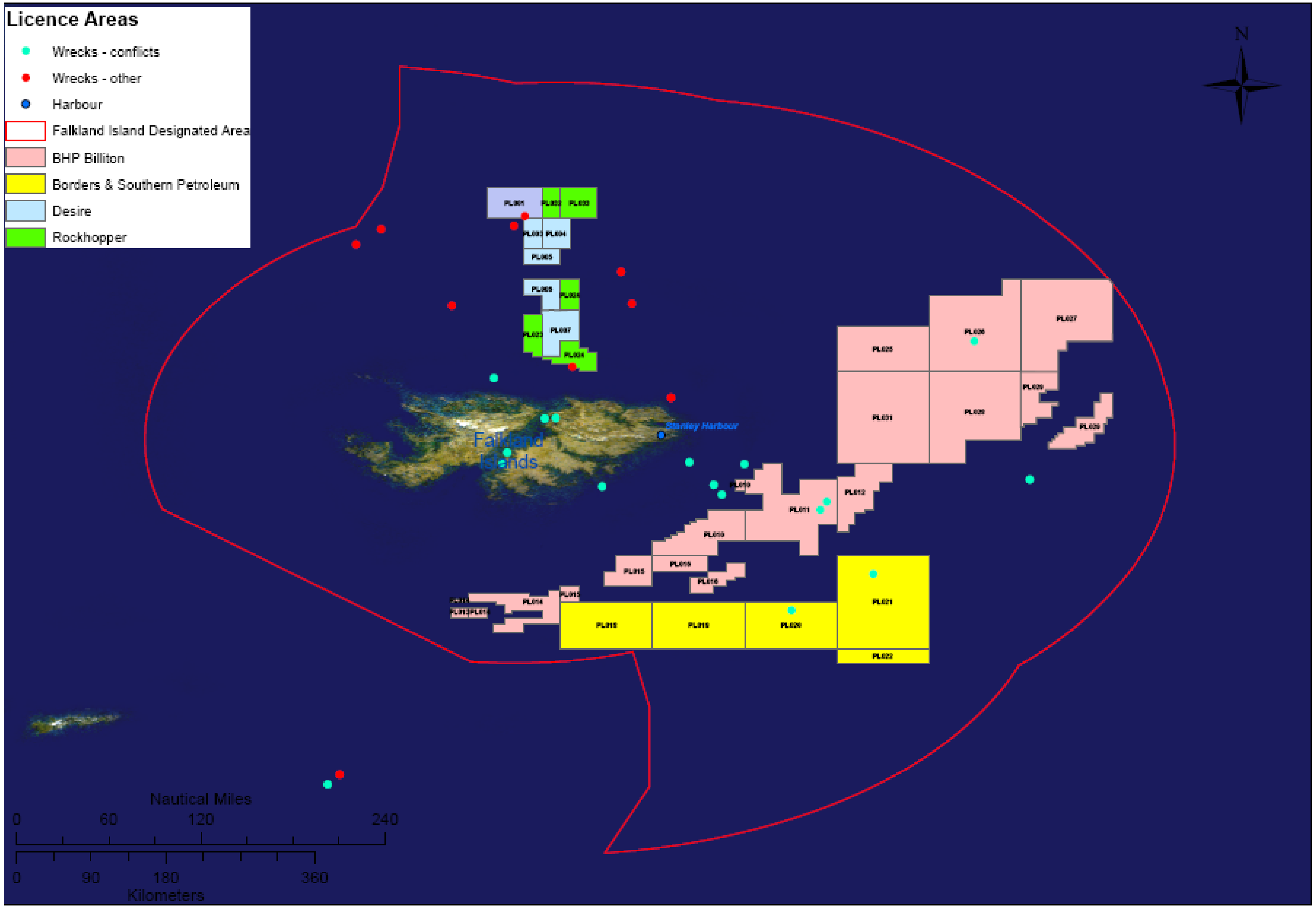

Figure 5.33 Known Shipwrecks in the Falklands Region

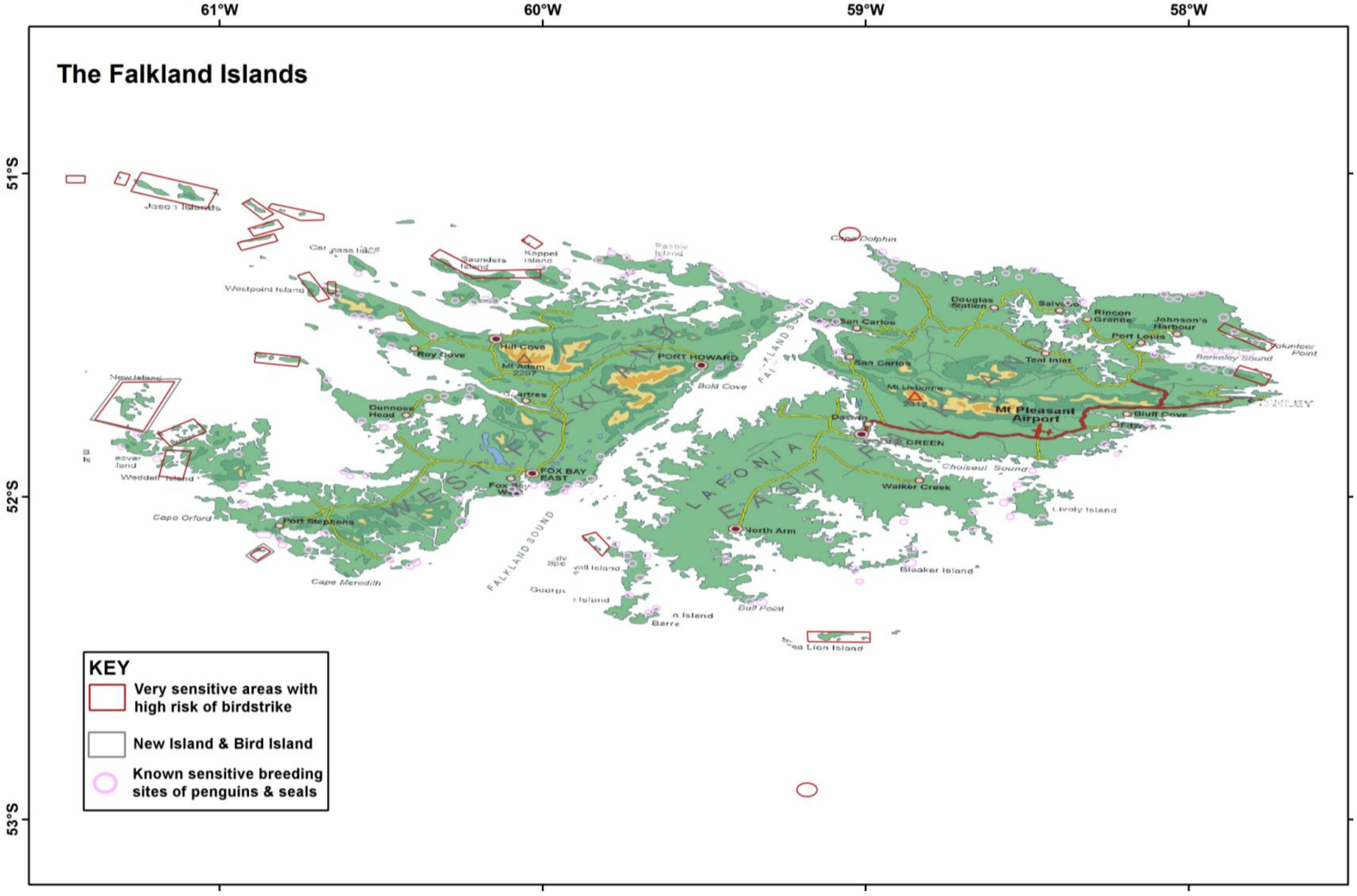

Figure 5.34 Identified ecologically sensitive areas to impacts from aircraft and helicopter activity

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5.4.4 Security

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 RFA support vessel, throughout the year. Air defence is provided by Royal Air Force interceptors, which are supported by VC-10 tankers, 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.

There are a number of wildlife avoidance areas around the Falklands. These are demonstrated in Figure 5.34 above. 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). The map has three categories of wildlife sensitive wildlife sites, which have specific regulations.

Known sensitive breeding sites of penguins and seals

Not to be over-flown by helicopters below 500 feet (150 metres). There are numerous sites identified across the Falkland Islands.

Very sensitive areas with high risk of bird strike

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 and Bird Island.

New Island and Bird Island

Should be avoided by helicopter below 500 feet at night due to prions and petrels which are nocturnal September and April.

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.

5.4.5 Navigation and Maritime Transport

Levels of shipping are low with no major shipping lanes within the licence areas.

Freight is transported to the Falklands from the UK and Chile by air and sea. The primary port is located in Stanley Harbour and known as FIPASS (Falklands Interim Port and Storage System). FIPASS, a floating system installed by the military after 1982 and purchased by the Falkland Islands Government 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 m 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. A recently introduced container feeder service by South American Atlantic Service Ltd services the ports of Montevideo (Uruguay) and Punta Arenas (Chile). The UK Ministry of Defence provides a 35 day sailing from the UK, which offers freight facility to the FIC (Falkland Islands Company Ltd.) and through the FIC to the local civilian community.

5.4.6 Waste Management Capability

There is very limited capacity of storing, managing and/or processing waste on the Islands. There is a government operated landfill, and the Islands do have the ability to recycle glass and aluminium but not plastic, paper or metal.

Used oil can be taken to a few waste oil burners via bowser or drums (e.g. Stanley Growers) and there is an independent incinerator at the slaughterhouse that could be available. Used batteries go to the landfill while some parts of vehicle batteries are recycled. The rest is stored for future export shipment.

5.4.7 Oil Industry Infrastructure

No permanent offshore oil industry infrastructure is currently in place. Shore based resources and infrastructure used for the previous drilling campaign, such as FIPASS and helicopter links, are likely to be utilised again for future drilling programmes.

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.

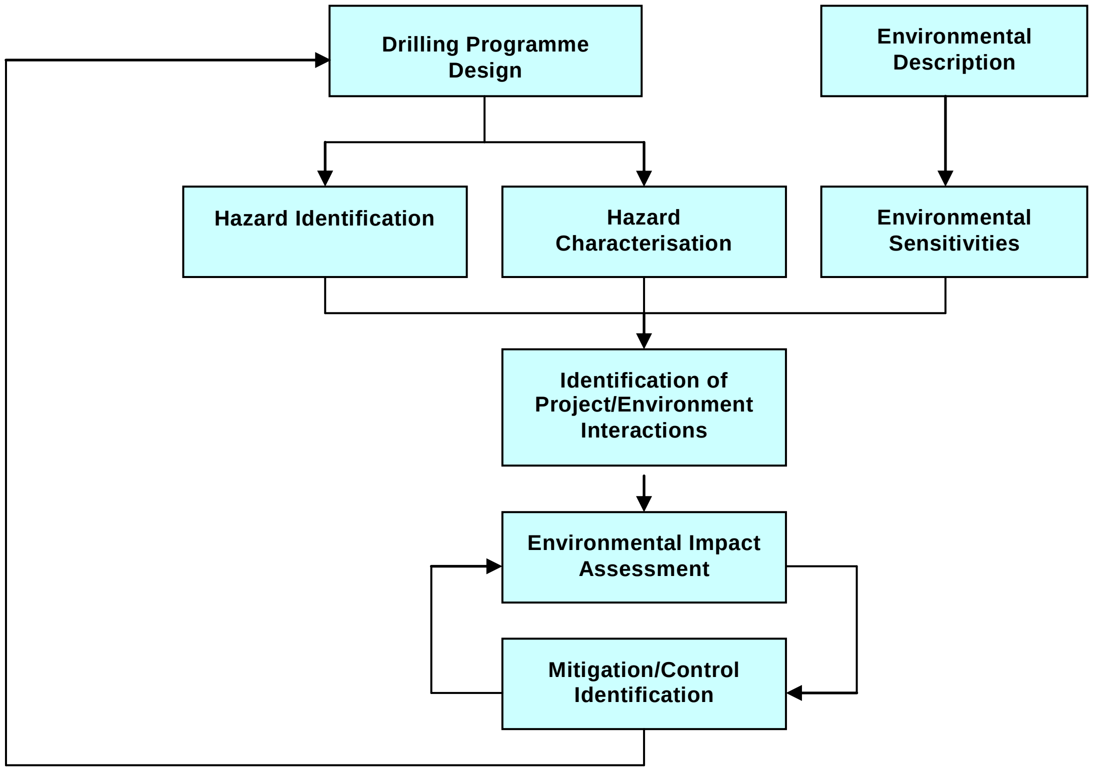

Figure 6.1 Methodology for Environmental Impact Assessment

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).

The information presented in these two sections (4 and 5) allows identification of the interactions between the planned activities and the environment.

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)

1	**Severe** Change in ecosystem leading to long term (>10 years) damage and poor potential for recovery to a normal state. Likely to effect 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.
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.
B	**Beneficial** Likely to cause some enhancement to ecosystem or activity within existing structure. May help local population.

6.2 Identification of Interactions

Table 6.2 summarises the interactions between the proposed exploration wells and the sensitivities of the local and regional environment.

Table 6.2: Potential Hazards and Associated Impacts from the Proposed Drilling Operations

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	Drilling & Support Crews	Dredging	Archaeology	Tourism / Leisure	Land Use	Sediments	Resource Use
Physical Presence										5	5									5
Seabed Disturbance				4															4	
Noise & Vibration					5			5												
Atmospheric Emissions		5																		
Marine Discharges	5		5	5	5															
Solid Waste																		3		
Minor Loss of Containment	4		4		5	4		5		5										
Major Loss of Containment	3		3		5	3		5		3	4									

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

1	Severe	2	Major	3	Moderate	4	Minor	5	Negligible		None	B	Beneficial

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 major design controls include:

- Extensive planning prior to commencing operations to ensure that no strains are placed on current onshore capacities.
- Mud selection: use of WBM as the preferred option for the well sections with careful selection of components to reduce potential environmental effects.
- Waste: currently, any solid waste, excluding drill cuttings, that can be returned to shore for appropriate disposal will be skipped and shipped to the Falkland Islands. If the waste management capacity does not exist on the Islands, then the waste will be stored and shipped to an appropriate facility at an alternate destination by a licensed waste management contractor.
- Management procedures will be in place to ensure environmental controls are operating effectively and efficiently. These are detailed in Section 7 of this EIS.
- Oil pollution emergency plan (OPEP) and emergency response procedures will be in place.

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

There is no subsea infrastructure, such as cables or pipelines, in the areas of proposed wells, and so no interference is expected.

Drilling the proposed exploration wells will not result in any significant obstruction to other marine activities (e.g. fishing and/or shipping operations) whilst the drilling rig is operational, as the proposed drilling locations are outside of the key fishing areas and there are no known shipping lanes passing through the proposed well sites. However there is some fishing activity to the landward side of the licence blocks. Vessel collision risk is minor and the following mitigation measures will be implemented:

- A safety exclusion zone that will be established during the drilling operations, and the presence of project related vessels will minimise the risk of vessel collision.
- The planned activities will be promulgated in advance through Notice to Mariners, Navtex and VHF broadcast for the duration of the operations.
- The British Military will also be continually informed of BHPBP(F)C’s proposed activities.

Resource consumption from acquisition of drilling consumables and equipment (casing, cement, mud, and chemicals) is assessed to be of low importance to the Falkland Islands as it is unlikely that these resources will be sourced in the Falklands, and are more likely to be sourced from elsewhere. 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 to the Falkland Islands as it is likely that the fuel will be sourced from the Islands. The consumption of helifuel, 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 to the Falkland Islands as some of it will be sourced from the sea and used as untreated seawater, some seawater will be treated in the desalination plant onboard the rig and a portion will be sourced locally in the Falkland Islands. However, if potable water has to be sourced from the Falkland Islands, it can be loaded outside peak times to minimise any impacts to the local community. In addition, water needs have been discussed with local authorities, and with adequate advance planning can be provided without effect to local needs.

6.5 Seabed Disturbance

6.5.1 Anchoring

The proposed 8 to 12 line moorings pattern will directly impact the seabed as they anchor onto the seabed surface. The impact is assessed to be minor as the benthic survey results show a homogenous environment with no habitats of conservation value. The small footprint (when compared to the legs of a jack-up rig, for example) and short duration of the drilling programme will limit potential impacts to the seafloor. It is anticipated that once the rig moves off location seabed communities will recover relatively quickly.

6.5.2 Deposition of Drill Cuttings

The main potential source of seabed disturbance from the Loligo and Toroa wells will be caused by the deposition of drill cuttings on the seabed in the vicinity of the drilling locations. 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 the discharge of cement during cementing of well casings.

Loligo Well – Model Set-up and Assumptions

It is estimated that drilling the Loligo exploration well will generate a maximum total of 1,396 tonnes of cuttings associated with WBM (refer to Section 4.4.4). These cuttings will be discharged to the sea, where the mud and cuttings will sink to the seabed and be deposited there 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. The model was set up according to the well parameters provided in Table 4.5 (refer to Section 4.4.4). Further details on the model set up and the way in which the model works are provided in Appendix G.

To simulate residual water movements in the area, due to the lack of background current data in the modelling programme, the current override function was used in the model in order to use the data obtained from the metocean current meters deployed at the Loligo and Toroa locations (refer to Section 5.2.6). The current override function applies a 'blanket' background 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). Using the Acoustic Doppler Current Profiler (ADCP) measurements from the metocean mooring deployed at the proposed Loligo well location over the period between 6th December 2008 and 26th April 2009, the minimum observed current speed and calculated residual observed surface current direction (refer to Section 5.2.6) were used as the 'current override' inputs for the model. The minimum observed current speed was used due to the fact that a slower current speed will give rise to less dispersion of the discharged cuttings, and hence represent a worst case scenario for the cuttings deposition (i.e. give rise to the thickest deposition on the seabed). Generally, a thicker deposition on the seabed is more environmentally significant than a larger, thinner area of coverage. Studies have shown that impacts from smothering can occur where the depth of cuttings is one millimetre or more (*Bakke et al., 1986*). The residual surface current direction was used to represent the net drift of the cuttings over the duration of the model run.

Toroa Well – Model Set-up and Assumptions

It is estimated that drilling the Loligo exploration well will generate a maximum total of 615 tonnes of cuttings associated with WBM. The model set-up used for the Toroa well was the same as that for the Loligo well described above (model set-up parameters are provided in Appendix G). However, the current override input for the Toroa model was slightly different.

The ADCP component of the metocean mooring deployed at the proposed Toroa well location over the period between 6th December 2008 and 26th April 2009 failed shortly after deployment, due to flooding of the equipment following failure of the equipment casing. Consequently, surface current data is not available for the Toroa location. However, data was recorded at two dedicated current meters, one located at 422 metres below sea level (270 metres above the seabed) and the other located at 682 metres below sea level (10 metres above the seabed). The only data available from these current meters were the observed maximum current and direction in which it occurred. The data from the Loligo mooring were then analysed again. It was considered that, had the ADCP unit at the Toroa mooring functioned correctly, it is likely that minimum surface current speeds observed at the Loligo mooring would have been similar to the results from the Toroa mooring with respect to the current shear effect. Therefore, the same minimum current speed was used for modelling the discharge at the Toroa location. In addition, using a minimum current speed would again represent a worst case scenario for cuttings deposition on the seabed (i.e. give rise to the thickest possible deposition on the seabed). For the surface current direction, the observed direction given at the time of the maximum observed current speed observed at Toroa was used, as it was impossible to calculate a residual current direction from the data provided at Toroa. In support of this decision, this current direction was in general agreement with the residual current direction given in the admiralty charts for the area (*Hydrographer of the Navy, 2008*).

Loligo Well – Modelling Results

Figure 6.2 shows the output from the PROTEUS model run for both the Loligo and Toroa wells in relation to the Falkland Islands. A close-up image of the cuttings deposition in the vicinity of the Loligo well is provided in Figure 6.3. This displays cuttings pile thickness contour plots with a thickness range from 0.01mm to 2.2 millimetres (mm). Figures 6.4 and 6.5 display cross sections through the long and short axes of the cuttings pile, respectively.

It can be seen from Figure 6.3 that the cuttings from the Loligo well are deposited along a north-east to south-west oriented axis, drifting away from the drilling location in a north-easterly direction. The distance covered along this axis is approximately 8 kilometres and the maximum width of the pile is around 1.4 kilometres (when measures to the 0.01mm thickness contour).

Three distinct piles are shown in Figure 6.3, which are formed as a result of the particle size distribution of the cuttings (different amounts of energy are required from the surrounding water column to entrain cuttings particles of different mass). In the model, a blanket current speed and direction were assumed, making the water column variables constant. Therefore, the main variable affecting the cuttings distribution on the seabed is particle size distribution. Cuttings particles of greater mass will require a greater amount of energy from the water column to remain entrained within it. Therefore, particles of greater mass will sink to the seabed quickest and are likely to be found in the immediate vicinity of the drilling location. Cuttings particles of smaller mass require less energy from the water column to entrain them and hence travel further through the water column before they are deposited. As the cuttings are released from the same position, particles of similar size tend to travel in groups, resulting in the formation of the three separate cuttings piles observed in Figure 6.3 all of varying thickness.

On consideration of the contour plots for Loligo in Figure 6.3, it can be seen that the majority of cuttings are expected to be located in the circular-shaped pile centred on the drilling location. It can also be seen that the cuttings pile closest to the well location is the thickest.

The pile shown closest to the well is likely to be generated as a result of the top-hole well sections (the 42” and 26” sections) as cuttings from these sections will be discharged directly to the seabed. They therefore have a limited chance to move through the water column and disperse away from the point of release, resulting in a thicker deposition of cuttings. This circular-shaped pile has a diameter of approximately 1.4 kilometres when measured to the 0.01 mm thickness contour. It is also the thickest of three piles shown in Figure 6.3 with a maximum deposition depth of 2.122mm at the drilling location itself.

The two other distinct cuttings pile areas are likely to be formed as a result of the finer cuttings discharged at the sea surface from the 17½”, 12¼” and 8 ½” well sections. When cuttings are discharged overboard, they can remain suspended in the water column for a significant period of time under the influence of the water column currents during settling, before finally being deposited on the seabed. This often results in more widespread deposition of the cuttings and a much less thick deposition of cuttings in general. In the case of the Loligo well, the water depths in the area are significant (1,376 metres at the drilling location), meaning the time over which the particles would settle to the seabed would likely be very great. As such, it is likely that the majority of cuttings, particularly smaller particles that require less energy to be entrained, would have been dispersed over a very great distance, and after settling on the seabed, their thickness would be so small that it would be undetectable against the normal background sediment.

It should be noted that Figures 6.2 and 6.3 do not denote the impact area from the cuttings pile, but simply displays the area where cuttings are deposited in a layer greater than or equal to 0.01mm thick.

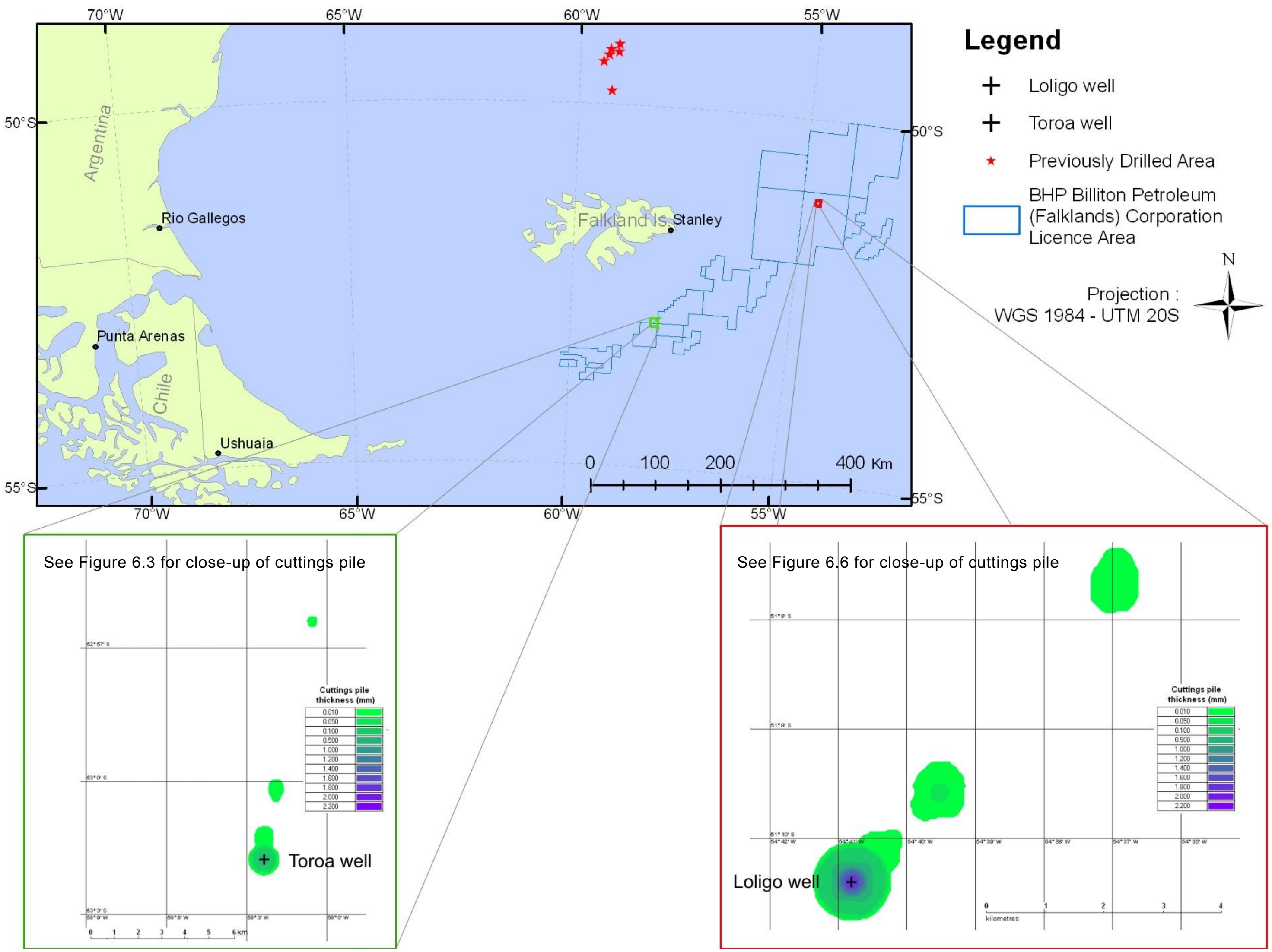

Figure 6.2. Predicted maximum extents of cuttings deposition on the seabed around the proposed Loligo and Toroa drilling locations in relation to the Falkland Islands

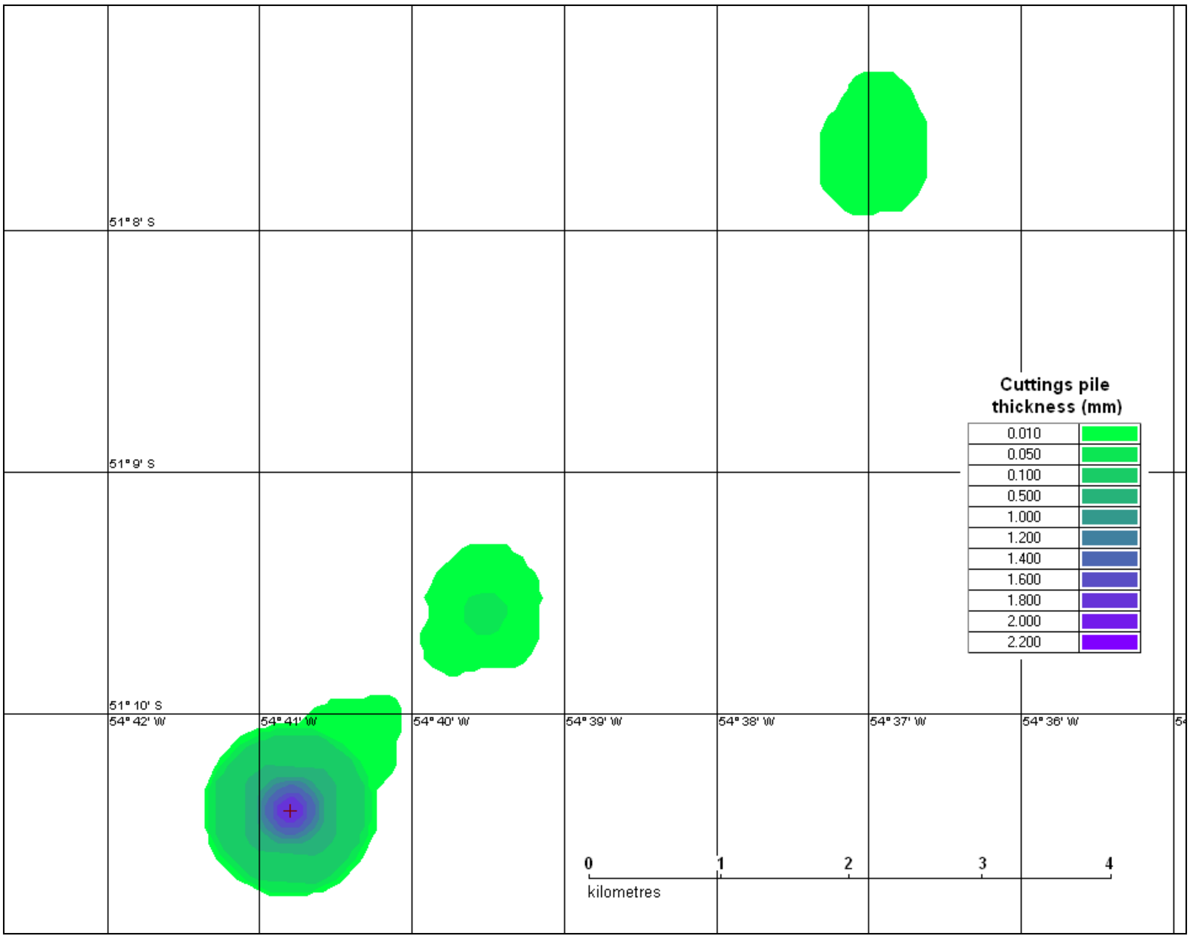

Figure 6.3. Predicted cuttings deposition on the seabed around the proposed Loligo drilling location showing detailed view of the cuttings pile

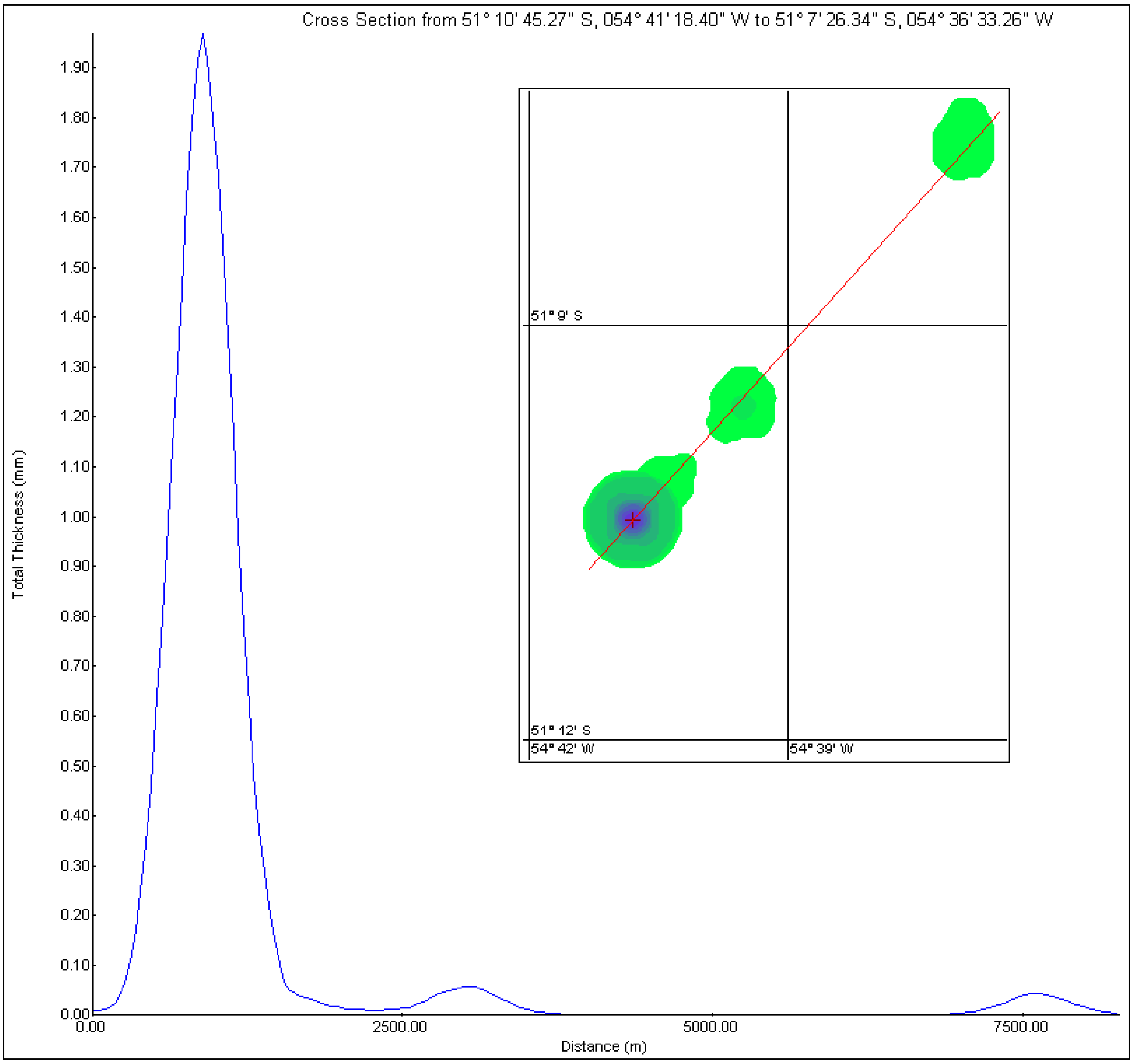

Figure 6.4. Cross section through the centre of the Loligo drilling location along the long axis of the cuttings pile

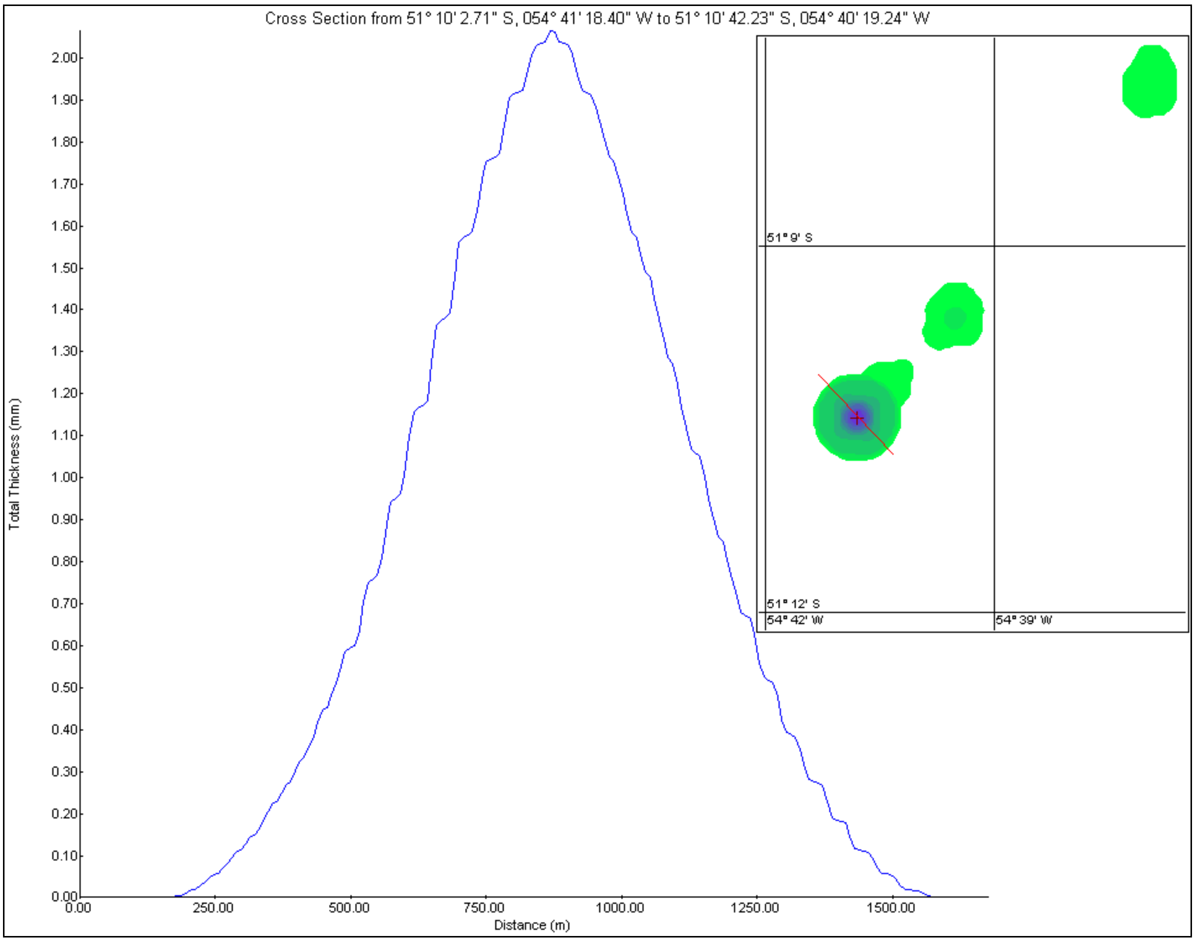

Figure 6.5. Cross section through the centre of the Loligo drilling location along the short axis of the cuttings pile

Toroa Well – Modelling Results

Figure 6.2, above, shows the output from the PROTEUS model run for both the Loligo and Toroa wells in relation to the Falkland Islands. A close-up image of the cuttings deposition in the vicinity of the Toroa well is provided in Figure 6.6, below. This displays cuttings pile thickness contour plots with a thickness range from 0.01 to 2.2 millimetres (mm). Figures 6.7 and 6.8 display cross sections through the long and short axes of the cuttings pile, respectively.

It can be seen from Figure 6.6 that the cuttings from the Toroa well are deposited along a north north-easterly to south south-westerly orientated axis. This is the result of the current characteristics input into the model (current in direction of bearing 012^{o}). The distance covered along this axis is approximately 11 kilometres and the maximum width of the pile is around 1.3 kilometres (when measures to the 0.01 mm thickness contour).

Three distinct piles are shown in Figure 6.6, which are formed as a result of the particle size distribution of the cuttings as explained for the Loligo well above. The majority of cuttings are located in a circular-shaped pile centred on the drilling location. This circular-shaped pile has a diameter of approximately 1.3 kilometres when measured to the 0.01 mm thickness contour. The maximum cuttings pile thickness found was 0.86 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, for the same reasons as stated above for the Loligo well.

Again, it should be noted that Figures 6.2 and 6.6 do not denote the impact area from the cuttings pile, but simply display the area where cuttings are deposited in a layer greater than or equal to 0.01mm thick.

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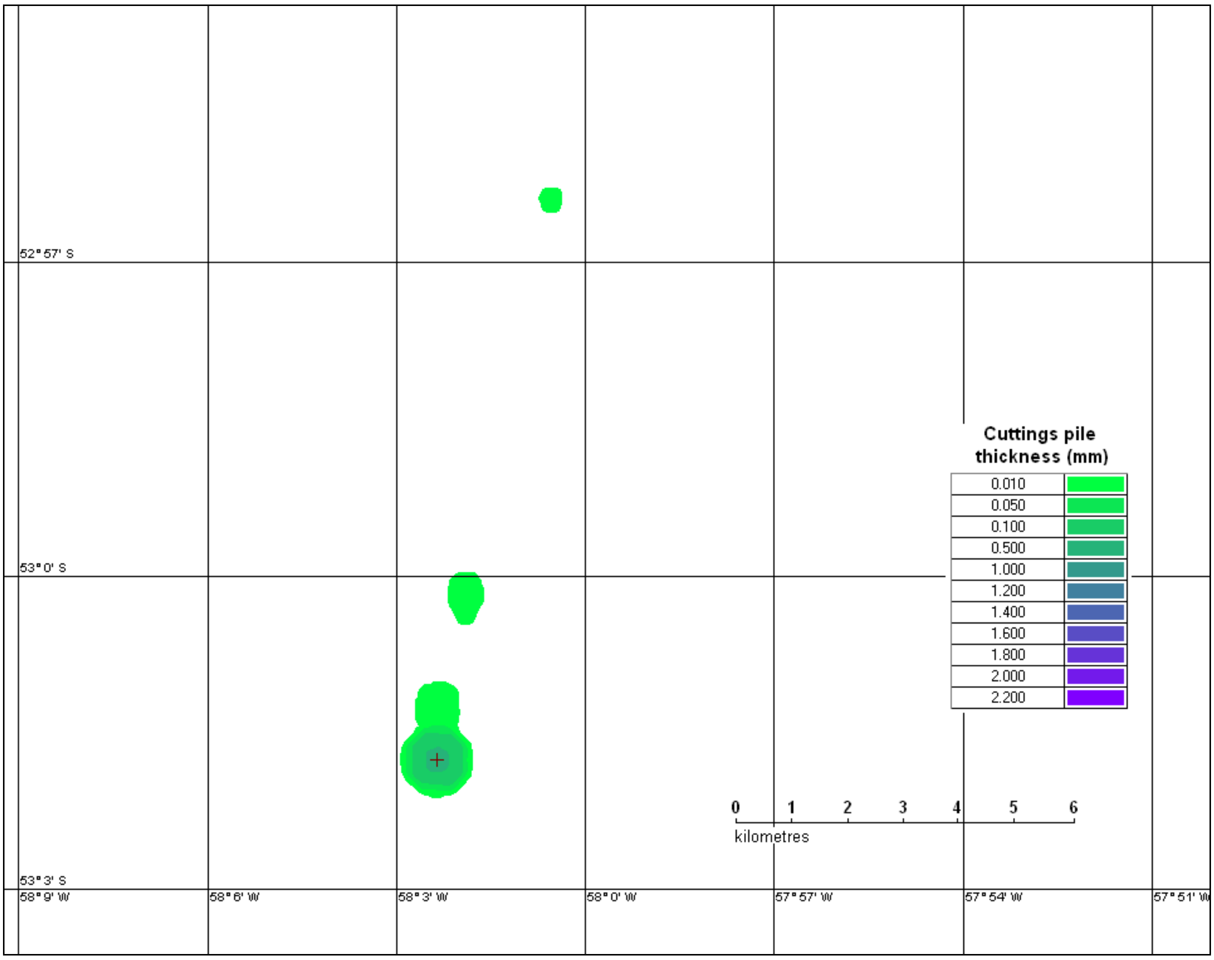


Figure 6.6. Predicted cuttings deposition on the seabed around the proposed Toroa drilling location showing detailed view of the cuttings pile

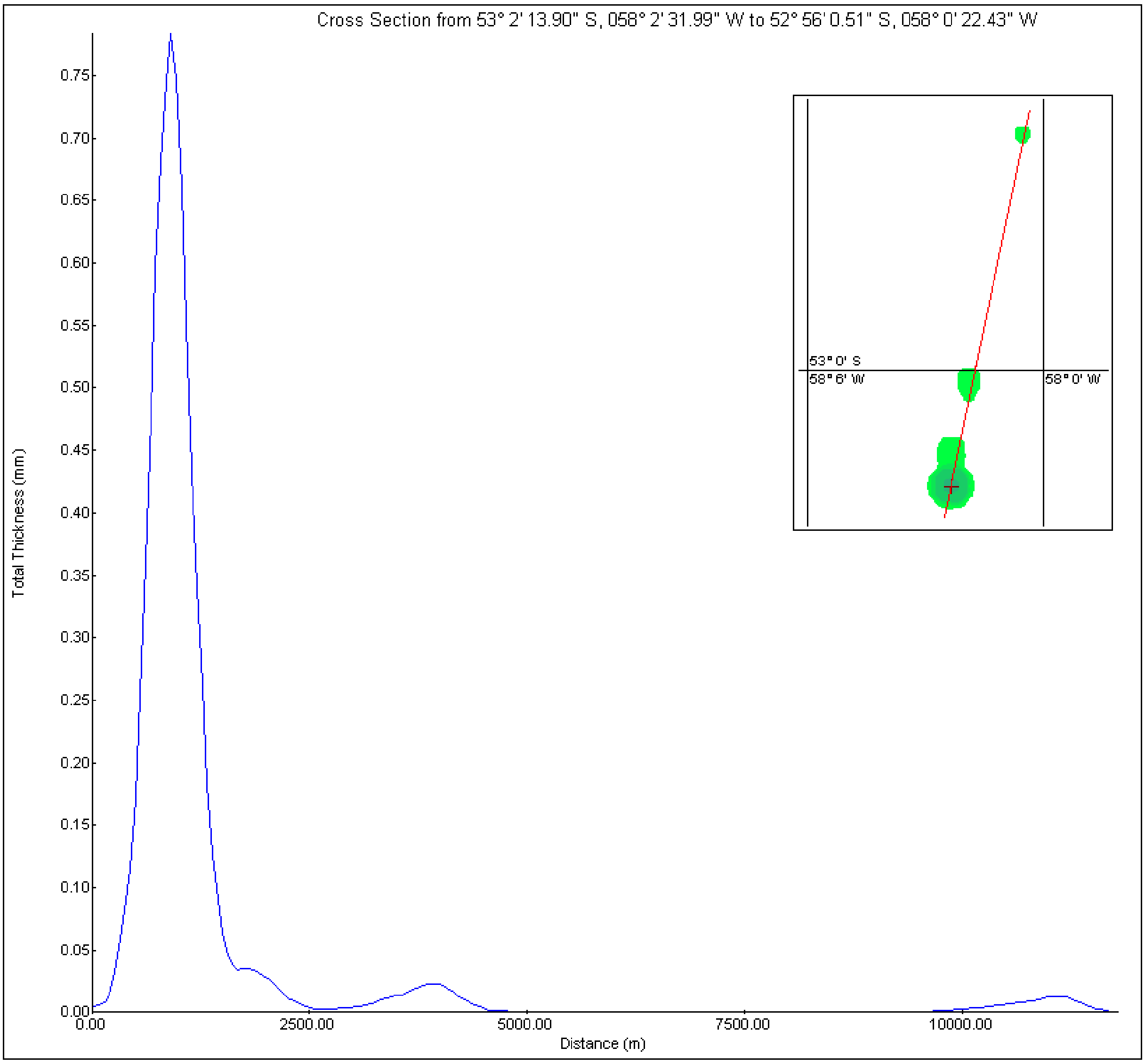


Figure 6.7. Cross section through the centre of the Toroa drilling location along the long axis of the cuttings pile

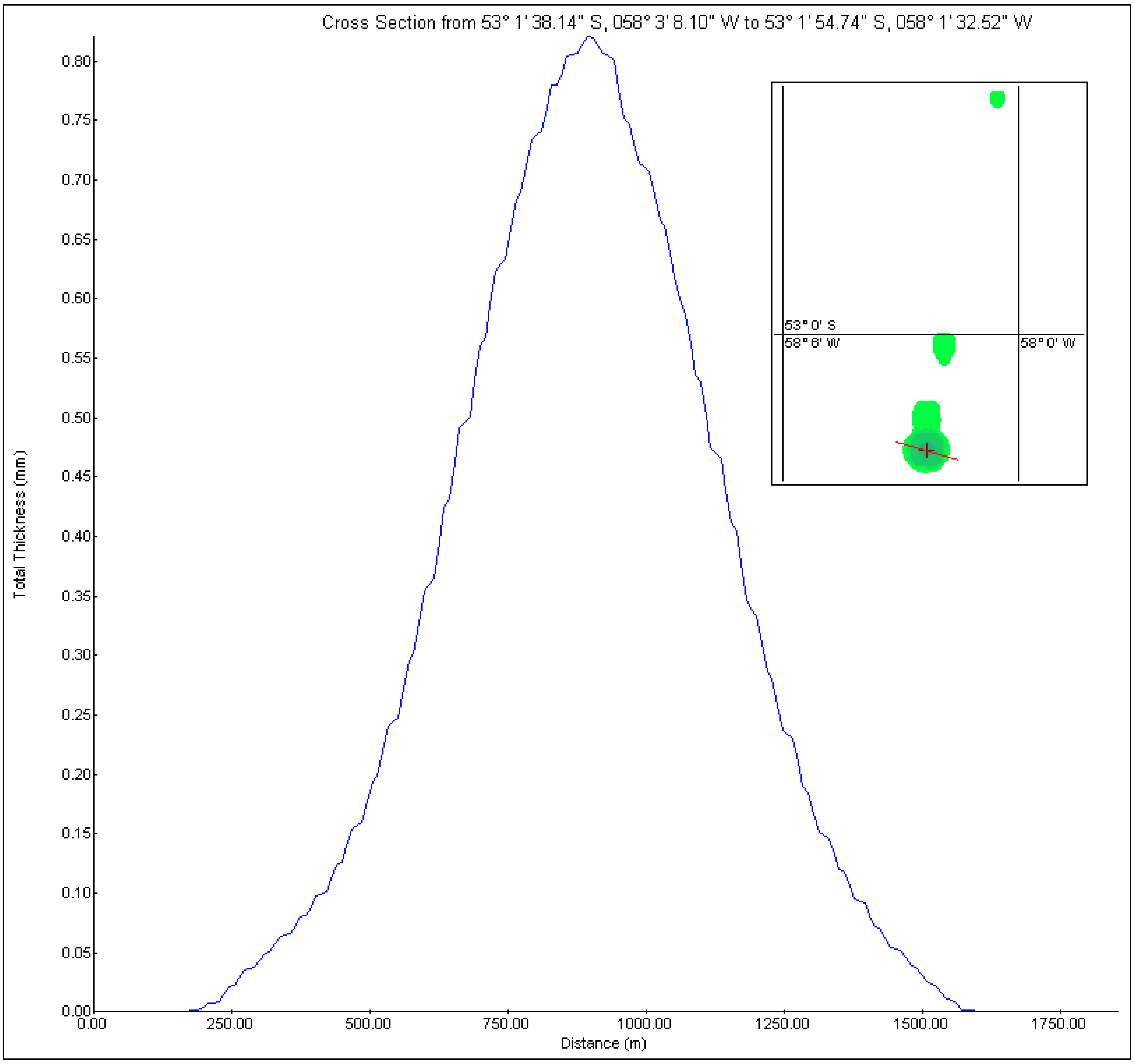


Figure 6.8. Cross section through the centre of the Toroa drilling location along the short axis of the cuttings pile

Conclusions

The deposition of cuttings and fine solids described above has the potential to directly affect the seabed fauna. Smothering effects and changes in the sediment grain size and chemistry combine to favour certain species over others. As a result, the population of seabed fauna within the areas influenced by cuttings deposition may differ from that of the surrounding unaffected sediments. Such effects have been well studied and indicate an effect broadly mirroring the area of deposition of the cuttings. 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 Toroa site, as the thickness of discharged drilling cuttings does not exceed 1 mm at any location within the area of deposition, smothering effects on the flora and fauna are not expected.

However, at the Loligo drilling location, the cuttings pile thickness exceeds 1 mm in a small area surrounding the drilling location, within a radius of approximately 270 metres. This represents an area of approximately 0.23 km^2. As there are no toxic components within the discharge of the vast majority of cuttings, the impacted area will begin to recover soon after drilling operations have ceased. Re-colonisation of the impacted area can take place in a number of ways including mobile species moving in from the edges of the area, juvenile recruitment from the plankton or from burrowing species digging back to the surface.

For example, in 1987 a benthic environmental survey was undertaken at a single well site in the Central North Sea, UK (*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*).

Given the shallowness of the predicted cuttings deposition and the action of movement of the bottom currents, it is likely that any cuttings will soon become mixed with the natural sediments and will eventually be dispersed. Evidence for this has been recorded from wells drilled on the UKCS by Burlington Resources (Irish Sea) Ltd. (now ConocoPhillips) in the eastern Irish Sea at the Dalton, Millom East and Millom West developments. It has been reported from ROV surveys undertaken during pipeline hook-up operations that there was no evidence of the presence of cuttings piles immediately after drilling operations had been completed (*BRIS, 2002*).

In conclusion, cuttings deposition is likely to temporarily impact a small area within the vicinity of the Loligo well which will rapidly recover soon after drilling operations have ceased. The maximum predicted cuttings thickness was 2.122 mm at the Loligo drilling location and 0.86 mm at the Toroa drilling location. Although the cuttings piles from the Loligo and Toroa wells in general potentially cover large areas, measuring 8.00 x 1.35 kilometres at the Loligo location and 11.00 x 1.3 kilometres at the Toroa location (at their longest and widest points, respectively, measured to the 0.01mm thickness contours), at no point did the cuttings pile thickness exceed 1 mm in the Toroa cuttings pile. In addition, the area in which the cuttings pile at the Loligo site exceeds 1 mm in thickness is very small (approximately 0.23 km^2). Studies have shown that impacts from smothering can occur where the depth of cuttings is one millimetre or more (*Bakke et al., 1986*). Therefore, significant smothering effects on the flora and fauna are not expected at the Toroa location. Some smothering effects may be experienced at the Loligo location, however the area in which this may happen is small and it is likely that the area will recover rapidly soon after drilling operations have finished.

6.6 Noise and Vibration

Operational activities at the proposed well sites will generate noise, both above and below the sea surface, mainly during drilling activities. Noise is thought to have the potential to disturb animals in the area, particularly cetaceans.

Typical subsea noise levels from offshore operations are shown in Table 6.3.

Table 6.3. Typical Noise Levels Associated with Offshore Operations

Source	Noise Level (dB)	Dominant Frequency(s) (Hz)
Piling	135-145 *	50-200
5m Zodiac with an out-board motor	152 *	6,300
Jack-up drilling rig	140-160*	100
Semi submersible drilling rig	150	100
Typical fishing vessel	150-160 **	-
Tug/barge traveling at 10 knots (18 kilometres per hour)	162 *	630
Large tanker	177 *	100
Seismic air gun	210 (average array)* 259 (large array)*	10-1,000

* *Richardson* et al *(1995)* ** *Gulland and Walker (1998)*

(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)). In this report all dB reported are re 1µPa @ one metre in water. Source: *Richardson et al 1995.*

Taking 150dB as an example of the typical noise level 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 Figure 6.9 that background noise levels will be reached within a kilometre of the source. An anchored semi-submersible will generate less noise than a dynamically positioned semi-submersible, which is more dependent on its thrusters for maintaining position.

Studies from drilling / production platforms off the Californian coast have indicated that the noise emitted was low frequency and was so weak as to be virtually undetectable from alongside the platform during sea states greater than three on the Beaufort scale (*Gales, 1982 in Richardson et al., 1995*). The winds in this region predominantly range between 11 to 21 knots (Beaufort scale 4 to 5). Noise from offshore operations is produced over a relatively large frequency range (typically between 7-4,000 Hertz), greater than that produced by ships (20-1,000 Hertz) (*Richardson et al., 1995*).

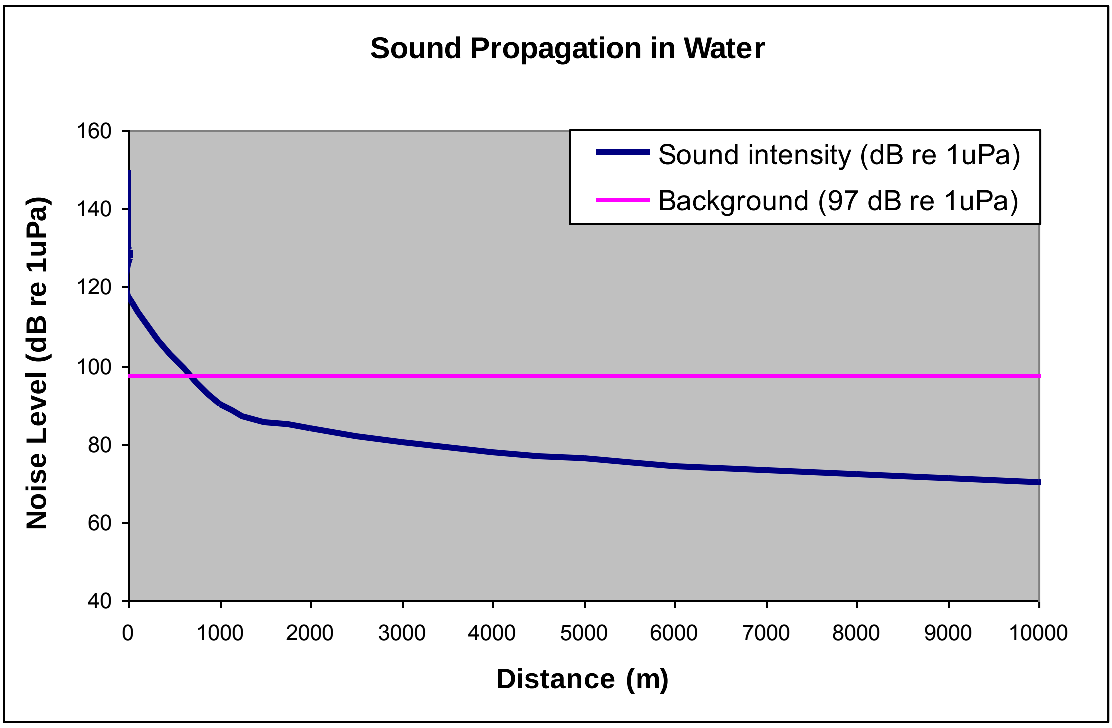


Figure 6.9 Propagation of Sound in Water (from Richardson et al., 1995)

6.6.1 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, 1993*). Some groups of fish, e.g. flatfish and elasmobranchs or cartilaginous fish such as sharks and rays, do not posses 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).

Fish are generally sensitive to noises within the frequency range of less than 1 Hertz to 3,000 Hertz, however, it has been reported that they will respond consistently to very low, or very high frequency noises (*Knudsen et al. 1992, 1994*). Sounds in the range of 50 to 2,000 Hertz, 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*).

Given the magnitude of sounds expected to be produced by the proposed drilling activities, there are not expected to be any physical impacts on fish (Figure 6.10).

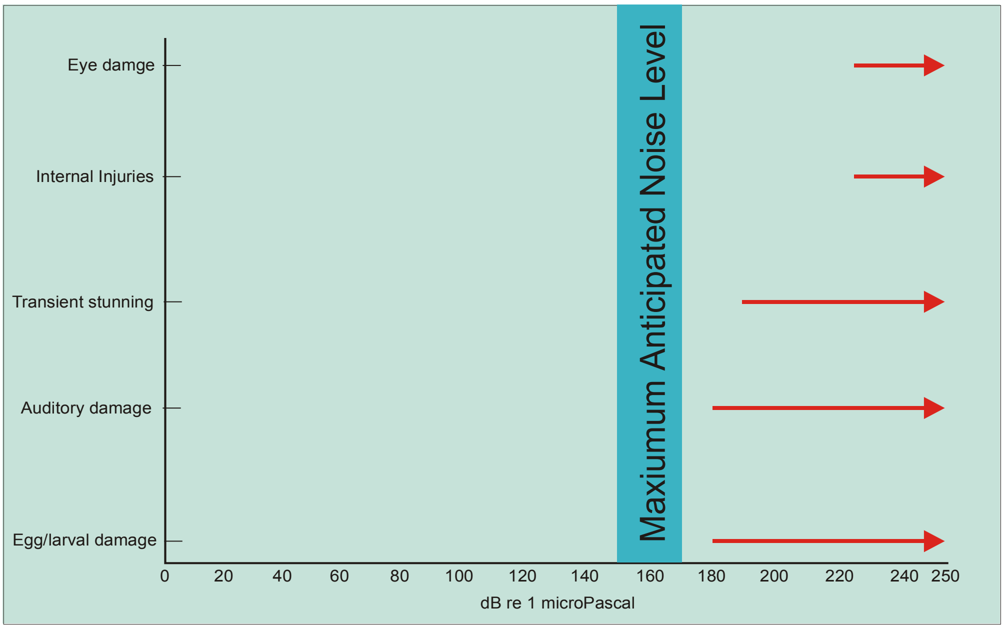


Figure 6.10 Sound Pressure Level Thresholds for the Onset of Fish Injuries (after Turnpenny & Nedwell, 1994)

6.6.2 Potential Impacts on Cetaceans

Cetaceans are in general believed to be fairly tolerant to noise disturbance and are unlikely to be affected by the magnitude and frequency of noise produced during planned offshore operations (*Richardson et al., 1995*). The distribution of cetaceans appears to be unaltered by the presence of a facility, with sightings rates reported to be similar with or without the presence of a rig, although it has been suggested that cetaceans will react within five kilometres of a noise source (*Richardson et al., 1995*). Studies have indicated that even when the noise generated by a drilling rig is well above the ambient (background) level, baleen whales exhibit no measurable change in behaviour and it is only at a distance of tens of metres from the rig that sound levels are likely to be high enough to initiate avoidance action (*Richardson et al., 1995*). In addition, anecdotal evidence indicates that cetaceans are not disturbed by the noise generated by large vessels.

A number of cetacean species have been recorded migrating through the BHPBP(F)C licence blocks at different times of the year. Impacts on particular species cannot be assessed until a drilling schedule is established when a rig becomes available for use. These impacts will be considered in the Addendum to this document.

6.6.3 Potential Impacts on Protected Birds

Although the majority of seabird species in the Falklands are observed in coastal and nearshore areas, a number have been recorded in the BHPBP(F)C licence blocks throughout the year. Impacts on particular species cannot be assessed until the drill rig has been contracted and a drilling schedule established. These impacts will be considered in the Addendum to this document.

Due to the localised and temporary nature of the majority of impacts described above, the impact of the proposed drilling activity on any cetaceans and birds which may be present in the area is considered to be negligible.

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.

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 (refer to Tables 6.4 and 6.5). These types of emissions are anticipated to disperse rapidly under most conditions to levels approaching background within a few tens of metres of their source. Although all such emissions will contribute in a small way to the overall pool of greenhouse and acidic gases in the atmosphere, local environmental and transboundary effects will be negligible.

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.

Table 6.4. Predicted Atmospheric Emissions from Power Generation from Drilling Loligo

Gas[1]	Drill Rig [2]	Standby Vessels[3]	Total
Carbon dioxide	1280.00	640.00	1,920.0
Carbon monoxide	6.28	3.14	9.4
Oxides of nitrogen	23.76	11.88	35.6
Nitrous oxide	0.09	0.04	0.1
Sulphur dioxide	1.60	0.80	2.4
Methane	0.07	0.04	0.1
Volatile organic chemicals	0.80	0.40	1.2

Note 1: Emission factors used from UKOOA 2002a based on methodology proposed by OGP

Note 2: Rig is estimated to consume @ 10 tonnes fuel/day for 40 days duration.

Note 3: Standby vessel is estimated to consume @ 5 tonnes fuel/day for 40 days duration.

Table 6.5. Predicted Atmospheric Emissions from Power Generation from Drilling Toroa

Gas[1]	Drill Rig [2]	Standby Vessels[3]	Total
Carbon dioxide	1120.00	560.00	1,680.0
Carbon monoxide	5.50	2.75	8.2
Oxides of nitrogen	20.79	10.40	31.2
Nitrous oxide	0.08	0.04	0.1
Sulphur dioxide	1.40	0.70	2.1
Methane	0.06	0.03	0.1
Volatile organic chemicals	0.70	0.35	1.1

Note 1: Emission factors used from UKOOA 2002a based on methodology proposed by OGP

Note 2: Rig is estimated to consume @ 10 tonnes fuel/day for 35 days duration.

Note 3: Standby vessel is estimated to consume @ 5 tonnes fuel/day for 35 days duration.

6.8 Marine Discharges

Sources of marine discharges for the proposed wells are:

- Water based mud (WBM) and drill cuttings;
- Cement;
- Drainage water;
- Sewage.

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 spent WBM will be discharged to sea. The drilling mud composition is essentially a brine solution, with naturally occurring barite and bentonite clay.

Small amounts of chemicals are added to this 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 (Appendix A). 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 and the vast majority of WBM 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 4.7 and 4.8 in Section 4.4.8).

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).

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 and this, together with the low toxicity, indicates that any impacts within the water column will be undetectable shortly after discharge. Discharge of the WBM will not contribute to any impacts on the local seabed communities 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*).

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. Only a small volume of cement will be lost from the well. The cement is comprised mostly of PLONOR chemicals (refer to Table 4.9 in Section 4.4.8).

All chemicals to be discharged which are non-PLONOR have a HQ band of GOLD or E (lowest environmental risk category) for the purposes of CHARM assessment. Any impacts will be very close to the wells in the same area affected by cuttings deposition (refer to Section 6.5.2).

6.8.3 Drainage Water and Sewage

Water generated from rig washdown and rainfall from the open deck areas may contain trace amounts of mud, lubricants and residual chemicals from small onboard leaks derived from activities such as re-fuelling of power packs or the laying down of dirty hoses or dope brushes etc. It should be stressed, however, that these would be relatively low volume discharges containing small residual quantities of contaminant. BHPBP(F)C will ensure that the rig is equipped with suitable containment, treatment and monitoring systems as part of the contract specification.

In addition, the BHPBP(F)C Drilling Representative will also ensure good housekeeping standards are 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.

6.9 Solid Wastes

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, and once a drill rig and drilling contractor have been chosen, the waste options will be assessed (with FIG) and a tailored project waste management plan will be developed and implemented.

Typically, 24 tonnes of general waste are generated per month from a single well drilling programme. Bulk wastes (e.g. garbage, scrap, etc.) generated on the drilling rig will be segregated by type, stored in covered, four tonne capacity skips. Periodically these will be transported to shore (either the Falklands, if practicable, or to an alternate location) and the waste recycled or disposed of in a controlled manner through authorised waste contractors. BHPBP(F)C will ensure that a waste management programme is implemented to minimise the amounts generated and to ensure material such as scrap metal, waste oil and surplus chemicals are sent for re-cycle or re-use as far as practicable. Other waste will be sent to authorised landfills or incineration facilities, depending on its precise nature, to the Falklands, if practicable, or an alternate location.

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 into the North East Atlantic Ocean.

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 special waste will be implemented in accordance with regulatory guidelines.

6.10 Loss of Containment

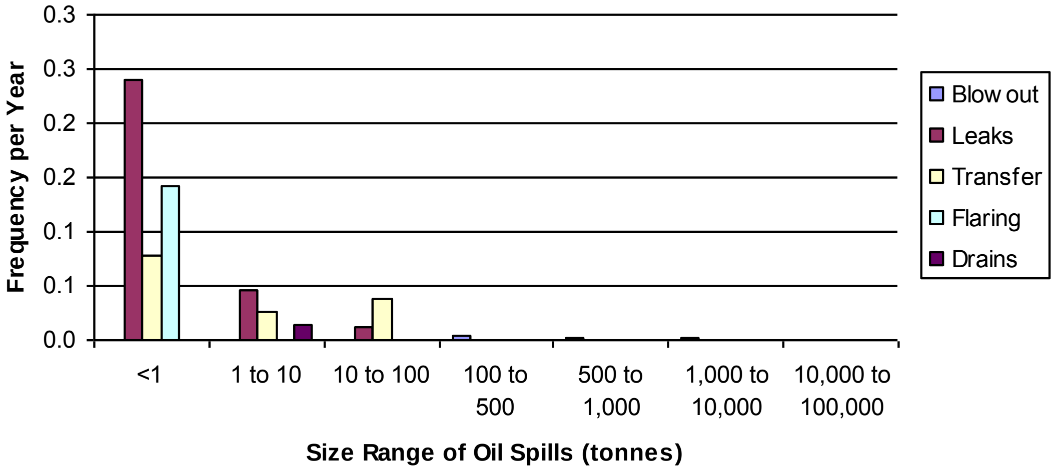
6.10.1 Drilling Operations

Potential Spill Scenarios

The main environmental risk associated with rig operations is a risk of accidental hydrocarbon release during drilling operations, mainly from fuel bunkering of diesel or a loss of well control.

Data recorded by the Department of Energy and Climate Change on oil spills on the UK Continental Shelf indicate that small spills are historically the most common during drilling operations, although these are still quite rare occurrences (Figure 6.5). The historical frequency is 0.15 'operational' spills per exploration well drilled on the UK Continental Shelf between 1994 and 1997 for all recorded spills of ten tonnes or less.

Figure 6.11. Frequency and Size of Oil Spills during Offshore Drilling Operations per Rig Per Year (data from UKCS and SINTEF Database)



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 two main sources of potential spillages, from historical oil spill records are listed in Table 6.6 with the measures that being taken by BHPBP(F)C within the drilling programme to minimise or eliminate the risks. These are discussed further in the sections below along with response measures in the unlikely event that a large spill does occur. Further information on the likelihood of spills and the size and type of spill that may be expected from the proposed wells is also provided in Appendix H.

Table 6.6. Sources of Oil Spills and Control Measures Planned

Potential Source of Spill	Risk and Control Measures Taken
Fuel or other utility fluids (e.g. diesel, lubricants)	The rig will arrive on site fully bunkered, so refuelling should be minimised. If refuelling is undertaken at sea, a refuelling procedure will be implemented, and will contain measures such as the following: • Where practicable, re-fuelling and transfer of lubricants and other utility fluids will only be undertaken during daylight and in good weather conditions. Non-return valves will be installed on fuel transfer hoses, hoses will be tested and inspected as a part of a regular maintenance programme and operations will be supervised at all times from both the supply boat and drill rig. • Bunding is integral to the fuel, oil and liquid storage areas. • The rig will be equipped with sorbent clean-up materials and storage capacity for recovered oil and sorbent. The crew are trained in oil spill response actions. An oil spill contingency plan will be in place and will compliment the Falkland Islands national oil spill plan.
Loss of well control	Precautions to prevent loss of well control include: • shallow gas survey • appropriate well design and engineering, such as using a blowout preventer • well monitoring programme • conducting well control training and emergency drills.

Worst Case Scenario Definition

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 only of 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 Loligo and Toroa is therefore very low.

Predicted Potential Impact on the Coastal Environment

For oil spill planning purposes, modelling, using the BMT (BMT Cordah is a UK based environmental consultancy and information systems company) OSIS 4.0 spill model, has been undertaken to estimate the minimum time to shore in the case of two worst-case oil spill scenarios:

1. 100 tonne instantaneous release with a 16 knot onshore wind (trajectory)
2. 6,110 tonnes released over 48 hours under typical weather conditions, and prevailing and atypical currents (stochastic).

The modelling concluded that under typical or atypical met-ocean conditions, it is not expected that a spill from the proposed Toroa or Loligo wells would beach on the Falkland Islands or on any of the landmasses in the general area.

The trajectory modelling data suggested that under worst case conditions of a constant 30 knot onshore wind, the minimum time for a spill to beach from proposed well locations is approximately 80 hours. In practice, if such a spill was to occur, the BHPBP(F)C in-house emergency response system would be activated and specialist responders would be deployed to address the situation. Oil Spill Response (OSR), of which BHPBP(F)C is a member, offer such services and appropriate shoreline or offshore spill response equipment could be onsite within 24 hours which would be sufficient to respond to possible shoreline threats.

The full modelling report is provided in Appendix H.

Table 6.7 Loglio and Toroa Exploration Wells OSIS Modelling Results

Oil Type	Spill Size	Scenario	Met-ocean Conditions	Fate of Spill
18°API crude	100 t (Instantaneous Release)	Partial inventory loss from the Toroa well	Trajectory 16 knot onshore wind	The spill plume makes contact with the south coast of the Falkland Islands shore after approximately 80 hours.
18°API crude	100 t (Instantaneous Release)	Partial inventory loss from the Loligo well	Trajectory 16 knot onshore wind	The spill plume makes contact with the east coast of the Falkland Islands shore after approximately 160 hours.
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Toroa well	Stochastic Typical weather conditions with 'prevailing' currents	Under typical conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching) (Figure 6.12).
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Toroa well	Stochastic Typical weather conditions with 'atypical' currents	Under typical weather and atypical current conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching.
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Loligo well	Stochastic Typical weather conditions with 'prevailing' currents	Under typical conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching (Figure 6.13).
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Loligo well	Stochastic Typical weather conditions with 'atypical' currents	Under typical weather and atypical current conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching.

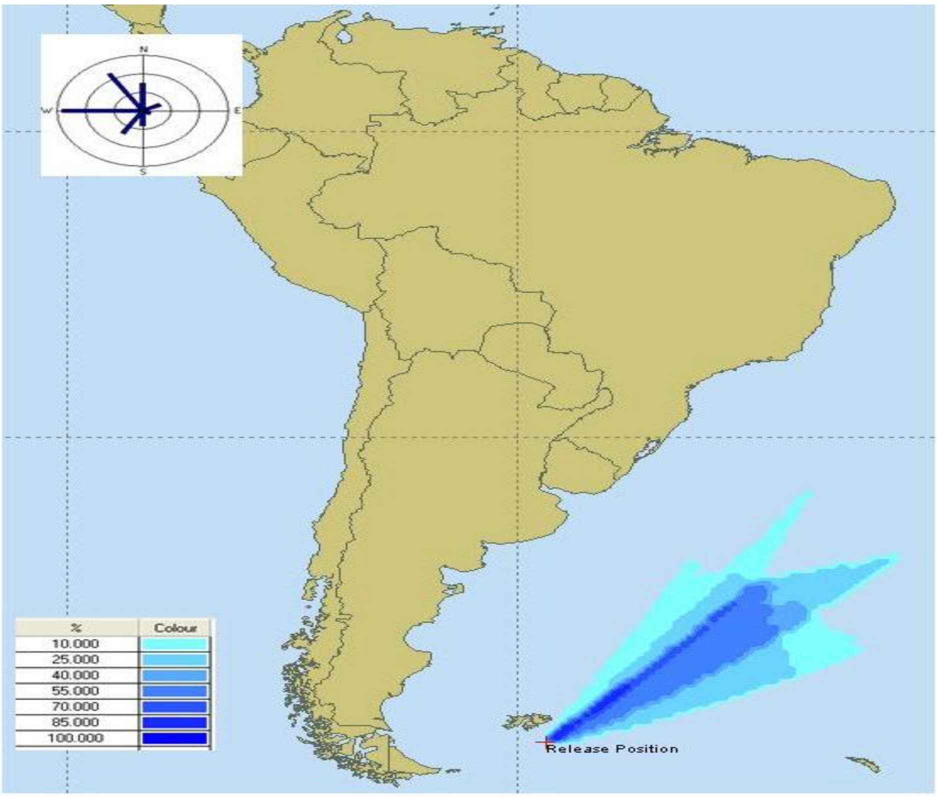


Figure 6.12 6,110 tonne 18°API crude spill from the Toroa well modelled using a trajectory simulation under prevailing currents

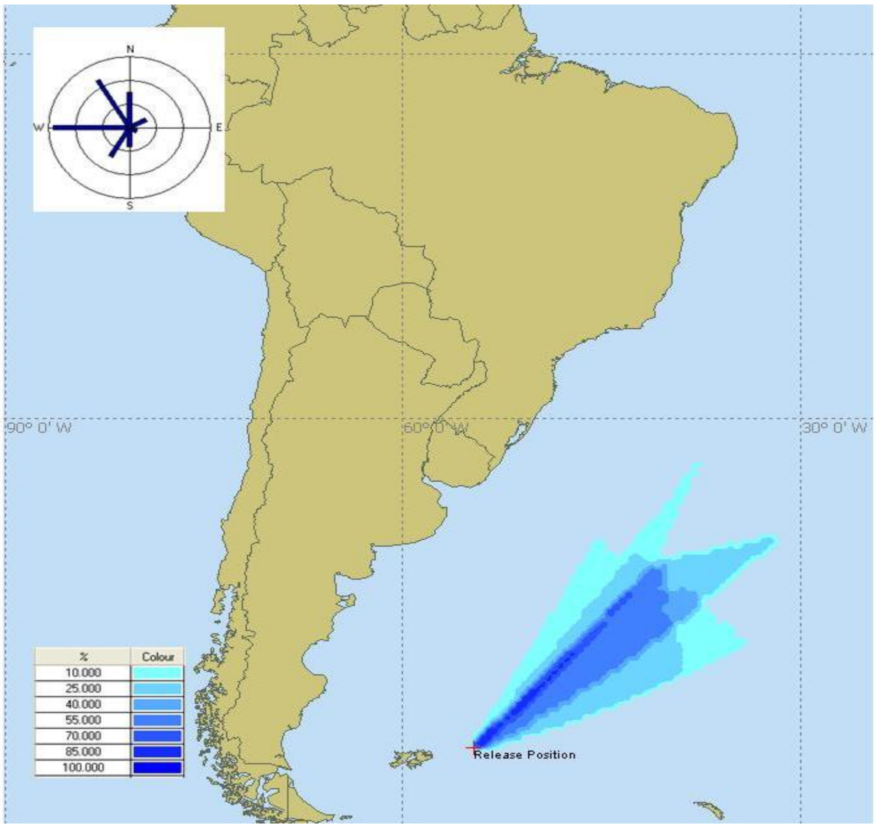


Figure 6.13 6,110 tonne 18°API crude spill from the Loligo well modelled using a stochastic simulation under prevailing currents

Potential Offshore Impacts

Offshore, the groups of animals that are most obviously distressed by a marine oil spill are the plankton, fish, seabirds and mammals.

Lethal effects may occur in adult fish species with hydrocarbon levels of above one part per million. Larvae tend to be more susceptible and lethal effects may occur above 0.1 parts per million. Sub-lethal effects may be observed at low parts per billion concentrations; this can result in behavioural changes or narcosis (*Baker et al, 1990*).

There has been concern that chronic exposure, particularly to the polycyclic aromatic hydrocarbons (PAH) fraction, will have long term effects through accumulation (particularly shellfish) and concentration within the food chain. It is argued that at levels that would cause concern, tainting would occur and the food would be rejected (*Baker, 1993*).

Plankton occupies the upper layers of the water column and may be exposed to toxic water soluble components from spills. The most serious consequence of this is seen where the water body is relatively small, i.e. in shallow, inshore water. However plankton show great variability in time and space and therefore the direct effects of oil are difficult to measure.

There is no definitive evidence that suggests that oil pollution has significant effects on adult fish populations in the open sea. Fish eggs and larvae are relatively immobile and under slicks there may be heavy mortalities that are exacerbated by the use of dispersants (*Swan et al, 1994*). Where oil is trapped in seabed sediments, sediment communities and demersal fish may be adversely affected. Offshore any such accumulations tend to be localised close to the spill source. Such deposits are relatively transient, disappearing as the release stops or the slick passes. As the oil weathers (typically weeks/months), these effects diminish.

Species of birds that spend much of their time on the sea surface are particularly vulnerable to spills. Oiling of the plumage destroys its integrity as insulation and allows the animals to die of hypothermia or by drowning. Concentrations of birds are most vulnerable to oil pollution during the breeding season near their colonies and at other times of the year over the feeding grounds. Evidence suggests that in most cases spills are unlikely to have long term effects overall on bird populations unless a substantial portion of the population is restricted to the immediate area of the spill (*Dunnet 1982, Leppakoski 1973*). The seabird vulnerabilities (as assessed by the JNCC), described in Section 5.3.10, indicate that vulnerability in the proposed drill site locations and the surrounding area is higher in the Austral summer months of December through to February. Offshore, the mobility of marine mammals means that they can usually avoid areas of oil pollution. Individuals that become trapped by oil in coastal waters or seal populations whose haul out sites are covered by beached oil may be affected (*Barne et al, 1996*).

Mitigation Measures

A number of control measures will however be in place to minimise the risk of a spill. An Oil Pollution Emergency Plan (OPEP) and an Emergency Response Plan (ERP) will also be in place prior to any well drilling operations taking place, to provide guidance on actions to be taken in the event of a release or spill. These measures will reduce the risk of a spill or release and provide control measures in the unlikely event of a major spill occurring.

6.11 Cumulative Impacts

Low levels of shipping and fishing activities currently cumulatively impact the surrounding environment within the proposed drilling locations and at the supply base in Stanley. It is not anticipated that the short-term exploratory drilling campaign will significantly, or permanently, add to these existing cumulative impacts.

A more detailed analysis of cumulative impacts cannot be provided as no rig has been contracted yet. The wells being planned by other operators in the region are located a considerable distance from those proposed by BHPBP(F)C, so the likelihood of any spatial overlap of impacts from different drilling operations must be considered to be remote.

7 Management Framework

Environmental management of the drilling programme will be conducted within a comprehensive framework comprising:

- BHP Billiton’s Charter
- BHP Billiton’s Sustainable Development Policy
- BHP Billiton Petroleum's Health, Safety and Environment Management System
- Contractor HSE Policy Statements
- Contractor HSE Management Systems
- Management System Interface Documents
- Contractor operational controls and specific environmental procedures for the drilling Environmental Management Plans (EMPs).

This section provides an overview of the current and proposed management framework as it relates to the environmental aspects of the programme.

7.1 BHP Billiton Charter

BHP Billiton’s Charter is provided in Appendix I and includes ‘an overriding commitment to health, safety, environmental responsibility and sustainable development.’

The Charter is signed by Marius Kloppers, Chief Executive Officer with BHP Billiton and dated October 2007.

7.2 BHP Billiton Policy Statement

BHP Billiton’s Sustainability Policy Statement is provided in Appendix I. This includes environmental commitments and goals and aspires to zero harm to the environment. Within the Policy, BHP Billiton aim to ensure:

- Risks to the environment are identified, assessed and managed.
- Applicable legal and other requirements are met or exceeded.
- Targets to promote efficiency and reduce or prevent pollution are set and achieved.
- Biodiversity protection is enhanced in investment, operational and closure activities.
- Stakeholders are engaged with and community partnerships fostered.
- Responsible product use and management through working with others in the product lifecycle.

The Sustainable Development Policy is signed by Marius Kloppers, Chief Executive Officer with BHP Billiton and dated October 2007.

7.3 BHP Billiton Petroleum Health, Safety and Environment Management System

BHP Billiton Petroleum operates according to a set of Health, Safety and Environment (HSE) Management System (August 2009). The Petroleum HSE Management System applies to Petroleum controlled activities and to Petroleum employees and contractors performing controlled activities. It applies to the entire lifecycle of Petroleum’s activities, processes and products, including exploration and planning, development, operation, closure (decommissioning, remediation and rehabilitation), marketing and acquisitions and divestments. The hierarchy of policies, standards and guidelines within BHP Billiton which together comprise the overall management of HSE issues is demonstrated in Figure 7.1.

Figure 7.1. BHP Billiton HSE Management System Hierarchy

Petroleum monitored activities should have equivalent systems in place that meet the intent of this document. Partners, suppliers and contractors are encouraged to adopt the intent and nature of the performance requirements in this document.

The scope of the Petroleum HSE Management System covers Petroleum activities that affect or have the potential to affect, beneficially or adversely, the health, safety and security of people, the physical environment and protection of assets. In particular, the scope covers systems to manage:

- Health – promoting and improving the health of Petroleum's workforce and host communities.
- Safety – ensuring that safety values are not compromised, personnel are protected and a workplace is provided where people are able to work without being injured.
- Environment – promoting the efficient use of resources, reducing and preventing pollution and enhancing biodiversity protection.
- Community – engaging the external community, managed through the Petroleum External Affairs Function.
- Asset protection – prevention of harm to and protection of personnel, physical and financial assets, and intellectual property.

The HSE Management System sets the framework for continual improvement through the application of consistent performance standards across all aspects of Petroleum activities, including:

- Identification of statutory obligations and commitments and the implementation of systems to ensure our license to operate is maintained.

- Development and implementation of Petroleum risk management processes, including the Safety Case requirements.
- Establishment of competencies for personnel and provision of training to promote expected behaviours and HSE leadership.
- Control and management of all contractors and suppliers of Petroleum goods and services.
- Conduct of reviews including self assessments, audits and compliance evaluations, and the reporting of outcomes from these reviews.

Policies and standards within the Management System are mandatory, whereas the guidelines and toolkits are advisory in nature. The Petroleum HSE Management Systems consist of both mandatory and advisory documents and the operational procedures will apply to those sites and operations where they are issued. For contracted operations such as the drilling operations, the contractors will operate according to their own operational HSE procedures, however these will have been audited against the applicable BHP Billiton Petroleum Standards and Policies to ensure compliance with the clients' expectations.

7.4 Management System Interface Documents

The Contractor policy statements and HSE management systems will be provided when a contractor is finalised.

Bridging the BHP Billiton Petroleum and contractor levels of control will be a Management System Interface Document (also known as a Bridging Document). This document outlines the systems and procedures developed to ensure that the well operations carried out by the drilling contractor on behalf of BHP Billiton Petroleum are managed safely, with due regard for the environment and in a quality manner. Included within this document are:

- Policy, Standards and Procedures
- Safety Management
- Emergency Response
- Environmental Considerations
- Risk Management
- Quality Assurance
- Organisation
- Document Control

The Management System Interface Document will be implemented, as mentioned above, when a contractor is finalised and their existing systems are known.

7.5 Operational Controls and Procedures

Environmental Management Plans (EMPs) specify the measures required to undertake the operations in accordance with the documented HSE standards and mitigation measures proposed in the preceding chapter. The EMP ties in with existing operational controls and should not duplicate controls and procedures already in place which are fit for purpose. Where suitable environmental controls have been put in place to manage the operations in accordance with the agreed standards and mitigation measures, the EMP references these procedures and summarises the roles and responsibilities of the various parties. The management and mitigation measures according to potential impact, responsibilities and monitoring requirements are presented in Table 7.2.

The contractor will comply with the applicable environmental legislation, standards and conditions. All crew members should be made aware of the standards and controls applicable to the conduct of this operation before the surveys commence. Non-conformances and areas for improvement highlighted by BHP Billiton Petroleum in both the HSE MS audits and the rig based HSE audits should be closed out with documented evidence of the actions taken and any preventative measures put in place.

Clear lines of communication and operational procedures will be established between the drilling rig, onshore support facilities, support vessels and helicopter facilities before the start of drilling. Organograms showing the management structure and lines of reporting for both the operational phase and the project initiation and definition phases will also be drawn up to illustrate the lines of communication.

7.6 Reporting

Environmental reporting will be governed by:

- Requirements of BHP Billiton Petroleum, as stipulated in the HSE Management System
- Practices of the contractors
- International standards regarding waste, oil spill and emissions reporting
- National regulatory environmental requirements

The UK standard Environmental Emissions Monitoring System (EEMS) reporting format will be used for monitoring the consumption of resources and emissions to air and water. Shipping manifests will be completed for all shipments to and from the drill rig and will be logged and reported in line with documented management procedures.

Monitoring of emissions to air and water, waste production and resource consumption will be undertaken in accordance with established procedures for similar operations in the UK based around the EEMS and Petroleum Operations Notice (PON) systems. Monitoring, calculating and reporting of greenhouse gas emissions requires various assumptions to be made and relies on a multiple tier approach based on degrees of uncertainty. The different levels of certainty and accuracy in emissions reporting are shown in Figure 7.2.

Types of Approaches	Hierarchy
1. Published emission factors 2. Equipment manufacturer emission factors 3. Engineering calculations 4. Monitoring over a range of conditions and deriving emission factors 5. Periodic monitoring of emissions or parameters for calculating emissions 6. Continuous emissions* or parameters monitoring	**Improved accuracy** **Additional data requirements** **Higher cost**

*Continuous emissions monitoring applies to most types of air emissions, but may not be directly applicable nor highly reliable for greenhouse gas emissions.

Figure 7.2. Emissions Estimation Approaches

During well operations, an Operational team will be established in Stanley, Falkland Islands. Daily reports will be sent from the rig to the drilling contractor Team Leader.

The following reports shall be forwarded to the offshore BHPBP(F)C representative in the Falkland Islands and (via the drilling contractor Manager) to the BHPBP(F)C representative in the United States:

- Daily Drilling/ Testing Report
- Daily Geological Report
- Mud logging report
- Six day look ahead

- Persons on board list
- Vessel and Helicopter Movements
- All accident or incident reports.

A weekly operational report and summary will be prepared by the drilling Team Leader and forwarded to the relevant Service companies (by way of an Operational update) to ensure that operational support is available.

At the end of operations an End of Well report including operational and financial sections will be compiled. The operational section of this report will include:

- Daily activities
- Time/depth curve
- Casing running and cementing report
- Materials usage report
- Bit record
- Mud logging report
- Formation evaluation report.
- Directional drilling report
- Testing report
- Abandonment/suspension/completion status report
- Down time Analysis/Lessons Learnt

EEMS reports and PONs will be completed in accordance with the production licence and regulatory requirements and submitted to FIG. Relevant EEMS reports encompass the following datasets:

- Form EEMS/007 - Chemical Term Permits
- Form EEMS/014 - Waste Report
- EEMSATMO - atmospheric emissions inventory - Form 2002

For UK operations, the EEMS data submission timetable for drilling activity is as follows:

Table 7.1. EEMS Data Submission Matrix

(Source: www.eems-database.co.uk)

Activity	EEMS/001	EEMS/004	EEMS/005	EEMS/006	EEMS/007	EEMS/008	ATMOS	EEMS/014
Drilling	N/A	N/A	One month from completion	N/A	One month from completion	N/A	One month from completion	Annually by 1st Mar

7.6.1 Oil Spill Contingency Plan

A project dedicated oil pollution emergency plan (OPEP) will be developed in support of the proposed drilling campaign. It will be developed when the contract for the drill rig and crew has been awarded, and will be based on the results of the oil spill modelling scenarios. The OPEP will provide for a multi-tier response dependent on the scale and type of spill.

Currently, BHP Billiton has a contract for global coverage with OSRL and the Clean Caribbean Coop (CCA) (covers all of the Americas). Dispersants, if required, from OSRL/CCA would take 24 hours to mobilise to the location. For continuous or large spill scenarios OSRL/CCA would be able to mobilise their large spray systems and surveillance personnel.

The OPEP will also correspond with the plans of the FIG and its national oil spill contingency plans.

7.7 Environmental Management Plan

The table below presents the Environmental Management Plan (EMP), which summarises the potential impacts and their corresponding proposed mitigation measures as discussed in this EIS for each aspect of the drilling related operations. The EMP will be confirmed when the drill rig and crew have been contracted and any changes will be presented in the Addendum.

Table 7.2. Environmental Management Plan

Project Phase & Activities	Aspect / Objective	Management and Mitigation Measures	Responsible Parties	Monitoring
1.0 PRE-ESTABLISHMENT PHASE				
1.1 Pre-drilling planning	Accommodation of needs for environmental monitoring and liaison with fishing industries	In order to minimise disruption to the drilling and other users of the sea: • Determine the extent of local fishing activities. • Establish contact with Fisheries Department. • Verify procedures for notifying local interests.	BHPBP(F)C	
1.2 Emergency preparedness	Preparation for any emergency that could result in an environmental impact	Have the following emergency plans, equipment and personnel in place to deal with all emergencies: • Company (or representative) Emergency Response Plan; and • Survey Contractor Emergency Response Plan. Note that in case of a major oil spill, emergency responses and/or Oil Pollution Emergency Plan(s) should refer to the BHPBP(F)C project specific OPEP.	BHPBP(F)C & Drilling Contractors	Management Audit
1.3 Permitting & approvals	Compliance with legislative requirements	Licensing of contractor and pre-notification with FIG.	BHPBP(F)C Drilling Contractors	Legal Register
2.0 ESTABLISHMENT PHASE				
2.1 Compliance with EMP	Operator and contractor to commit to adherence to EMP Establish necessary bridging documents to BHP Billiton Petroleum HSEC MS	Ensure that a copy of the approved EMP is on the drill rig and support vessels during the drilling programme. Appropriately inform the rig and shipboard personnel of the purpose and requirements of the EMP. Ensure correct equipment and personnel are available to meet the requirements of the EMP. Operator to commit organisation and contractor to meet the requirements of the EMP.	BHPBP(F)C & Drilling Contractors	Audit results Training records
2.2 Notifying other users	Ensure that other users are aware of the forthcoming survey	Liaise with Fisheries Department at FIG & local fisheries interests, as well as the British Military. Issue Radio Navigation Warnings and Notices to Mariners as appropriate.	BHPBP(F)C & Drilling Contractors	Records of communications Copies of notices issued

Project Phase & Activities	Aspect / Objective	Management and Mitigation Measures	Responsible Parties	Monitoring
3.0 OPERATIONAL PHASE				
3.1 Use of Resources				
Adherence to EMP Implementation of mitigation measures	Fuel consumption Drilling muds Sea water abstraction	• Extensive planning to ensure that no strains are placed on current capacities. • Appropriate and well-maintained equipment. • Accurate monitoring and recording of consumption figures. • Minimisation of water use. Appropriate use of water resources.	Party Chief Chief Mechanic Drilling Manager Project Manager	Record of fuel used. Maintenance records External HSE audits Internal HSE audits Incident reporting
3.2 Emissions to water				
	Grey water discharge Sewage discharge Food waste OWS discharge Cooling water Deck drainage Oil/chemical spills	• Materials handling, operating and maintenance procedure. • Strict bunkering procedures to be implemented and monitored. • No contaminated and/or solid wastes to be discharged overboard. • Suitable contained storage of hydrocarbons and chemicals. • No release of chemical spills on deck overboard. • Contaminated water directed to the oil water separator (OWS). • Implement suitable waste segregation and storage. • Biodegradable cleaning agents used wherever possible. • Utilise IMO compliant sewage treatment plant.	Party Chief Chief Mechanic Drilling Manager Project Manager	Oil record log Maintenance records External HSE audits Internal HSE audits Incident reporting Survey Report

Project Phase & Activities	Aspect / Objective	Management and Mitigation Measures	Responsible Parties	Monitoring
	Fugitive release of waste Ballast water exchange	• No discharge of 'high risk' ballast water in Falklands' waters. • Ballast water exchange to take place in open waters.		Ballast exchange records
3.3 Emissions to Air				
	Engine / generator emissions Incinerator emissions Fugitive emissions Fire fighting chemicals	• Regular maintenance of engines, compressors and generators. • Internal 'housekeeping audits' to check for leaks and spills. • Use of non ozone depleting fire fighting foam. • Batch processing waste to minimise operational time of incinerator, if one is available onboard the rig. • Incineration of non-hazardous combustible waste only. • Using designated personnel to carry out incineration. • Reduction of waste at source. • Recycling of waste where possible.	Party Chief Chief Mechanic Drilling Manager Project Manager	Monitor fuel consumption. Maintenance records Garbage record log Incinerator records External HSE audits Internal HSE audits Chemical inventory
3.4 Waste disposal				
	Onshore burial of waste Onshore incineration of waste	• Reduction of waste production and recycling of materials where possible. • No onshore disposal of hazardous wastes to landfill in the Falkland Islands. • Correct segregation and appropriate containment of wastes prior to disposal. • Removing metal and hazardous wastes to appropriate	Party Chief Drilling Manager Project Manager	Garbage record log Waste disposal transmittals Survey Final Report

Project Phase & Activities	Aspect / Objective	Management and Mitigation Measures	Responsible Parties	Monitoring
		disposal facilities. • Containment/netting of skips to prevent fugitive release during transport. • Where onshore incineration in an approved incinerator is a viable option, emissions abatement equipment should be used where available. • Proper disposal of ashes. • Correct segregation of wastes prior to disposal. • Disposal of waste at approved sites.		
3.5 Underwater sound				
	Engine and propeller noise Drilling equipment	• Regular maintenance of vehicles and equipment. • Selection of appropriate drilling equipment and materials.	Party Chief Chief Surveyor	Maintenance records Internal HSE audits
3.6 Physical Impacts				
	Vessel presence Emergency anchoring Lost equipment	• Use of water based bentonite mud. • Advanced consultation with FIG, fisheries and the British Military. • Reasonable efforts made to retrieve lost equipment.	Party Chief Chief Surveyor Client Representative	Sampling and coring locations External HSE audits Internal HSE audits Incident reporting HSE Statistics Survey Final Report

Project Phase & Activities	Aspect / Objective	Management and Mitigation Measures	Responsible Parties	Monitoring
4.0 POST-DRILLING PHASE				
4.1 Post-drilling area	Leave drilling area in an acceptable state	Ensure that all deployed equipment is retrieved.	Drilling Contractor	Equipment logs Incident reports
4.2 Inform relevant parties of drill completion	Ensure that relevant parties are aware that drilling work is complete	Inform the FIG of the drill completion.	BHPBP(F)C & Survey Contractors	Records of communications
4.3 Final waste disposal	Minimise pollution and ensure correct disposal of waste	Refer to Operational Aspects above.	BHPBP(F)C & Survey Contractors	Garbage book Waste transfer notes

8 Conclusion

Sufficient baseline data exists for the proposed well locations in the East Falklands Basin through the detailed surveys and modellings commissioned by BHP Billiton Petroleum (Falklands) Corporation and undertaken by Fugro Survey Limited. This Environmental Impact Statement (EIS) makes a thorough assessment of the potential impacts that may arise from the planned drilling programme. Mitigation measures have been proposed for all potential impacts with extra attention given to those deemed to be of high to medium significance. This will allow operations to proceed without any significant long lasting impacts to the marine or coastal environment of the Falkland Islands.

To successfully implement the proposed mitigation measures the focus is now on ensuring the operations follow established procedures, key personnel are trained in emergency response such as oil spill response, joint exercises are run with the Falkland Islands oil spill response plan, all personnel receive basic environmental awareness training and contingency plans are in place to prevent any environmental incidents from occurring.

The operations specific addendum to this EIS that will be produced, will further define the environmental management, operational controls and employee training necessary to keep impacts to ALARP (as low as reasonably practicable) levels.

Finalising the drilling unit and crew is not likely to cause a significant deviation from the operation aspects identified in this EIS. Should there be any operational changes likely to cause a significant change to the assessment of impacts, they will be incorporated within the operational addendum. At this stage it is thought most likely that potential changes will be minor and that these will not significantly alter the results of the impact assessment.

Correspondence with the Falkland Islands Government (FIG) has highlighted interaction with the relevant authorities is required on important issues such as waste management on the Islands and the incorporation of the national oil spill contingency plan with project specific plans. FIG has commissioned OSRL to make some recommendations regarding the national oil spill response and a consultant from OSRL visited the Islands at the end of 2008 and submitted a report for consideration by FIG. FIG also continues to review the situation regarding onshore waste management and is seeking ways to better deal with waste onshore, commensurate with the resources available.

Socio-economic aspects of the oil and gas industry have been deliberately limited at the request of the FIG to avoid overlaps with existing studies.

In conclusion, despite the high sensitivity and international importance of the Falkland Islands' waters, there is clear dedication to carrying out these operations to a high environmental standard. Given the current operational commitments and proposed mitigation measures, it is considered that the proposed operations can be undertaken without significant impacts to the Falkland Islands' environment.

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Appendix A: Drilling Operations – Supporting Information

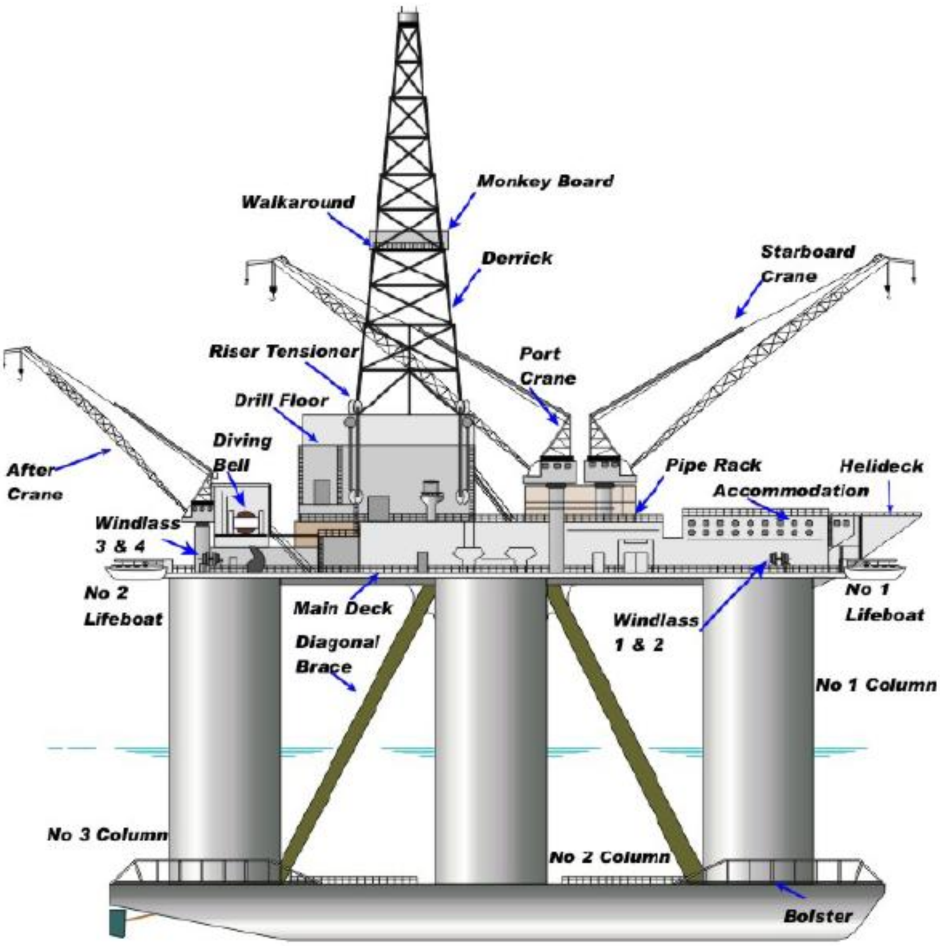
The Drilling Rig

The exploitation of hydrocarbons requires the construction of a conduit between the surface and the reservoir. This is achieved by the drilling process. Offshore wells are typically drilled by mobile drilling units of which there are three broad designs currently in use: drill ship, semi-submersible drilling rig and jack-up drilling rig. The proposed wells will be drilled using a third / fourth generation drill rig.

Semi-submersibles float in deep water and provide a stable platform to allow drilling of the sea floor. Semi-submersibles reduce 'heave'—the vertical motion of a vessel in response to the action of waves—by reducing the area of hull in contact with the water to a minimum. Vertical circular sectioned columns are fitted beneath the deck at each side, terminating in underwater pontoons hulls containing large tanks for ballast, fuel and fresh water. The columns and pontoon provide the buoyancy to keep the vessel afloat and some of the tanks can be flooded to lower the vessel to a sufficient depth in the water to maximise stability and minimise wave movements whilst drilling.

A typical semi-submersible drilling rig has dimensions of approximately 90 m by 80 m with a draught of about 30 m. Semi-submersible rigs are capable of operating in water depths well in excess of that to be encountered at the potential drilling location.

Figure A.1. A typical Semi-Submersible Rig Layout



To support the drilling operation, the following systems and services are usually located on a rig:

- Bulk Storage – is provided for fuel oil, bulk mud and cement, liquid mud, drill water and potable water;
- Pipe and Materials Storage – covered storage is provided for sacked material, drilling equipment, spares, etc. and deck storage for drill pipe and casing;
- Helideck – normally rated for a Sikorsky S-61 helicopter or equivalent;
- Craneage – two cranes provided for loading/off loading equipment / supplies from supply vessels;
- Emergency Systems – this includes life saving appliances, fire detection and protection equipment, combustible gas detection systems and life vessels; and
- Environmental Protection – sewage treatment unit, blow-out preventer (BOP) system, cuttings cleaning equipment and hazardous and non-hazardous drainage systems, which collect rainwater and/or any minor spills to a drains tank for treatment prior to discharge to sea, or allow transfer to tote tanks for shipment to shore and disposal by licensed waste disposal contractors.

Drilling Mud

During drilling operations a fluid known as drilling mud is pumped through the drill string down to the drilling bit and once a conductor tube or riser is set is place, is returned to the rig, in the space (or annulus) between the drill string and the casing (Figure A.2).

Drilling mud is essential to the operation. It performs the following functions:

- The hydrostatic pressure generated by the mud's weight controls the downhole pressure and prevents formation fluids from entering the well bore;
- It removes the rock cuttings from the bottom of the hole and carries them to the surface and when circulation is interrupted it suspends the drill cuttings in the hole;
- It lubricates and cools the drill bit and string; and
- It deposits an impermeable cake on the wall of the well bore effectively sealing and stabilising the formations being drilled.

The mud is recycled and maintained in good condition throughout the operation. The mud and suspended cuttings are processed on the rig through screens called "shale shakers" to maximise recovery of the mud. The recovered mud is then passed through a desander to remove sand particles and, if necessary, subsequent treatment is provided by a centrifuge or desilter. This additional equipment removes the fine colloidal solids, the particles too small to be removed by the conventional equipment, which if allowed to build up can make the mud too viscous.

Three major types of mud are typically used in offshore drilling:

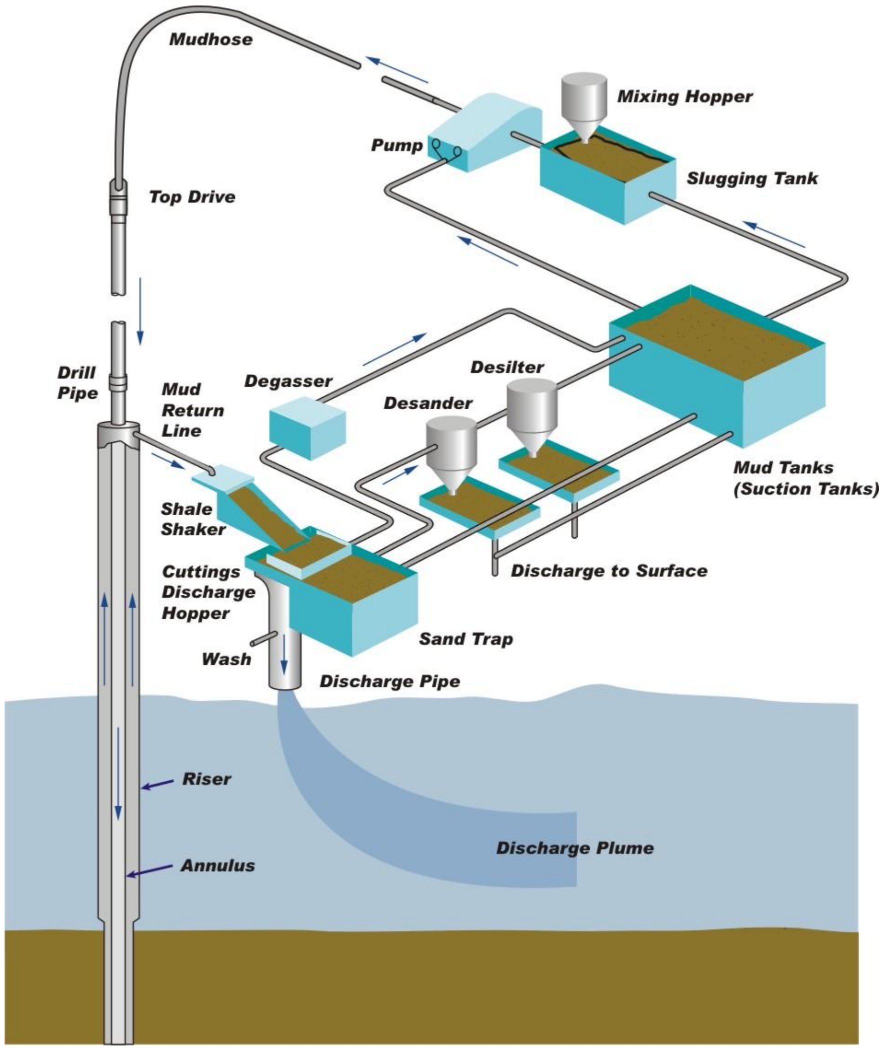
- Water based mud (WBM) – water forms the continuous phase of the mud (up to 90 percent by volume);
- Low toxicity oil based mud (LTOBM) – base oils, refined from crude oil, form the continuous phase of the mud; and
- Synthetic based mud (SBM) – the continuous phase is refined from a number of organic compounds chosen because they act like base oil but are selected to be more biodegradable.

The base muds form a viscous gel to which a variety of additives may be added for various reasons, including:

- Fluid loss control. The layer of mud on the wall of the wellbore retards the passage of liquid into the surrounding rock formation. Bentonite is the principal material for fluid loss control although additional additives such as starch and cellulose, both naturally occurring substances, are also used.

- Lost circulation. Naturally occurring fibrous, filamentous, granular or flake materials are used to stop lost circulation when the drill bit enters a porous or fractured formation. Typical materials include ground nut shells and mica.
- Lubricity. Normally the drilling mud alone is sufficient to adequately lubricate and cool the bit. However, under extreme loading, other lubricants are added to prevent the drill string from becoming stuck. No oil based chemicals will be required for BHP's drilling programme.
- pH control. Caustic and lime are used to control the alkalinity of the mud to a pH of 9 to 10. This ensures the optimum performance of the polymers in the mud and controls bacterial activity.
- Pressure control. Barite is generally used as a weighting agent to control downhole pressure.

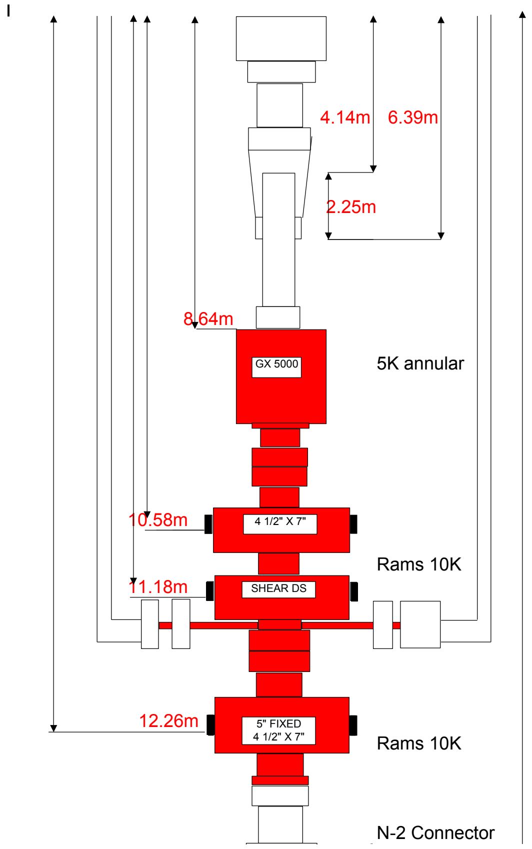
Figure A.2. A Typical Mud Recycling System, once Marine Riser is in Place.



Well Control and Blow out Prevention

In addition to careful monitoring and control of the fluid system and the installation of casing in each section of the well, a blow-out preventer stack, abbreviated to BOP, consisting of a series of individual preventers will be installed on the wellhead at the seafloor, after the surface casing has been installed (Figure A.3).

The function of the BOP is to prevent uncontrolled flow from the well by positively closing in the well-bore, if flow from the well-bore is detected. The BOP is made up of a series of hydraulically operated rams and would be operated in an emergency on the drill rig.



The well is not anticipated to encounter any zones of abnormal pressure and the BOP will be rated for pressures well in excess of those expected to be encountered in the well.

During drilling operations small amounts of BOP fluid are typically discharged every two weeks, during testing of the BOP.

Figure A.3. A typical Blow-Out Preventer Stack

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). 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 LC_{50} – the concentration of the test substance in sea water that kills 50 percent of the test batch; and
- An EC_{50} – 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 P_{ow}) 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

P_{ow} 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 a 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.

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 – FIDA 42/02 LOLIGO

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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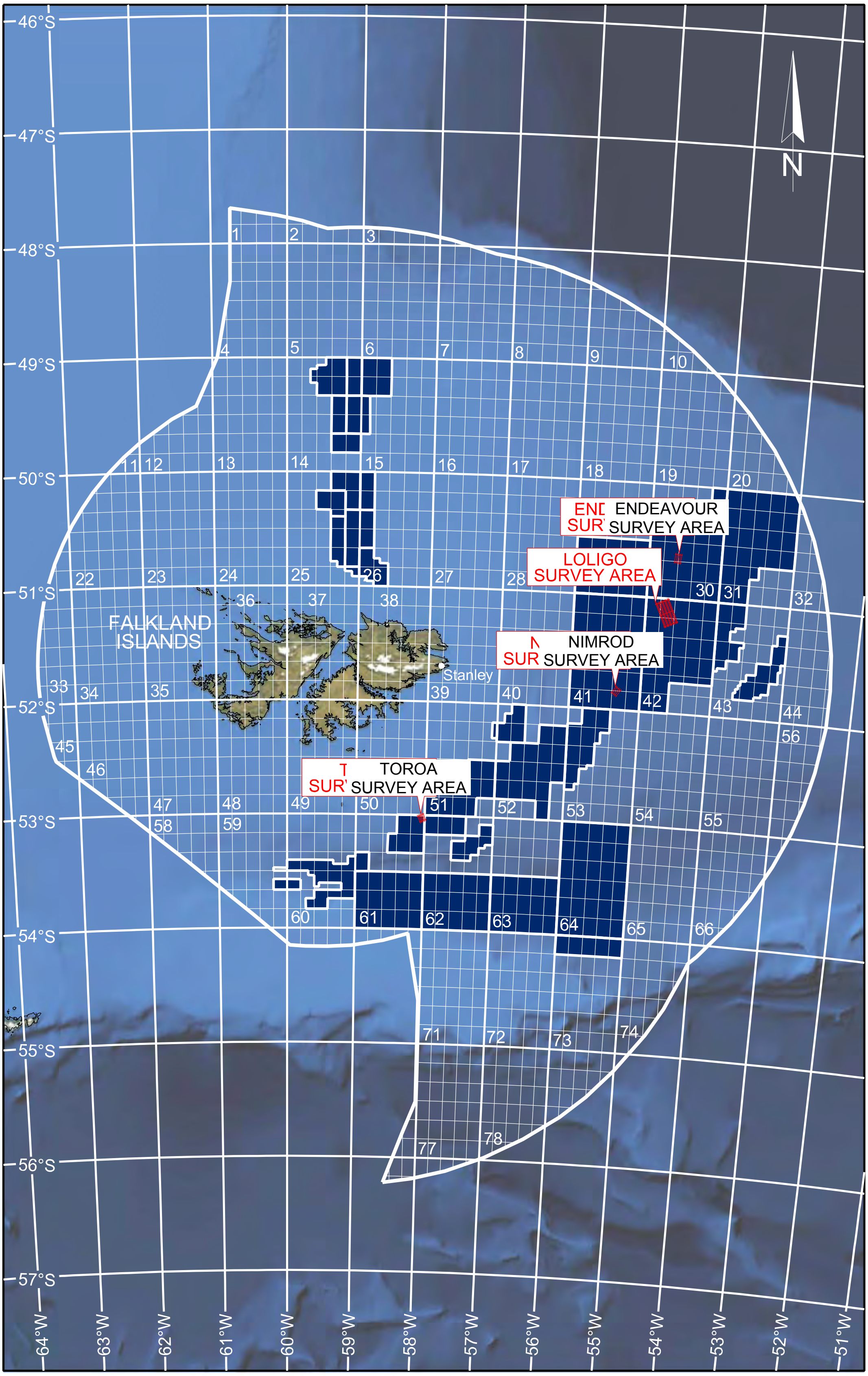
1	Issued as Final	D. Sutherland	P. Collins	R. Walters	15 September 2009
0	Issued as Proof	G Harris-Bryant	P. Collins	R. Walters	22 May 2009
Rev	**Description**	**Prepared**	**Checked**	**Approved**	**Date**



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

<table>
<tr><th colspan="9">Global Positioning System Geodetic Parameters [1)]</th></tr>
<tr><td colspan="3">Datum:</td><td colspan="6">World Geodetic System 1984 (WGS84)</td></tr>
<tr><td colspan="3">Spheroid:</td><td colspan="6">World Geodetic System 1984 (WGS84)</td></tr>
<tr><td colspan="3">Semi major axis:</td><td colspan="6">a = 6 378 137.000 m</td></tr>
<tr><td colspan="3">Inverse Flattening:</td><td colspan="6">$^{1}/_{f}$ = 298.2572235630</td></tr>
<tr><th colspan="9">Local Datum Geodetic Parameters [2)]</th></tr>
<tr><td colspan="3">Datum:</td><td colspan="6">World Geodetic System 1984 (WGS84)</td></tr>
<tr><td colspan="3">Spheroid:</td><td colspan="6">World Geodetic System 1984 (WGS84)</td></tr>
<tr><td colspan="3">Semi major axis:</td><td colspan="6">a = 6 378 137.000 m</td></tr>
<tr><td colspan="3">Inverse Flattening:</td><td colspan="6">$^{1}/_{f}$ = 298.2572235630</td></tr>
<tr><th colspan="9">Datum Transformation Parameters [2)] from WGS84 to WGS84</th></tr>
<tr><td>Shift dX:</td><td>0.000</td><td>m</td><td>Rotation rX:</td><td>0.000</td><td>arcsec</td><td>Scale Factor:</td><td>0.000</td><td>ppm</td></tr>
<tr><td>Shift dY:</td><td>0.000</td><td>m</td><td>Rotation rY:</td><td>0.000</td><td>arcsec</td><td></td><td colspan="2"></td></tr>
<tr><td>Shift dZ:</td><td>0.000</td><td>m</td><td>Rotation rZ:</td><td>0.000</td><td>arcsec</td><td></td><td colspan="2"></td></tr>
<tr><th colspan="9">Project Projection Parameters</th></tr>
<tr><td colspan="3">Grid Projection:</td><td colspan="6">Transverse Mercator, Southern Hemisphere</td></tr>
<tr><td colspan="3">UTM Zone:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="3">Central Meridian:</td><td colspan="6">60° 00’ 00” West</td></tr>
<tr><td colspan="3">Latitude of Origin:</td><td colspan="6">00° 00’ 00” S</td></tr>
<tr><td colspan="3">False Easting:</td><td colspan="6">500 000 m</td></tr>
<tr><td colspan="3">False Northing:</td><td colspan="6">10 000 000 m</td></tr>
<tr><td colspan="3">Scale factor on Central Meridian:</td><td colspan="6">0.9996</td></tr>
<tr><td colspan="3">Units:</td><td colspan="6">Metre</td></tr>
<tr><td colspan="9"><u>Notes:</u>
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.</td></tr>
</table>

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.

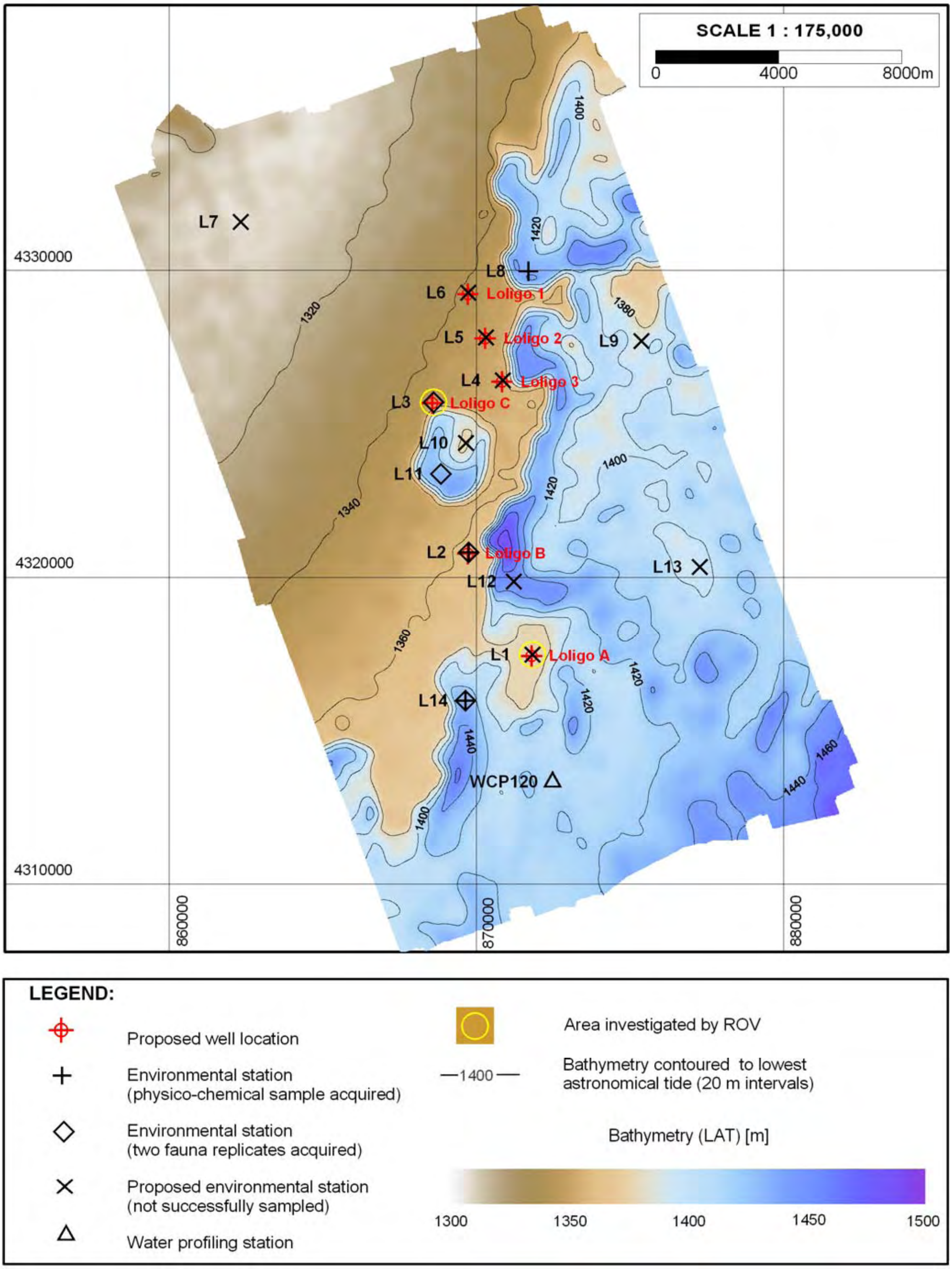

Figure 2.1: Survey Bathymetry Showing Sampling Locations

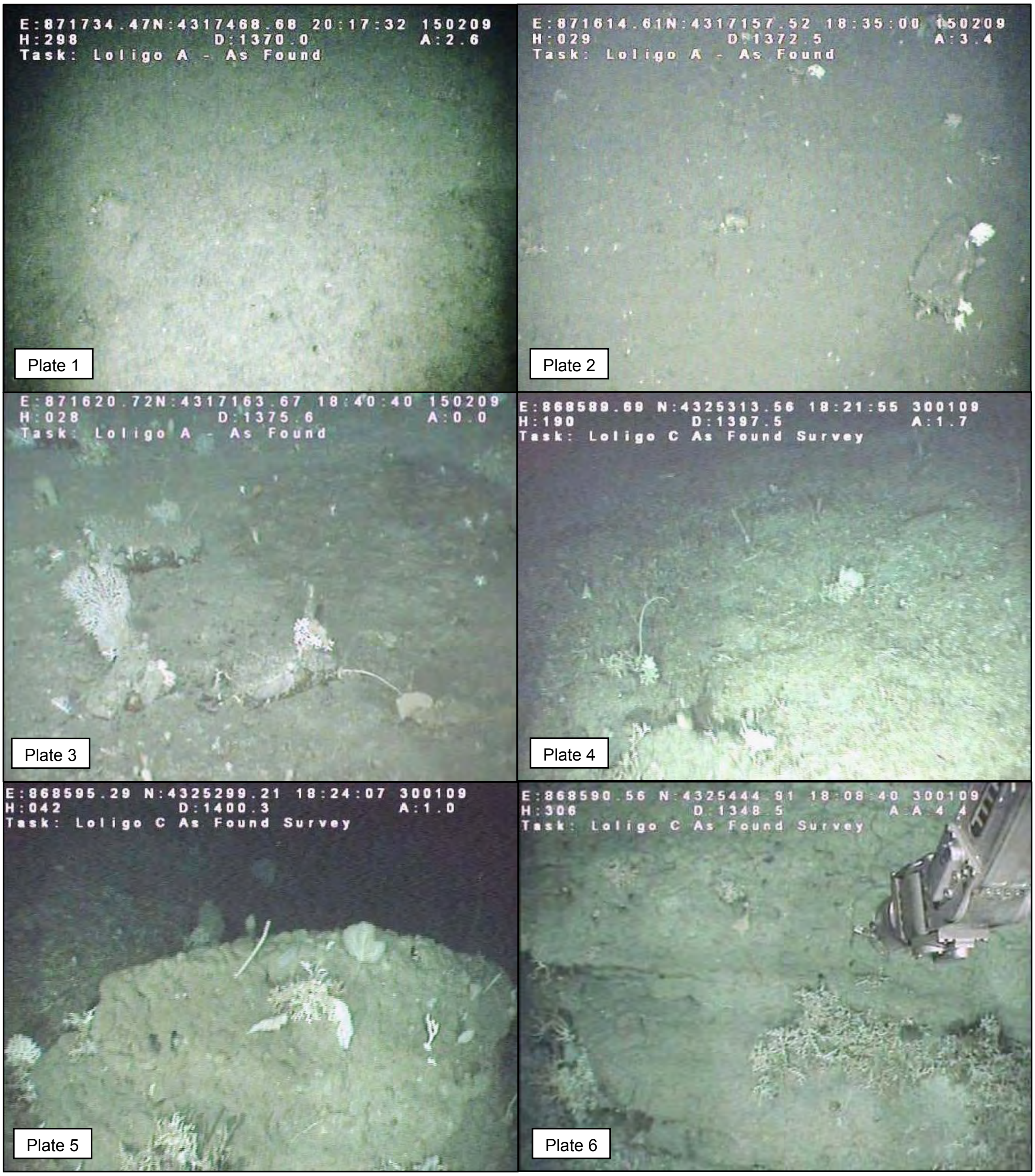

Plate 1: Homogeneous muddy fine sand in the vicinity of the proposed Loligo A location

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).

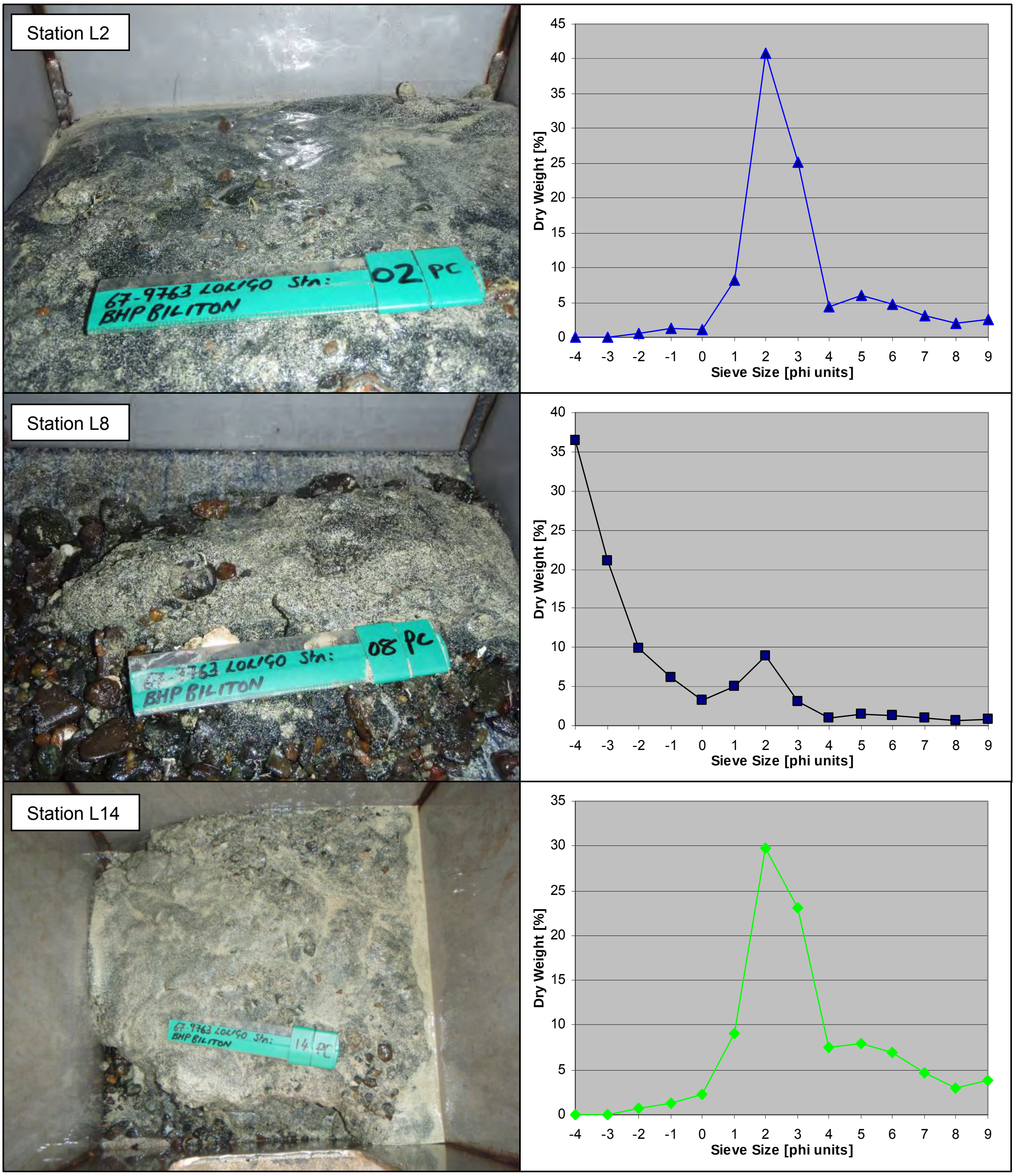

Figure 2.3: Particle Size Analysis – Sample Photographs and Particle Size Distributions

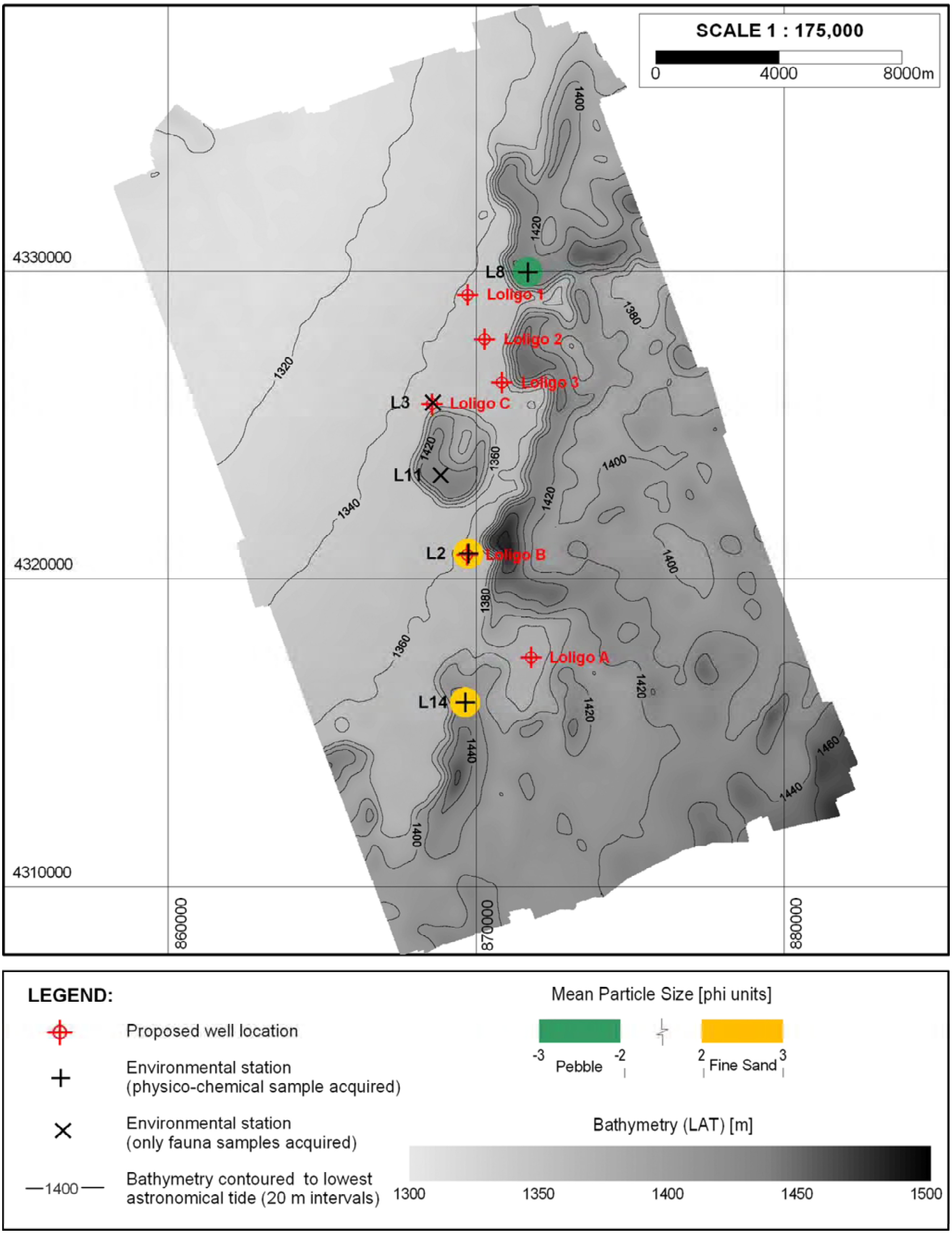

Figure 2.4: Particle Size Analysis – Mean Phi

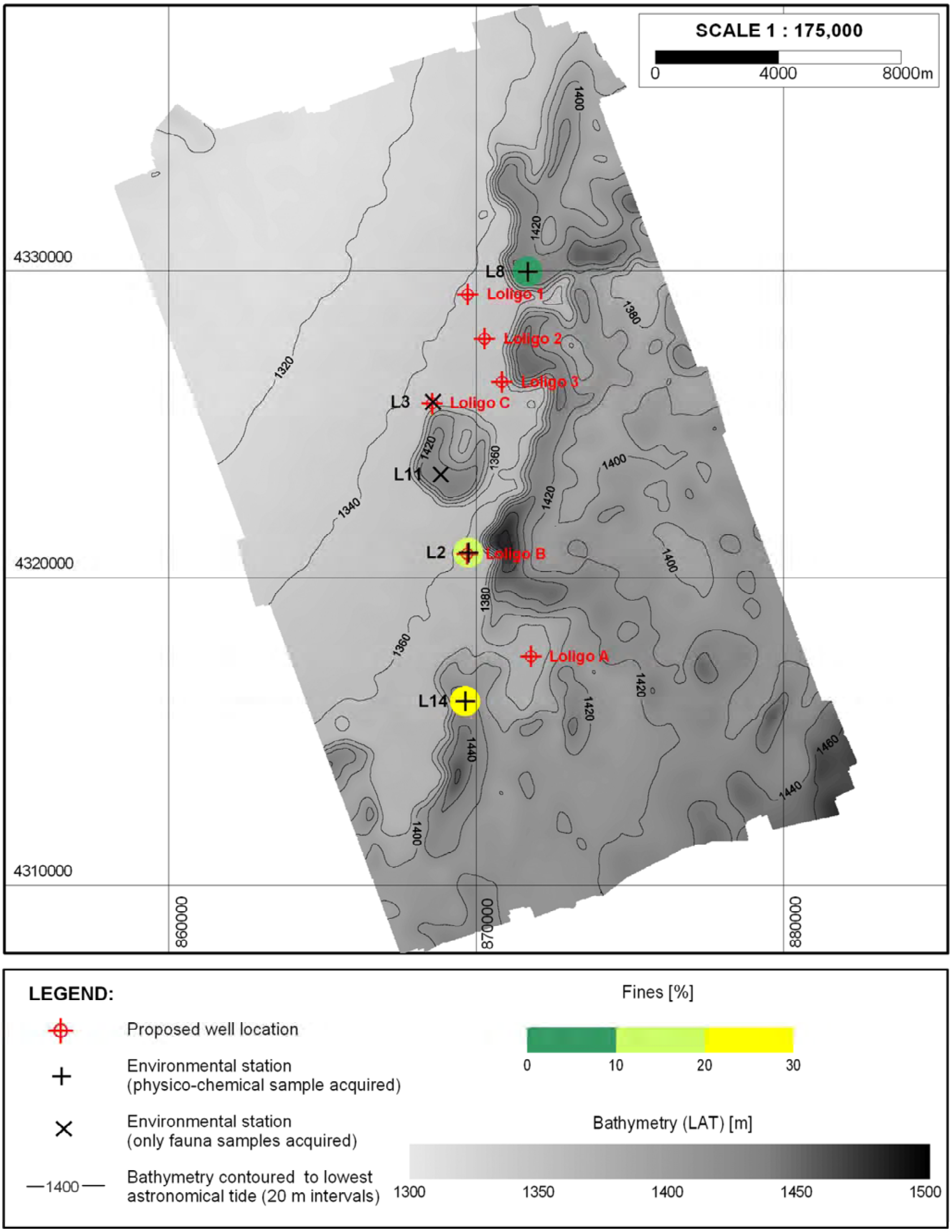

Figure 2.5: Particle Size Analysis – Fines

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.

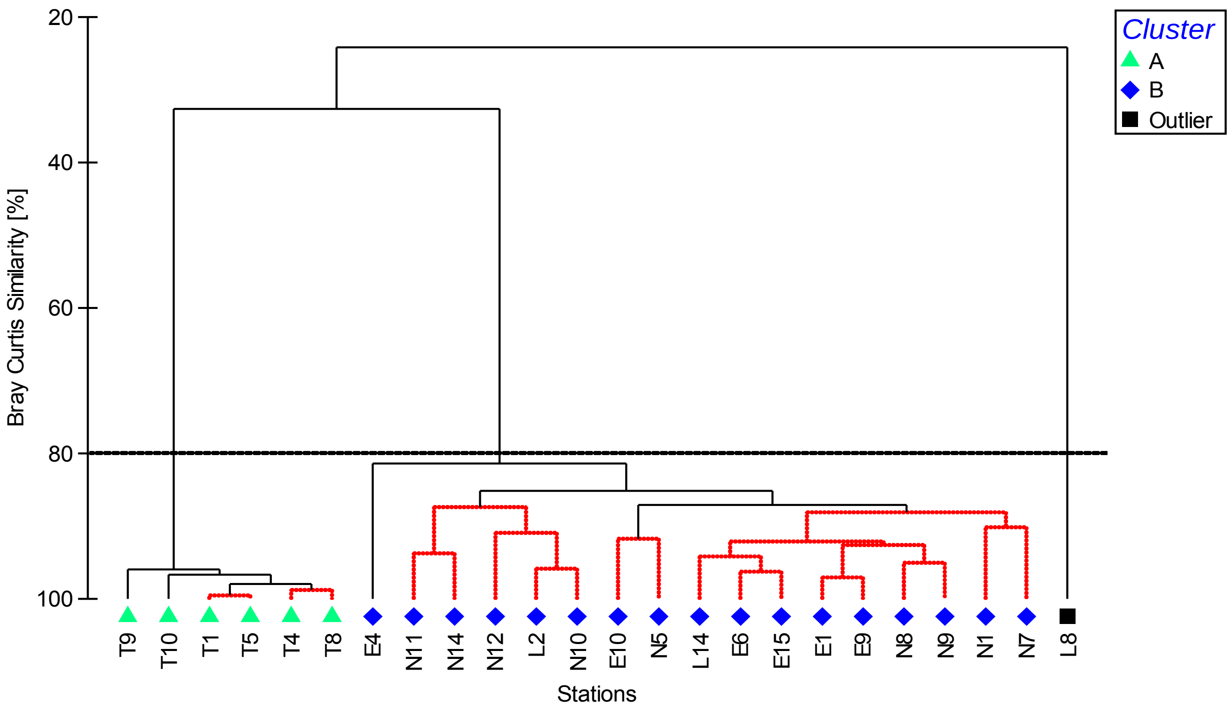

Figure 2.6: Dendrogram by Bray-Curtis Similarity of Particle Size Data for 1 Phi Unit Size Classes

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.

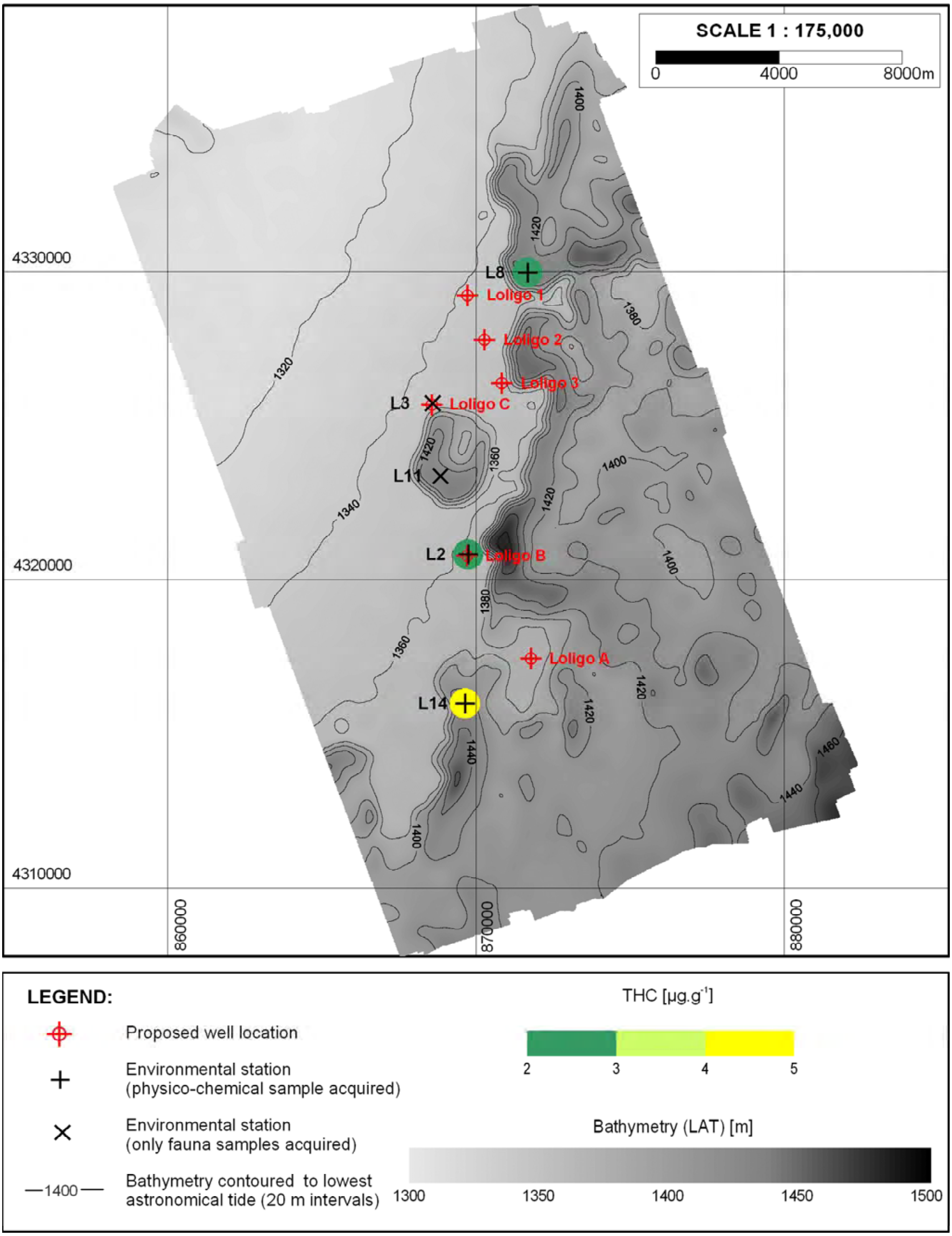

Figure 2.7: Hydrocarbon Analysis – Total Hydrocarbon Concentration [µg.g^{-1}]

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.

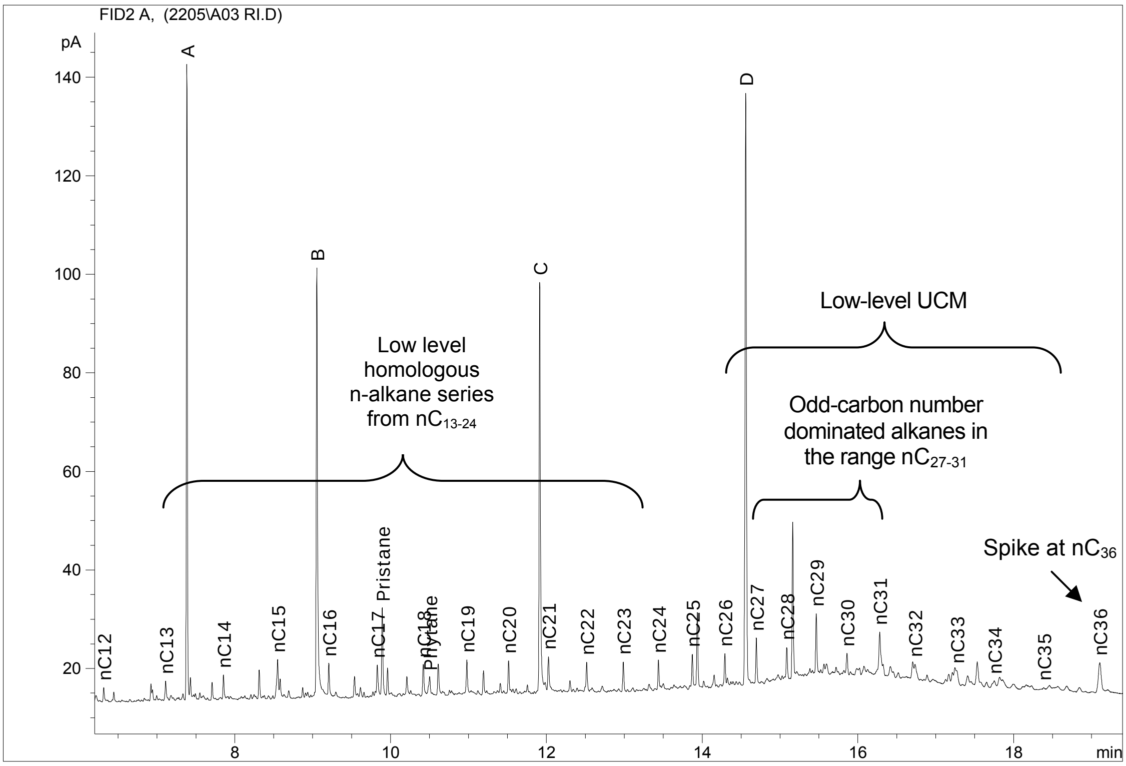

Figure 2.8: Hydrocarbon Analysis – Gas Chromatography Trace (Station L14)

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).

<u>NPD and 4-6 Ring PAH</u>

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.

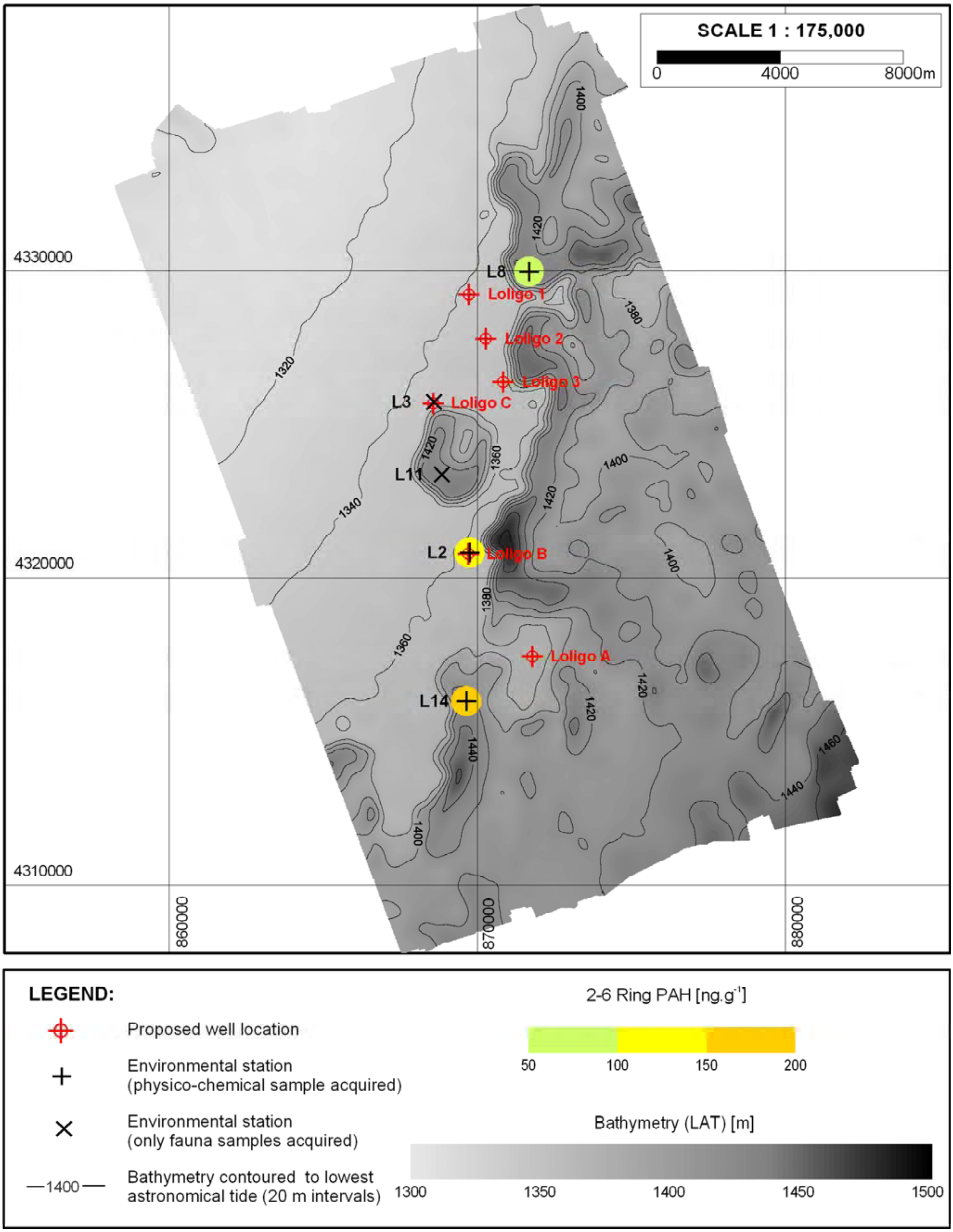

Figure 2.9: Hydrocarbon Analysis – Total PAH Concentration [ng.g^{-1}]

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.

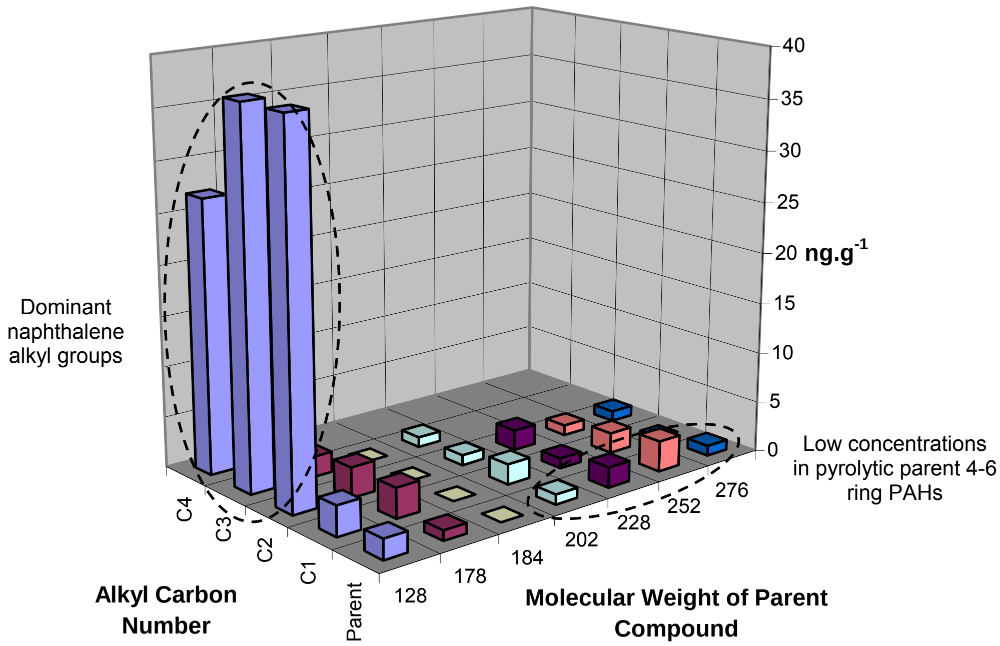

Figure 2.10: 2-6 Ring PAH Parent / Alkyl Distribution – Station L2

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

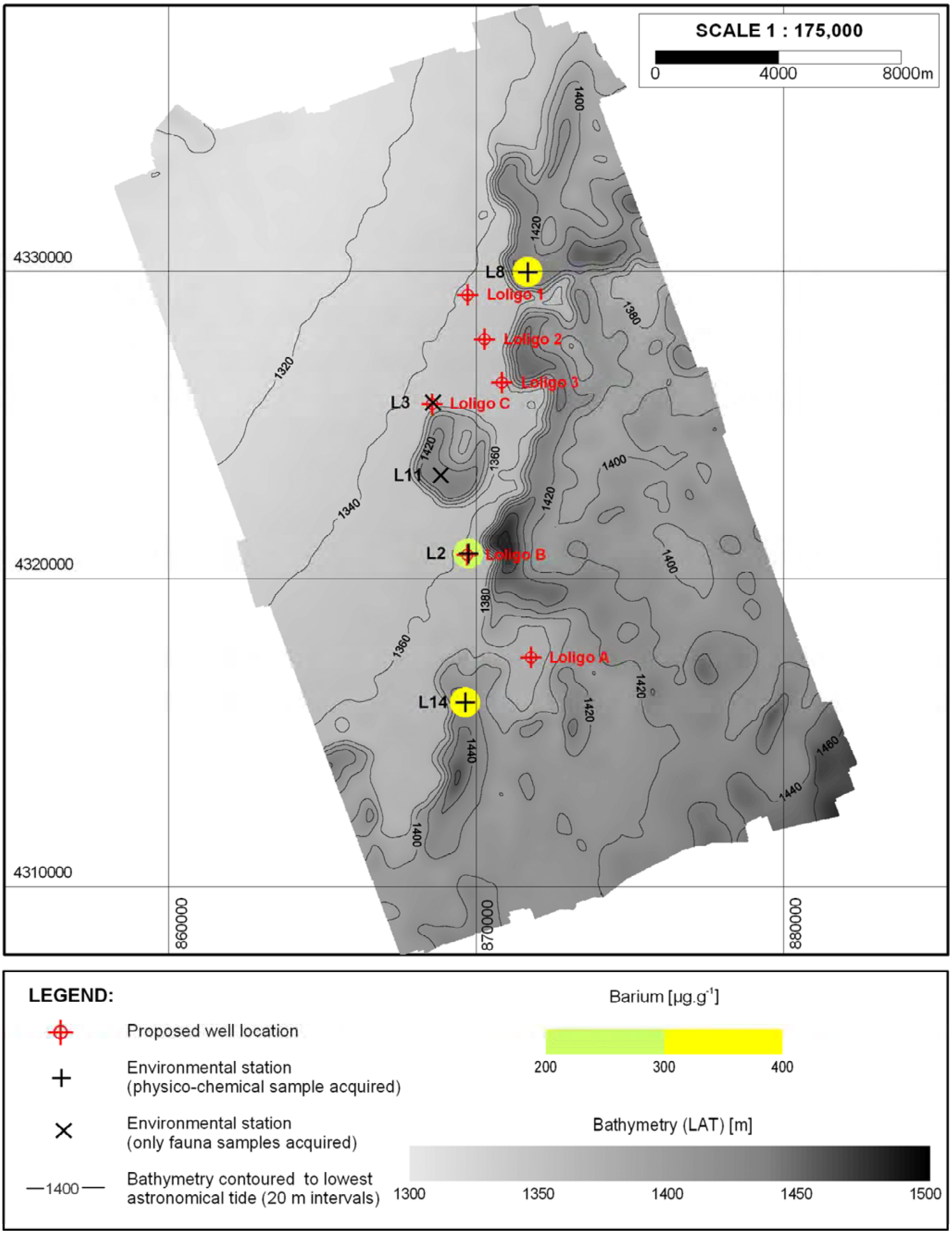

Figure 2.11: Heavy and Trace Metal Analysis – Barium [µg.g^{-1} Dry Weight by HF Digest]

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)

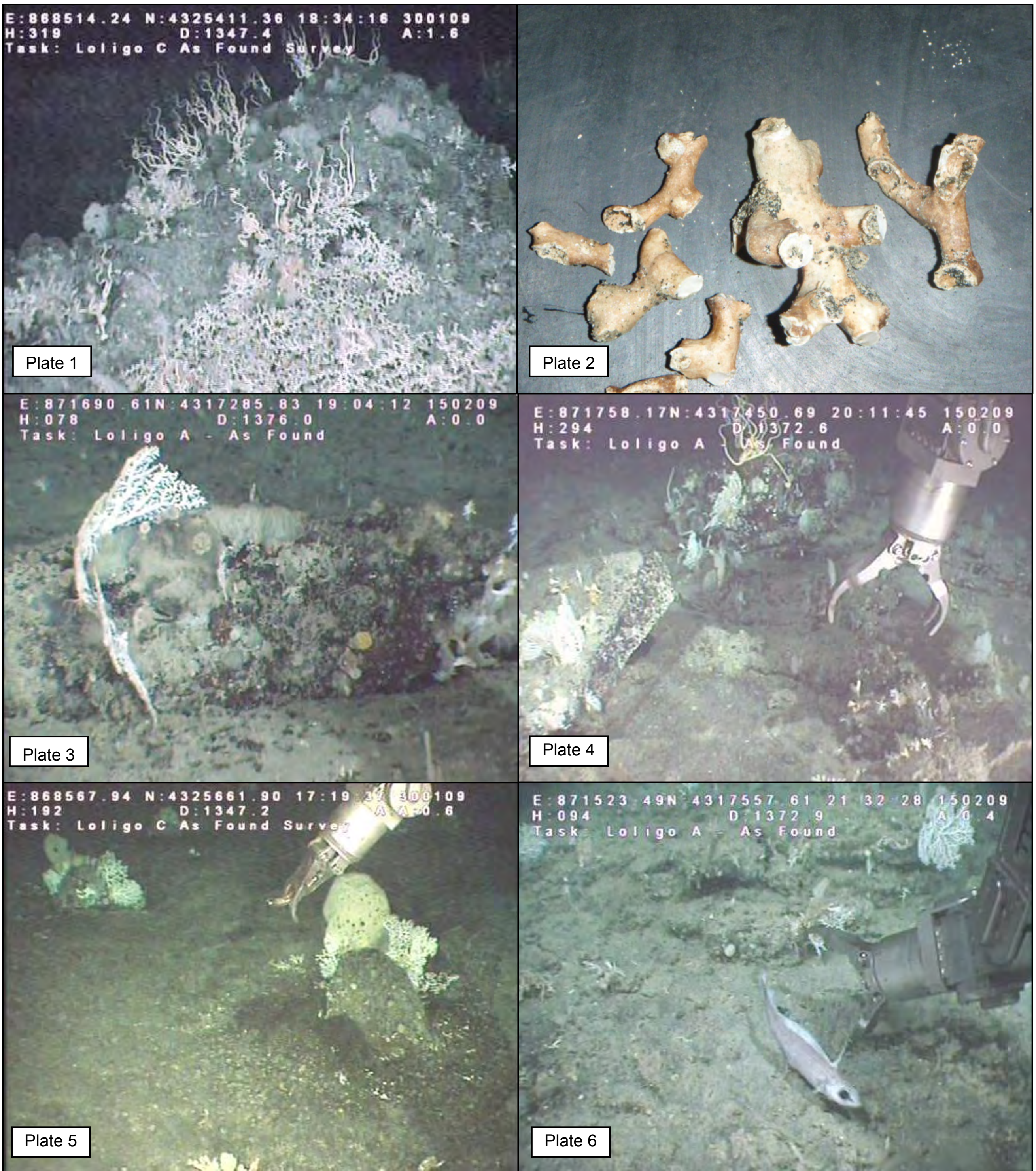

Plate 1: Dense coverage of a hard coral (possibly *Lophelia pertusa*) with filter-feeding brittle-stars (Ophiuroidea) on a consolidated sediment outcrop in the depression near Loligo C

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

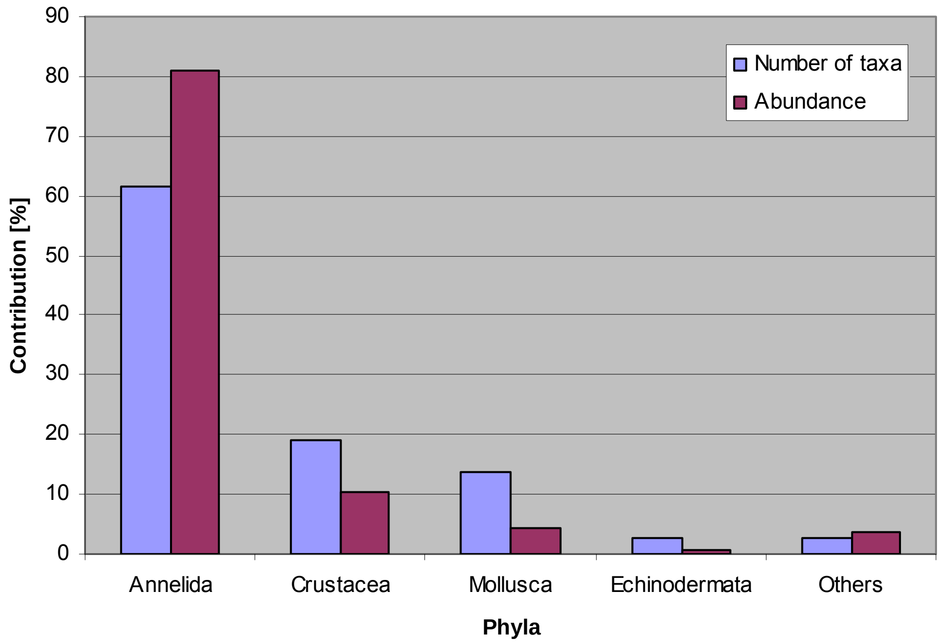

Figure 2.13: Abundance of Taxonomic Groups

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.

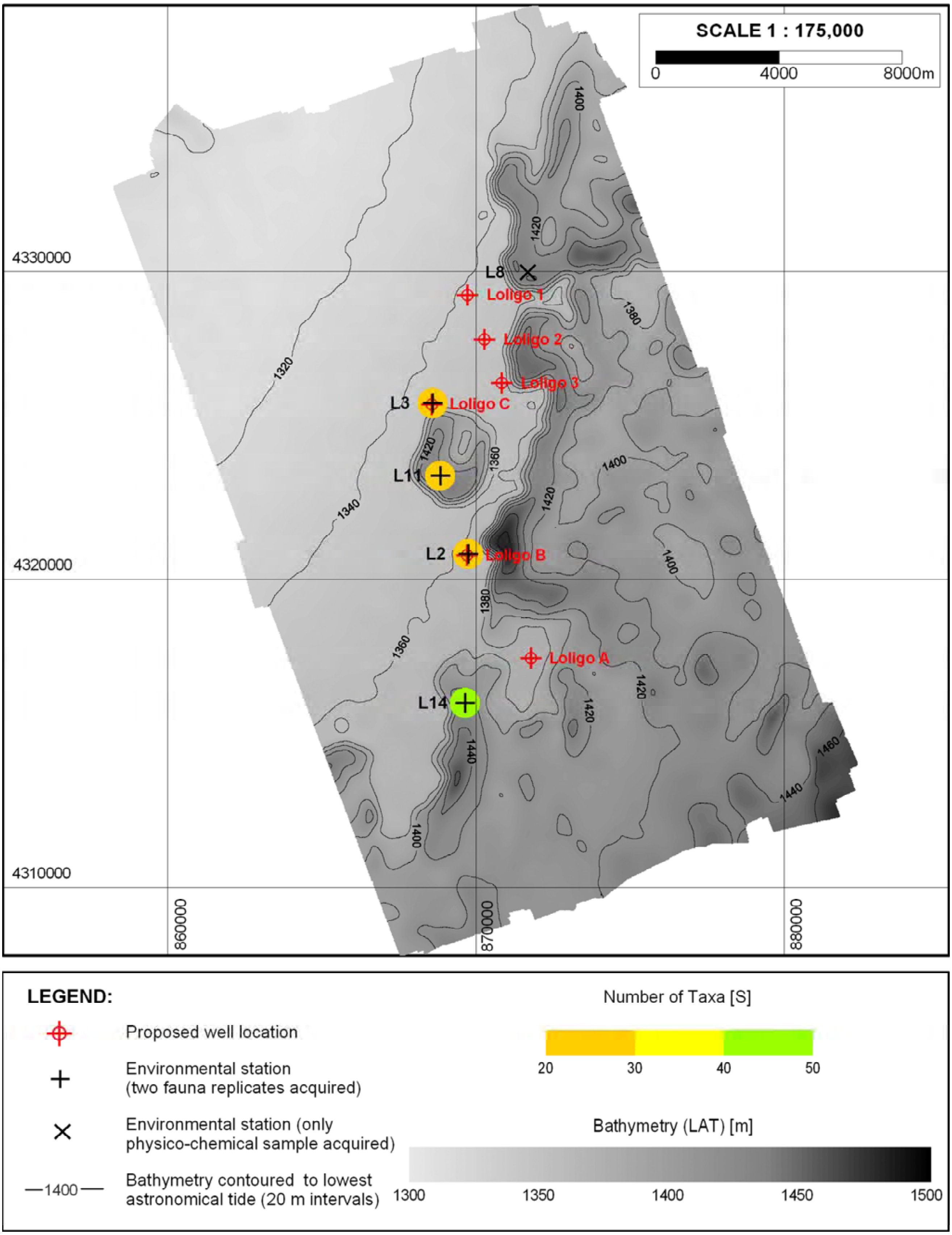

Figure 2.14: Macrofaunal Analysis – Number of Taxa [S]

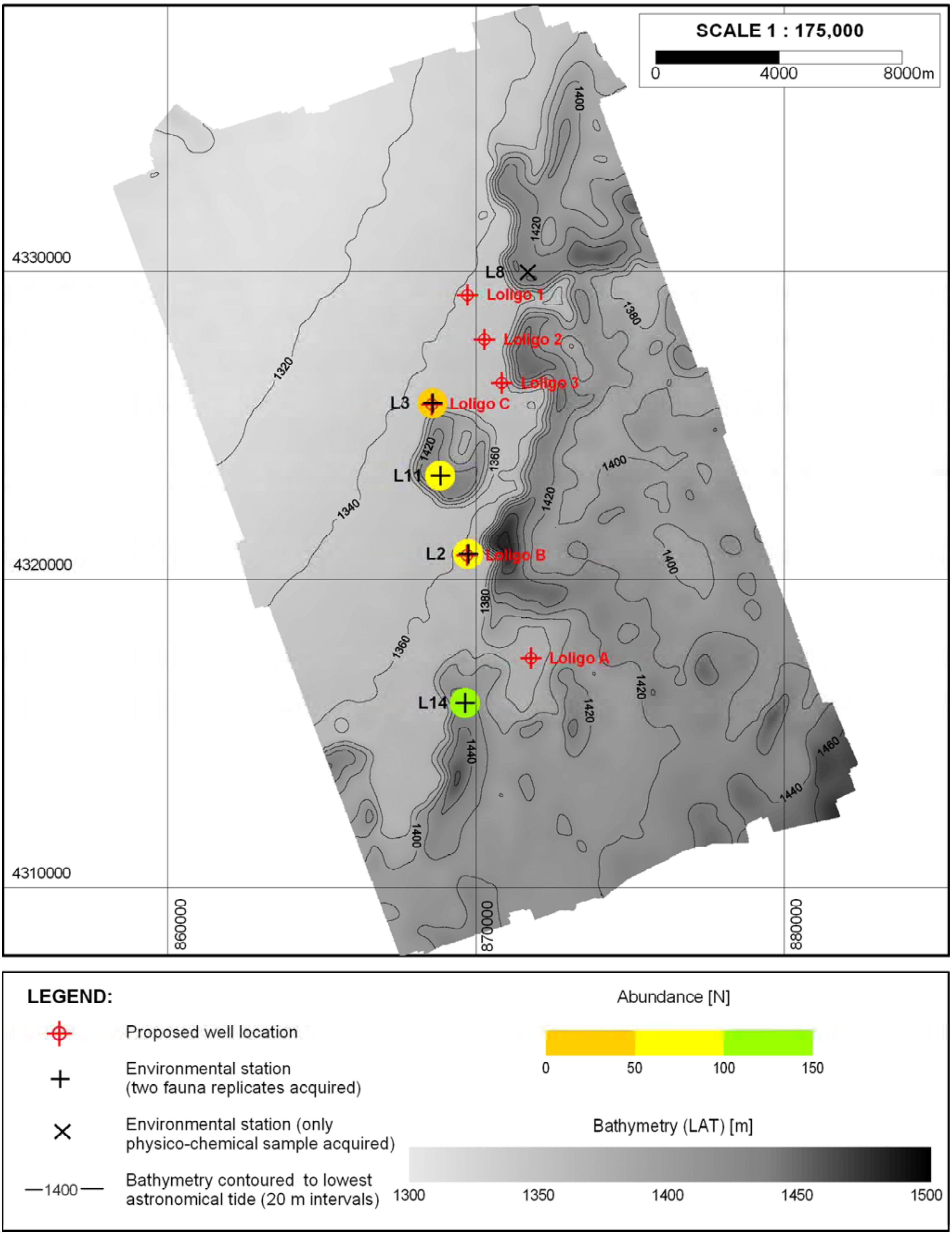

Figure 2.15: Macrofaunal Analysis – Number of Individuals [N]

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.

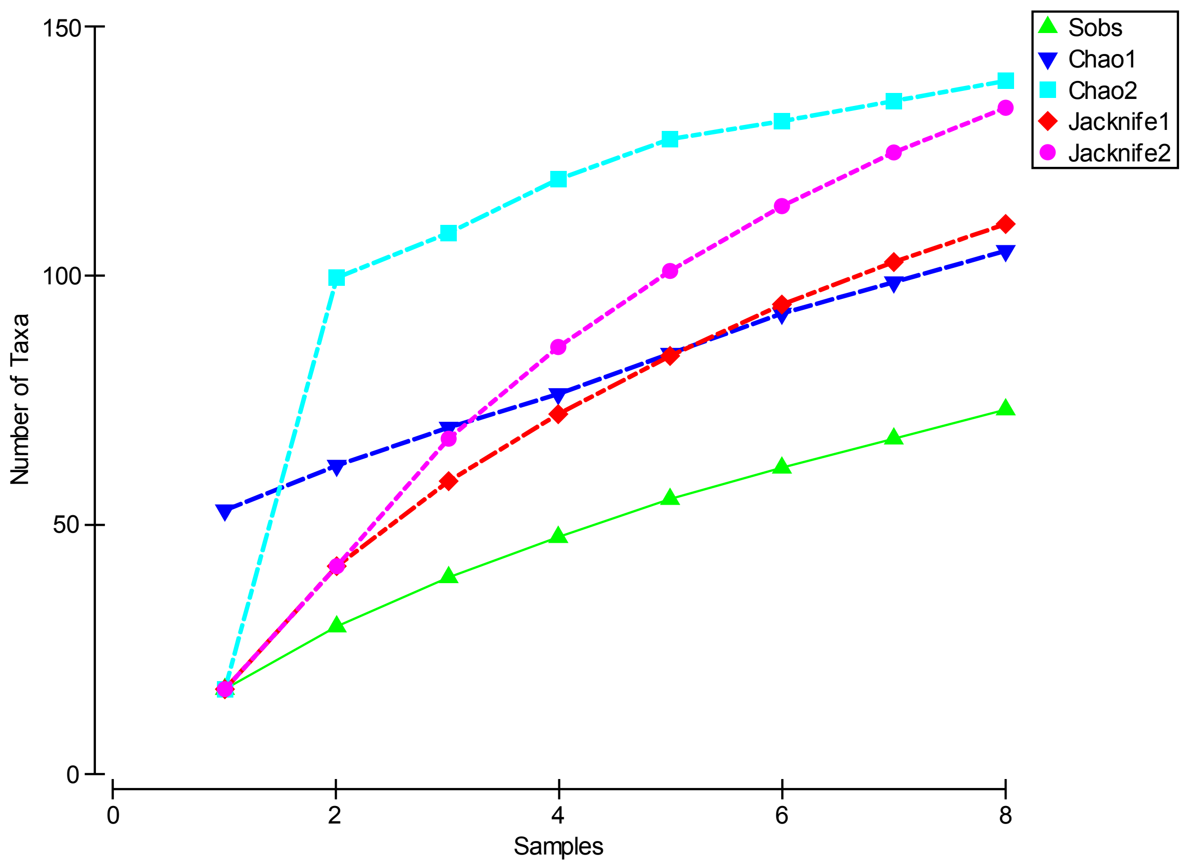

Figure 2.16: Species Accumulation Plot

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.

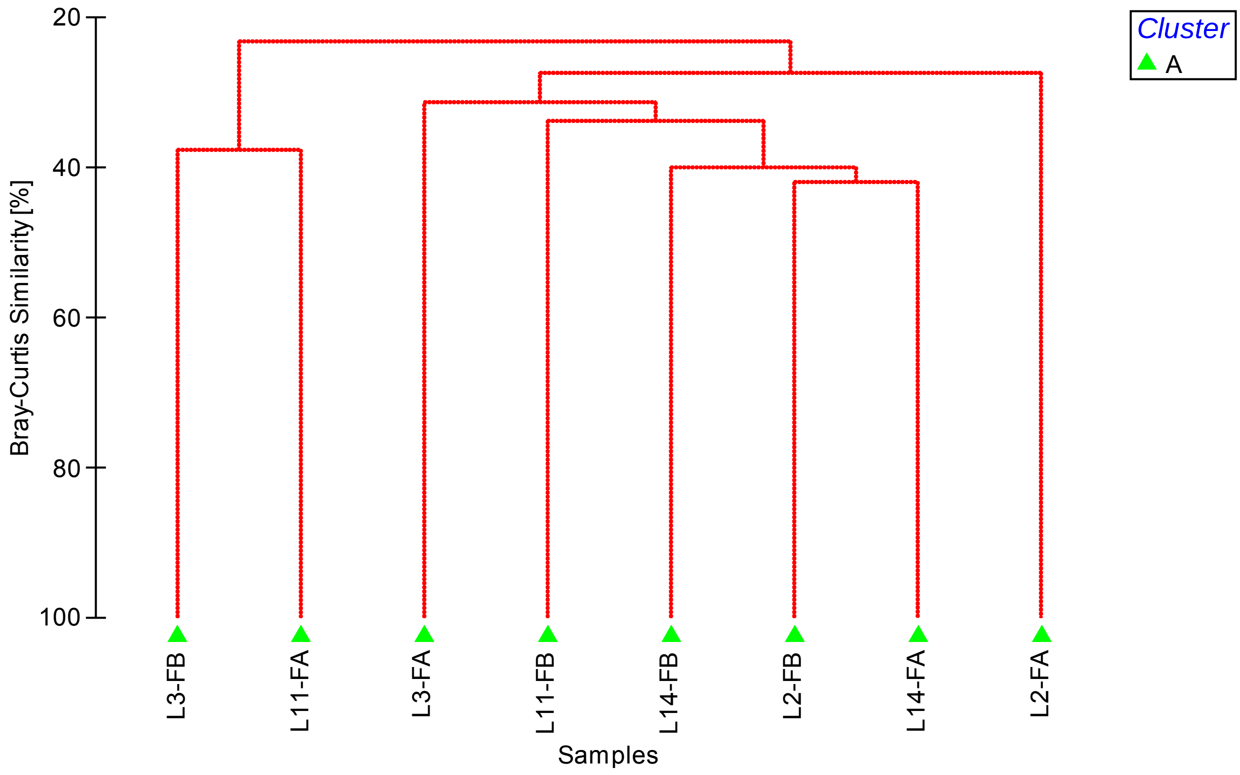

Figure 2.17: Dendrogram by Bray Curtis Similarity for Square Root Transformed Sample Data

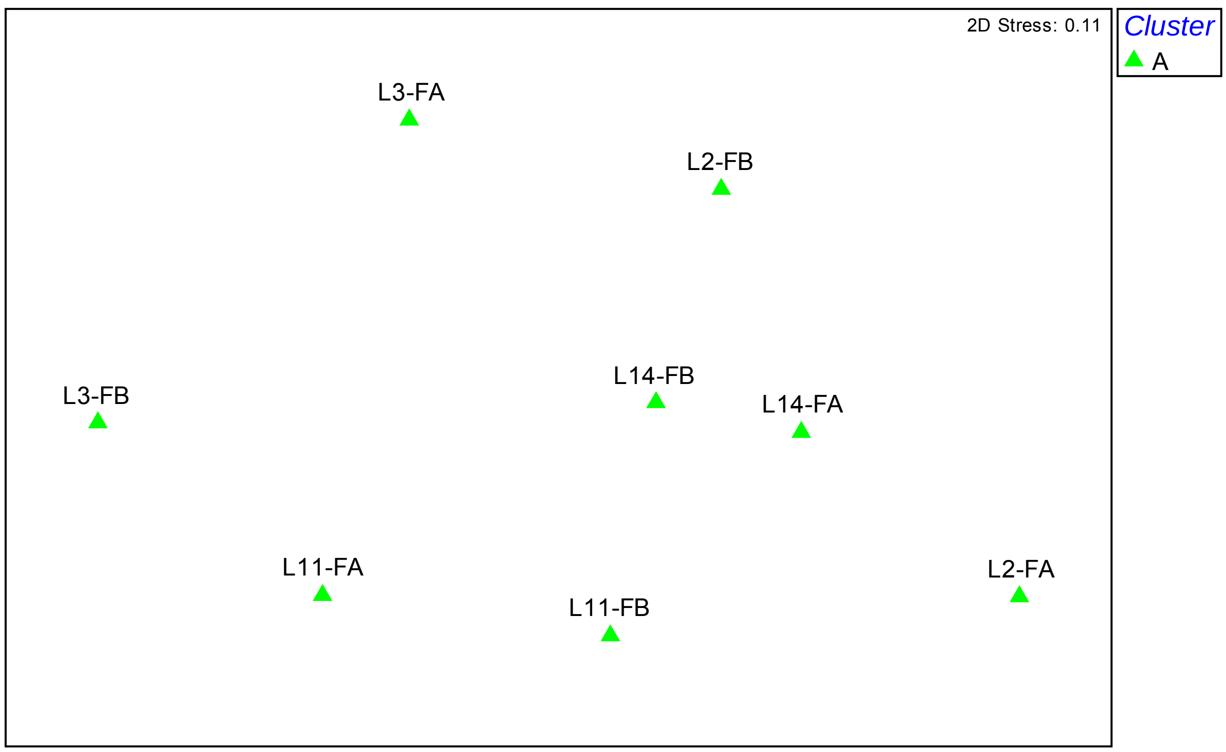

Figure 2.18: nMDS by Bray Curtis Similarity for Square Root Transformed Sample Data

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.

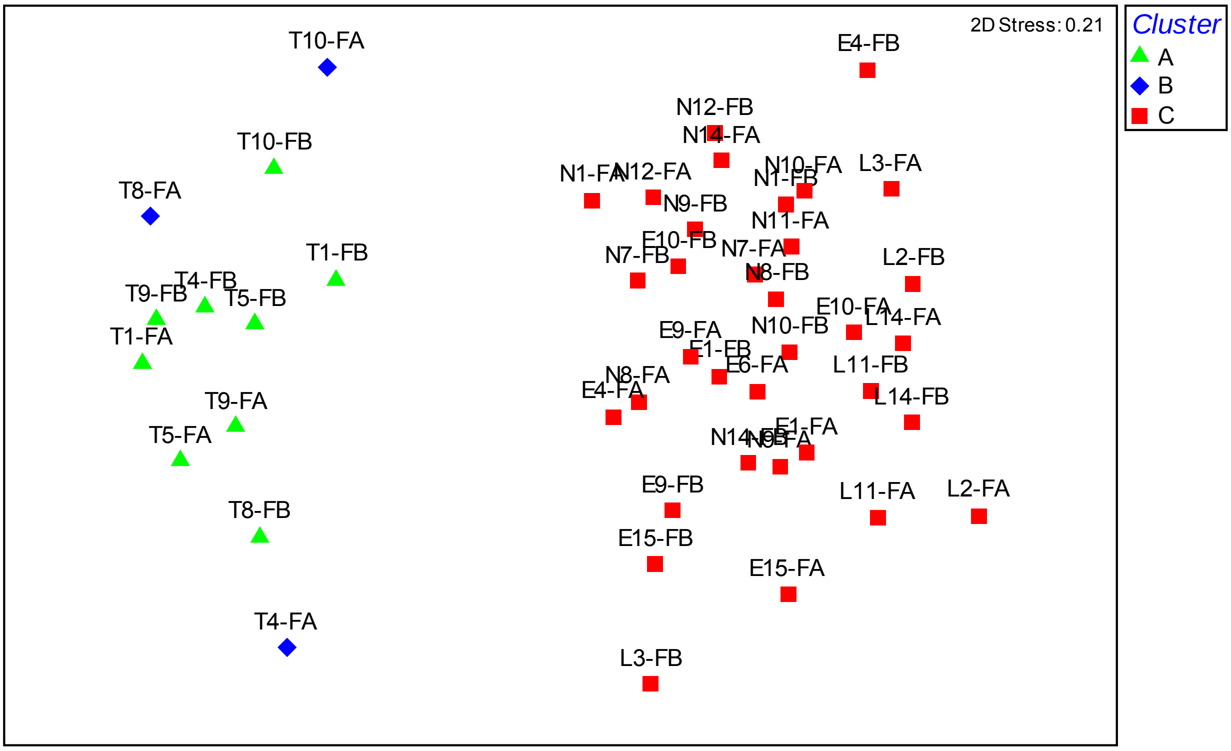

Figure 2.19: nMDS by Bray Curtis Similarity for Square Root Transformed Sample Data [0.1 m^2] for All Sites

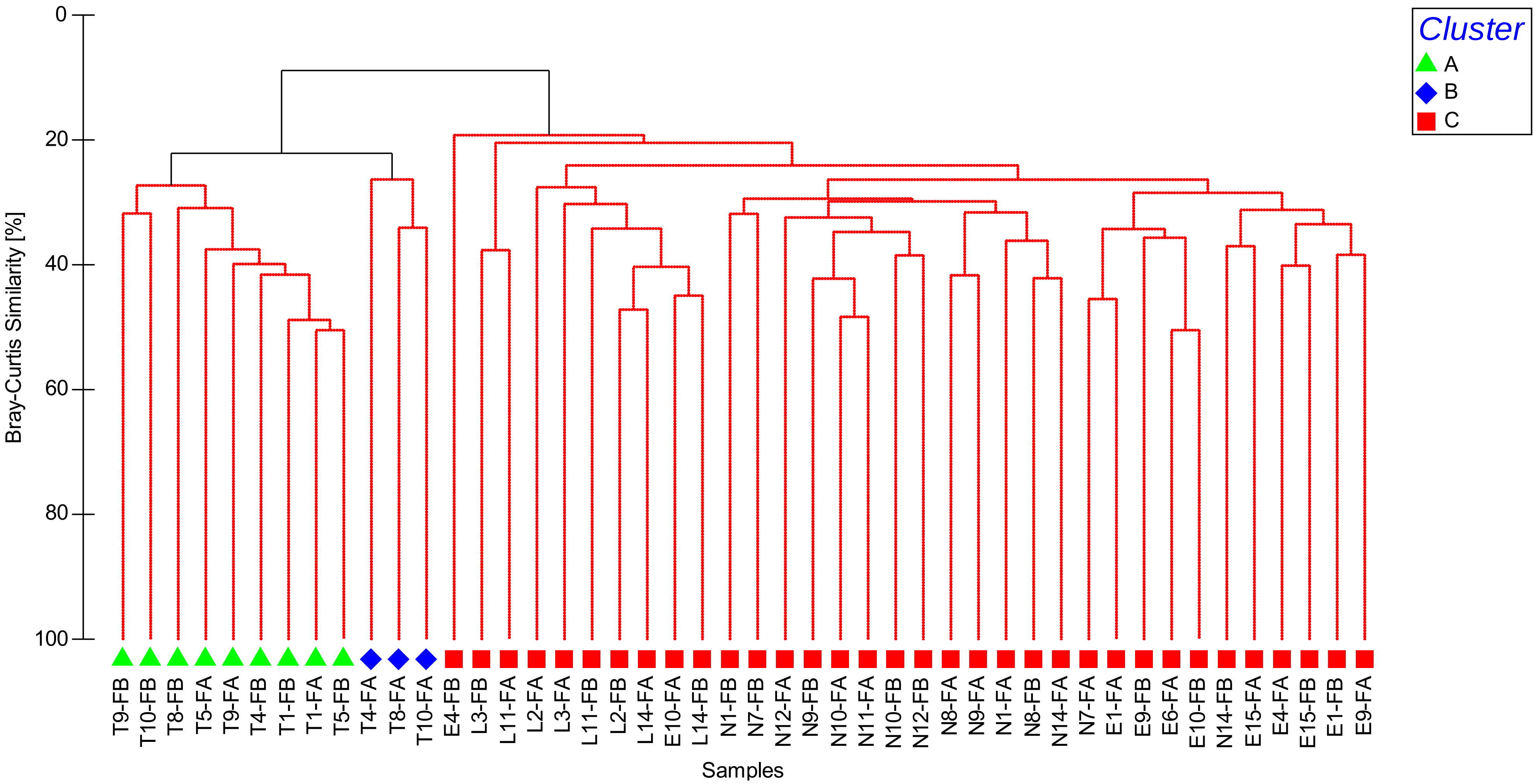

Figure 2.20: Dendrogram by Bray Curtis Similarity for Square Root Transformed Sample Data [0.1 m^2] for All Sites

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.

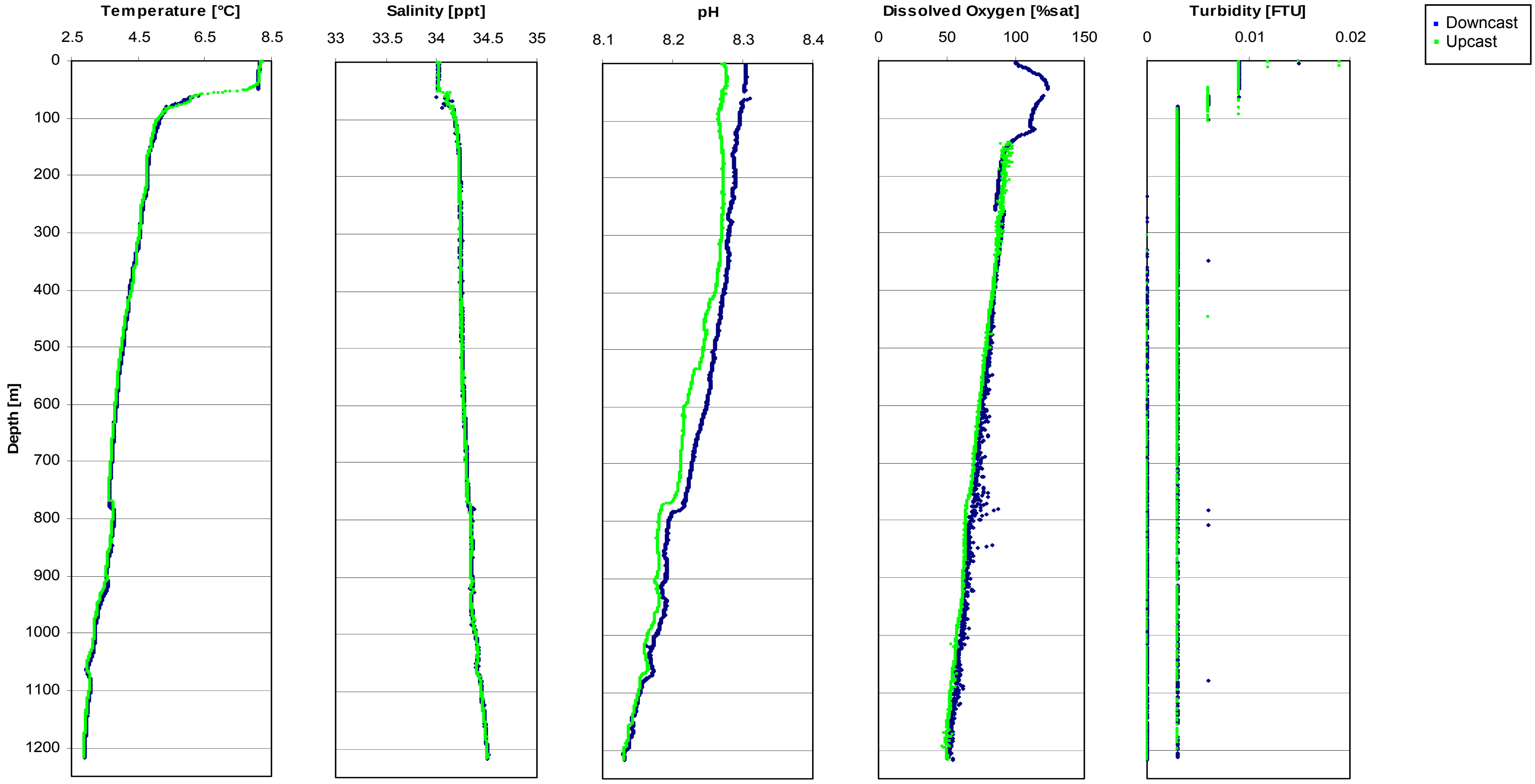

Figure 2.21: Profile Data for Individual Water Column Parameters

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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

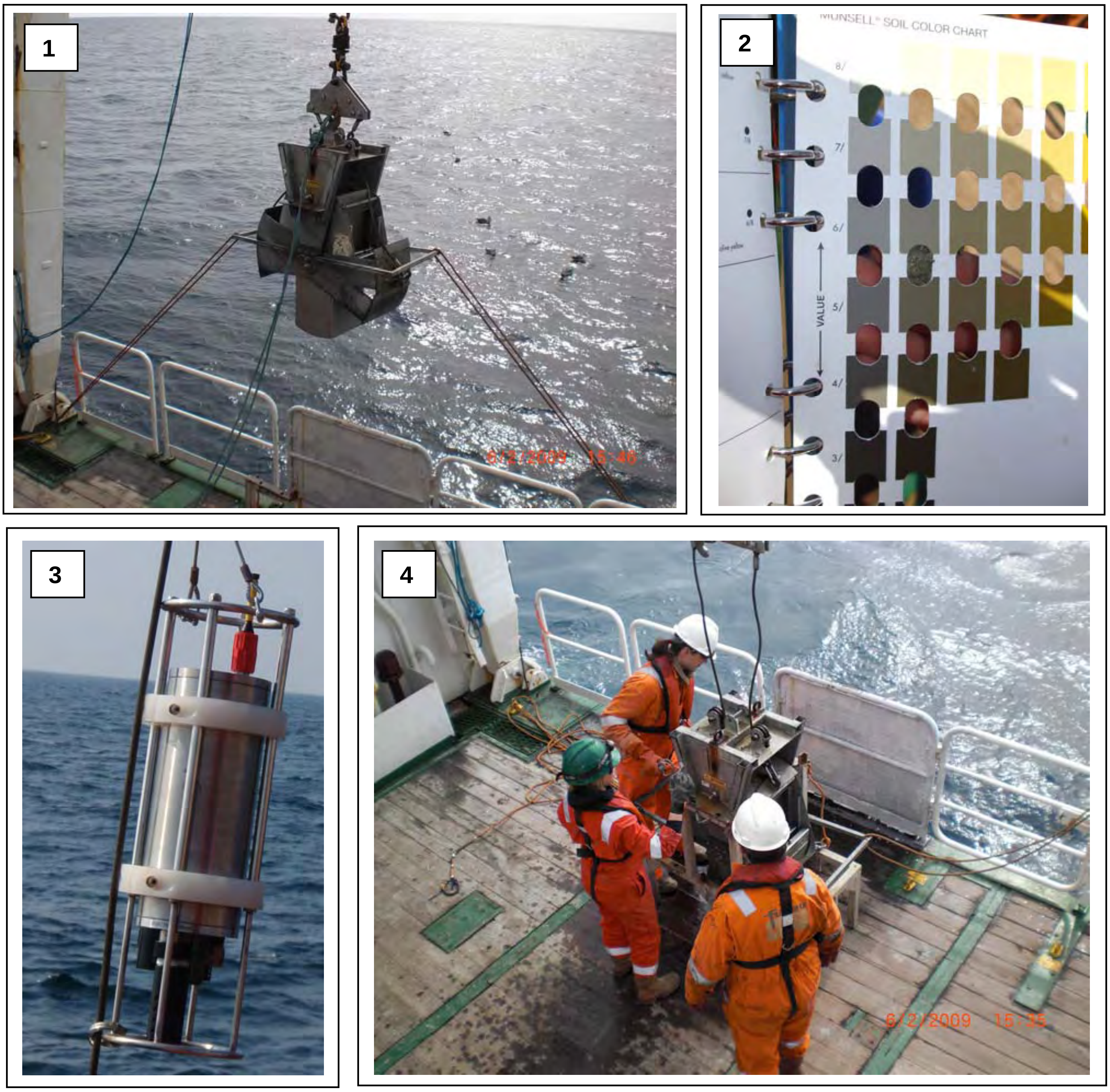


Plate 1: Deployment of the 0.1 m^2 box corer

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°C.

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°C for at least four hours to remove impurities and residual moisture then stored at 200°C 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°C, split flow 40 ml / min, vent time 1 min (1 µl injection)
Oven Temperature Programme	80°C - 1 min 80 to 320°C at 15°C / min 320°C – 10 min 320 to 350°C at 10°C / min	60°C - 1 min 60 to 120°C at 15°C / min 120 to 325°C at 5°C / min 325°C – 9 min
Source / Detector Temperature	300°C (FID)	280°C
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

<u>Total Hydrocarbons by Gas Chromatography – Flame Ionisation Detection (GC-FID)</u>
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.

<u>N-Alkanes, Pristane and Phytane</u>
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.

<u>Polycyclic Aromatic Hydrocarbons</u>
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

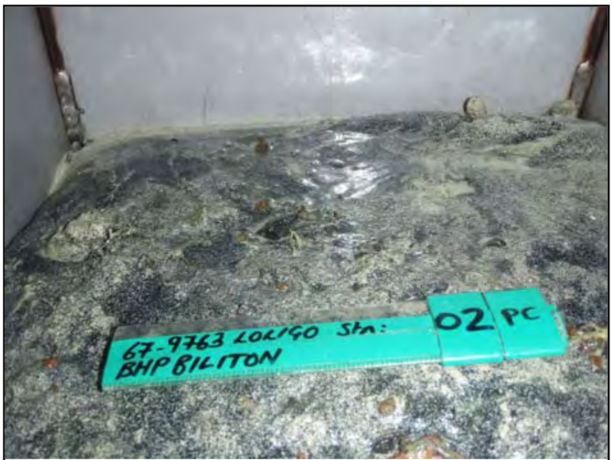
D.3 ROV VIDEO LOG

Date	Location	File(s)	Time	Video Coordinates [m]		Transcect 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

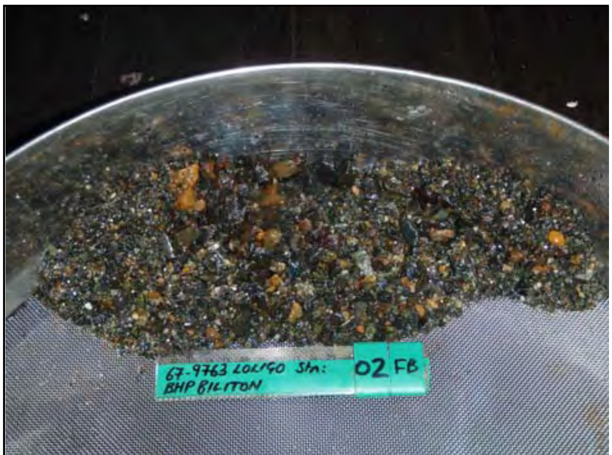


Easting: 869 735 m
Northing: 4 320 895 m

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

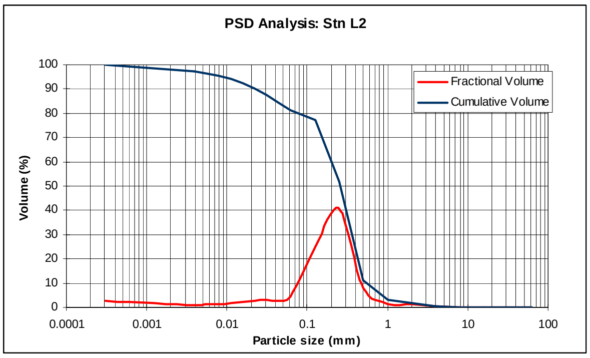
PSD – LASER AND SIEVE DATA

Aperture (mm)	Aperture (phi units)	Percentage Fractional	Percentage 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		

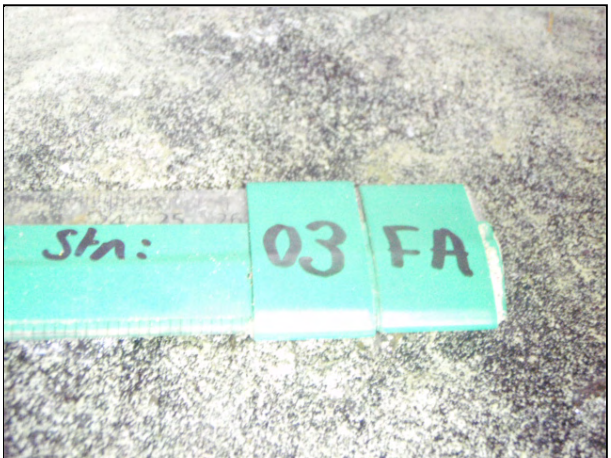
CHART REPRESENTING LASER DATA



STATION 3

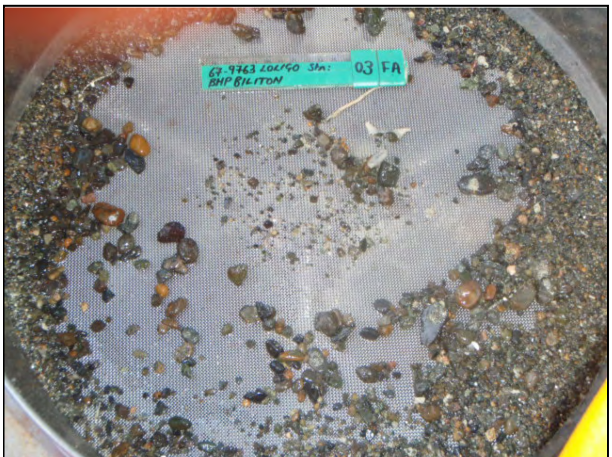
Easting: 868 553 m
Northing: 4 325 750 m

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

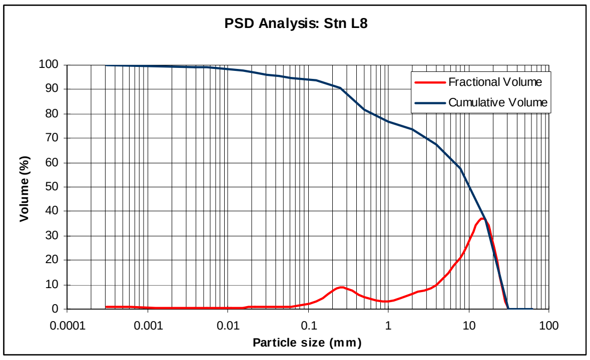
PSD – LASER AND SIEVE DATA

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

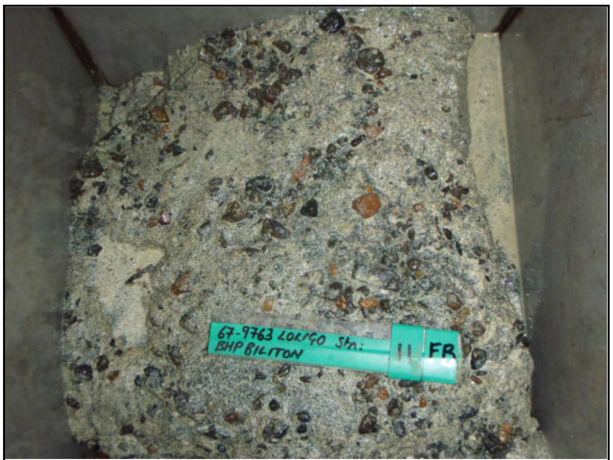
SEDIMENT CHARACTERISTICS

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

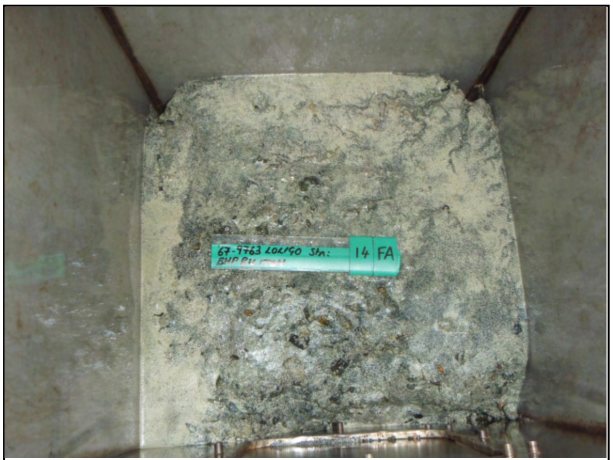
SEDIMENT CHARACTERISTICS

Data Unavailable

CHART REPRESENTING LASER DATA

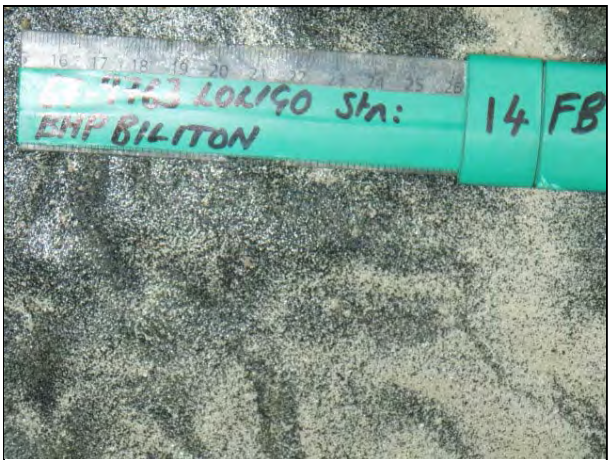
Data Unavailable

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

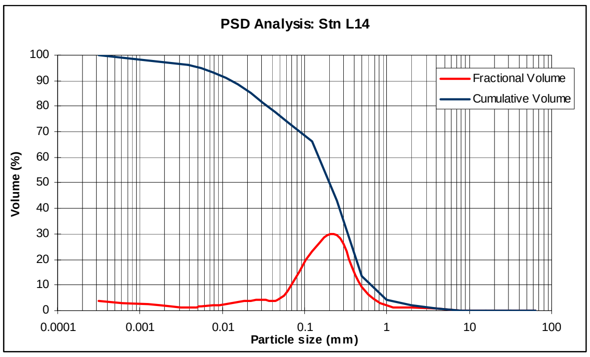
PSD – LASER AND SIEVE DATA

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

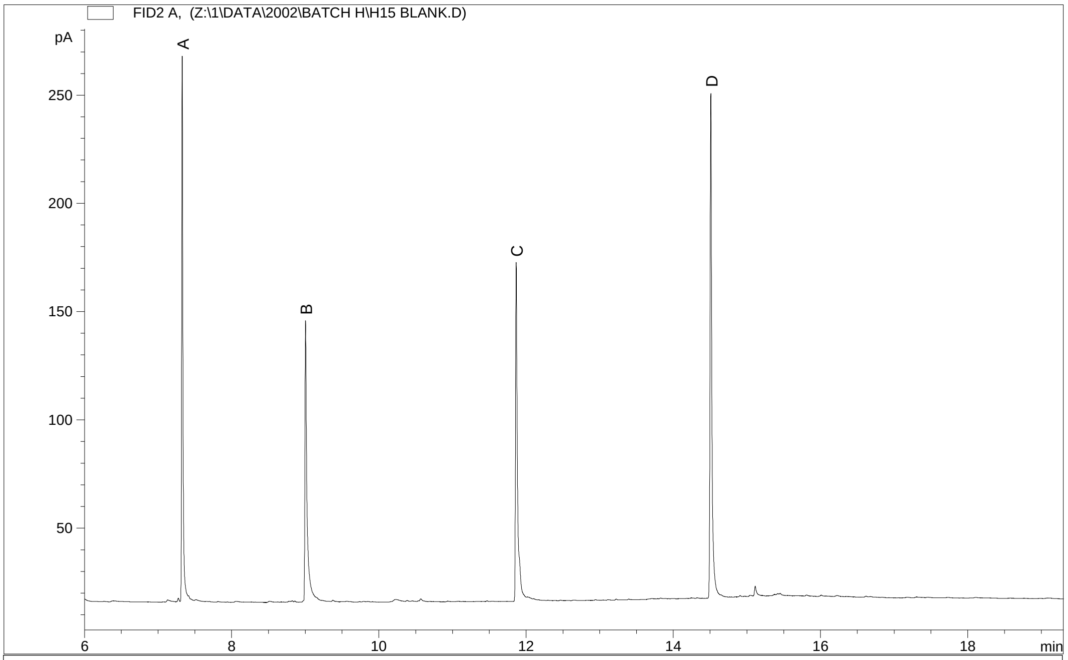


F. HYDROCARBON ANALYSIS

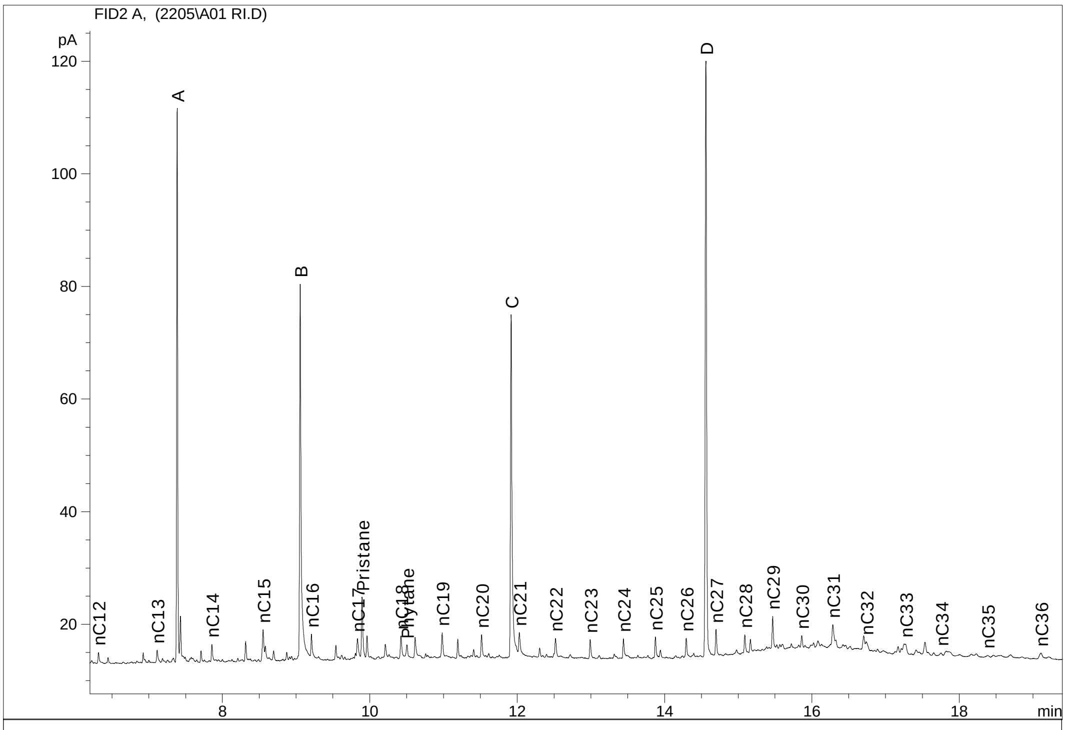
F.1 GAS CHROMATOGRAPHY TRACES

Table F.1 Internal Standard Concentrations

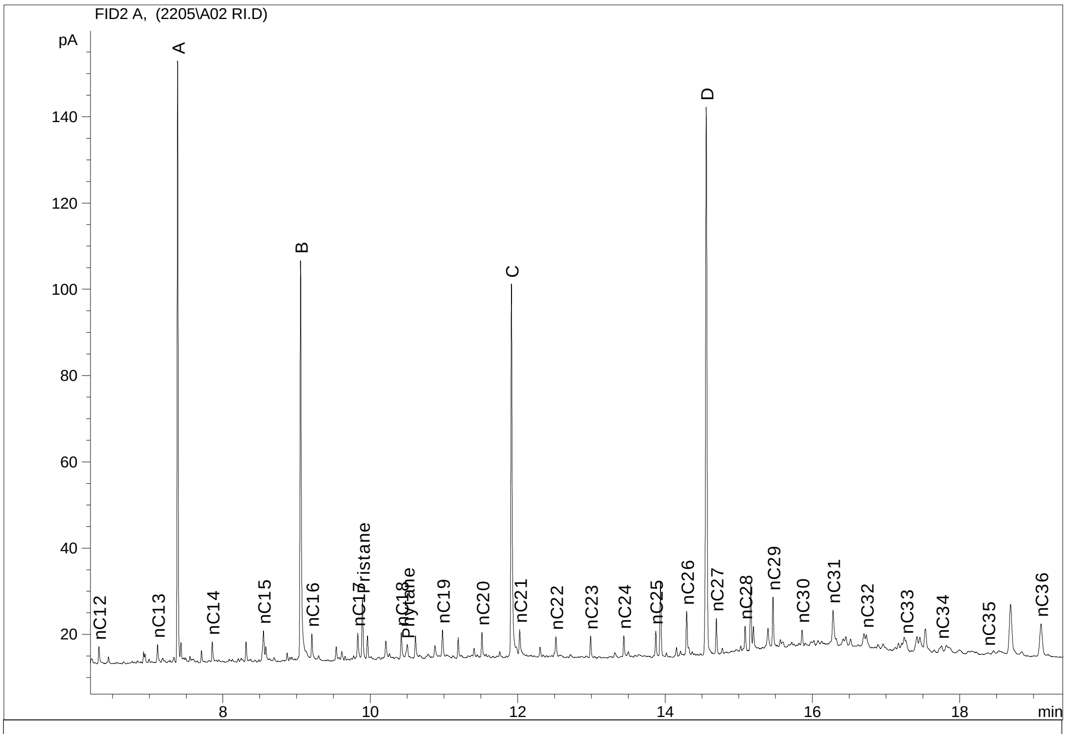
[All Concentrations Expressed as $\mu g g^{-1}$]				
Station ID	**Heptamethylnonane (A)**	**D34 Hexadecane (B)**	**1-Chlorooctadecane (C)**	**Squalane (D)**
1	0.199	0.192	0.170	0.202
2	0.172	0.166	0.147	0.174
3	0.204	0.198	0.175	0.207



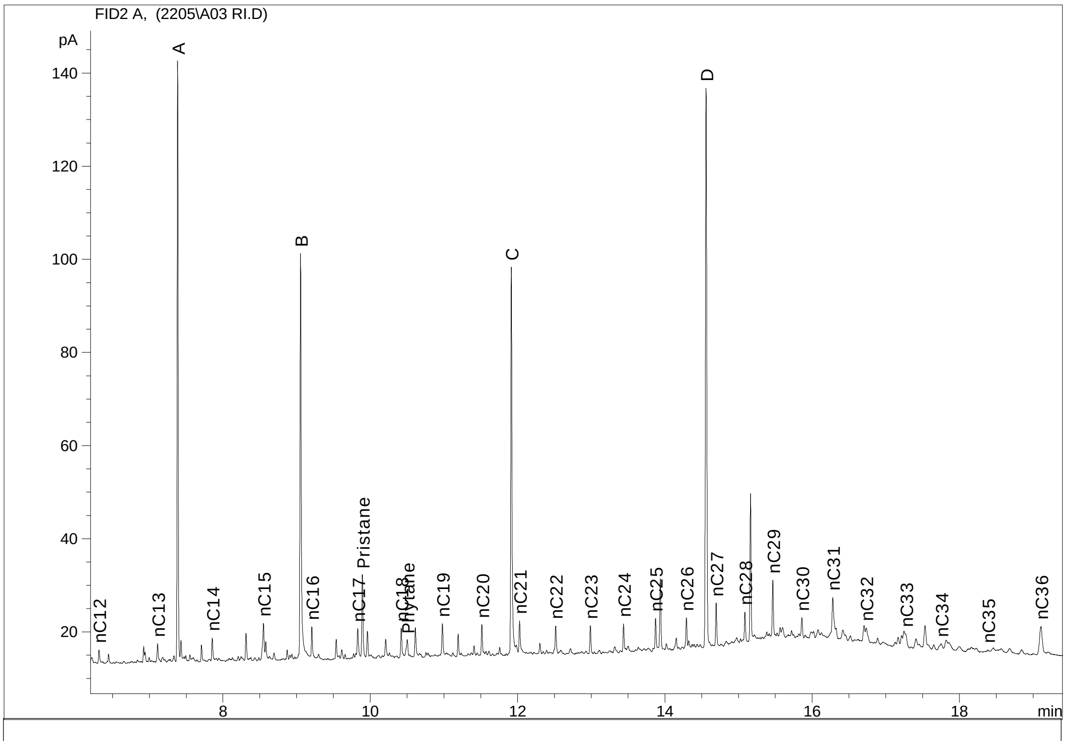
Blank GC trace with internal standards



Station 2 – Sediment GC Trace

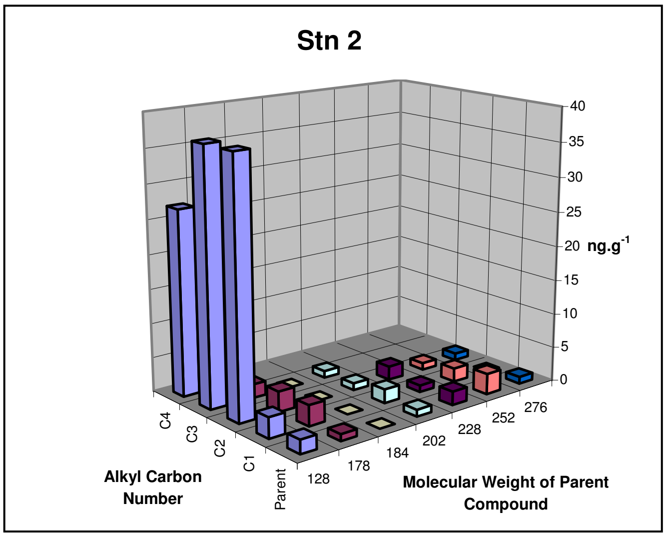


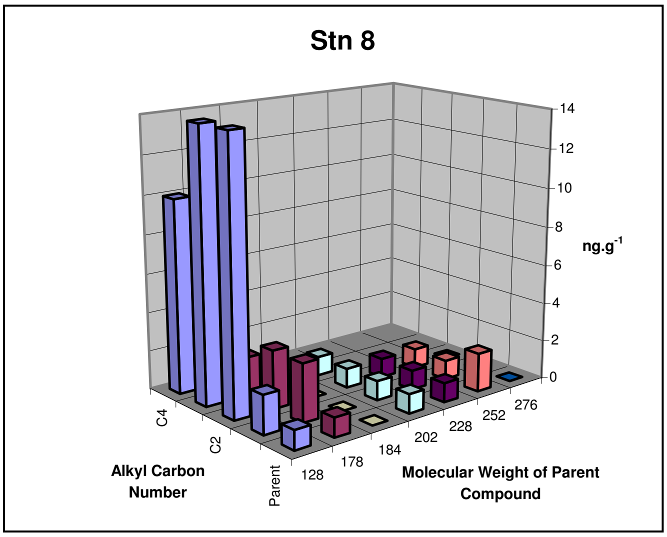
Station 8 – Sediment GC Trace

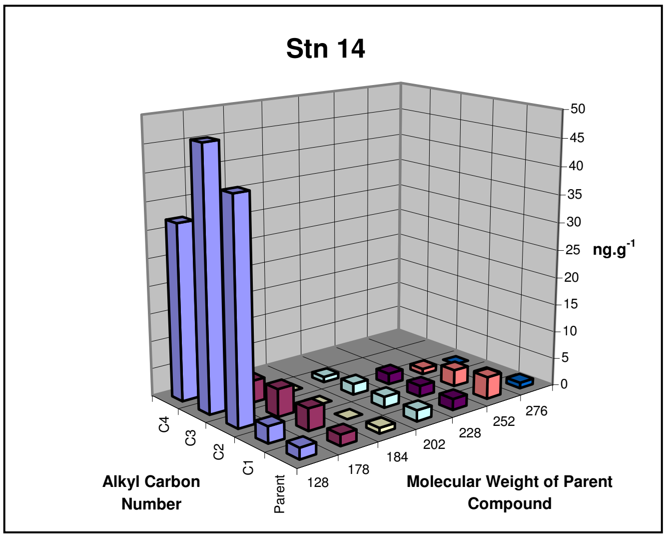


Station 14 – Sediment GC Trace

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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Appendix D: Rig Site Survey – FIDA 61/05 TOROA

RIG SITE SURVEY
OFFSHORE FALKLAND ISLANDS
FIDA 61/05 TOROA

Survey Period: 01 – 02 February 2009
Report Number: 9763V3.1

Volume 3 of 5: Environmental Baseline Survey

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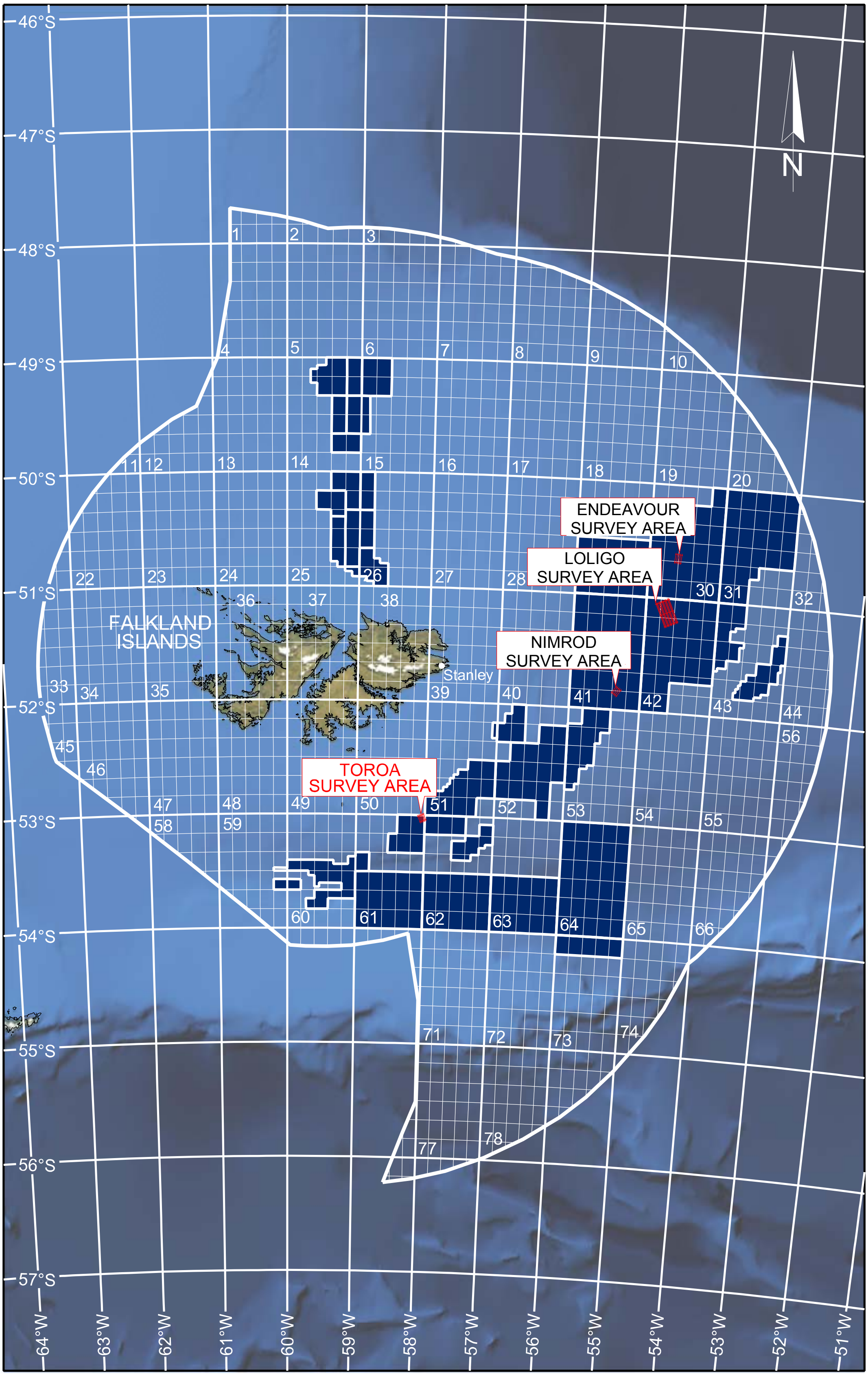
1	Issued as Final	K. O'Connell	P. Collins	R. Walters	14 September 2009
0	Issued as Proof	G Harris-Bryant	P. Collins	R. Walters	05 June 2009
Rev	**Description**	**Prepared**	**Checked**	**Approved**	**Date**



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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	Hierarchical 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
$nC_{12\text{-}20}$	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 Toroa prospect (FIDA 61/05). This work was undertaken aboard the M/V Fugro Meridian between the 1st and 2nd February 2009 and comprised a combination of benthic sampling at six 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.

The survey area ranged in depth from 552 m below lowest astronomical tide (LAT) in the northern extreme of the site to approximately 728 m below LAT in the south. The only topographic features of note were localised trenches / areas of seafloor flattening to the north of the site and in its centre. Surficial sediments were shown to be homogeneous across the site, particle size analysis showing that these comprised silts and clays throughout.

Levels of organic carbon were consistently low throughout the site, indicating minimal organic enrichment of the site's sediments. Hydrocarbon concentrations were relatively high given the geographical isolation of the site, and the concentrations seen in certain n-alkanes and polycyclic aromatic hydrocarbons (PAHs) suggested some diffuse natural petrogenic input to the area. Preliminary examination of diagnostic PAHs (methyl-phenanthrenes) suggested that these inputs came from crude (rather than refined) oil and, given the absence of drilling activity in the survey area, this was thought likely to have come from natural oil seeps. Heavy metal concentrations were low throughout the survey area, being found at levels typical for unimpacted silt / clay sediments.

An undifferentiated faunal community occurred throughout the site, with no spatial distribution being evident within the benthic faunal data recorded. The infaunal community was dominated by polychaete worms, which contributed over half of the total number of species and of the total faunal abundance. The community was diverse, with estimates of total diversity for the site ranging from 150 to 196 species, but population density was fairly low, with a mean density of fauna of approximately 400 animals per square metre being recorded from the infaunal sampling.

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 15 m and 140 m, after which temperature gradually declined to the seabed; dissolved oxygen saturation appeared to decline in line with temperature. Little variation was evident in either salinity or turbidity and the water column was considered to consist of a single water mass.

SUMMARY OF SURVEY RESULTS

Central Point:

Geodetic Datum and Spheroid WGS84, TM (Southern Hemisphere) CM 60˚ W				
Location	**Easting [m]**	**Northing [m]**	**Latitude**	**Longitude**
Toroa	631 239 m	4 123 246 m	53° 01' 27.143" S	58° 02' 35.586" W

Study Area: An 8.7 km by 7.4 km bathymetric survey with seven main lines bearing 157° / 337° and two cross lines bearing 67° / 247°.

Environmental Survey Strategy: Seabed sampling was successfully undertaken at six stations using a 0.1 m^2 box corer. Three samples including two faunal and one physico-chemical sample were retained at all stations. Water profiling was carried out at one location using a Valeport Midas 606+ CTD probe. Video data obtained by ROV during borehole operations at Toroa A were also reviewed and re-interpreted 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 552 m in the northern extreme of the site to approximately 728 m in the south. The seafloor dipped regionally down to the south-east with slopes ranging from approximately 0.6 degrees in the north-western portion of the study area, and increasing gradually to about 1.8 degrees in the south-east.

The only topographic feature of note were a series of west-south-west to east-north-east trending curvilinear features in the extreme north-west of the site and one similar south-west to north-east trending feature in the central part of the study area.

Seabed Features: The geophysical data suggested that surficial sediments were extremely homogeneous and this was supported by the evidence of the box corer and gravity corer sampling, drilling and ROV programs, all of which showed that seafloor materials consisting of sandy silt / clay throughout the site.

Granulometry: Examination of the sample photographs suggested that similar sediments occurred at all of the stations that were sampled, no spatial or bathymetric trend were apparent from these data. The field logs described all samples as unstratified soft sandy silt or clay of an olive colour. This was consistent with the results of the particle size analysis, which showed that all stations had poorly sorted silt sediments, the graphical means of the samples' distributions ranging from 4.87 phi units (34.1 µm) to 5.08 phi units (29.5 µm).

Organic Carbon: Both fractionated organic carbon (FOC) and total organic matter (TOM) were consistent across the sampling stations, the former ranging from 0.62% to 0.77% (stations T10 and T9, respectively) and the latter from 4.7% to 6.8% (stations T10 and T4, respectively). The lowest proportions of both FOC and TOM were identified from the deepest of the station samples (station T10). The higher values for TOM may be due to carbonates present in the samples.

Hydrocarbons: Total hydrocarbon concentrations (THC) were low compared to North Sea UKOOA data, though considered moderate for the remote nature of the survey area, ranging from 7.0 $\mu g.g^{-1}$ to 10.1 $\mu g.g^{-1}$ (stations T8 and T5, respectively). These concentrations are presumed to originate from local natural oil seeps and are considered to be typical background concentrations for the area.

Total n-alkane concentration was moderate, ranging from 0.505 $\mu g.g^{-1}$ to 0.749 $\mu g.g^{-1}$ (stations T8 and T5, respectively), this trend (and those seen in concentrations of individual aliphatics) generally reflected that seen in THC. The lack of odd or even-carbon number preference in the n-alkanes, the carbon preference index (CPI) being close to unity, may have been the result of diffuse inputs from natural seeps to the survey area.

Total PAH concentrations were low, but higher than expected for this region, again suggesting a local presence of natural oil seeps. They showed little correspondence with the patterns identified in other hydrocarbon concentrations and instead appeared to show a spatial (or depth-related) trend, being measured at their lowest (195 $ng.g^{-1}$) at the shallowest station (station T9) and at their highest (243 $ng.g^{-1}$) at the deepest station (station T10). No clear causal mechanism for this trend (e.g. sedimentary gradient) was apparent.

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. The former technique is the less stringent of the two measures and provides a partial estimate of metals, indicative of bioavailable concentrations, while the more stringent HF digestion releases matrix locked metals to provide a ‘near total’ estimate of both bioavailable and unavailable concentrations. As would be expected given the differing stringency of the two extraction procedures, the concentrations measured by aqua regia digestion were generally much lower than those measured by HF digestion. The concentrations of heavy and trace metals appeared consistent across the site, being found at levels typical for unimpacted silt / clay sediments.

Macrofauna: The epifauna observed across the site was dominated by motile species, with the onuphid polychaetes *Onuphis pseudoirirescens* and brittle-stars (probably *Amphiura* sp.) being prominent in the ROV footage. The only sessile epifaunal animal identified was what was thought to be a seapen (order Pennatulacea). A porbeagle shark (*Lamna nasus*) was observed from ROV footage during drilling operations at Toroa A.

Of the dominant infaunal taxa identified the majority were polychaetous annelids, although the most abundant species overall was the amphipod crustacean Haustoriidae 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 station data could be grouped within a single statistically undifferentiated cluster. This cluster was shown to be characterised by the amphipod Haustoriidae sp. 1 and polychaete *O. pseudoirirescens*, species that were consistently abundant at all stations.

Water Column Characteristics: The surface temperature was approximately 9.7°C and this remained relatively constant in the upper layers of the water column to approximately 14 m depth. Below this there was a distinct thermocline over which the water temperature descended fairly rapidly to 5.3°C at approximately 140 m depth before declining gradually to a temperature of 4.4°C at the seabed.

Although salinity showed minimal variation throughout the water column, ranging from a minimum of 34.1 ppt at the surface to 34.2 ppt at the seabed. As expected it exhibited a typical negative relationship with temperature. This corresponds with patterns observed in the profiles of the other survey sites.

Dissolved oxygen (DO) declined rapidly from a surface concentration of approximately 85% saturation (%sat.) to 72%sat. at around 130 m depth. DO then decreased steadily to the seabed (minimum concentration of 66%sat.). Turbidity was low throughout the water column, fluctuating between 0.00 FTU and 0.03 FTU. Again these patterns were evident at the other survey sites. The water column at Toroa was considered to consist of one water body, with typical surface stratification.

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 channeling 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 single beam 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 and to characterise physical water column characteristics. The environmental surveys comprised sampling using a 0.1 m2 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 bore hole operations at Loligo and Toroa, were also viewed and reinterpreted 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. Separate environmental baseline survey reports for the four sites were also produced (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 3, details the results of the environmental baseline survey of the Toroa site, which was situated approximately 145 km to the south-east of Stanley, Falkland Islands in Falklands Island Designated Area (FIDA) block 61/05. The proposed well locations within the Toroa 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**
Toroa F	631003	4123820	53° 01' 08.788" S	58° 02' 49.130" W
Toroa F-ALT	631483	4122680	53° 01' 45.236" S	58° 02' 21.740" W

1.2 Environmental Survey Strategy

Box corer sampling stations were selected by BHP Billiton in conjunction with onboard FSLTD environmental scientists and using preliminary bathymetric data and multibeam echo sounder (MBES) backscatter data for assessment of surface sediment type. Ten stations were originally proposed with stations T1 to T8 positioned in cruciform formations around the two proposed well locations Toroa F and Toroa F-ALT. The remaining stations T9 and T10 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. The coordinates of the 10 box corer sampling locations originally proposed are provided in Table 1.2.

After consultation with the client after arrival on site the number of box corer sampling stations was reduced from ten stations to six stations, the stations omitted from the campaign being stations T2, T3, T6 and T7. The locations of the remaining stations were not altered. Actual sampling station locations are displayed spatially in Figure 2.1.

At all six sampling stations two replicates were completely screened over a 0.5 mm mesh and fixed for macrofaunal analysis, and one physico-chemical sample was retained which was sub-sampled for hydrocarbon, heavy metal, organic carbon and particles size analysis.

Water profile data were collected using a Valeport Midas 606+ CTD probe at a single location (WCP210), 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 reinterpreted by FSLTD to assist with the environmental baseline survey reporting. Data were obtained from the proposed location Toroa A, located in the vicinity of station T8.

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
T1	631 040	4 123 855	50 m downstream (NE) of proposed well F	FA, FB, PC
T2	631 500	4 125 900	Cruciform station for proposed well F (situated downstream NE)	Not sampled
T3	629 300	4 124 100	Cruciform station for proposed well F (situated westerly)	Not sampled
T4	632 900	4 124 000	Cruciform station for proposed well F (situated easterly) Cruciform station for proposed well F_ALT (situated downstream NE)	FA, FB, PC
T5	629 600	4 122 800	Cruciform station for proposed well F_ALT (situated westerly)	FA, FB, PC
T6	629 900	4 120 300	Cruciform station for both proposed well F and F-ALT (situated downstream – SW- from both)	Not sampled
T7	634 000	4 122 550	Cruciform station for proposed well F_ALT (situated easterly)	Not sampled
T8	631 520	4 122 715	50 m downstream (NE) of proposed well F_ALT	FA, FB, PC
T9	628 270	4 126 060	Depression (approximately 250 m by 100 m) situated in northern shallow extremes of site	FA, FB, PC
10	632 250	4 119 300	Situated in southern deep extremes of site	FA, FB, PC
Toroa A	631 409	4 122 866	ROV investigations of bore hole location	ROV
WCP210	631 245	4 123 250	Selected by the client	WP

ROV = ROV video footage; FA = fauna sample A; FB = fauna sample B; PC = physico-chemical sample; WP = water profile.

1.3 Comparative Data

Throughout this report comparison is drawn to data obtained from the other sites surveyed during the current survey program (Loligo, Endeavour and Nimrod). It should be noted however that these sites were considerably deeper than the Toroa survey area (their constituent stations ranging in depth from 1262 m to 1438 m) and different in terms of their sediment type and seabed topography. This suggested that the deeper sites were subject to a significantly different hydrodynamic regime than Toroa.

Comparison is also made to data obtained during pre-drill surveys of FIDA 14/05 - B1 (Gardline Surveys Limited, 1998a) and FIDA 14/09 - Little Blue A (Gardline Surveys Limited, 1998b) in the North Falkland Basin during February 1998. Although neither site were of strictly comparable depth to Toroa (depths at B1 and Little Blue A being 464.4 m and 416.8 m, respectively) and were a considerable distance away (400 km), similarities in sediment type meant that cautious comparisons could be justified. Comparisons of total hydrocarbon data were also made to determine how the survey area may differ from the those studied in the previous surveys. It should be noted though that variations may have been the result of differing analytical techniques from different laboratories.

1.4 Survey Reference System

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 30 coring attempts were made at the six stations with 18 good samples being retained (a 60% sampling success rate). The no-samples were caused by the corer not triggering. In attempts to solve this problem weights on the box corer were redistributed and the trigger mechanism was adjusted and this appeared to improve sampling efficiency. A positioning accuracy of 50 m tolerance was agreed with the Client prior to the commencement of the field work. A broad tolerance was decided on due to the great depths of the survey area and the strong, variable currents. Positioning accuracy for the survey was very good, with all the samples obtained within the 50 m tolerance zone and 61% of samples taken within 20 m of the target location. The actual sampling coordinates are provided in Appendix D.1.

Of the 18 samples retained twelve were processed for macrofaunal analysis, with two replicates (samples FA and FB) acquired from all six stations. The remaining samples from the six stations were sub-sampled for physico-chemical analysis.

Two water profiling attempts were made at location Toroa WCP210. The first deployment returned erroneous data so a second attempt was made using a different water profiler which acquired good data for all parameters except pH (as no functioning sensor was available); this profile was accepted by the client.

2.2 Bathymetry and Seabed Morphology

The following text is taken from the Shallow Hazards Assessment produced by FGI (Report No. 27.2008-2275). A plot showing the survey area bathymetry is presented in Figure 2.1 and a shaded relief rendering of the survey area is provided in Figure 2.2. The shaded relief rendering comprises a composite of images obtained from the lower resolution regional bathymetric survey and the higher resolution data obtained over the proposed well locations.

Water depths have been reduced to metres below Lowest Astronomical Tide (LAT) using predicted tidal data at Stanley, Falkland Islands, which lies approximately 145 km north-west of the Toroa site.

Water depths in the study area ranged from approximately 552 m in the northern corner to approximately 728 m in the south. The seafloor dipped regionally down to the south-east with slopes ranging from approximately 0.6 degrees in the north-western portion of the study area, and increasing gradually to about 1.8 degrees in the south-east. There is no indication of past or incipient seafloor slope instability within the study area.

The only seafloor topographic or geologic features identified within the study area were a series of west-south-west to east-north-east trending curvilinear features in the extreme north-west of the site and one similar south-west to north-east trending feature in the central part of the study area. These features were characterised either by a slight local flattening of the seafloor or a shallow seafloor trough and are probably the result of differential erosion of variable seafloor sediments by marine currents. It is possible that the erosional processes responsible for generating these features are active.

2.3 Seabed Features

The following text is taken from the Shallow Hazards Assessment produced by FGI (Report No. 27.2008-2275). Screen grabs of ROV footage and grab sample photographs showing seabed sediments across the survey area are provided in Figure 2.4.

The geophysical data suggested that the sites surface sediments were extremely homogeneous. The seven gravity cores obtained in the Toroa area all indicated that the seafloor sediments to a depth of about 2 m consisted of very soft to soft clay to silty clay. Results from the ROV survey around the Toroa A borehole location and box corer sampling also identified silt / clay sediments throughout the survey area (Figure 2.4, Plate 1 to 3, 5 and 6). In addition environmental data identified a significant proportion of sand throughout the survey site.

2.4 Shallow Soils

The following text is taken from the Shallow Hazards Assessment produced by FGI (Report No. 27.2008-2275).

The preliminary log of the Toroa boring indicates that Sequence I sediments consisted of very soft to stiff clay, with some pockets or interbedded layers of silt or clayey silt / silty clay to a depth of approximately 41.5 m BML. Visual examination of sediment samples from the boring indicates that the sediments in Sequence I are predominantly of clastic origin (BHPB, 2009), probably with some interbedded contourite deposits. Sequence I thickens steadily from about 14 m in the northern part of the study area to a maximum thickness of approximately 56 m in the southern corner of the area. All box corer samples would have been acquired from this sequence hence their predominantly homogenous silt / clay composition, in addition notable proportions of sand.

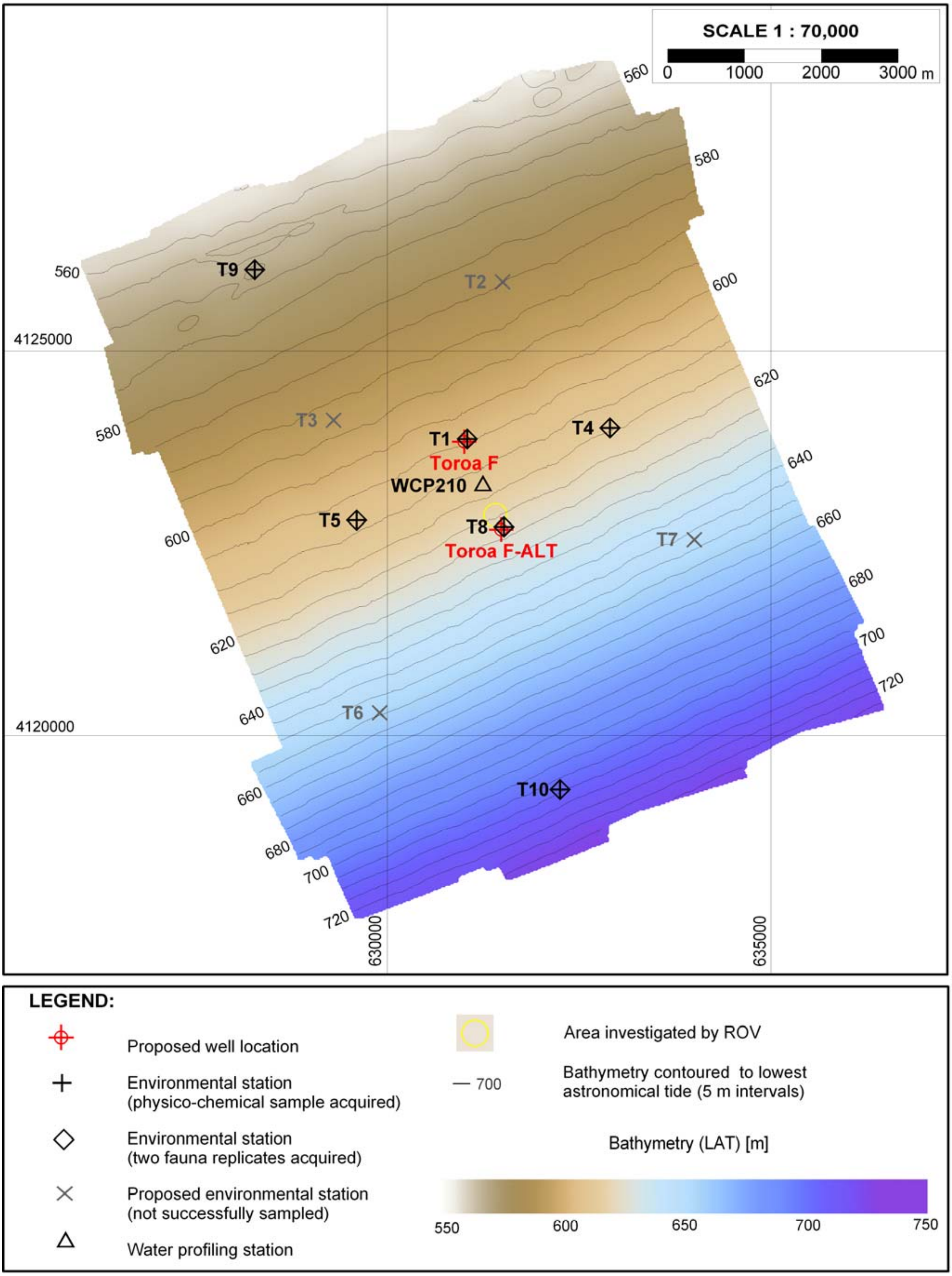

Figure 2.1: Survey Bathymetry Showing Sampling Locations

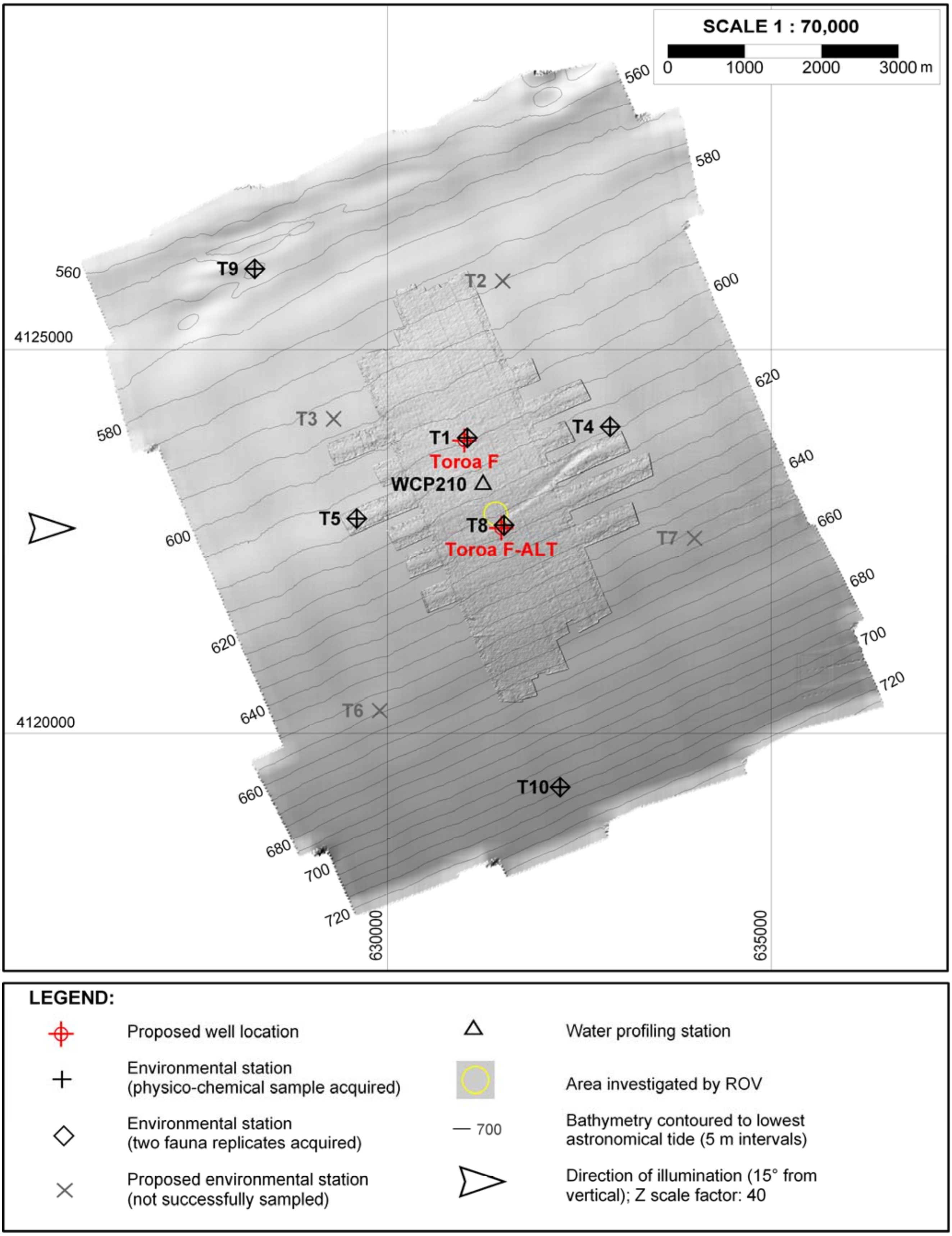

Figure 2.2: Shaded Relief Rendering showing Seabed Morphology

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 mean particle size distribution of the samples is shown in Figure 2.3 and example screen dumps of ROV footage and photographs of samples are provided in Figure 2.4. 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
T1		600	29.5	5.08	1.54	0.0	20.3	79.7	Poorly sorted medium silt
T4		615	30.7	5.03	1.53	0.0	21.1	78.9	Poorly sorted medium silt
T5		610	29.9	5.06	1.54	0.0	20.6	79.4	Poorly sorted medium silt
T8		622	31.3	5.00	1.54	0.0	22.3	77.7	Poorly sorted coarse silt
T9		571	34.1	4.87	1.54	0.0	25.1	74.9	Poorly sorted coarse silt
T10		702	32.6	4.94	1.53	0.0	23.7	76.3	Poorly sorted coarse silt
Current Survey	Mean	620	31.4	5.00	1.54	0.0	22.2	77.8	Poorly sorted coarse silt
	SD	44	1.7	0.08	0.01	0.0	1.9	1.9	
Loligo	Mean	1412	1742.6	1.02	2.29	25.7	57.5	16.7	Very poorly sorted medium sand
	SD	41	2744.8	2.88	0.51	41.3	31.7	10.6	
Endeavour	Mean	1372	156.5	2.71	2.34	4.3	69.1	26.5	Very poorly sorted fine sand
	SD	23	35.9	0.36	0.24	4.7	4.7	4.6	
Nimrod	Mean	1284	179.3	2.51	2.31	6.2	71.3	22.6	Very poorly sorted fine sand
	SD	14	37.3	0.30	0.32	4.0	5.4	3.9	

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 2.4) suggested that similar sediments occurred at all of the stations that were successfully sampled. The field logs (Appendix D.2) described all samples as unstratified soft silt or clay of an olive colour (Munsell classification 5Y/3/4). This description appeared in keeping with the video footage obtained by ROV around the Toroa A borehole (see Figure 2.4).

Particle size analysis of the data also suggested that sediments across the survey area were extremely homogeneous, the graphical means of the samples' distributions ranging from 4.87 phi units (34.1 µm) to 5.08 phi units (29.5 µm). The Wentworth classification of the graphical means categorise the sediments in two separate classes (poorly sorted medium silt or poorly sorted coarse silt), however all graphical means fall only marginally above or below the threshold between the two classes (5 phi units). Both sand and fines content of the samples are consistent across the stations, the former ranging between approximately 20% and 25% and the latter between approximately 75% and 80%. No coarse material was identified from the analysis, although occasional shell and coral fragments were seen from the ROV footage and in the sieved fauna samples (Figure 2.4).

Examination of fractional data for the six stations sampled also identified strong similarity between their particle size distributions. Statistics for each fraction (1 phi unit intervals) are provided in Table 2.2 and an example graph of laser diffraction data (for Station T1) is provided in Figure 2.3.

The sediment identified from Toroa was distinctly different from that identified from the deeper sites surveyed (Loligo, Endeavour and Nimrod), all of which were shown to have much coarser sand-dominated sediments. Difficulties in sampling the deeper sites (especially Loligo) also suggested that consolidated or coarse sediments were also present at these; the presence of such hard substrates was confirmed by ROV investigations at Loligo. The relationships between the sediments of the four survey areas are explored further using multivariate statistical analysis (Section 2.5.1).

Table 2.2: Statistics for Particle Size Analysis Fractional Data [1 phi unit Intervals]

Distribution Parameters	Sieve Size [phi units]									
	0	1	2	3	4	5	6	7	8	9
Maximum	0.1	0.6	2.0	2.0	22.1	35.2	21.4	11.1	5.8	7.4
Mean	0.0	0.1	0.3	1.3	20.4	34.6	20.4	10.4	5.5	7.1
Minimum	0.0	0.0	0.0	1.0	19.3	34.0	19.2	9.8	5.0	6.3
SD	0.0	0.2	0.8	0.4	1.0	0.5	0.9	0.5	0.3	0.4

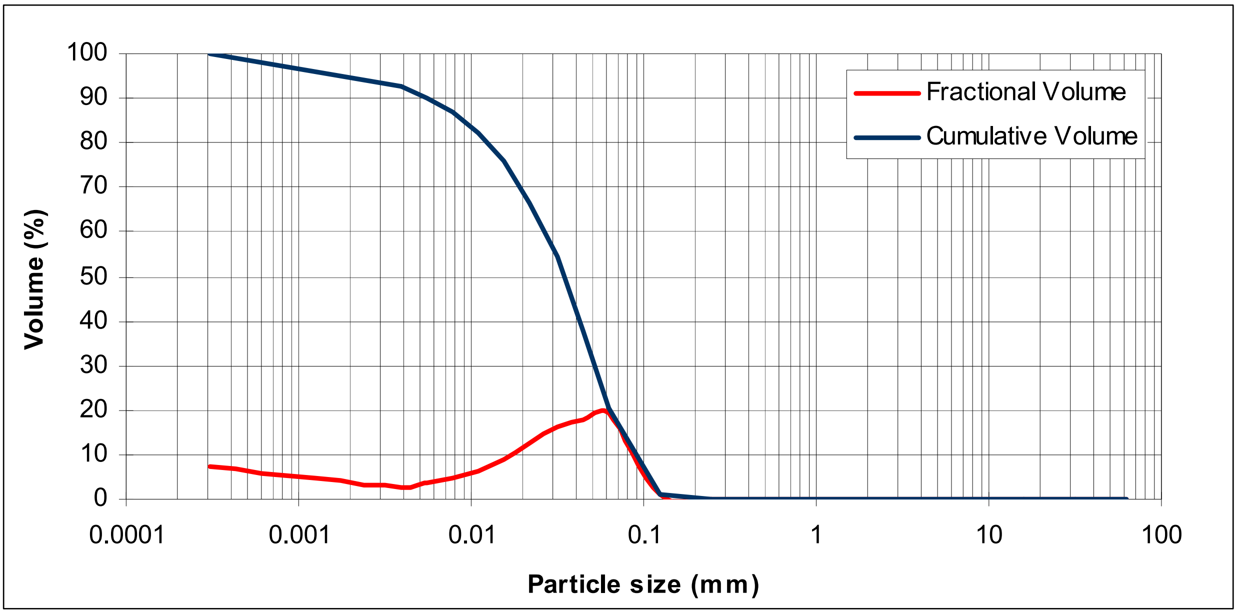

Figure 2.3: Graph of Particle Size Laser Data [Station T1]

-

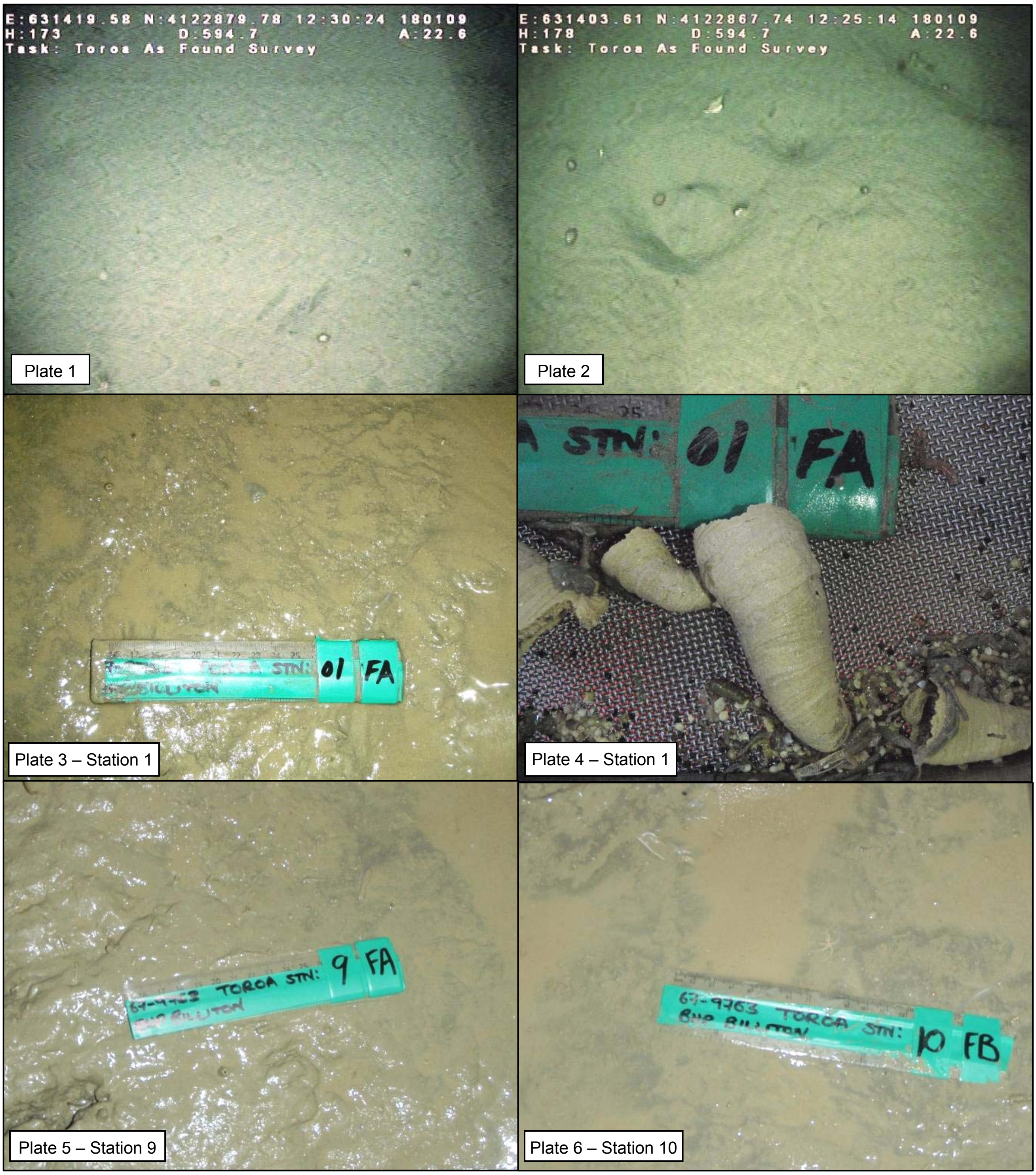

Plate 1: Homogeneous silt / clay sediment in the vicinity of the Toroa A borehole. Fauna may be Echinoidea, *Brisaster* sp.

Plate 2: Silt / clay sediment with some coarse material and conspicuous bioturbation in the vicinity of the Toroa A borehole

Plate 3: Sample 1FA, showing silt / clay sediment near the centre of the site (the proposed Toroa F location)

Plate 4: Sample 1FA after sieving, showing coral and shell fragments and some sand

Plates 5 and 6: Samples 9FA and 10FB demonstrate the homogeneity of the site's sediment, having been taken at its shallowest and deepest extremes, respectively

Figure 2.4: Screen Grabs of ROV Footage and Sample Photographs Demonstrating Sediment Type

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 programme.

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 2.5 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.

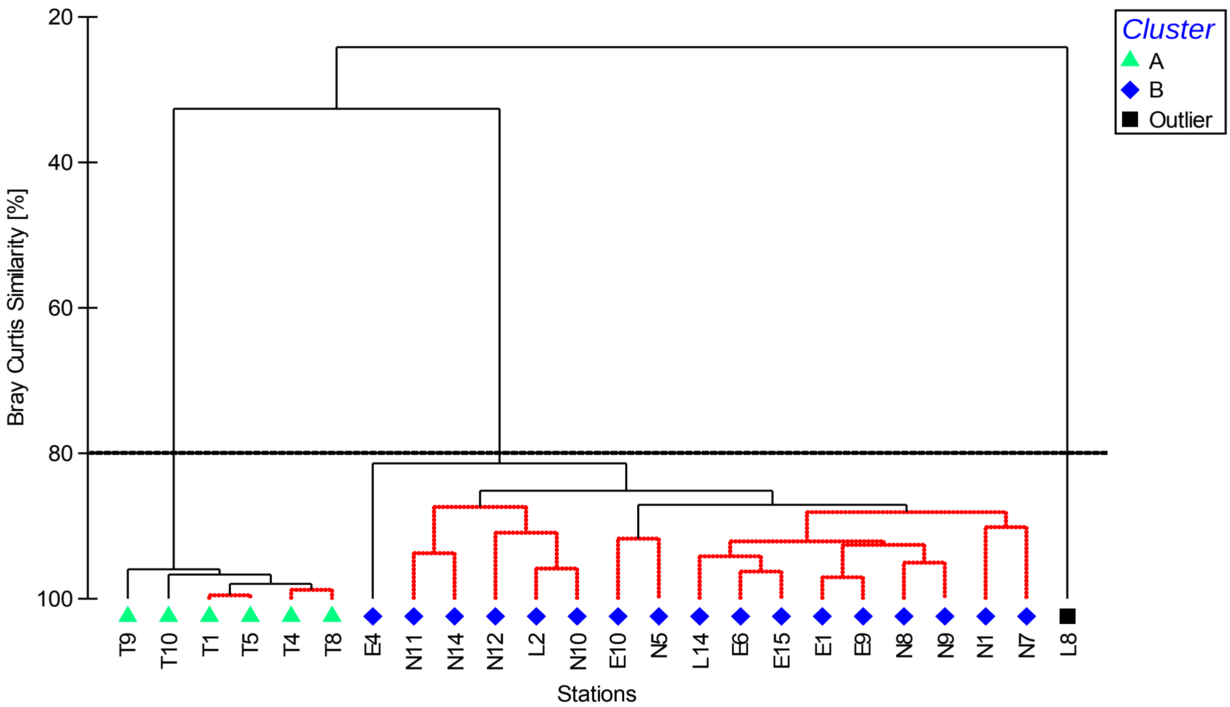

Figure 2.5: Dendrogram by Bray-Curtis Similarity of Particle Size Data for 1 Phi Unit Size Classes

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 fed upon 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 2.3: Summary of Organic Carbon Analyses

Station		Depth [m]	Fines [%]	Fractionated Organic Carbon [% Carbon]	Total Organic Matter [% Loss on Ignition]
T1		600	79.7	0.73	5.3
T4		615	78.9	0.76	6.8
T5		610	79.4	0.75	6.7
T8		622	77.7	0.74	6.3
T9		571	74.9	0.77	6.0
T10		702	76.3	0.62	4.7
Current Survey	Mean	620	77.8	0.73	6.0
	SD	44	1.9	0.05	0.8
Loligo	Mean	1412	16.7	0.27	5.3
	SD	41	10.6	0.04	0.5
Endeavour	Mean	1367	26.5	0.36	4.8
	SD	24	4.6	0.04	0.5
Nimrod	Mean	1284	22.6	0.27	6.8
	SD	14	3.9	0.02	0.8

SD = standard deviation of dataset

Both FOC and TOM were consistent across the sampling stations, the former ranging from 0.62% to 0.77% (stations T10 and T9, respectively) and the latter from 4.7% to 6.8% (stations T10 and T4, respectively). The lowest concentrations of both FOC and TOM were recorded from station T10. Percentage of total organic matter appeared relatively high compared to fractionated organic carbon, by as much as over 6% difference at station T4. It is possible that the larger proportions of TOM were attributable to the presence of carbonates (i.e. shell fragments) and the bodies of organisms in the sediment, in particular fragments of cup corals which were frequently retained on the sieve (see grab photographs in Appendix E).

Comparison with the data collected from the other survey sites showed that FOC concentrations were substantially higher than at the deeper sites (Loligo, Endeavour and Nimrod). This appeared to be due to the higher proportion of fines at Toroa, which resulted in a highly statistically significant correlation ($P < 0.01$) being calculated between FOC and fines when all the sites were considered together. This correlation did not exist when the Toroa site was considered alone. No similar trend was evident with TOM concentration and fines when all sites were considered together or when the Toroa data was considered alone, suggesting that variable amounts of inorganic carbon were present within the surficial sediments, biasing the results of TOM analyses. TOM in the previous surveys of the North Falkland Basin sites was far more variable than at Toroa, ranging from 2.1% to 12.1% (Gardline Surveys Limited, 1998a; Gardline Surveys Limited, 1998b). No comparative FOC data were available from these previous surveys.

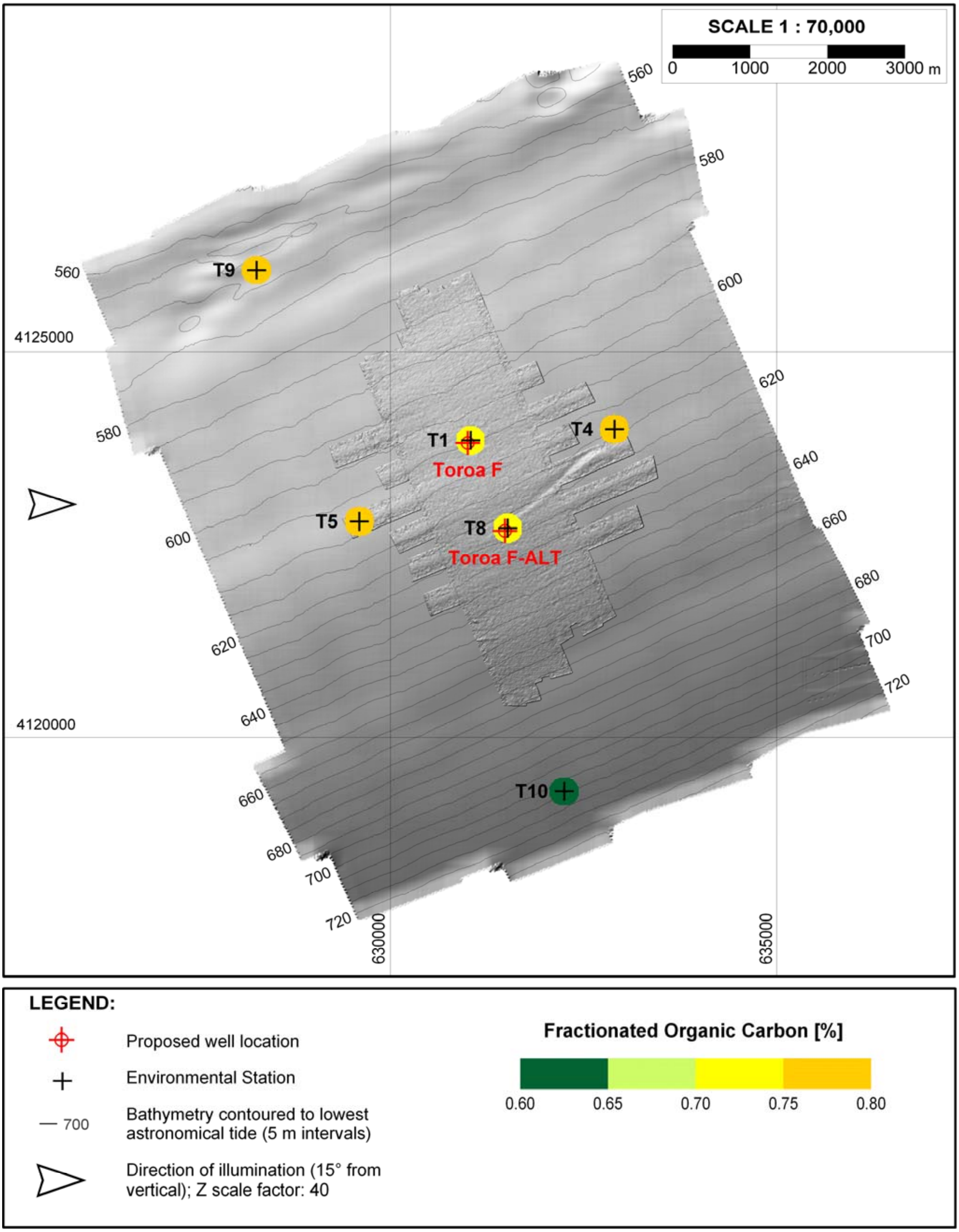

Figure 2.6: Organic Carbon Analysis – Fractionated Organic Carbon [%]

2.7 Hydrocarbon Analysis

Hydrocarbon concentrations (total hydrocarbon concentrations, total n-alkanes and carbon preference index (CPI)) are summarised for each station in Table 2.4, while values for individual n-alkanes are given in Table 2.5. 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 levels or the means by which hydrocarbons enter its benthic environment. 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 2.4: 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}		
T1		79.7	9.4	0.72	5.9	1.15	0.97	1.03	0.093	0.019
T4		78.9	8.3	0.66	5.3	1.17	1.11	1.13	0.090	0.022
T5		79.4	10.1	0.75	6.5	1.13	1.03	1.06	0.093	0.022
T8		77.7	7.0	0.51	4.8	1.12	1.58	1.36	0.081	0.016
T9		74.9	9.3	0.70	6.3	1.20	0.94	1.02	0.075	0.023
T10		76.3	7.9	0.59	5.4	1.17	1.08	1.12	0.086	0.021
Current Survey	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
Loligo	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

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 consistent and fairly high, when compared with the ‘background’ concentrations typically found in the North Sea (UKOOA, 2001) given the remote nature of the survey area. Values ranged from 7.0 $\mu g.g^{-1}$ to 10.1 $\mu g.g^{-1}$ (stations T8 and T5, respectively). These relatively high concentrations are possibly derived from natural oil seeps and are therefore considered to be typical background concentrations for the area. As would be expected given the homogeneity of the seabed sediments, there was no spatial trend in THC distributions.

The Toroa stations had the highest THC of the four sites surveyed west of the Falklands during the current survey cruise. 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 the data from all sites was considered together, a correlation which did not exist when the Toroa data was considered alone. Examination of mean values across the four sites clearly illustrate this relationship, the lowest THC and fines content being found at Loligo, the second lowest values for both parameters being found at Nimrod and third lowest at Endeavour. There is a well documented relationship between hydrocarbon concentrations and granulometry, with higher levels of hydrocarbons generally being associated with fine sediment areas (Benson and Essien, 2009).

THC concentrations in the previous surveys of the North Falkland Basin sites were much lower than at Toroa, ranging from 0.04 $\mu g.g^{-1}$ to 1.42 $\mu g.g^{-1}$ (Gardline Surveys Limited, 1998a; Gardline Surveys Limited, 1998b). These survey areas were approximately 400 km away from the current site and comprised more coarse sediments, which may explain the lower THC values. However these differences in THC concentrations may support the possible occurrence of natural oil seeps proximal to Toroa.

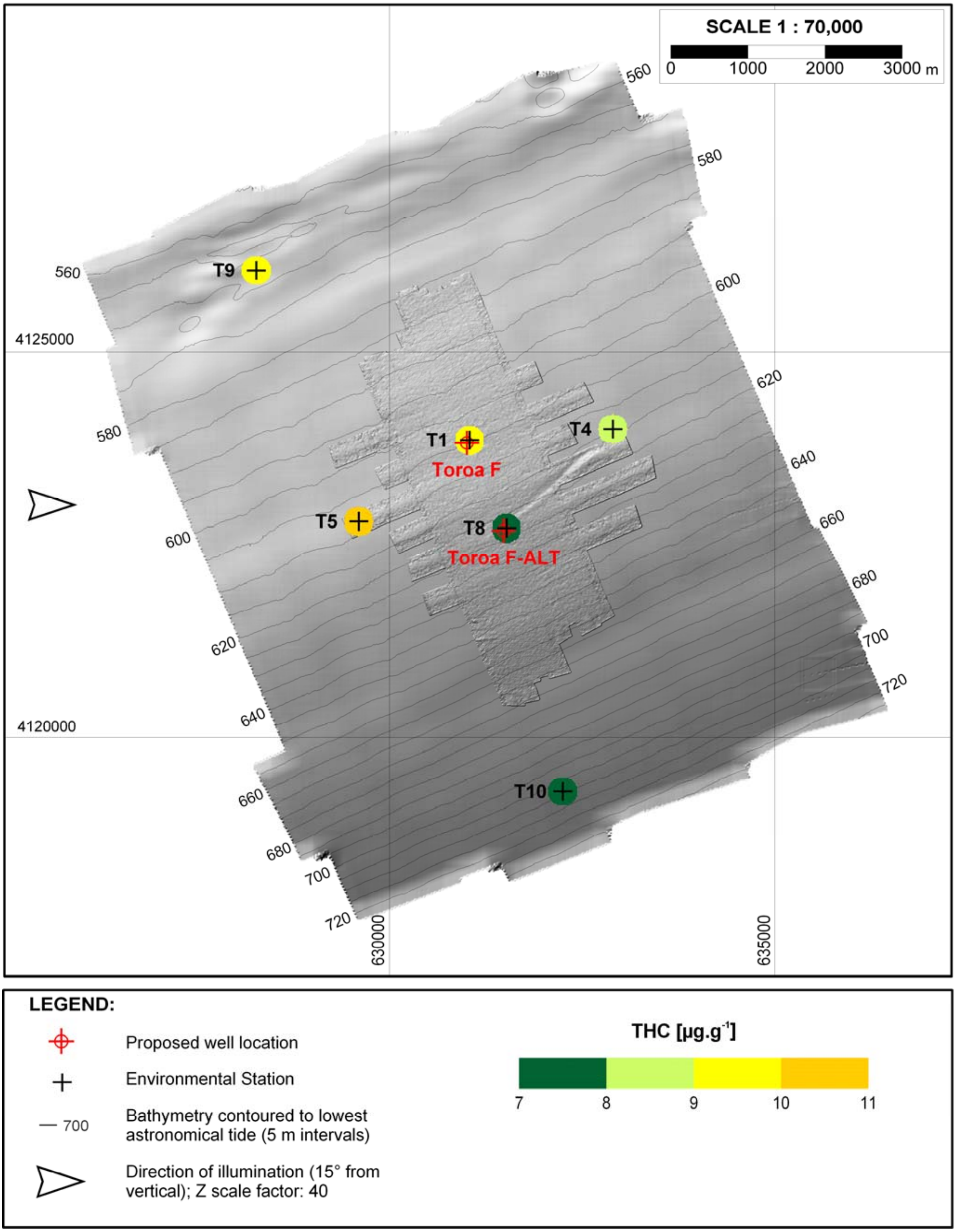

Figure 2.7: Hydrocarbon Analysis – Total Hydrocarbon Concentration [µg.g^{-1}]

2.7.2 Alkanes

Concentrations of individual alkanes are shown in Table 2.5 and the alkane distribution at station T5 is shown graphically in the GC trace in Figure 2.8.

N-Alkanes
Total n-alkane concentration was moderate given the site's isolation from anthropogenic activites, ranging from 0.505 $\mu g.g^{-1}$ to 0.749 $\mu g.g^{-1}$ (stations T8 and T5, respectively), this trend (and those seen in concentrations of individual aliphatics) generally reflected that seen in THC. The n-alkane concentrations found at Toroa were substantially higher than at the three deeper sites (Loligo, Endeavour and Nimrod) surveyed and this was again thought likely to relate to the comparative fines content of the sediments, with a statistically significant ($P < 0.01$) correlation being identified between total n-alkane concentration and fines when the data from all sites was considered together. This correlation was not evident when the Toroa data was considered alone.

Examination of the distributions of 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). In crude oil or refined petroleum products there will generally be no preference for odd or even carbon number alkanes.

In the current survey there was an elevated series of alkanes in the range nC_{12-26}. There was a distinct odd carbon number preference within the intermediate chain lengths within this series (nC_{15-21}) which may relate to inputs from marine phytoplankton, but across the remainder of the series n-alkane distributions appeared equitable. Within the range nC_{27-31} there was a distinct predominance of odd over even carbon number n-alkanes. This signature would generally be consistent with inputs from terrestrial plants, but given the site's distance from land masses the significance of such inputs may be comparatively low. The largely homologous series of alkanes may indicate diffuse inputs of petroleum hydrocarbons into the Toroa site, and appear likely to have come from natural oil seeps.

With the exception of station T8, all stations showed distinct peaks at nC_{36} that ranged from 36.7 $ng.g^{-1}$ to 72.7 $ng.g^{-1}$ (stations T5 and T9, respectively) (bold type in Table 2.5); the concentrations of n-alkanes of this chain length were the highest of all of the individual aliphatics at stations T1 and T9 and the second and third highest at stations T10 and T4, respectively. No increase at this chain length was apparent at station T8 (3.8 $ng.g^{-1}$). 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 Toroa.

Total n-alkane concentrations in the previous surveys of the North Falkland Basin sites were considerably lower than at Toroa, ranging from 0.003 $\mu g.g^{-1}$ to 1.167 $\mu g.g^{-1}$ (Gardline Surveys Limited, 1998a; Gardline Surveys Limited, 1998b). These survey areas were approximately 400 km away from the current site and comprised lower levels of fine sediments, which may explain the lower THC values. However These differences in total n-alkane concentrations may support the possible occurrence of natural oil seeps proximal to Toroa.

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).

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 (nC_{12-36}) across the site were close to unity, ranging from 1.02 at station T9 to 1.36 at station T8 possible due to the influence of natural oil seeps.. It is noteworthy that for all stations except T8 CPI was higher for the series nC_{12-20} than it was for series nC_{21-36}, the lower CPI within the longer chain length n-alkanes resulted from the influence of the homologous series between nC_{21-26} in combination with the large contribution from the nC_{36} aliphatics.

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 75.1 $ng.g^{-1}$ to 93.5 $ng.g^{-1}$ (stations T9 and T5, respectively) and phytane concentration from 16.3 $ng.g^{-1}$ (station T8) to 22.4 $ng.g^{-1}$ (stations T4 and T5). The pristane levels appear high and may originate from a biogenic source. Previous observations in the Southern Ocean have shown blooms of copepod crustaceans to be the greatest contributor to pristane levels (Cripps, 1990; Ward et al., 1996), as some species are known to accumulate pristane in their body fats which is a metabolite derived from the breakdown of chlorophyll. The phytane levels, though outweighed by pristane concentrations, may be considered moderately high as well given the remote location of the survey area. The high possible contribution of pristane from plankton blooms may be masking signs of natural petrogenic input which typically exhibits an equal ratio of pristane to phytane.

Table 2.5: Individual Aliphatic Concentrations [ng.g^{-1} – dry weight]

N-Alkane [ng.g^{-1}]	Station					
	T1	T4	T5	T8	T9	T10
nC_{12}	12.0	10.6	11.9	9.8	10.9	12.3
nC_{13}	17.4	17.3	17.7	15.9	17.2	17.0
nC_{14}	19.7	18.6	19.5	17.0	17.6	21.1
nC_{15}	33.1	32.5	41.8	28.5	32.8	38.3
nC_{16}	29.1	27.7	30.6	25.8	24.3	27.6
nC_{17}	39.4	36.8	36.8	29.4	30.6	32.7
nC_{18}	31.1	31.5	33.3	26.4	28.8	29.9
nC_{19}	45.3	49.8	41.2	40.9	42.4	47.1
nC_{20}	26.1	28.0	25.8	23.3	20.8	25.1
nC_{21}	24.7	23.9	25.2	29.0	22.8	24.7
nC_{22}	23.7	23.5	25.2	21.1	21.9	22.3
nC_{23}	22.6	21.4	22.7	18.9	19.0	19.6
nC_{24}	17.8	17.2	18.8	17.6	15.2	16.8
nC_{25}	22.5	24.1	25.8	21.9	22.8	21.0
nC_{26}	21.7	20.3	22.7	16.5	19.6	16.4
nC_{27}	31.4	31.9	36.9	25.3	32.0	26.1
nC_{28}	22.8	20.6	22.7	16.0	21.5	17.8
nC_{29}	45.0	41.8	45.3	28.6	49.2	28.5
nC_{30}	16.5	14.5	18.9	11.2	16.0	11.0
nC_{31}	50.5	39.8	61.4	29.4	49.8	32.4
nC_{32}	33.4	16.2	32.8	8.0	31.3	19.6
nC_{33}	23.0	18.3	20.7	15.9	22.3	15.4
nC_{34}	38.3	38.5	64.2	17.6	48.3	14.5
nC_{35}	11.7	11.5	10.2	7.2	14.0	9.3
nC_{36}	63.9	41.4	36.7	3.8	72.7	45.6
Pristane	93.4	90.4	93.5	80.8	75.1	85.8
Phytane	18.9	22.4	22.4	16.3	23.2	21.4
THC [µg.g^{-1}]	9.4	8.3	10.1	7.0	9.3	7.9
UCM [µg.g^{-1}]	5.9	5.3	6.5	4.8	6.3	5.4
Total n-Alkanes [µg.g^{-1}]	0.723	0.658	0.749	0.505	0.704	0.592
CPI (nC_{12-20})	1.15	1.17	1.13	1.12	1.20	1.17
CPI (nC_{21-36})	0.97	1.11	1.03	1.58	0.94	1.08
CPI (nC_{12-36})	1.03	1.13	1.06	1.36	1.02	1.12

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 T5) is provided in Figure 2.8 and plots for the remaining stations are presented in Appendix F.

The characteristically elevated series of n-alkanes in the range nC_{12-26} is apparent from the traces, this may relate to diffuse input of hydrocarbons from natural oil seeps near the survey area. The series appears largely homologous in the range nC_{12-26}, but in the range nC_{15-21} there is a distinct odd over even-carbon number preference that may have resulted from superimposition of odd-carbon number alkanes synthesised by phytoplankton. The odd-carbon dominated series in nC_{27-31} (thought to relate to inputs from terrestrial plants) and the peak at nC_{36} (which may indicate inputs of coccolithophore biomass) are also evident.

Unresolved complex mixture (UCM) humps constitute a combination of (largely weathered) hydrocarbons derived from natural and anthropogenic sources that cannot be resolved by gas chromatography. The low level UCM in the range nC_{26-35} apparent on the Toroa traces (Figure 2.8 and Appendix F) was consistent with the undeveloped, remote nature of the site, which would limit both point source anthropogenic inputs and diffuse inputs (natural and anthropogenic) from terrestrial run-off.

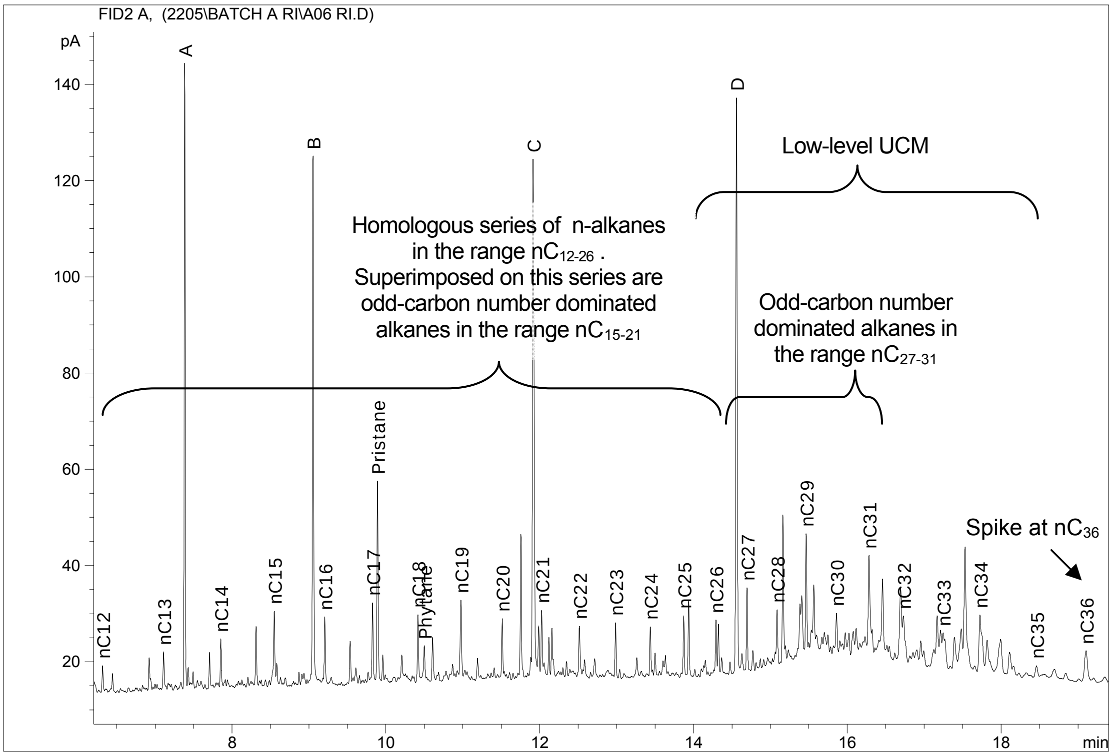

Figure 2.8: Hydrocarbon Analysis – Gas Chromatography Trace (Station T5)

2.7.4 Polycyclic Aromatic Hydrocarbons (PAHs)

A summary of results obtained from polycyclic aromatic hydrocarbons (PAH) analysis is presented in Table 2.6. Concentrations of individual fractions in the EPA (U.S. Environmental Protection Agency) 16 PAHs are shown in Table 2.8 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 2.8.

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).

Another PAH source is petroleum hydrocarbons, often associated with natural seeps and localised drilling activities. 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 is the dominant PAH in petrogenic hydrocarbons but is quickest to degrade and weather over time.

Total Polycyclic Aromatic Hydrocarbons

Total PAH concentrations were low in comparison to areas of active oil and gas production, but were again perhaps higher than would be expected in a site with no petrogenic inputs.. They showed little correspondence with the patterns identified in other hydrocarbon concentrations and instead appeared to show a spatial (or depth-related) trend, being measured at their lowest (195 $ng.g^{-1}$) at the shallowest station (station T9) and at their highest (243 $ng.g^{-1}$) at the deepest station (station T10) (Figure 2.8 and Figure 2.9); the reason for this trend was unclear as there was no accompanying granulometric gradient that might facilitate / inhibit accumulation of PAHs. A highly significant correlation ($P <0.01$) was calculated between total PAH concentration and fines when all the data was considered together. This correlation was not found when the Toroa data was considered alone.

Mean total PAH concentrations were substantially higher than at the deeper sites surveyed (Loligo, Endeavour and Nimrod) and this was again attributed to the higher proportion of fine sediment at Toroa. Fines were found to correlate highly significantly ($P <0.01$) with PAH concentration across the four sites. 2-6 ring PAH concentrations in the previous surveys of the North Falkland Basin sites were generally lower, but comparable in magnitude to those recorded at Toroa, ranging from 10.8 $ng.g^{-1}$ to 294.6 $ng.g^{-1}$ (Gardline Surveys Limited, 1998a; Gardline Surveys Limited, 1998b). However NPD levels in the previous surveys generally comprised less than 45% total PAH for most stations (maximum 75%), while Toroa recorded NPD levels of 72% to 78% of total PAH supporting the possible occurrence of natural oil seeps proximal to Toroa.

NPD and 4-6 Ring PAH

Concentrations of NPD mirrored total PAH concentration, ranging from 139 $ng.g^{-1}$ to 189 $ng.g^{-1}$ (stations T9 and T10, respectively). Concentrations of 4-6 ring PAHs did not follow this trend, being measured consistently across the site within the range of 53 $ng.g^{-1}$ to 62 $ng.g^{-1}$ (stations T8 and T4, respectively). The NPD / 4-6 ring PAH ratio ranged from 2.5 (station T9) to 3.5 (stations T8 and T10). The reason for the dominance of NPD (in particular the alkyl derivatives of naphthalene – see Section 2.7.5) was unclear, but may relate to inputs from natural oil seeps. However one would expect higher levels of dibenzothiophenes if this was the case, given that they are generally present in hydrocarbons of thermogenic origin. The minimal concentration of 4-6 ring PAH was most probably attributable to the lack of local pyrolytic sources of PAH.

Mean concentration of NPD was substantially higher than at the deeper sites (Loligo, Endeavour and Nimrod) and this again appeared to be related to granulometry; a highly statistically significant correlation ($P < 0.01$) was calculated between NPD concentration and fines when the data from all four sites was considered together. This correlation was not found when the Toroa data was considered alone.. The concentration of 4-6 ring PAH was considerably higher at Toroa than at the other sites and it constituted a higher proportion of the total PAH, the mean NPD / 4-6 ring PAH ratio being lower than that of the other sites.

The higher concentrations of both NPD and 4-6 ring PAH at Toroa may be related to better PAH retention in its finer sediments. As it is also likely that the finer sediments of Toroa are indicative of a more depositional environment than at the deeper sites, this may facilitate accumulation of what limited pyrolytic sources of PAH (4-6 ring compounds) are available. In more depositional environments PAHs that enter the water column (from atmospheric deposition or run-off) could be transferred to the benthic environment via sedimentation (adsorption onto particles in the water column) and / or biosedimentation (absorption by plankton) (Patin, 1999).

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: Summary of Polycyclic Aromatic Hydrocarbon Concentrations [$ng.g^{-1}$ dry weight]

Station		Depth [m]	Sum All PAH (2-6 Ring)	Sum NPD	Sum 4-6 Ring	NPD / 4-6 Ring Ratio	Total EPA 16
T1		600	210	151	59	2.6	21.0
T4		615	232	170	62	2.7	22.9
T5		610	223	162	61	2.7	22.0
T8		622	238	185	53	3.5	20.5
T9		571	195	139	56	2.5	21.5
T10		702	243	189	54	3.5	20.8
Current Survey	Mean	620	224	166	58	2.9	21.5
	SD	44	18	19	4	0.5	0.9
Loligo	Mean	1412	119	102	17	5.8	9.6
	SD	41	52	46	6	1.1	2.4
Endeavour	Mean	1367	84	66	17	3.9	7.7
	SD	24	23	17	6	0.6	1.8
Nimrod	Mean	1284	70	55	15	3.6	7.3
	SD	14	13	12	1	0.6	1.0

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).

<u>EPA 16 Polycyclic Aromatic Hydrocarbons Concentrations</u>

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 2.7.

Total EPA 16 PAH concentrations were consistent across the site, ranging from 20.5 $ng.g^{-1}$ to 22.9 $ng.g^{-1}$ (stations T8 and T4, respectively). The concentrations of individual EPA 16 PAHs mirrored the totals, with the highest concentrations in all samples being measured for phenanthrene, followed by naphthalene.

Total EPA 16 concentration was substantially higher at Toroa than at the deeper sites surveyed (Loligo, Endeavour and Nimrod).

Table 2.7: Individual Polycyclic Aromatic Hydrocarbon Concentrations – EPA 16 [ng.g^{-1} – dry weight]

PAH Fraction	Station					
	T1	T4	T5	T8	T9	T10
Naphthalene	2.7	4.1	3.1	2.8	2.5	2.7
Acenaphthylene	0.6	0.9	0.2	0.4	0.1	0.9
Acenaphthene	0.5	0.7	0.7	0.8	0.6	0.7
Fluorene	1.2	1.4	1.4	1.7	1.3	1.5
Phenanthrene	4.9	4.8	4.8	4.7	5.0	4.8
Anthracene	0.1	0.2	0.2	0.2	0.2	0.1
Fluoranthene	1.6	1.6	1.9	1.6	2.2	1.5
Pyrene	2.7	2.6	2.9	2.6	2.9	2.7
Benzo(a)anthracene	0.7	0.7	0.8	0.7	0.9	0.7
Chrysene	1.9	1.9	1.9	1.6	1.7	1.6
Benzo(b)fluoranthene	1.6	1.6	1.6	1.5	1.5	1.4
Benzo(k)fluoranthene	0.5	0.6	0.6	0.5	0.7	0.6
Benzo(a)pyrene	0.5	0.4	0.5	0.4	0.6	0.5
Indeno(123cd)pyrene	0.3	0.2	0.3	0.2	0.3	0.2
Benzo(ghi)perylene	1.0	1.0	0.9	0.7	0.9	0.8
Dibenzo(ah)anthracene	0.2	0.2	0.2	0.1	0.1	0.1
Total EPA 16	**21.0**	**22.9**	**22.0**	**20.5**	**21.5**	**20.8**

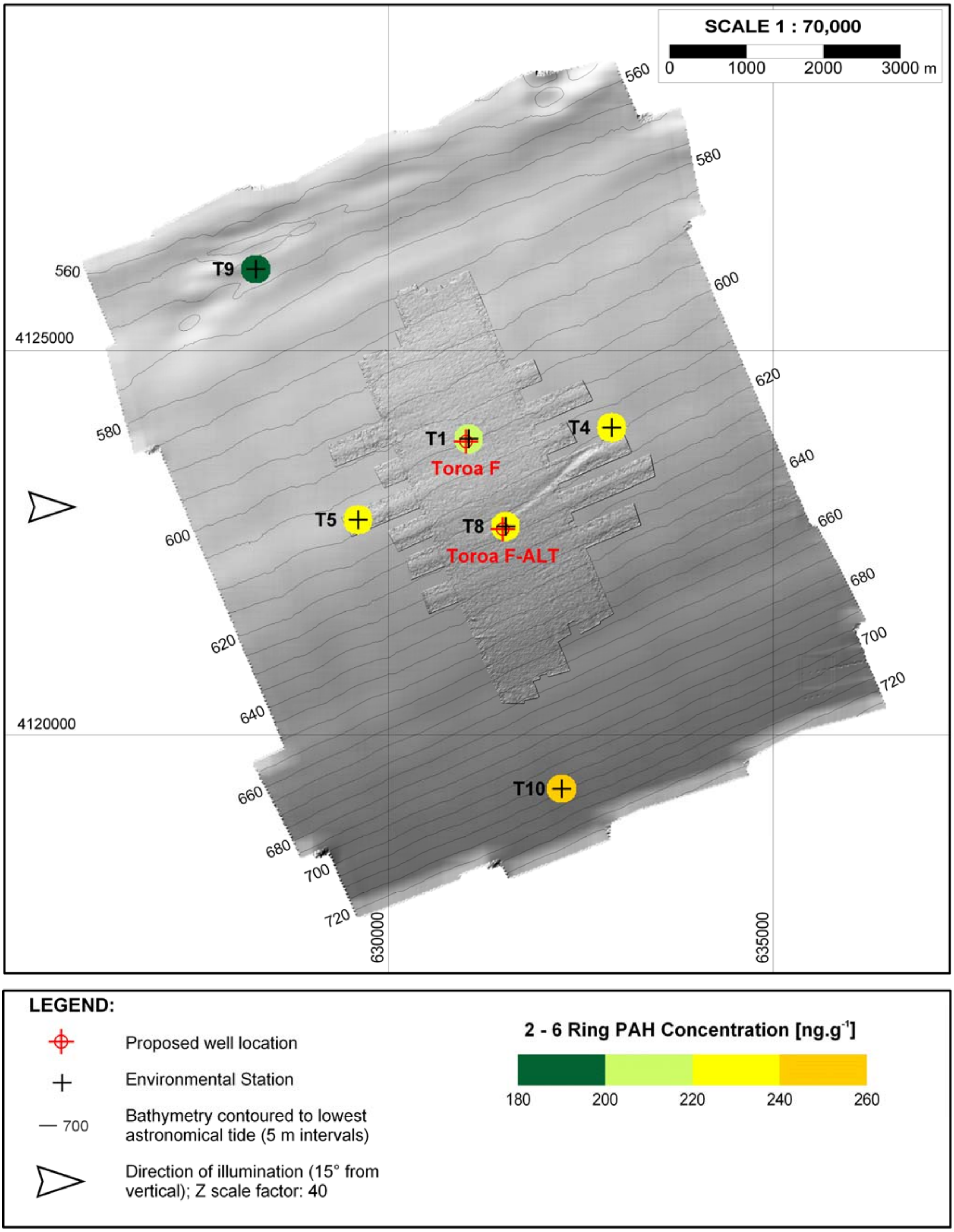

Figure 2.9: Hydrocarbon Analysis – Total PAH Concentration [ng.g^{-1}]

2.7.5 Parent / Alkyl Distributions

An example parent / alkyl distribution plot (station T5) 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 2.8.

As suggested by the summary PAH data all of the distributions were skewed towards NPD. In areas where oil production and / or processing occurs this would generally be considered indicative of anthropogenic contamination, but at Toroa, 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 total PAH concentration at all stations, cumulatively contributing between 46% (stations T1 and T9) and 57% (stations T8 and T10) of their total PAH concentrations. Alkyl derivatives of phenanthrene / anthracene also made substantial contributions to total PAH concentration (approximately 20% at all stations). Both naphthalene and phenanthrene / anthracene and their alkyl derivatives are dominant components of crude oils (Bence *et al*, 2007), but while the parent compounds weather easily their alkyl homologues increase in persistence with increasing alkylation (Irwin *et al*, 1997). The elevated concentrations of naphthalene and phenanthrene / anthracene derivatives detected in the current survey may have been related to diffuse inputs from natural oil seeps, the less stable parent compounds, which would generally be present in high concentrations in crude oil (Bence *et al*, 1997) presumably having been weathered. Within the 4-6 ring PAHs there were generally equitable parent / alkyl distributions, the notable exception to this being seen in the m/z 252 group of PAHs (benzoflouranthenes, benzopyrenes and perylene) where the parent PAH was dominant across all stations.

The parent / alkyl distributions identified were less NPD-skewed than the deeper survey areas (Loligo, Endeavour and Nimrod), suggesting greater input and / or retention of (presumably pyrolytic) 4-6 ring compounds. Although the dominant NPD compounds at Toroa were alkyl homologues of naphthalene, as seen at the other sites, the proportional contribution of phenanthrene / anthracene derivatives was much greater than at the other sites.

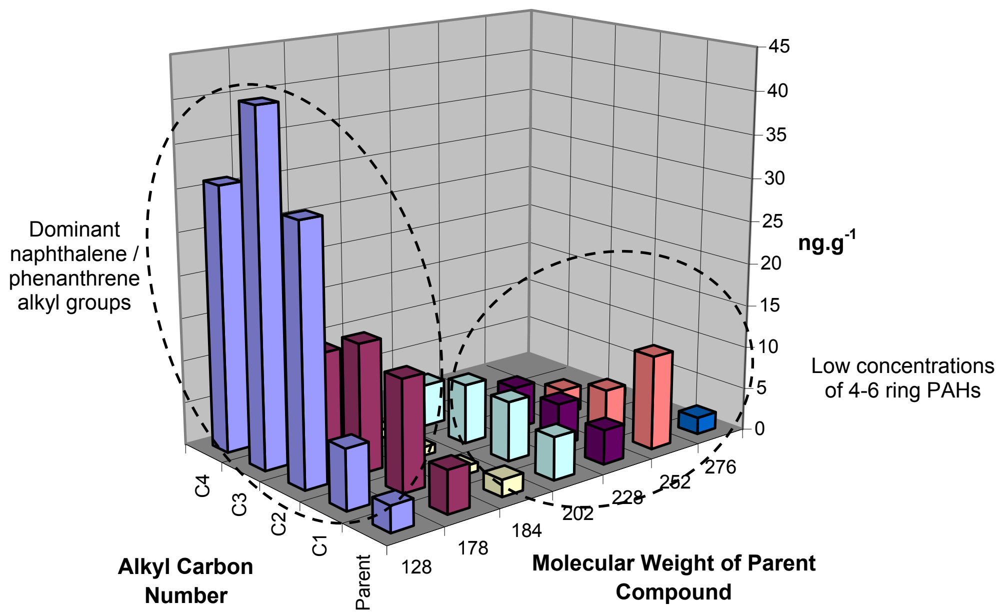

Figure 2.10: 2-6 Ring PAH Parent / Alkyl Distribution – Station T5

Table 2.8: Individual Polycyclic Aromatic Hydrocarbon Concentrations – DTI Specification [ng.g^{-1} dry weight]

PAH Fraction	Station					
	T1	T4	T5	T8	T9	T10
Naphthalene (128)	3	4	3	3	3	3
C1 128	7	7	7	7	6	7
C2 128	26	31	30	37	25	39
C3 128	36	44	41	53	33	52
C4 128	27	32	31	38	25	40
TOTAL 128	**99**	**118**	**112**	**138**	**92**	**141**
Phenanthrene/Anthracene (178)	5	5	5	5	5	5
C1 178	13	13	13	13	13	13
C2 178	15	16	15	13	14	14
C3 178	13	13	12	11	11	11
TOTAL 178	**46**	**47**	**45**	**42**	**43**	**43**
Dibenzothiophene (DBT)	2	2	2	2	1	2
C1 184	2	1	1	1	1	1
C2 184	1	1	1	1	1	1
C3 184	1	1	1	1	1	1
TOTAL 184	**6**	**5**	**5**	**5**	**4**	**5**
Fluoranthene/Pyrene (202)	5	5	5	5	5	5
C1 202	7	7	7	6	6	6
C2 202	7	7	7	6	6	6
C3 202	5	5	5	4	4	4
TOTAL 202	**24**	**24**	**24**	**21**	**21**	**21**
Benzanthracenes/Benzphenanthrenes (228)	4	4	4	4	4	4
C1 228	5	5	5	5	4	5
C2 228	5	6	5	5	5	5
TOTAL 228	**14**	**15**	**14**	**14**	**13**	**14**
m/z 252	10	11	11	9	10	10
C1 252	5	5	5	4	5	4
C2 252	3	3	3	2	3	2
TOTAL 252	**18**	**19**	**19**	**15**	**18**	**16**
m/z 276	1	2	2	1	2	1
C1 276	1	1	1	1	1	1
C2 276	1	1	1	1	1	1
TOTAL 276	**3**	**4**	**4**	**3**	**4**	**3**

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), although the less stringent aqua regia extraction is the more appropriate method to consider for assessment of this. Calculating bioavailable metal concentrations is notoriously difficult as metals take different forms (with varying degrees of bioavailibity) 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 2.9. As would be expected given the differing stringency of the two extraction procedures, the concentrations measured by aqua regia digestion were generally much lower than those measured by HF digestion. Where concentrations were higher when measured following aqua regia digestion (zinc at stations T4 and T9, highlighted in bold in Table 2.9), they were not notably so, suggesting that both techniques achieved similarly efficient metal extraction.

Heavy and trace metal concentrations are thought to generally increase with fines content, as clays are negatively charged, which facilitates adsorption of positively charged metal ions. Unsurprisingly, given the consistent fines content across the stations, no clear relationship between granulometry and heavy / trace metal concentration within the site was apparent.

The concentrations of heavy and trace metals appeared similar across the site, their levels being consistent with those expected for uncontaminated silt / clay sediments. Mercury concentration was below detectable limits with either extraction technique and tin concentrations were not quantifiable by aqua regia digestion. As would be expected given the lack of drilling activity in the survey area, barium concentrations were low, ranging from 92 $\mu g.g^{-1}$ to 134 $\mu g.g^{-1}$ (stations T5 and T10, respectively) for the aqua regia digest and from 396 $\mu g.g^{-1}$ to 420 $\mu g.g^{-1}$ (stations T9 and T10, 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, which did not exist when the Toroa data was considered alone. The opposite trend was observed for aluminium concentration, which appeared substantially higher at Toroa. 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 in the sediments (BHPB, 2009). 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 $\mu g.g^{-1}$) and aluminium (8.4% as opposed to 8.2%).

During the earlier North Falkland Basin surveys barium concentrations were found to range from 322 $\mu g.g^{-1}$ to 453 $\mu g.g^{-1}$ (Gardline Surveys Limited, 1998a; Gardline Surveys Limited, 1998b), these concentrations appeared consistent with those of Toroa.

Table 2.9: Total Heavy and Trace Metal Concentrations [µg.g^{-1} dry weight]

Station		Fines [%]	Heavy and Trace Metals [µg.g^{-1} dry weight by Aqua Regia Digest]												
			Aluminium	Arsenic	Barium	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Tin	Vanadium	Zinc
T1		79.7	7080	1.3	95	0.1	16.4	13.4	14100	4.0	<0.1	12.0	<0.5	27.8	46.2
T4		78.9	7530	1.0	114	<0.1	15.4	12.4	14500	3.5	<0.1	10.7	<0.5	27.2	**42.4**
T5		79.4	6740	1.2	92	0.1	17.7	12.8	13000	2.5	<0.1	11.6	<0.5	28.8	41.8
T8		77.7	7110	0.9	107	<0.1	13.8	11.5	13200	2.9	<0.1	9.1	<0.5	25.8	37.8
T9		74.9	7780	1.0	105	0.1	14.5	12.2	14500	2.5	<0.1	10.9	<0.5	25.2	**42.7**
T10		76.3	7340	0.7	134	<0.1	10.8	10.4	14600	2.1	<0.1	8.7	<0.5	18.5	40.0
Current Survey	Mean	77.8	7263	1.0	108	0.1	14.8	12.1	13983	2.9	n/a	10.5	n/a	25.6	41.8
	SD	1.9	367	0.2	15	0.0	2.4	1.1	708	0.7	n/a	1.3	n/a	3.7	2.8
Loligo	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	26.7	4016	1.8	143	0.1	33.4	10.9	18080	1.9	n/a	**23.4**	n/a	13.9	31.1
	SD	4.2	1135	0.8	29	0.0	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	0.1	46.4	**10.9**	27156	3.2	n/a	**22.5**	n/a	19.7	36.3
	SD	3.9	1084	0.7	39	0.0	13.1	2.9	6602	0.7	n/a	1.2	n/a	3.3	4.0

Station		Fines [%]	Heavy and Trace Metals [µg.g^{-1} dry weight by HF Digest]												
			Aluminium	Arsenic	Barium	Cadmiu	Chromium	Copper	Iron	Lead	Mercury	Nickel	Tin	Vanadium	Zinc
T1		79.7	61700	1.6	401	1.0	32.7	14.6	22900	7.2	<0.1	14.7	1.5	54.9	48.6
T4		78.9	62610	1.5	409	1.0	31.2	15.0	23100	7.1	<0.1	11.6	1.4	54.1	**38.8**
T5		79.4	55900	1.3	402	0.9	30.9	15.3	22000	5.5	<0.1	12.0	1.1	53.1	42.1
T8		77.7	57700	1.3	416	1.0	28.1	12.9	22120	6.0	<0.1	11.4	1.3	53.5	40.0
T9		74.9	60200	1.4	396	1.0	40.7	12.2	22160	5.6	<0.1	12.3	1.1	55.5	**39.0**
T10		76.3	58400	1.3	420	1.0	29.0	12.3	22000	5.9	<0.1	11.3	1.2	53.4	40.8
Current Survey	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
Loligo	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	26.7	23467	6.7	307	1.1	128.7	9.1	71083	6.1	n/a	**7.5**	1.4	36.3	54.9
	SD	4.2	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

SD= standard deviation of dataset; na = not applicable. Bold highlighted values = concentrations higher by aqua regia digestion than those of hydrofluoric acid digestion.

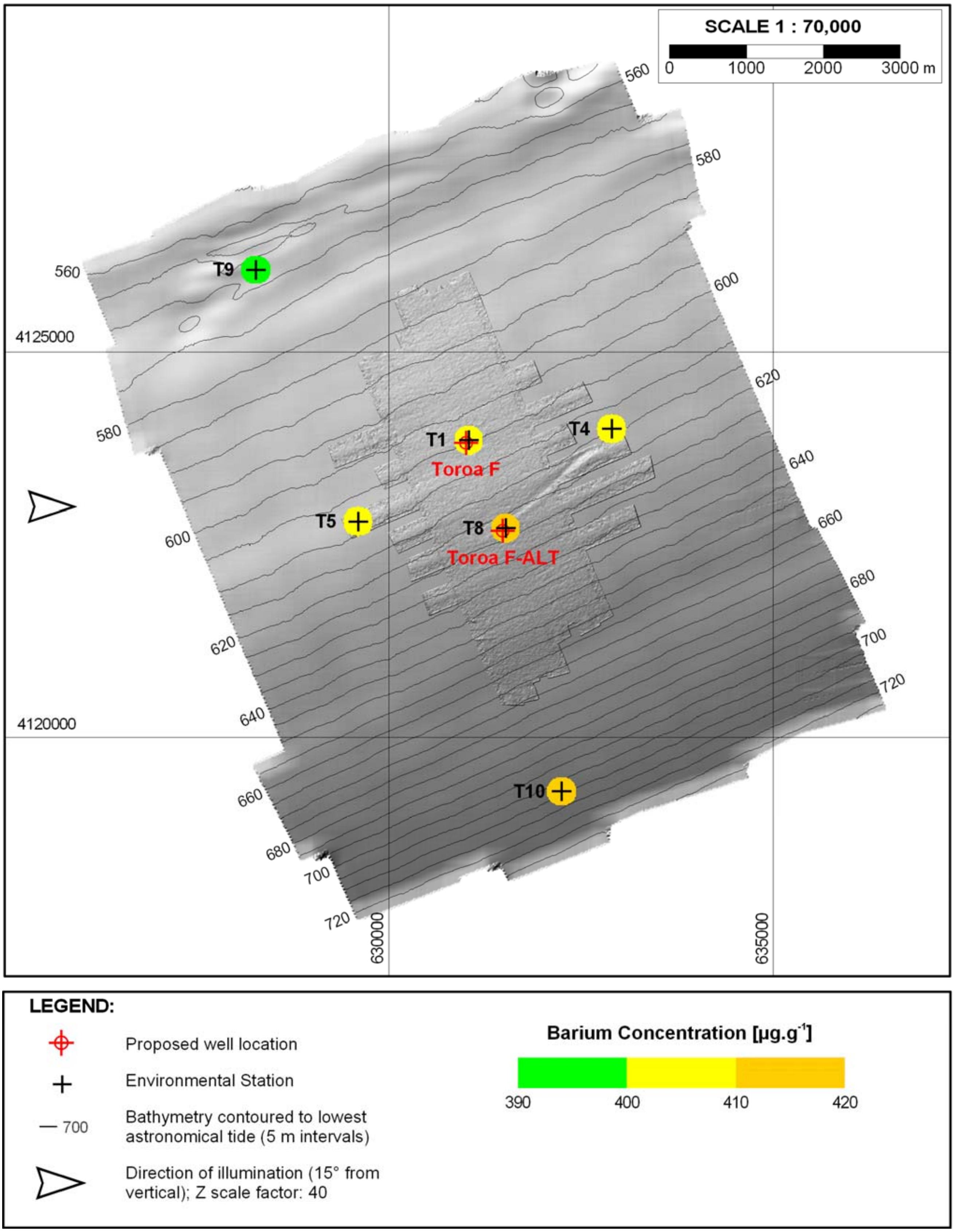

Figure 2.11: Heavy and Trace Metal Analysis – Barium Concentration [µg.g^{-1} Dry Weight by HF Digest]

2.9 Benthic Fauna

2.9.1 Epifauna / Pelagic Fauna

ROV obtained video footage, taken during bore hole operations at Toroa A, were reviewed and reinterpreted 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 footage are provided in Figure 2.12, with Plates 1 and 2 linking to embedded video files (mpeg2 format).

The most dramatic footage obtained from the Toroa site was of a porbeagle shark (*Lamna nasas*) which was briefly observed at a depth of approximately 590 m during drilling operations at Toroa A (Figure 2.12, Plate 1). Porbeagles have a circumglobal distribution throughout temperate and subtropical zones and are typically oceanic, having been recorded down to depths of 715 m (FishBase, 2009). They belong to the family Lamnidae, which, as its vernacular name of mackerel sharks suggests, largely comprises species that feed pelagically; the Lamnidae includes the (largely surface feeding) makos (*Isurus* spp.) and the great white (*Carcharodon carcharias*). Porbeagles are perhaps unusual within this family as they feed on schooling pelagic fish such as herring, mackerel and pilchard and on demersal (bottom feeding) species including cod fishes (gadoids) and flatfish, they are also known to take squid and other cephalopods (Wheeler, 1969). The specimen observed was, by porbeagle standards, probably fairly small, its estimated length from the clip being approximately 2 m; the maximum recorded length for a porbeagle is 3.5 m and the maximum published weight 230 kg.

The most frequently occurring epifaunal taxa encountered were tubicolous (tube-dwelling) onuphid worms, at least the majority of which were probably *Onuphis pseudoirirescens*, a dominant component of the community sampled (Section 2.9.2). These motile surface feeding omnivores were frequently observed from the ROV footage (Figure 2.12, Plates 3 and 4) and in grab sample photographs (Figure 2.12, Plate 6). Brittle-stars, which appeared from their gross morphology to largely comprise members of the family Amphiuridae (three species of which were recorded from the sample data) were frequently seen (Figure 2.12, Plates 3 and 4). A prominent, if sparsely distributed, member of the epifaunal community that was tentatively identified as a seapen (order Pennatulacea) was also occasionally observed (Figure 2.12, Plate 2).

Although not showing epifaunal taxa Figure 2.12, Plate 5 was included as it shows examples of the largest infaunal taxa recorded. The starfish *Ctenodiscus australis* is unusual within its class as it adopts an infaunal, deposit feeding habit; it was frequently recorded from samples acquired across the Toroa site (mean abundance of 1.1 individuals per sample). The sea cucumber *Molpadia* cf *musculus* was certainly the largest infaunal species recorded, the specimens in the photograph shown are at least 5 cm long, but will have inevitably contracted substantially when disturbed. *Molpadia* cf *musculus* was only present in the sample shown (sample T9-FA).

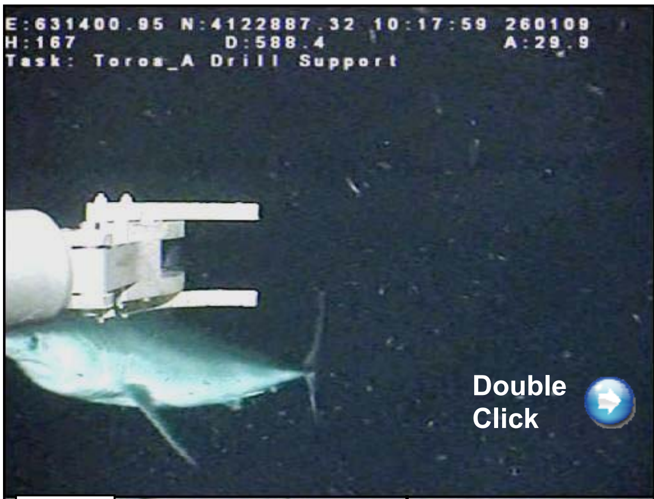

Plate 1

Plate 2

Plate 3

Plate 4

Plate 5

Plate 6

Plate 1: The porbeagle shark (*Lamna nasus*) seen during drilling operations at Toroa A

Plate 2: A seapen? (Pennatulacea?) with a cup coral in the background (Scleractinia)?

Plate 3: An onuphid polychaete (*Onuphis pseudoiridescens*) and brittle-stars (probably *Amphiura* sp.)

Plate 4: A close up of the same onuphid (*Onuphis pseudoiridescens*)

Plate 5: The sea cucumbers *Molpadia* cf. *musculus* and starfish *Ctenodiscus australis* in grab sample T9-FA after sieving

Plate 6: Tubes of the onuphid polychaete *Onuphis pseudoiridescens* in grab sample T1-FA after sieving

Figure 2.12: Screen Grabs of ROV Footage and Grab Sample Photographs, Showing Notable Fauna

2.9.2 Infauna

Two 0.1 m^2 macrofaunal grab samples were analysed from each of the six stations sampled, giving a total of twelve 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 G.

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 6 (5.2%) of the 115 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 five taxa representing indeterminate specimens that may have been represented elsewhere in the dataset were also excluded from the dataset and records of one indeterminate taxon (Sipuncula indet.) were merged with a taxon identified to species level (Sipuncula sp. 1) for analysis (Appendix G).

A total of 103 discrete macrofaunal taxa were found during the course of this survey, excluding the six juvenile and three indeterminate taxa, records for which were not included in the analysis (Appendix H). Of the taxa recorded 55 (53.4%) were annelid, 21 (20.4%) were crustacean, 18 (17.5%) were molluscan and seven (6.8%) were echinoderm. Sipunculans and nemerteans made up the two taxa (2.7% of the total) which belonged to other phyla (see Figure 2.13 and Table 2.10). In terms of abundance the Annelida were dominant, representing 54.5% of the 488 individuals recorded in total from the samples. The Crustacea, which contributed 24.2% of the total abundance, were the second most abundant phylum, followed by the Mollusca (14.5%) and Echinodermata (5.9%). Members of the other phyla contributed just 0.8% of the total faunal abundance recorded. Percentage abundances of phyla identified in the current survey were comparable to those determined by Blake and Narayanaswamy (2004) in Antarctica; 67% Polychaeta, 20% Crustacea and 13% remaining phyla.

Table 2.10: Abundance of Taxonomic Groups

Phyla	Number of Taxa	Total Taxa [%]	Abundance	Total Abundance [%]
Annelida	55	53.4	266	54.5
Crustacea	21	20.4	118	24.2
Mollusca	18	17.5	71	14.5
Echinodermata	7	6.8	29	5.9
Others	2	1.9	4	0.8
Total	103	100.0	488	100.0

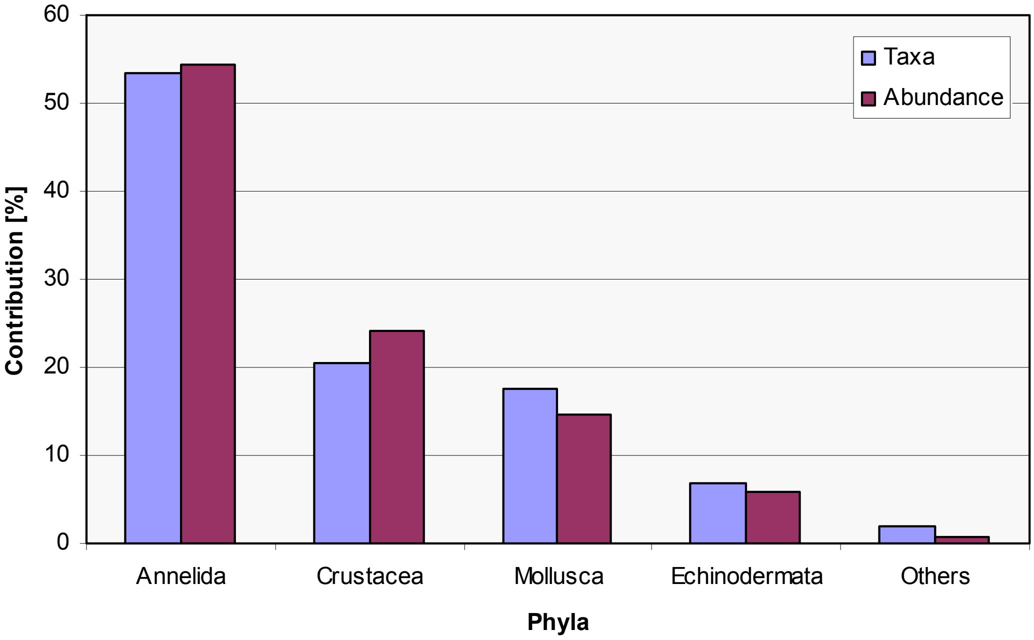

Figure 2.13: Abundance of Taxonomic Groups

The dominant taxa recorded from the survey area are shown in Table 2.11. As would be expected given the predominance of the phylum overall, the majority of the dominant taxa belonged to the Annelida. Seven of the twelve dominant taxa listed are polychaetous annelids, the exceptions being the amphipod crustaceans Haustoriidae sp. 1 and *Harpinia* sp. 2, the starfish *Ctenodiscus australis*, the bivalve molluscs *Nucula falklandica*, *Thyasira subovata* and *Axinulus* cf *croulinensis* and the scaphopod mollusc (tusk shell) *Pulsellum falklandicum*. The most abundant species overall was Haustoriidae sp. 1, which was recorded at a mean abundance of 5.6 individuals per sample, and the second most abundant species the onuphid polychaete *Onuphis pseudoiridescens*, which was recorded at a mean abundance of 5.3 individuals per sample. The remainder of the dominant taxa identified were of comparatively low abundance, all being recorded at mean abundances of less than 2.7 individuals per sample.

The frequencies of occurrence calculated showed that only *O. pseudoiridescens* occurred in all of the samples acquired. The numerically dominant Haustoriidae sp. 1 occurred in 10 (83.3%) of the twelve samples analysed and the remainder of the dominant taxa in 8 (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 2.11). This method is less susceptible to bias toward species which may occur at 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. *Pulsellum falklandicum* was absent from all but three of the samples, but these were the richest of the samples obtained, as the total dominance score calculable for any sample is up-weighted by its diversity, this served to elevate this species' rank dominance.

Table 2.11: Dominant Taxa by Abundance and Dominance Rank for Samples [0.1 m^2]

Taxon	Rank Abundance	Mean Abundance	Frequency [%]	Rank Dominance
Haustoriidae sp. 1	1	5.6	83.3	1
Onuphis pseudoiridescens	2	5.3	100.0	2
Ampharete sp. 1	3	2.7	75.0	3
Sternaspis sp. 1	4	1.7	50.0	4
Ctenodiscus australis	5	1.1	50.0	6
Nucula falklandica	6	0.9	66.7	8
Thyasira subovata	6	0.9	41.7	9
Axinulus cf croulinensis	6	0.9	41.7	6
Harpinia sp. 2	9	0.8	41.7	11
Chaetozone andersenensis?	10	0.8	50.0	13
Pulsellum falklandicum	11	0.7	25.0	5
Myriochele riojai	14	0.6	25.0	10

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 2.12 and Table 2.13, 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 2.12. 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 32.1% and 40.4%, respectively. The high variability in these parameters was reflected in the moderate variation in richness (V = 23.7%). 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.

The Toroa site was shown to be marginally more speciose than the deeper Loligo site, but appeared to have a similarly populous benthic community. The values calculated for evenness, dominance and Shannon-Wiener diversity suggested that Toroa's community was less dominated than that of Loligo and Nimrod, and Endeavour.

Table 2.12: 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']
T1-FA		17	52	4.05	0.848	0.892	3.47
T1-FB		19	49	4.63	0.890	0.923	3.78
T4-FA		12	14	4.17	0.982	0.978	3.52
T4-FB		33	64	7.69	0.899	0.953	4.54
T5-FA		20	40	5.15	0.915	0.938	3.95
T5-FB		26	54	6.27	0.900	0.943	4.23
T8-FA		14	26	3.99	0.928	0.932	3.53
T8-FB		14	22	4.21	0.932	0.939	3.55
T9-FA		28	62	6.54	0.910	0.950	4.37
T9-FB		28	45	7.09	0.955	0.973	4.59
T10-FA		17	24	5.03	0.964	0.967	3.94
T10-FB		20	36	5.30	0.950	0.959	4.10
Current Survey	Mean	20.7	40.7	5.34	0.923	0.946	3.96
	SD	6.6	16.4	1.27	0.037	0.024	0.41
	V	32.1	40.4	23.7	4.0	2.5	10.2
Loligo	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
Endeavour	Mean	21.1	39.7	5.48	0.904	0.930	3.95
	SD	3.9	11.1	0.73	0.069	0.053	0.35
	V	18.7	28.1	13.4	7.7	5.7	8.8
Nimrod	Mean	19.8	30.5	5.50	0.924	0.942	3.95
	SD	4.8	8.5	1.10	0.044	0.040	0.46
	V	24.5	27.8	19.9	4.7	4.2	11.6

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 2.13. 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.

The primary parameters for the station data (0.2 m^2) are spatially presented in Figure 2.14 and Figure 2.15.

As seen from comparison of the sample data, the station data for Toroa suggested that its community was marginally more species rich and less highly dominated than that of the deeper Loligo and Nimrod sites. Endeavour showed a slightly higher number of taxa and richness value.

Table 2.13: 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']
T1		29	101	6.07	0.821	0.910	3.99
T4		39	78	8.72	0.915	0.963	4.84
T5		39	94	8.36	0.865	0.942	4.57
T8		25	48	6.20	0.896	0.940	4.16
T9		47	107	9.84	0.901	0.963	5.00
T10		33	60	7.82	0.955	0.975	4.82
Current Survey	Mean	35.3	81.3	7.84	0.892	0.949	4.56
	SD	7.9	23.6	1.48	0.046	0.023	0.41
	V	22.5	29.0	18.8	5.1	2.5	8.9
Loligo	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
Endeavour	Mean	36.0	80.0	8.00	0.873	0.935	4.51
	SD	2.9	11.1	0.56	0.054	0.031	0.30
	V	8.1	13.9	7.0	6.2	3.3	6.7
Nimrod	Mean	32.4	61.7	7.62	0.897	0.942	4.49
	SD	5.7	12.3	1.12	0.042	0.031	0.41
	V	17.6	20.0	14.7	4.7	3.3	9.1

SD = standard deviation of dataset; V = coefficient of variation of dataset.

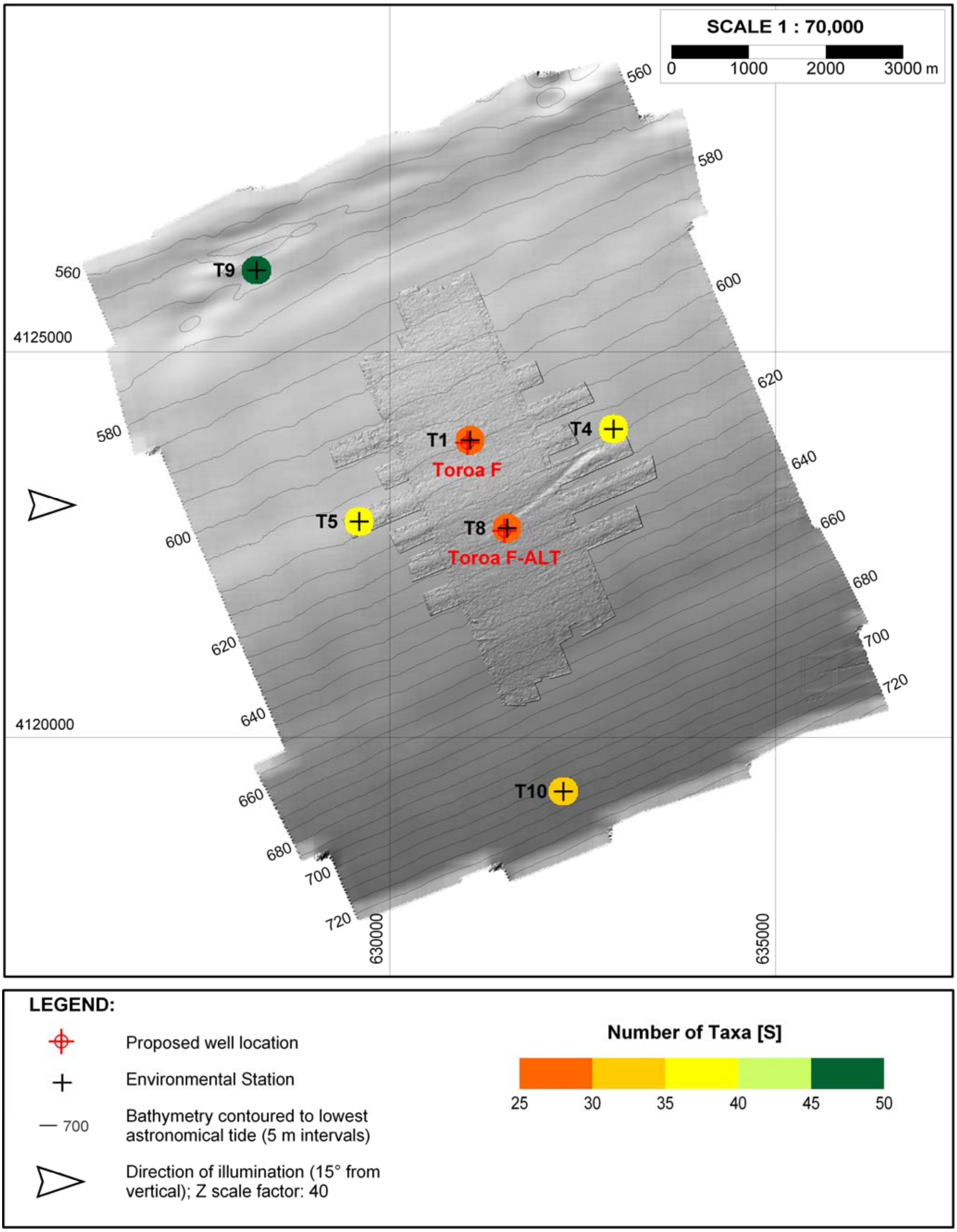

Figure 2.14: Macrofaunal Analysis – Number of Taxa [S]

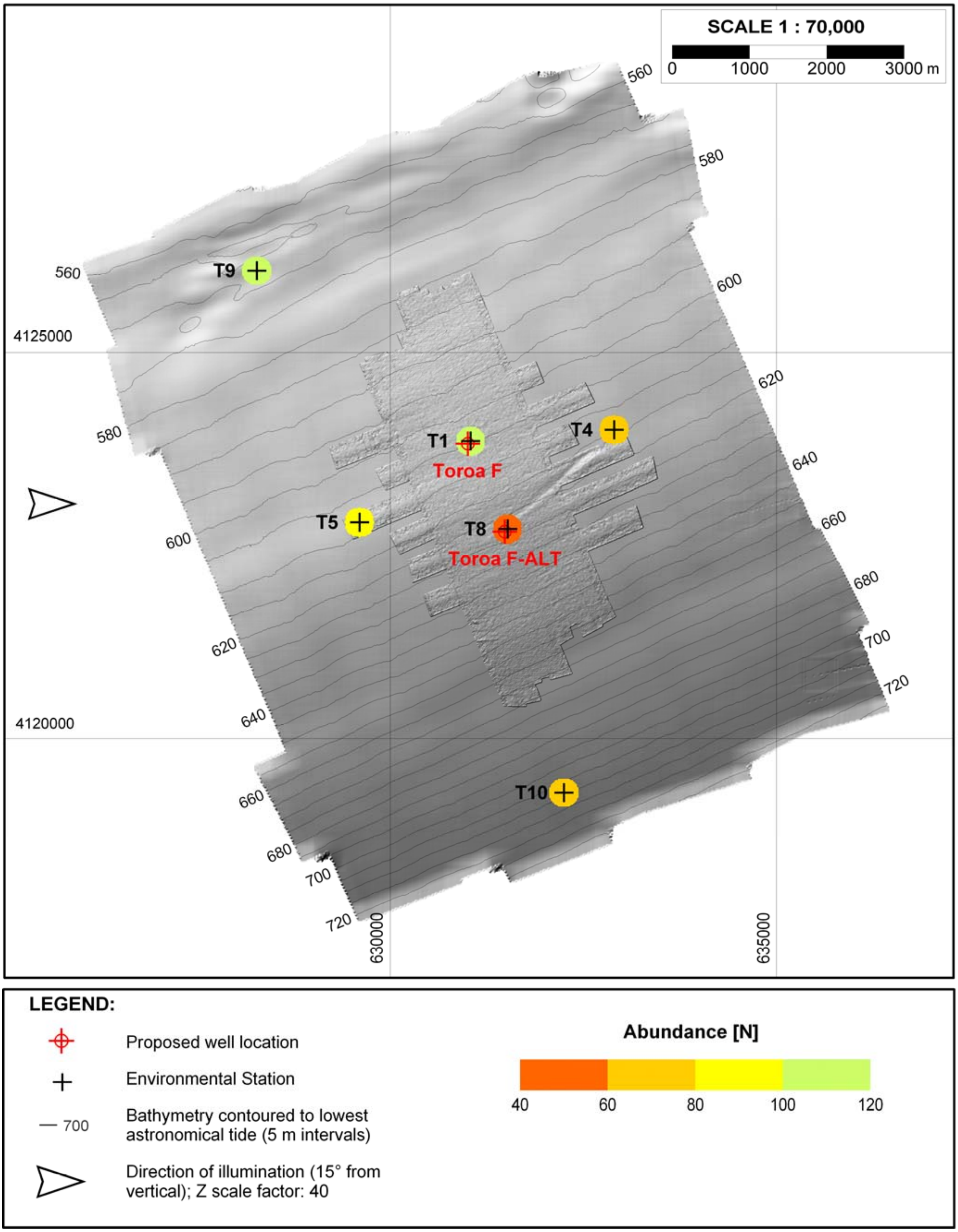

Figure 2.15: Macrofaunal Analysis – Number of Individuals [N]

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 149.8 taxa (Jacknife1) to 195.9 taxa (Chao2) in comparison to the 103 taxa observed. These estimates suggested that between 52.6% and 68.8% of the area's total macrofaunal diversity had been detected. The estimates of percentage species encountered at Toroa are equivalent to those at Loligo (between 52.5% and 69.5%), though eight samples were taken there compared to twelve for the current survey. This suggests greater faunal variability at Toroa, despite the consistency in sediment composition between stations. This may relate to patchiness in community structure and distributions of rarer taxa across the survey area. An overarching multivariate analysis of all four survey sites (Section 2.9.6) suggested that the community was different to the three 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.

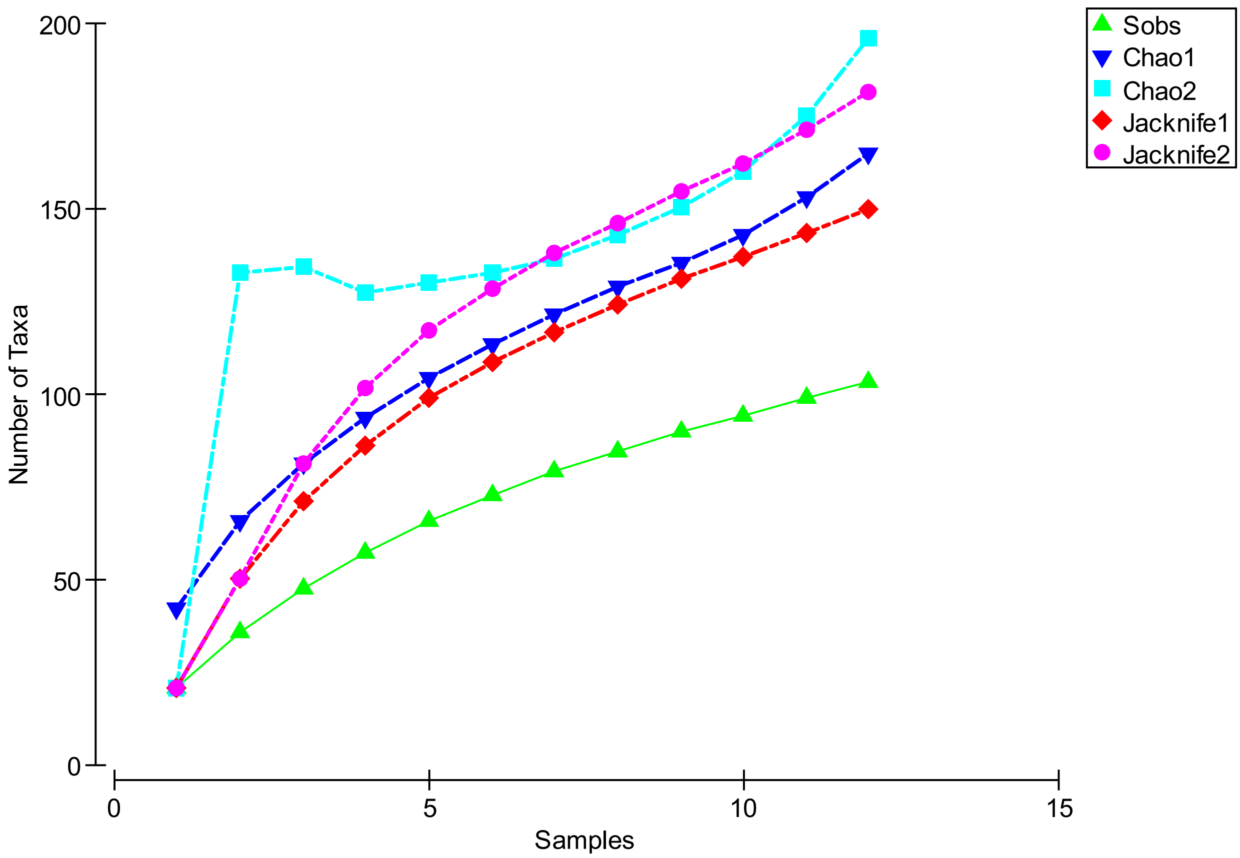

Figure 2.16: Species Accumulation Plot

2.9.5 Multivariate Analysis

CLUSTER and Non-Metric Multidimensional Scaling (nMDS) 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 s 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. Two statistically significantly differentiated clusters were identified within the dataset, cluster A and cluster B. Cluster A comprised the majority of samples and cluster B just three samples (samples T8-FA, T10-FA and T14-FA). The lack of spatial patterns in the data (i.e. the grouping of samples taken from the same station) suggested that the relationships observed resulted from small-scale patchiness in the area's benthic community, rather than clear cut community differentiation. Examination of the data suggested that much of the differentiation was richness driven, the simple graph of number of taxa against abundance showing that cluster B comprised three of the poorest samples obtained. There were however some differences in the presence of rarer taxa and it was differences of this type that differentiated the poorest cluster A sample (sample T8-FB) from cluster B; sample T8-FB was closely associated with the cluster B samples in Figure 2.18.

The clusters identified were poorly defined in the nMDS ordination (not shown) and the moderate stress value of 0.13 suggested that detailed relationships between the data may have been somewhat distorted.

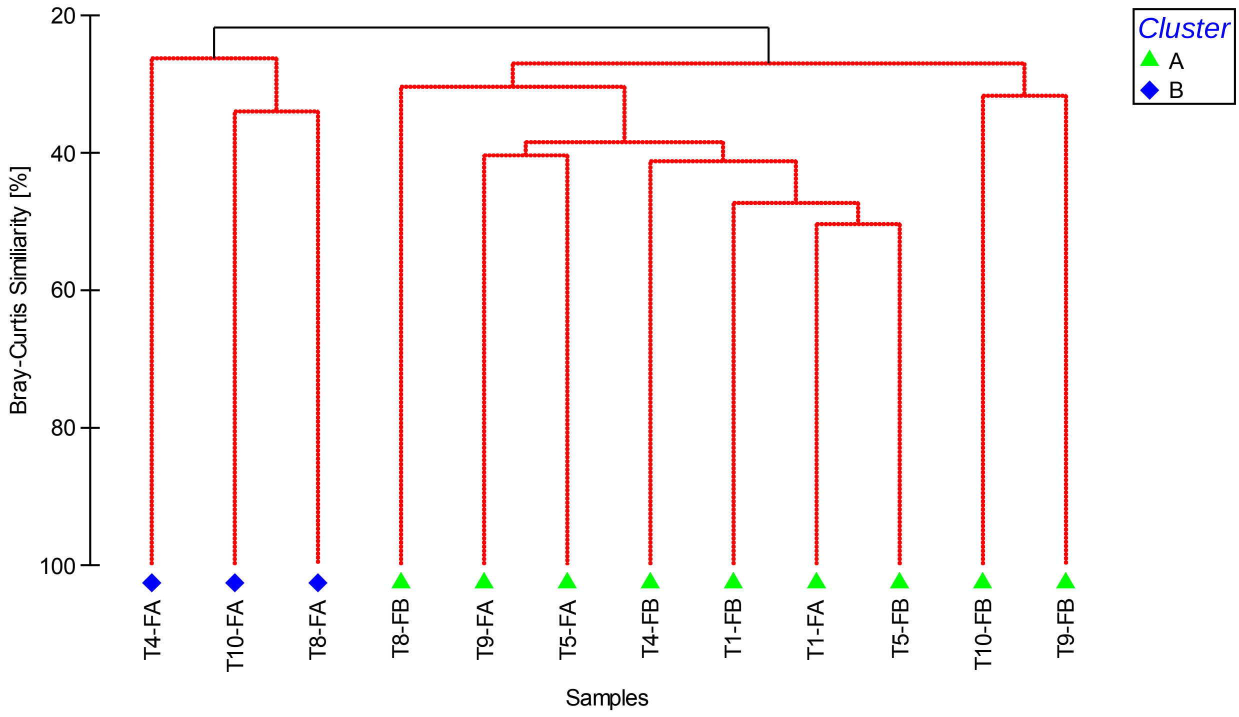

Figure 2.17: Dendrogram by Bray Curtis Similarity for Square Root Transformed Sample Data [0.1 m^2]

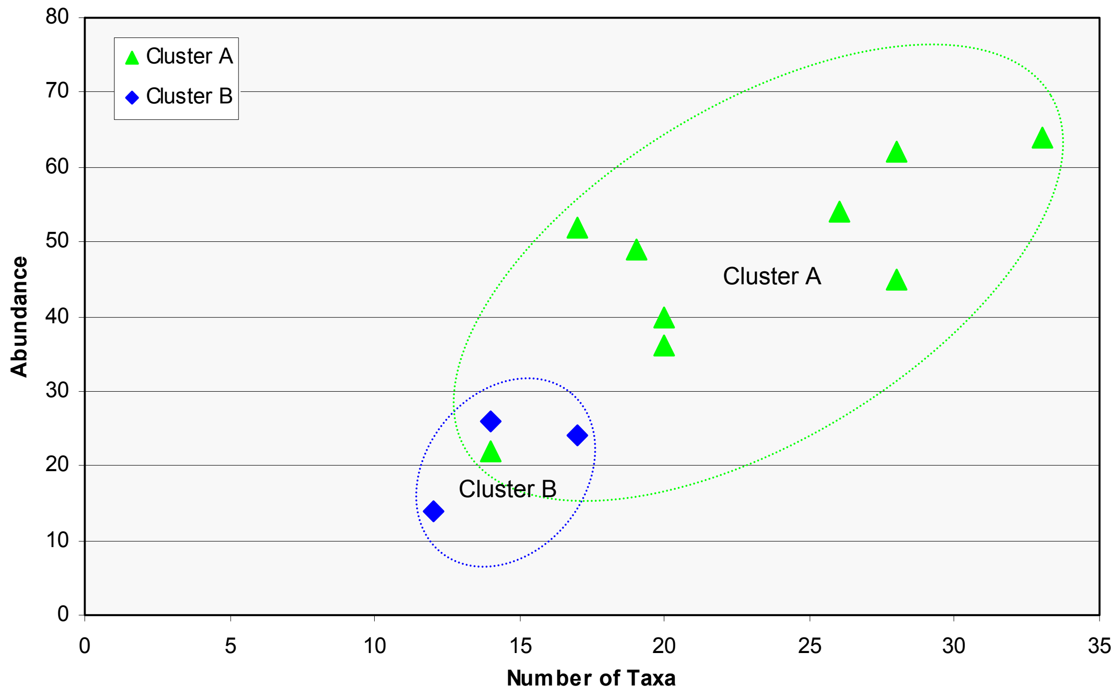

Figure 2.18: Graph Showing Number of Taxa against Abundance for Sample Data [0.1 m^2], Overlain with Multivariate Clusters

Aggregated station data (0.2 m^2) were also analysed using the same multivariate techniques. CLUSTER analysis with the SIMPROF algorithm showed that there was no statistically significant differentiation within the data. The nMDS plot (Figure 2.19) ordinates the majority of the stations in a reasonably tight grouping, with stations T8 and T10 (both of which comprised cluster B samples from the sample level analysis) slightly offset from this group; the low stress value (0.07) calculated for the ordination suggested that it was a reliable representation of the data.

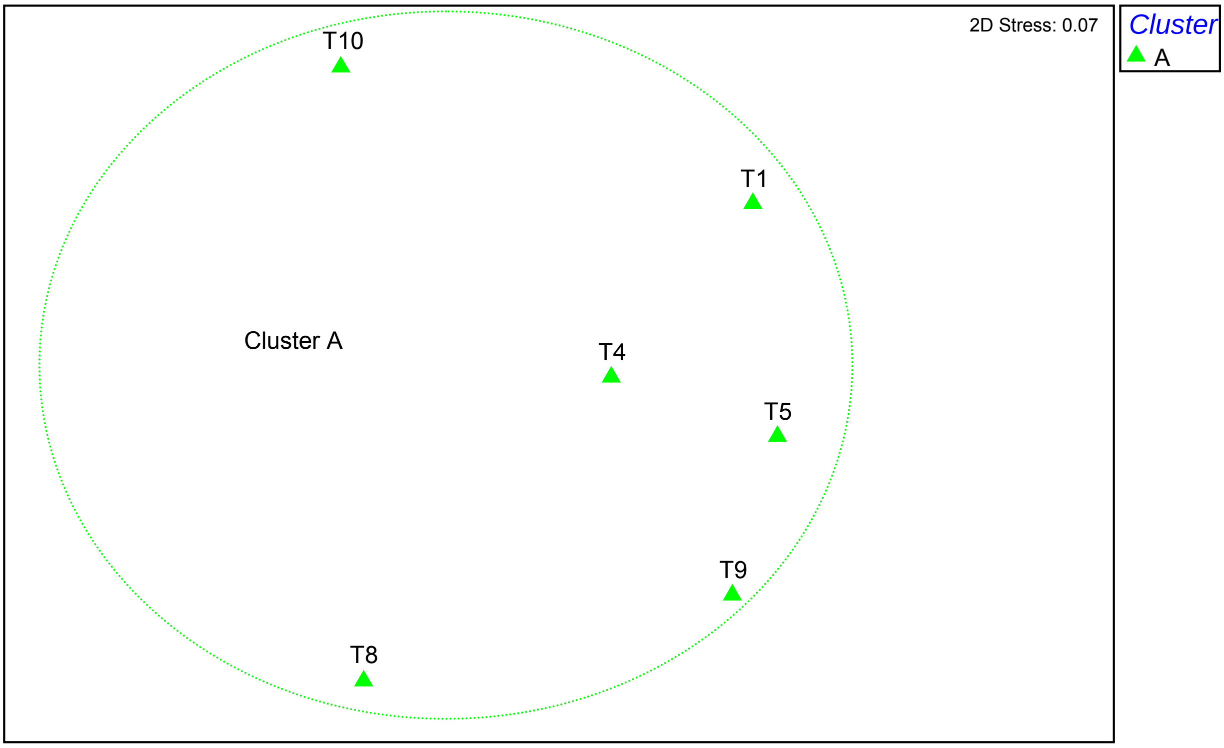

Figure 2.19: nMDS by Bray-Curtis Similarity for Square Root Transformed Station Data [0.2 m^2]

<u>SIMPER Analysis</u>

The PRIMER similarity percentage analysis (SIMPER) routine was run on the square root transformed sample and station datasets. SIMPER analysis was used to identify the taxa which contributed the greatest level of dissimilarity between the cluster A and B samples in the sample level analysis and to characterise the single undifferentiated cluster identified from the station level analysis.

The taxa that contributed the highest degree of dissimilarity between clusters A and B in the multivariate analysis of sample data (0.1 m^2) are shown in Table 2.14. As suggested by examination of the primary variables for the samples, cluster B's differentiation appeared to largely result from its lower abundance and diversity of taxa; four of the five taxa listed in Table 2.14 were present at substantially higher abundance in cluster A than in cluster B. A notable exception to this was seen for the starfish *Ctenodiscus australis*, which was found to be more abundant in the cluster B samples.

Table 2.14: SIMPER Results Showing the Top Five Taxa that Differentiated Cluster A from Cluster B in the Sample Level Analysis

Taxa	Mean Abundance (Cluster A)*	Mean Abundance (Cluster B)*	Contribution to Similarity [%]	Cumulative Contribution [%]
Haustoriidae sp. 1	6.9	1.7	5.3	5.3
Ampharete sp. 1	3.3	0.7	3.8	9.0
Sternaspis sp. 1	2.2	0.0	3.2	12.2
Ctenodiscus australis	0.7	2.3	3.1	15.3
Onuphis pseudoiridescens	6.2	2.7	2.9	18.2

* Non-transformed abundance provided. Analysis undertaken on square root transformed data

The top five characterising taxa of cluster A in the station level (0.2 m^2) analysis are listed in Table 2.15. As would be expected due to the lack of differentiation in the dataset the numerically dominant Haustoriidae sp. 1 and *Onuphis pseudoiridescens* contributed a high proportion of the inter-station similarity (cumulatively contributing 28.1% of the total). The remainder of the top five characterising taxa were the ampharetid polychaete *Ampharete* sp. 1, the starfish *Ctenodiscus australis* (shown in Figure 2.12, Plate 5) and the bivalve mollusc *Nucula falklandica*.

Table 2.15: SIMPER Results Showing the Top Five Characterising Taxa for Cluster A in the Station Level Analysis

Taxa	Mean Abundance (Non-Transformed)	Mean Abundance (√ Transformed)	Contribution to Similarity [%]	Cumulative Contribution [%]
Haustoriidae sp. 1	3.3	11.2	14.7	14.7
Onuphis pseudoiridescens	3.2	10.7	13.4	28.1
Ampharete sp. 1	2.0	5.3	6.7	34.7
Ctenodiscus australis	1.4	2.2	6.5	41.2
Nucula falklandica	1.2	1.8	4.2	45.4

BIOENV Analysis

The BIOENV algorithm in the PRIMER BEST routine was utilised to correlate physico-chemical variables against the patterns in the infaunal station data (0.1 m^2). This algorithm correlates resemblance matrices generated for single or multiple physico-chemical variables against the resemblance matrix generated for the community data and calculates the significance of the resultant correlations by random permuting additional matrices. Untransformed particle size data (1 phi unit sieve size intervals) were analysed using Bray-Curtis similarity whereas crude granulometric and chemical data were normalised prior to analysis (by subtraction of their standard deviations, followed by division by their means) before being analysed using Euclidean distance. The reasons for these differing approaches are explained in Appendix B. In each analysis single variables were correlated along with the cumulative influence of two or three variables.

Unsurprisingly, given the homogeneity of the site's infauna and physico-chemical environment no statistically significant correlations were identified between community structure and particle size or physico-chemical variables.

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 2.21 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 2.20), 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.

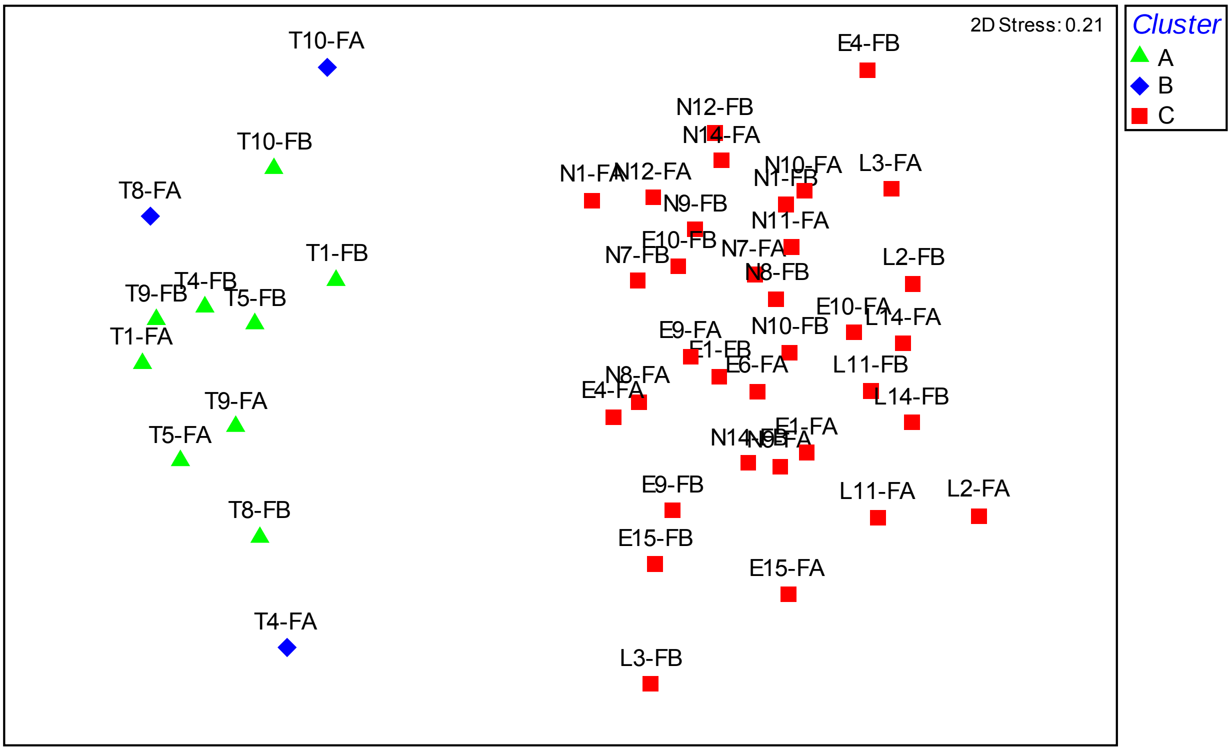

Figure 2.20: nMDS by Bray Curtis Similarity for Square Root Transformed Sample Data [0.1 m^2] for All Sites

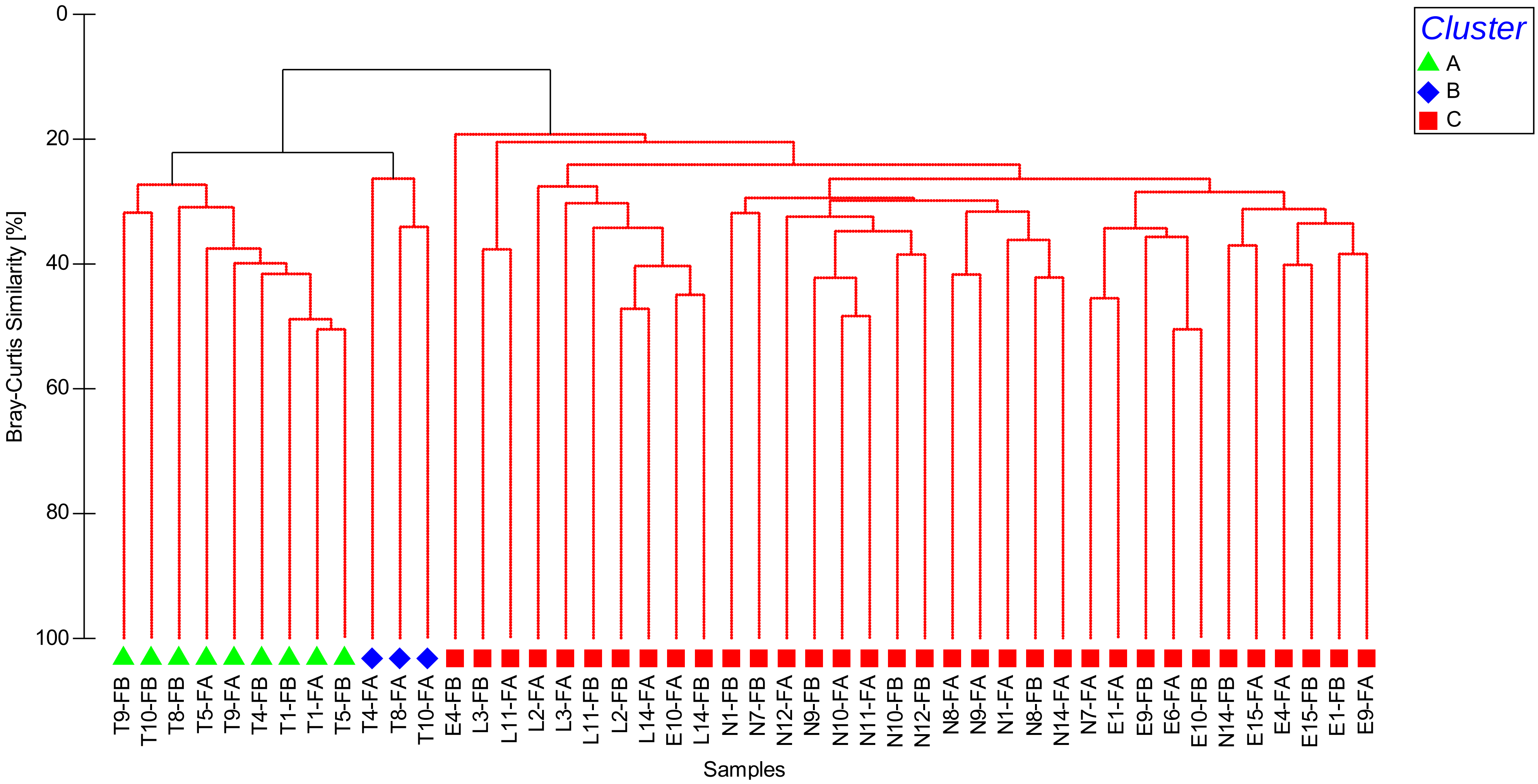

Figure 2.21: Dendrogram by Bray Curtis Similarity for Square Root Transformed Sample Data [0.1 m^2] for All Sites

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 2.16; 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 codominant 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 2.16: 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 focused 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 this cold water influence.

Polychaetous annelids made up over half of the total faunal diversity and abundance recorded and seven of the twelve dominant taxa identified (in terms of rank abundance and rank dominance) were also polychaetes. Despite this annelid dominance, the most abundant (but not most frequently occurring) species recorded was the amphipod Haustoriidae sp. 1. The Haustoriidae have a global distribution and a member of the family (not identified beyond family level) has previously been reported from South of Falkland, although at substantially greater depth than that of the current survey area (GBIF, 2009). Haustoriids have large, spinose appendages that allow them to rapidly burrow by means of hydraulic tunnelling (displacing sediments by generating a current around their bodies). They are thought to be either suspension (filter) feeders or deposit feeders (feed by ingestion of sediment) and some may utilise a combination of both strategies (Bousfield, 1970). The second most abundant species was the onuphid polychaete Onuphis pseudoiridescens. To date this species has only been recorded from the south-west Atlantic (including in the vicinity of the Falkland islands) and from the south-east Pacific coast of Chile (Rozbaczylo et al, 2006). It is presumed that K. oligobranchiata is, like other onuphids, an omnivorous scavenger (Fauchald and Jumars, 1979). Unlike most of the dominant species recorded, which were burrowers, O. pseudoiridescens adopts an epifaunal habit, dragging its sediment encrusted mucous tube over the sediments surface; the onuphids observed from the ROV footage appeared likely to have been O. pseudoiridescens (Figure 2.12 Plates 3 and 4). With the exceptions of Haustoriide sp. 1, which may at least partially exploit suspension feeding and the omnivorous O. pseudoiridescens, all of the dominant taxa identified were though to be burrowing deposit feeders.

Only two of the species recorded had been documented by Bastida et al (1992), these were the astartid bivalve Astarte longirostris and the brittle-star Amphiura euginiae, neither of which were found at significant abundance. This is unsurprising given that the current survey area was deeper (between

540 m and 740 m below LAT) than the Bastida et al (1992) study area, which was restricted to shelf habitats shallower than 200 m depth.

Crude abundance / dominance and univariate analyses of the macrofaunal data suggested that a single community occurred throughout the survey area. While limited differentiation of the community was identified by multivariate analyses of sample data (CLUSTER and SIMPROF), this was thought to result from patchiness in community, rather than to indicate clear community differentiation due to differing habitat; there was no spatial pattern evident in the analyses, the smaller of the two clusters comprising single replicates from three different stations. Station level multivariate analysis failed to identify any significant differentiation in the infaunal dataset, all stations being grouped within a single cluster characterised by the numerically dominant Haustoriide sp. 1 and Onuphis pseudoiridescens.

The community at the Toroa site was similarly rich and exhibited a similar (non-dominated) abundance structure to the community of the deeper Loligo site. There also appeared to be some overlap in species distributions between the two sites, with 24 of the taxa co-occurring at the two survey areas (out of those taxa differentiated at species level). Despite this similarity the two different communities were clearly distinct from each other, with none of the shared species assuming equal prominence at both sites. Out of the taxa recorded from both sites only a small number were dominant components of the Toroa community (Haustoriidae sp. 1, Ampharete sp. 1 and Harpinia sp. 2) and they were all recorded at low abundance at Loligo. Only two prominent members of the Loligo community were apparent at Toroa (Kinbergonuphis oligobranchiata and Melinna sp. 1), neither being recorded at particularly high abundance.

2.10 Water Column Characteristics

Two water profiling attempts were made at location Toroa WCP210. The first deployment returned erroneous data so a second attempt was made using a different water profiler which acquired good data for all parameters except pH (as no functioning sensor was available). The results for relevant parameters (temperature, salinity, dissolved oxygen (DO) and turbidity) obtained from the final profile are presented in Figure 2.22; this profile was acquired over the course of approximately one hour from 0409 FKST (0709 GMT) on February 1st 2009. The profile was collected before sunrise (which was at approximately 0530 FKST). DO in surface waters have been shown to exhibit diurnal patterns of concentration, relating to a combination of biological and weather processes on the mixed layer (McNeil *et al*., 1995).

2.10.1 Temperature

The surface temperature at the time of data collection was approximately 9.7°C and this remained relatively constant in the well mixed upper layers of the water column (between the surface and approximately 14 m depth). Below this well mixed layer there was a distinct thermocline over which the water temperature descended fairly rapidly to 5.3°C at approximately 140 m depth. Below the thermocline the temperature declined gradually to a temperature of 4.4 °C just above the seabed.

2.10.2 Salinity

Although salinity showed minimal variation throughout the water column, ranging from a minimum of 34.1 ppt at the surface to 34.2 ppt at the seabed, it exhibited a typical negative relationship with temperature. From the surface salinity noisily increased from 34.1 ppt to 34.2 ppt at approximately 200 m depth; the reason for the fluctuation in these data (which are typically very stable) was unknown. From 200 m depth salinity readings appeared to stabilise, showing a very slight trend of increase to the seabed, where the maximum salinity of just over 34.2 ppt was measured.

2.10.3 Dissolved Oxygen

Dissolved oxygen (DO) data were inconsistent between the up- and down-casts between the surface and approximately 300 m depth. The trend in the up-cast data perhaps appeared more realistic as the sub-surface peak in DO evident in the down-cast data would not generally be expected during summer nights when phytoplankton would be consuming, rather than producing oxygen, provided wind speed was low or negligible (Fransson *et al*., 2004). Erroneous data obtained from the initial part of the down-cast may have resulted from inadequate equilibration of the probe at the surface prior to deployment, the down-cast profile data being shown to converge with the up-cast data below 300 m depth.

Up-cast data suggested that surface DO was approximately 85% saturation (%sat.) and that this remained reasonably constant in the well mixed upper 15 m of the water column. Below this depth DO rapidly decreased to 72%sat. at approximately 130 m depth (this decrease coinciding with the thermocline) before decreasing more slowly from this depth to the seabed. DO at the seabed was around 66%sat. This expected pattern of decreasing DO with depth was consistent with profiles recorded at the other three survey sites.

2.10.4 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 were not thought indicative of increased suspended solids load, but may have resulted from sensor interference, in the very upper layers of the water column this may have been from incandescent lighting on the vessel itself, to which the sensor is known to be sensitive. Alternatively the increased turbidity near the surface may have resulted from sensor interference due to 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.

2.10.5 Discussion of Water Profiles

The temperature, salinity and turbidity measured appeared broadly consistent with that of the other survey areas (Loligo, Endeavour and Nimrod) although unsurprisingly, given the shallower water depth at Toroa, seabed temperatures were substantially higher. The profiles obtained from Toroa also lacked the fluctuation in certain parameters seen in depth at Loligo and Endeavour, which were thought to relate to inflow of a separate water body. The water column at Toroa is therefore considered to comprise a single water body with typical surface stratification. DO was lower than at all of the other sites and this may have related to the Toroa data being the only data acquired during darkness, when phytoplankton will deplete rather than produce oxygen. Gradually decreasing trends were apparent in DO saturation at all sites except Loligo, which showed marked super-saturation in the upper layers of the water-column, thought possibly to relate to day time oxygen production by phytoplankton.

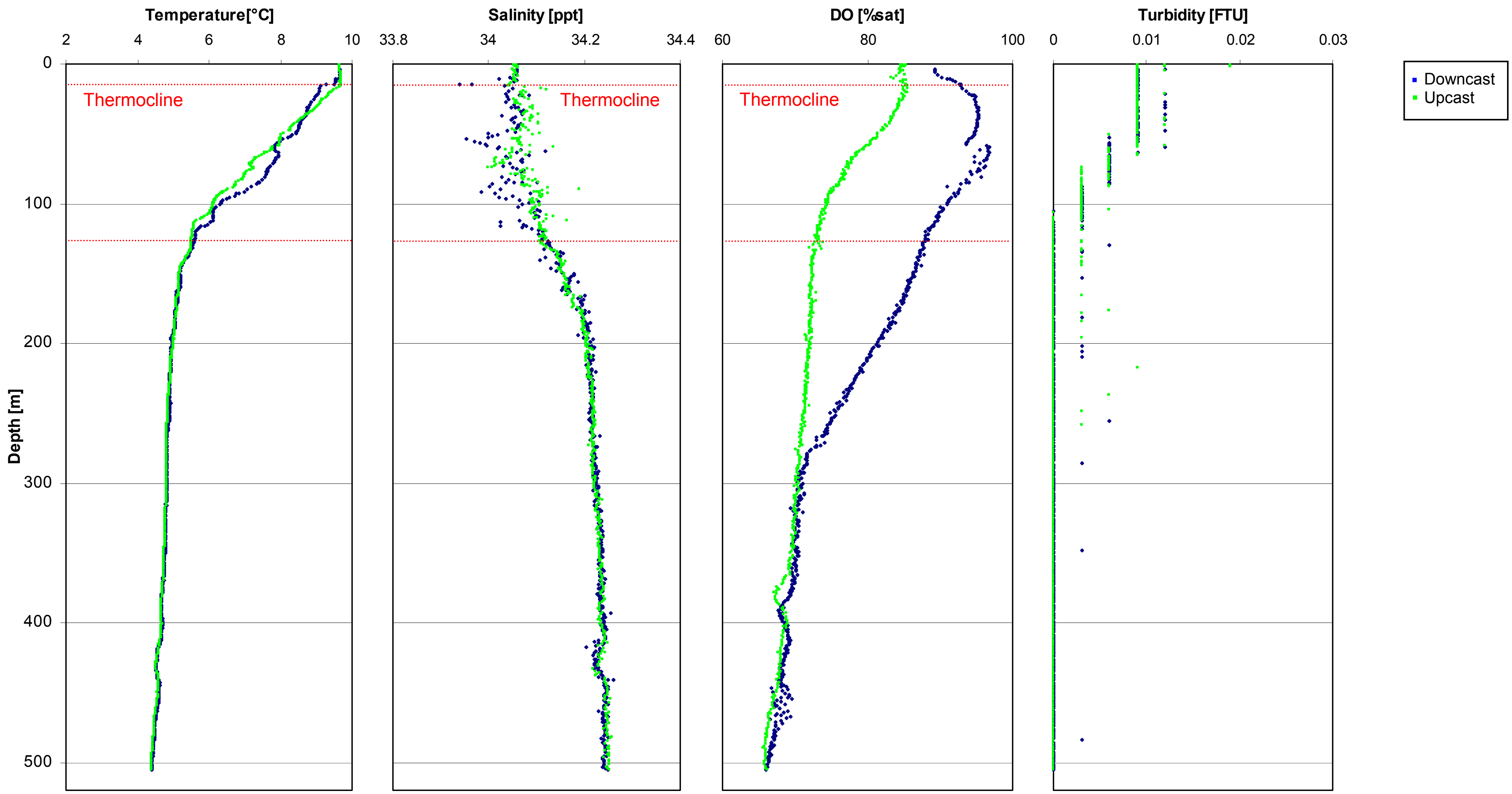

Figure 2.22: Profile Data for Individual Water Column Parameters

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A. SURVEY METHODOLOGIES

A SURVEY METHODOLOGIES

A.1 Sediment Sampling

Sediment samples were acquired at 6 stations (out of the 15 originally proposed), with a full suite of samples (two fauna replicates and a single physicochemical sample) acquired at each.

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

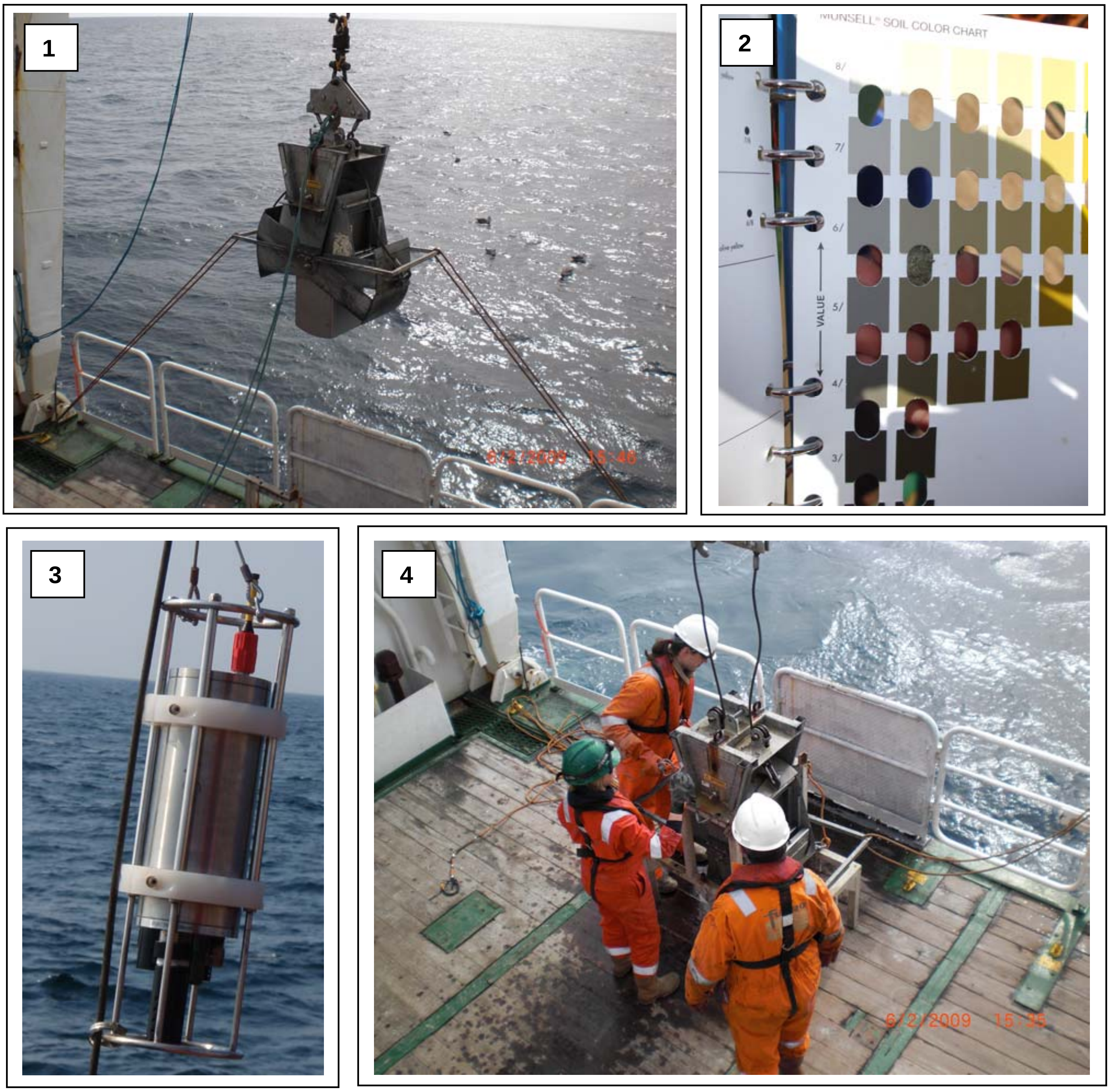


Plate 1: Deployment of the 0.1 m^2 box corer

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 Analyses

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.

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°C.

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°C for at least four hours to remove impurities and residual moisture then stored at 200°C 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°C, split flow 40 ml / min, vent time 1 min (1 µl injection)
Oven Temperature Programme	80°C - 1 min 80 to 320°C at 15°C / min 320°C – 10 min 320 to 350°C at 10°C / min	60°C - 1 min 60 to 120°C at 15°C / min 120 to 325°C at 5°C / min 325°C – 9 min
Source / Detector Temperature	300°C (FID)	280°C
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.

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.

B2.4 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°C 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°C 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 Analyses

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.

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 0.5 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 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 $\bar{X}$ and $\bar{Y}$ = 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.

B4.10 BIOENV Analysis

The BIOENV algorithm in the PRIMER BEST routine is used to correlate patterns in community structure against physico-chemical parameters. It uses the resemblance matrix generated for community data and then correlates this against individual matrices generated for each physico-chemical parameter using the Spearman rank correlation coefficient. This algorithm can generate matrices for single physico-chemical parameters or for the cumulative influence of a number of parameters. In order to test the degree of statistical significance of the correlations derived a BEST permutation test is performed, this involves generating correlations between community structure and random permutated resemblance matrices, which can then be compared to the calculated test statistics.

Different techniques are used to correlate particle size data (at 1 phi sieve size intervals) and crude granulometric and chemical parameters. Resemblance matrices for particle size data are generated using the Bray-Curtis similarity measure, which will effectively ignore similarities that result from joint absence (i.e. will not consider lack of particles of the same size from two samples a source of similarity). Crude granulometric and chemical parameters are treated using the Euclidean distance measure, which will consider joint absence a source of similarity.

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	200 m
Contour Scaling	Coded on each figure
Grid Line Spacing	20 m
Image Scale	1 : 70,000

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 and to previous surveys of FIDA 14/05 – B1 and FIDA 14/09 – Little Blue A in the North Falkland Basin (Gardline Surveys Limited, 1998a; Gardline Surveys Limited, 1998b).

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	
01/02/09	08:31	9	Box corer	166	FA	571.0	628270.0	4126060.0	628297.0	4126054.0	27.7
01/02/09	09:51	9	Box corer	168	Misfire	571.0	628270.0	4126060.0	628301.0	4126047.0	33.6
01/02/09	10:19	9	Box corer	171	Misfire	571.0	628270.0	4126060.0	628295.0	4126064.0	25.3
01/02/09	11:27	9	Box corer	173	Misfire	571.0	628270.0	4126060.0	628295.0	4126064.0	25.3
01/02/09	12:03	9	Box corer	175	Misfire	571.0	628270.0	4126060.0	628293.0	4126059.0	23.0
01/02/09	12:47	9	Box corer	177	PC	571.0	628270.0	4126060.0	628287.0	4126058.0	17.1
01/02/09	13:44	9	Box corer	179	FB	571.0	628270.0	4126060.0	628286.0	4126058.0	16.1
01/02/09	15:06	4	Box corer	180	No-trigger	615	632900.0	4124000.0	632886.8	4123994.0	14.5
01/02/09	15:33	4	Box corer	181	FA	615	632900.0	4124000.0	632880.0	4123997.3	20.2
01/02/09	16:30	4	Box corer	182	Misfire	615	632900.0	4124000.0	632891.5	4123996.3	9.3
01/02/09	16:57	4	Box corer	183	PC	615	632900.0	4124000.0	632893.7	4123990.6	11.4
01/02/09	17:54	4	Box corer	184	FB	615	632900.0	4124000.0	632905.1	4123991.6	9.8
01/02/09	18:55	1	Box corer	185	Misfire	600	631040.0	4123855.0	631051.5	4123864.0	14.7
01/02/09	19:33	1	Box corer	186	No-trigger	600	631040.0	4123855.0	631057.6	4123870.6	23.5
01/02/09	20:00	1	Box corer	187	Misfire	600	631040.0	4123855.0	631049.3	4123874.2	21.4
01/02/09	20:52	1	Box corer	188	Misfire	600	631040.0	4123855.0	631064.0	4123878.0	33.2
01/02/09	21:18	1	Box corer	190	FA	600	631040.0	4123855.0	631068.3	4123880.2	37.9
01/02/09	22:12	1	Box corer	191	PC	600	631040.0	4123855.0	631054.0	4123889.5	37.3
01/02/09	22:57	1	Box corer	192	FB	600	631040.0	4123855.0	631051.5	4123892.7	39.5
02/02/09	00:09	5	Box corer	193	FA	610	629600.0	4122800.0	629588.5	4122793.2	13.3
02/02/09	00:53	5	Box corer	195	PC	610	629600.0	4122800.0	629582.6	4122797.0	17.7
02/02/09	01:43	5	Box corer	196	No-trigger	610	629600.0	4122800.0	629579.2	4122791.1	22.6
02/02/09	02:14	5	Box corer	197	FB	610	629600.0	4122800.0	629572.5	4122792.6	28.5
02/02/09	03:33	8	Box corer	200	FA	621	631520.0	4122715.0	631512.0	4122713.0	8.2
02/02/09	04:37	8	Box corer	203	Misfire	623	631520.0	4122715.0	631515.0	4122714.0	5.1
02/02/09	05:13	8	Box corer	205	PC	622	631520.0	4122715.0	631514.0	4122710.0	7.8
02/02/09	06:05	8	Box corer	207	FB	621	631520.0	4122715.0	631517.0	4122712.0	4.2
02/02/09	07:20	10	Box corer	210	FA	702	632250.0	4119300.0	632256.0	4119303.0	6.7
02/02/09	08:15	10	Box corer	212	PC	702	632250.0	4119300.0	632257.0	4119301.0	7.1
02/02/09	09:07	10	Box corer	214	FB	702	632250.0	4119300.0	632278.0	4119311.0	30.1

D.2 DECK LOG

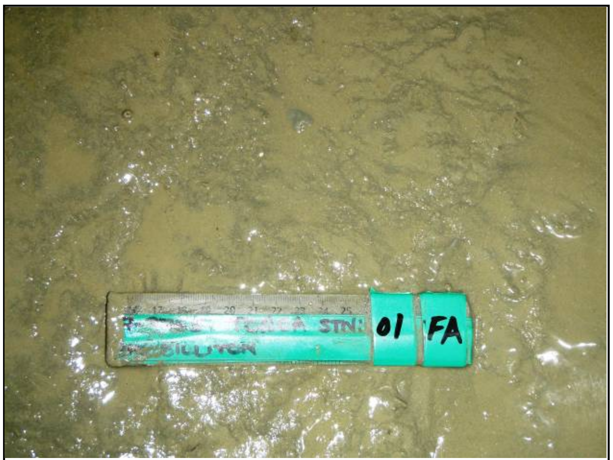
Date	Time	Station	Grab	Fix	SampleDepth	Sediment Description	Layer 1				Smell Y\N	Redox	pH	Temp.	COMMENTS
							Hue	Chroma	Value	Colour					
01/02/09	08:31	9	FA	166	25 cm	soft silt / clay	5Y	3	4	Olive	N	78	7.6	4.6℃	Tube worms
01/02/09	09:51	9	NS	168	—	—									No-trigger
01/02/09	10:19	9	NS	171	—	—									No-trigger
01/02/09	11:27	9	NS	173	—	—									No-trigger
01/02/09	12:03	9	NS	175	—	—									No-trigger
01/02/09	12:47	9	PC	177	23 cm	soft silt / clay	5Y	3	4	Olive	N	-37	7.6	4.8℃	
01/02/09	13:44	9	FB	179	26 cm	soft silt / clay	5Y	3	4	Olive	N	-14	7.3	5.7℃	
01/02/09	15:06	4	NS	180	—	—									No-trigger
01/02/09	15:33	4	FA	181	35 cm	soft silt / clay	5Y	3	4	Olive	N	-69	7.6	4.9℃	
01/02/09	16:30	4	NS	182	—	—									No-trigger
01/02/09	16:57	4	PC	183	3.5 cm	soft silt / clay	5Y	3	4	Olive	N	-12	7.5	5℃	Tube worms
01/02/09	17:54	4	FB	184	3.5 cm	soft silt / clay	5Y	3	4	Olive	N	-34	7.6	5℃	Echinoderm
01/02/09	18:55	1	NS	185	—	—									No-trigger
01/02/09	19:33	1	NS	186	—	—									No-trigger
01/02/09	20:00	1	NS	187	—	—									No-trigger
01/02/09	20:52	1	NS	188	—	—									No-trigger
01/02/09	21:18	1	FA	190	35 cm	soft silt / clay	5Y	3	4	Olive	N	-91	7.5	5.0℃	
01/02/09	22:12	1	PC	191	35 cm	soft silt / clay	5Y	3	4	Olive	N	-25	7.6	5.2℃	
01/02/09	22:57	1	FB	192	30 cm	soft silt / clay	5Y	3	4	Olive	N	-67	7.6	5.1℃	
02/02/09	00:09	5	FA	193	35 cm	soft silt / clay	5Y	3	4	Olive	N	-77	7.6	5.2℃	
02/02/09	00:53	5	PC	195	30 cm	soft silt / clay	5Y	3	4	Olive	N	-18	7.5	5.0℃	
02/02/09	01:43	5	NS	196	—	—									No-trigger
02/02/09	02:14	5	FB	197	25 cm	soft silt / clay	5Y	3	4	Olive	N	-12	7.6	4.5℃	
02/02/09	03:33	8	FA	200	31 cm	soft silt / clay	5Y	3	4	Olive	N	-20	7.3	6.2℃	
02/02/09	04:37	8	NS	203	—	—									No-trigger
02/02/09	05:13	8	PC	205	37 cm	soft silt / clay	5Y	3	4	Olive	N	-53	7.6	4.3℃	
02/02/09	06:05	8	FB	207	35 cm	soft silt / clay	5Y	3	4	Olive	N	-8	7.4	5.1℃	
02/02/09	07:20	10	FA	210	38 cm	soft silt / clay	5Y	3	4	Olive	N	5	7.6	6.4℃	
02/02/09	08:15	10	PC	212	25 cm	soft silt / clay	5Y	3	4	Olive	N	101	7.6	6.8℃	
02/02/09	09:07	10	FB	214	32 cm	soft silt / clay	5Y	3	4	Olive	N	175	7.6	8.8℃	

D.3 ROV VIDEO LOG

Date	Location	File(s)	Time	Video Coordinates [m]		Transect Distance	Sediment Type	Fauna
				Easting	Northing			
26/01/09	Toroa A	Shark at Toroa.VOB	10:17:51	631402	4122886	1	Off-bottom	Porbeagle shark (Lamna nasus)
			10:18:03	631401	4122886			
26/01/09	Toroa A	Worm at Toroa.VOB	20:31:44	631363	4122876	4	Silt	Onuphid polychaete worm (Onuphis pseudoiridescens), brittle-stars (Amphiura sp.), sabellid polychaete
			20:38:24	631363	4122872			
26/01/09	Toroa A	20090118134822_0	10:48:24	631401	4122868	10	Silt	Seapen (Pennatulacea), gastropods?, onuphid polychaetes (Onuphis pseudoiridescens), brittle-stars (Ophiuroidea)
			10:58:14	631411	4122865			
26/01/09	Toroa A	20090118152410_0	12:24:10	631405	4122877	18	Silt	Seapen (Pennatulacea), gastropods?, squid (Teuthida), onuphid polychaetes (Onuphis pseudoiridescens), brittle-stars (Ophiuroidea)
			12:33:25	631411	4122860			

E. PARTICLE SIZE ANALYSIS

STATION T1



Easting: 631 068 m
Northing: 4 123 880 m
Depth: 571 m
Sed Type: Soft silt

Easting: 631 068 m
Northing: 4 123 880 m
Depth: 571 m
Sed Type: Soft silt

Easting: 631 068 m
Northing: 4 123 880 m
Depth: 571 m
Sed Type: Soft silt

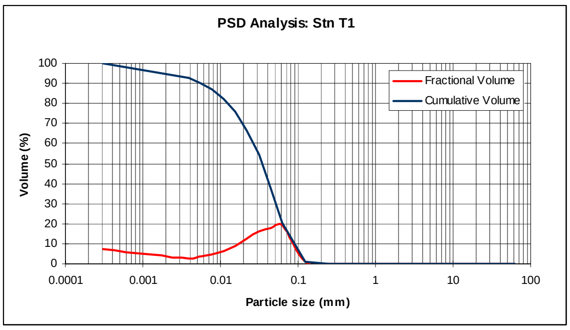
PSD – LASER AND SIEVE DATA

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	0.00	0.00
2	-1.0	0.00	0.00
1	0.0	0.00	0.00
0.5	1.0	0.00	0.00
0.250	2.0	0.00	0.00
0.125	3.0	0.99	0.99
0.06250	4.0	19.27	20.27
0.04420	4.5	17.67	37.94
0.03120	5.0	16.38	54.31
0.02210	5.5	12.44	66.75
0.01560	6.0	8.92	75.67
0.01108	6.5	6.33	82.00
0.00780	7.0	4.78	86.77
0.00550	7.5	3.42	90.19
0.00390	8.0	2.39	92.58
0.00031	8.5	7.42	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

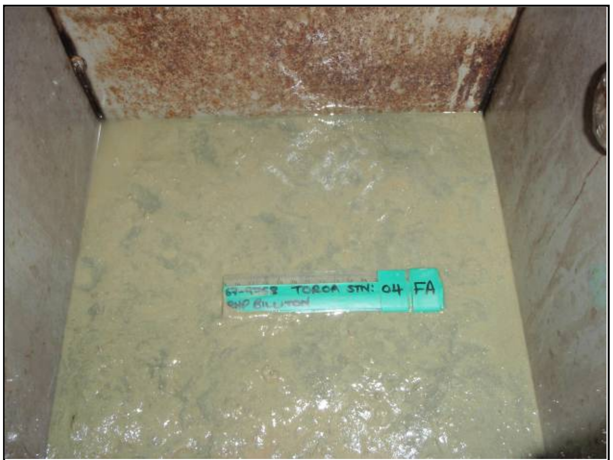
SEDIMENT CHARACTERISTICS

Sorting	1.542	Poorly Sorted	
Skewness	0.297	Fine Skewed	
Kurtosis	1.163	Leptokurtic	
Mean (µm)	29.541	% Gravel	0.00
Median(µm)	34.793	% Sand	20.27
Mean (phi)	5.081	% Fines	79.73
Median (phi)	4.845		

CHART REPRESENTING LASER DATA



STATION T4



Easting: 632 880 m
Northing: 4 123 997 m
Depth: 615 m
Sed Type: Soft silt

Easting: 632 880 m
Northing: 4 123 997 m
Depth: 615 m
Sed Type: Soft silt

Easting: 632 880 m
Northing: 4 123 997 m
Depth: 615 m
Sed Type: Soft silt

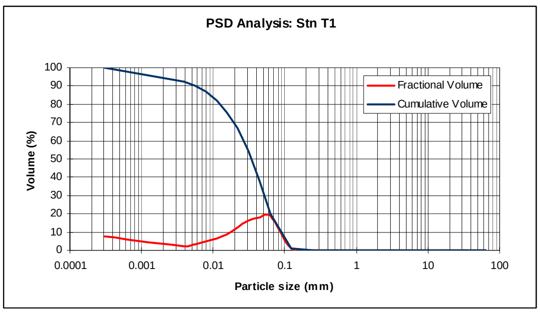
PSD – LASER AND SIEVE DATA

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	0.00	0.00
2	-1.0	0.00	0.00
1	0.0	0.00	0.00
0.5	1.0	0.00	0.00
0.250	2.0	0.00	0.00
0.125	3.0	1.05	1.05
0.06250	4.0	20.03	21.08
0.04420	4.5	18.24	39.32
0.03120	5.0	16.66	55.98
0.02210	5.5	12.33	68.31
0.01560	6.0	8.57	76.88
0.01108	6.5	5.97	82.85
0.00780	7.0	4.50	87.34
0.00550	7.5	3.24	90.59
0.00390	8.0	2.28	92.87
0.00031	8.5	7.13	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

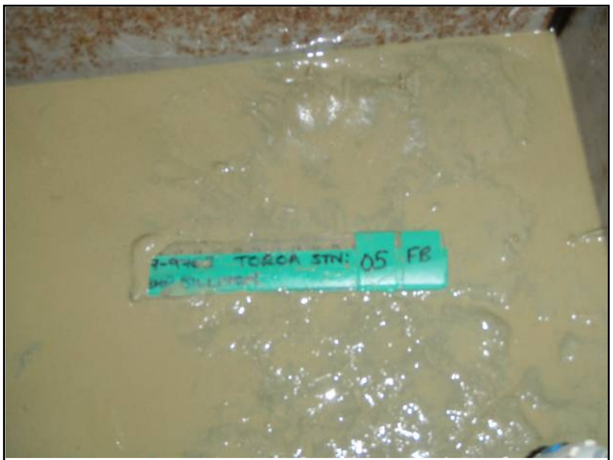
SEDIMENT CHARACTERISTICS

Sorting	1.542	Poorly Sorted	
Skewness	0.297	Fine Skewed	
Kurtosis	1.163	Leptokurtic	
Mean (µm)	29.541	% Gravel	0.00
Median(µm)	34.793	% Sand	20.27
Mean (phi)	5.081	% Fines	79.73
Median (phi)	4.845		

CHART REPRESENTING LASER DATA



STATION T5



Easting: 629 572 m
Northing: 4 122 792 m
Depth: 610 m
Sed Type: Soft silt

Easting: 629 572 m
Northing: 4 122 792 m
Depth: 610 m
Sed Type: Soft silt

Easting: 629 572 m
Northing: 4 122 792 m
Depth: 610 m
Sed Type: Soft silt

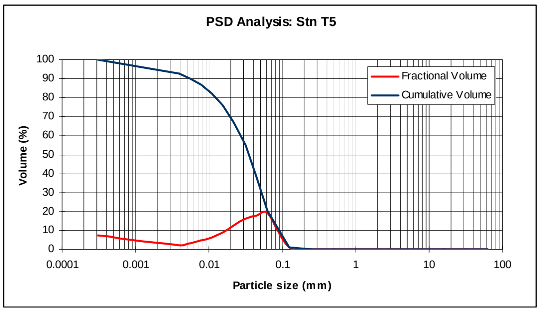
PSD – LASER AND SIEVE DATA

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	0.00	0.00
2	-1.0	0.00	0.00
1	0.0	0.00	0.00
0.5	1.0	0.00	0.00
0.250	2.0	0.00	0.00
0.125	3.0	1.12	1.12
0.06250	4.0	19.44	20.56
0.04420	4.5	17.75	38.31
0.03120	5.0	16.47	54.77
0.02210	5.5	12.48	67.26
0.01560	6.0	8.86	76.12
0.01108	6.5	6.19	82.31
0.00780	7.0	4.62	86.93
0.00550	7.5	3.30	90.23
0.00390	8.0	2.33	92.56
0.00031	8.5	7.44	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

SEDIMENT CHARACTERISTICS

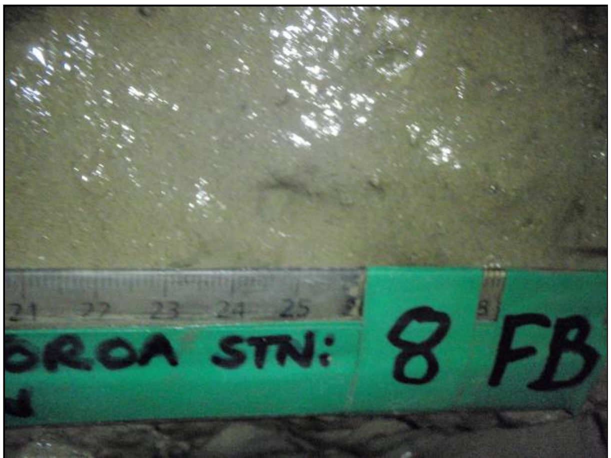
Sorting	1.541	Poorly Sorted	
Skewness	0.297	Fine Skewed	
Kurtosis	1.178	Leptokurtic	
Mean (µm)	29.918	% Gravel	0.00
Median(µm)	35.125	% Sand	20.56
Mean (phi)	5.063	% Fines	79.44
Median (phi)	4.831		

CHART REPRESENTING LASER DATA



STATION T8

Easting: 631 517 m
Northing: 4 122 712 m
Depth: 621 m
Sed Type: Soft silt



Easting: 631 517 m
Northing: 4 122 712 m
Depth: 621 m
Sed Type: Soft silt

Easting: 631 517 m
Northing: 4 122 712 m
Depth: 621 m
Sed Type: Soft silt

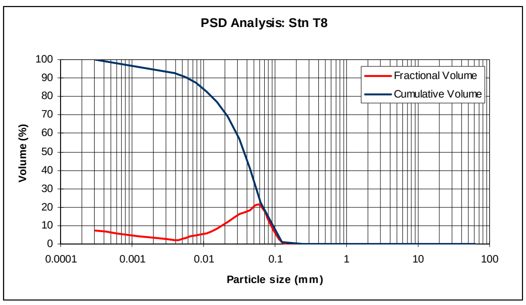
PSD – LASER AND SIEVE DATA

T8	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	0.00	0.00
2	-1.0	0.00	0.00
1	0.0	0.00	0.00
0.5	1.0	0.00	0.00
0.250	2.0	0.00	0.00
0.125	3.0	1.26	1.26
0.06250	4.0	21.00	22.26
0.04420	4.5	18.50	40.76
0.03120	5.0	16.39	57.15
0.02210	5.5	11.79	68.94
0.01560	6.0	8.12	77.07
0.01108	6.5	5.78	82.84
0.00780	7.0	4.47	87.31
0.00550	7.5	3.25	90.56
0.00390	8.0	2.27	92.83
0.00031	8.5	7.17	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

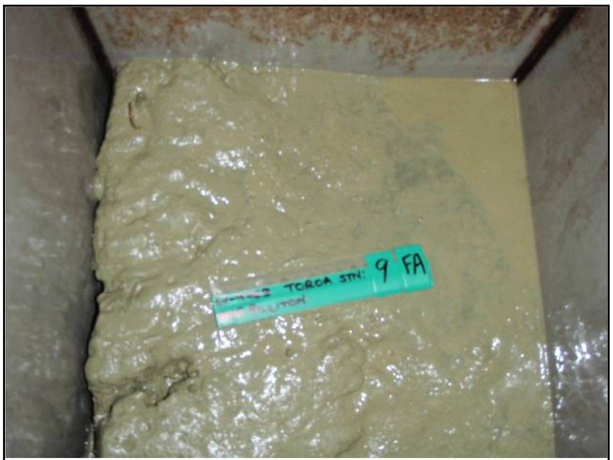
SEDIMENT CHARACTERISTICS

Sorting	1.544	Poorly Sorted	
Skewness	0.310	Strongly Fine Skewed	
Kurtosis	1.189	Leptokurtic	
Mean (µm)	31.289	% Gravel	0.00
Median(µm)	36.956	% Sand	22.26
Mean (phi)	4.998	% Fines	77.74
Median (phi)	4.758		

CHART REPRESENTING LASER DATA



STATION T9



Easting: 628 297 m
Northing: 4 126 054 m
Depth: 571 m
Sed Type: Soft silt

Easting: 628 297 m
Northing: 4 126 054 m
Depth: 571 m
Sed Type: Soft silt

Easting: 628 297 m
Northing: 4 126 054 m
Depth: 571 m
Sed Type: Soft silt

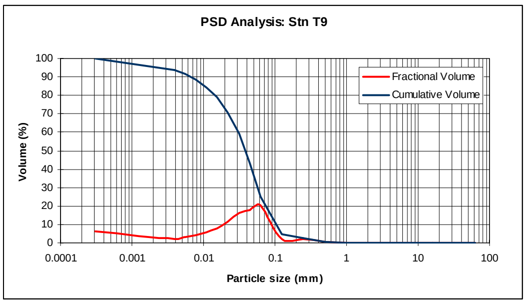
PSD – LASER AND SIEVE DATA

Aperture (mm)	Aperture (phi units)	Percentage Fractional	Percentage 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	0.00	0.00
2	-1.0	0.00	0.00
1	0.0	0.00	0.00
0.5	1.0	0.58	0.58
0.250	2.0	1.99	2.57
0.125	3.0	1.98	4.55
0.06250	4.0	20.55	25.10
0.04420	4.5	17.99	43.09
0.03120	5.0	16.08	59.17
0.02210	5.5	11.67	70.84
0.01560	6.0	8.02	78.86
0.01108	6.5	5.58	84.44
0.00780	7.0	4.20	88.64
0.00550	7.5	2.98	91.62
0.00390	8.0	2.05	93.67
0.00031	8.5	6.33	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

SEDIMENT CHARACTERISTICS

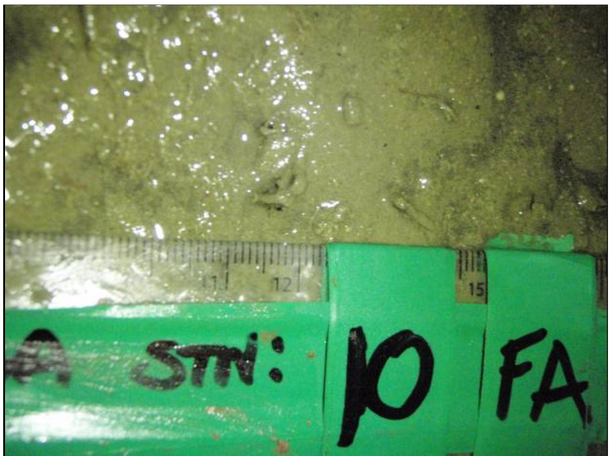
Sorting	1.541	Poorly Sorted	
Skewness	0.269	Fine Skewed	
Kurtosis	1.218	Leptokurtic	
Mean (µm)	34.116	% Gravel	0.00
Median(µm)	38.628	% Sand	25.10
Mean (phi)	4.873	% Fines	74.90
Median (phi)	4.694		

CHART REPRESENTING LASER DATA



STATION T10

Easting: 632 256 m
Northing: 4 119 303 m
Depth: 702 m
Sed Type: Soft silt



Easting: 632 256 m
Northing: 4 119 303 m
Depth: 702 m
Sed Type: Soft silt

Easting: 632 256 m
Northing: 4 119 303 m
Depth: 702 m
Sed Type: Soft silt

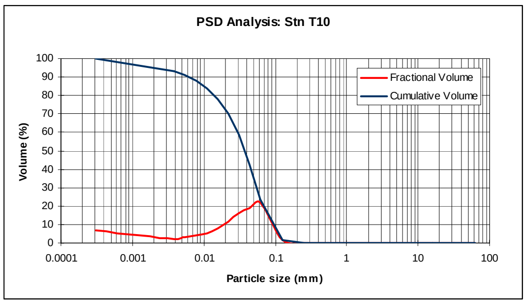
PSD – LASER AND SIEVE DATA

Aperture (mm)	Aperture (phi units)	Percentage Fractional	Percentage 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	0.00	0.00
2	-1.0	0.00	0.00
1	0.0	0.08	0.08
0.5	1.0	0.00	0.08
0.250	2.0	0.00	0.08
0.125	3.0	1.53	1.61
0.06250	4.0	22.05	23.66
0.04420	4.5	18.85	42.51
0.03120	5.0	16.36	58.87
0.02210	5.5	11.48	70.35
0.01560	6.0	7.76	78.11
0.01108	6.5	5.50	83.61
0.00780	7.0	4.28	87.88
0.00550	7.5	3.11	90.99
0.00390	8.0	2.16	93.16
0.00031	8.5	6.84	100.00
<0.00031	9.0	0.00	100.00
n/a	n/a	100.00	100.00

SEDIMENT CHARACTERISTICS

Sorting	1.535	Poorly Sorted	
Skewness	0.311	Strongly Fine Skewed	
Kurtosis	1.211	Leptokurtic	
Mean (µm)	32.600	% Gravel	0.00
Median(µm)	38.280	% Sand	23.66
Mean (phi)	4.939	% Fines	76.34
Median (phi)	4.707		

CHART REPRESENTING LASER DATA

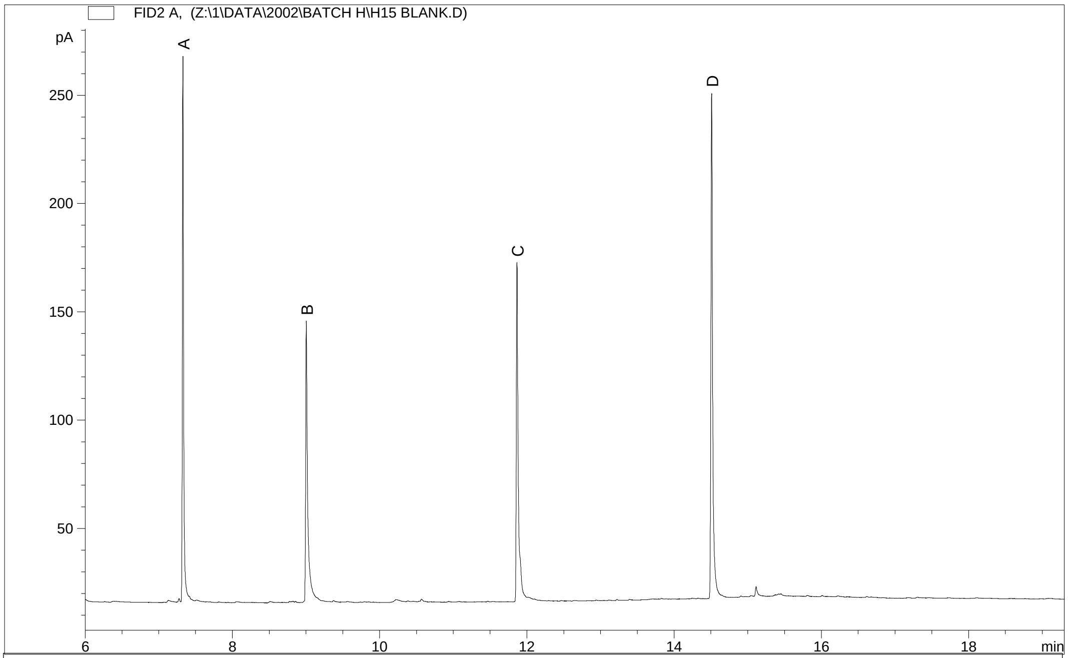


F. HYDROCARBON ANALYSIS

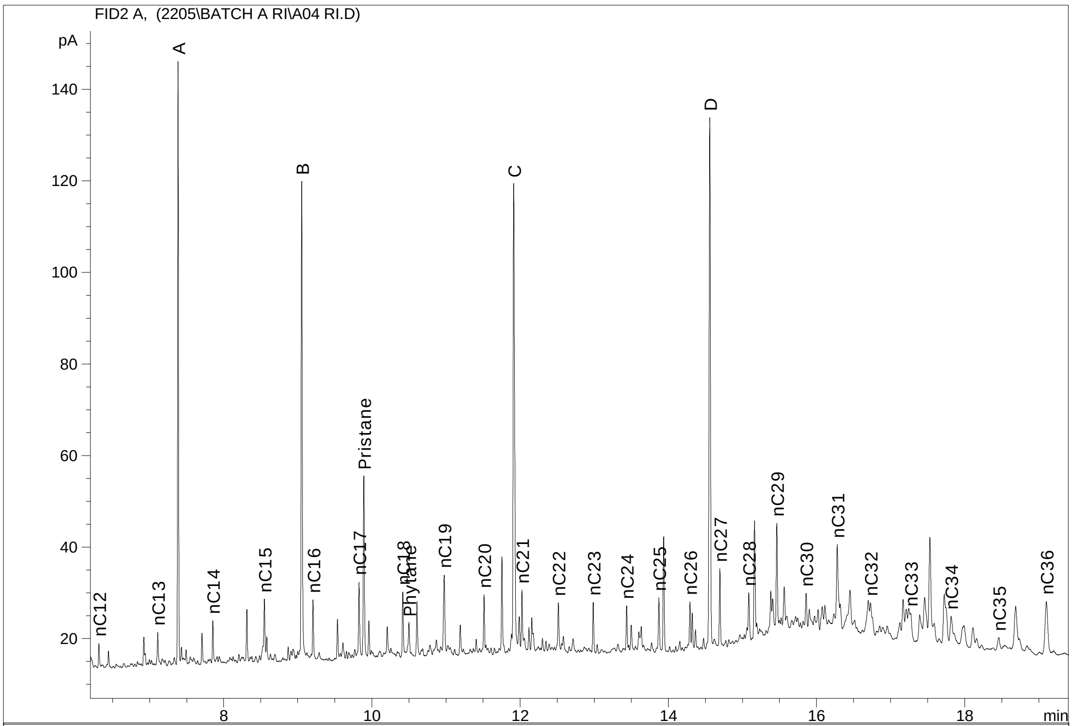
F.1 GAS CHROMATOGRAPHY TRACES

Table F.1 Internal Standard Concentrations

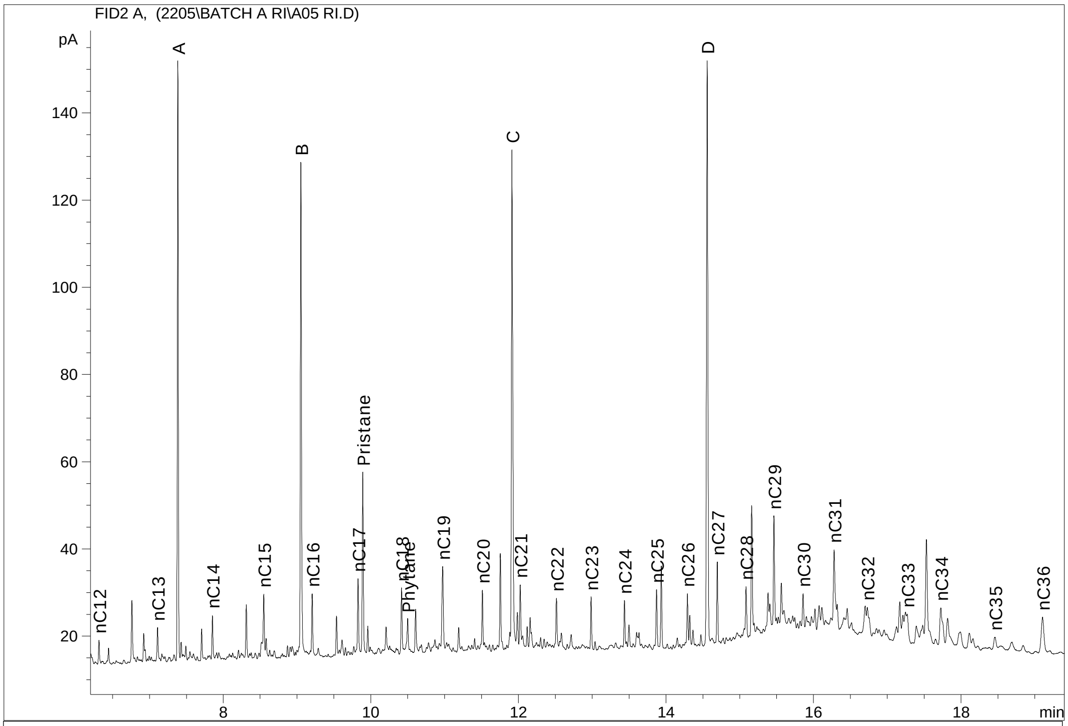
All Concentrations Expressed as µg.g^{-1}				
Station	**Heptamethylnonane (A)**	**D34 Hexadecane (B)**	**1-Chlorooctadecane (C)**	**Squalane (D)**
T1	0.271	0.262	0.232	0.275
T4	0.266	0.258	0.228	0.270
T5	0.272	0.264	0.234	0.277
T8	0.264	0.256	0.226	0.268
T9	0.247	0.240	0.212	0.251
T10	0.253	0.245	0.217	0.257



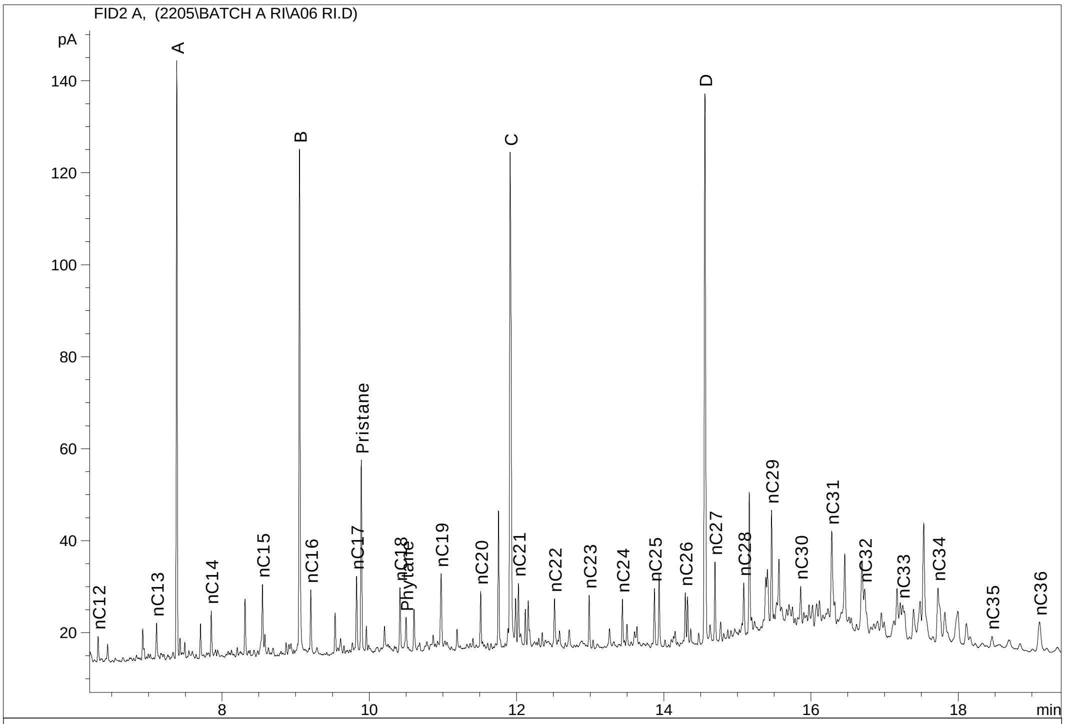
Blank GC trace with internal standards



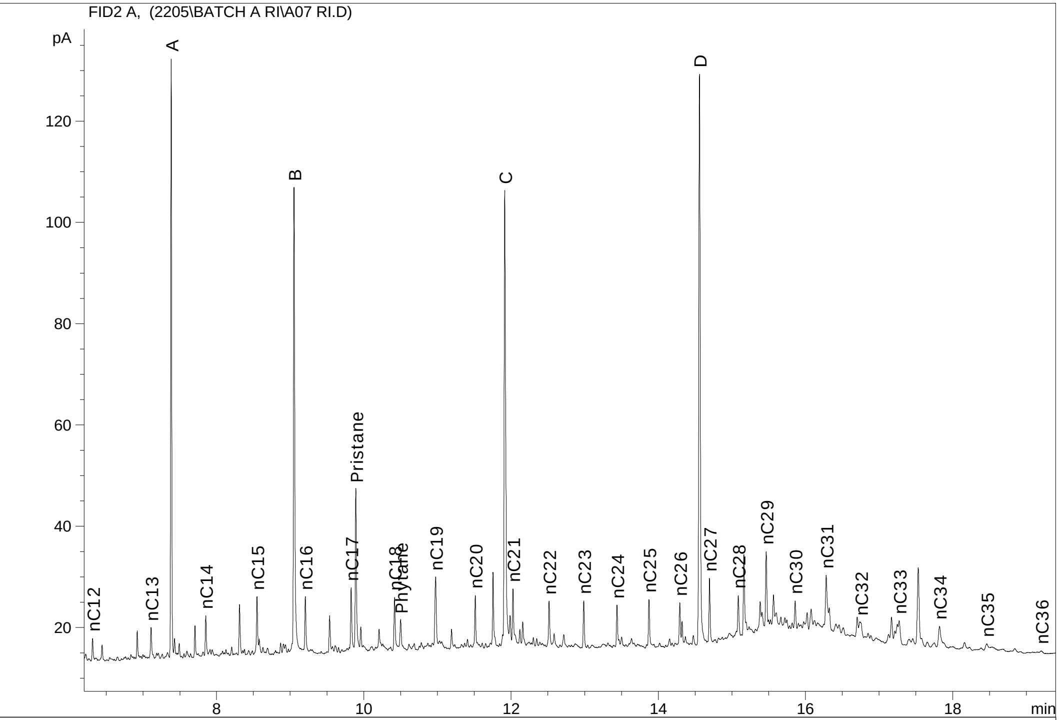
Station T1 – Sediment GC Trace



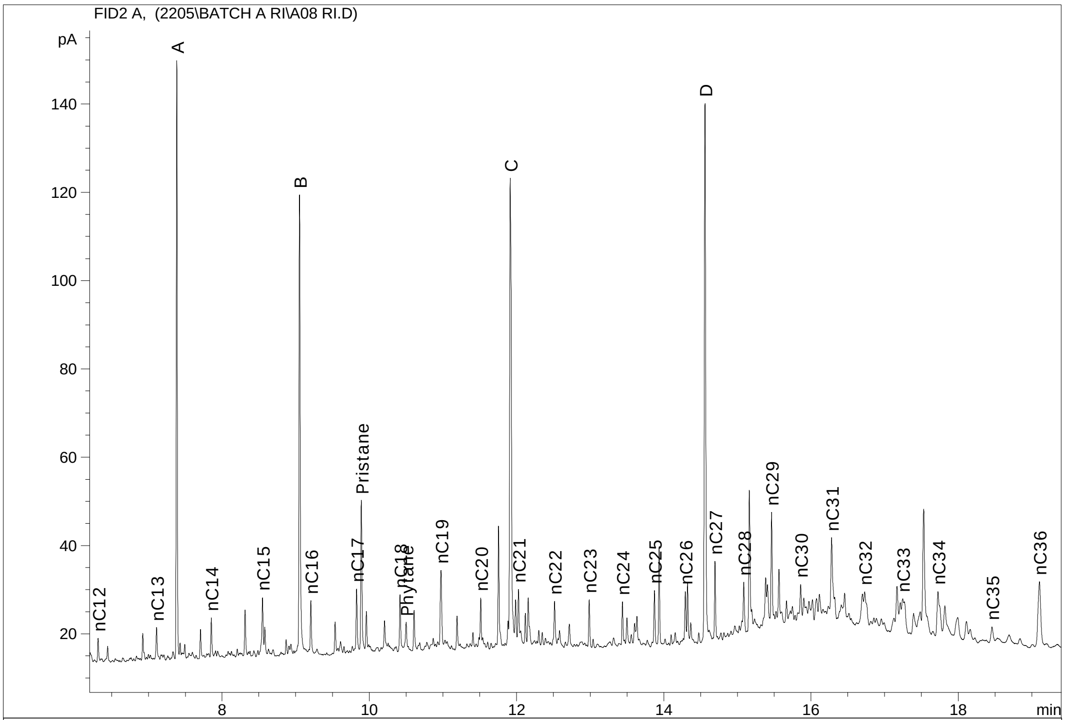
Station T4 – Sediment GC Trace



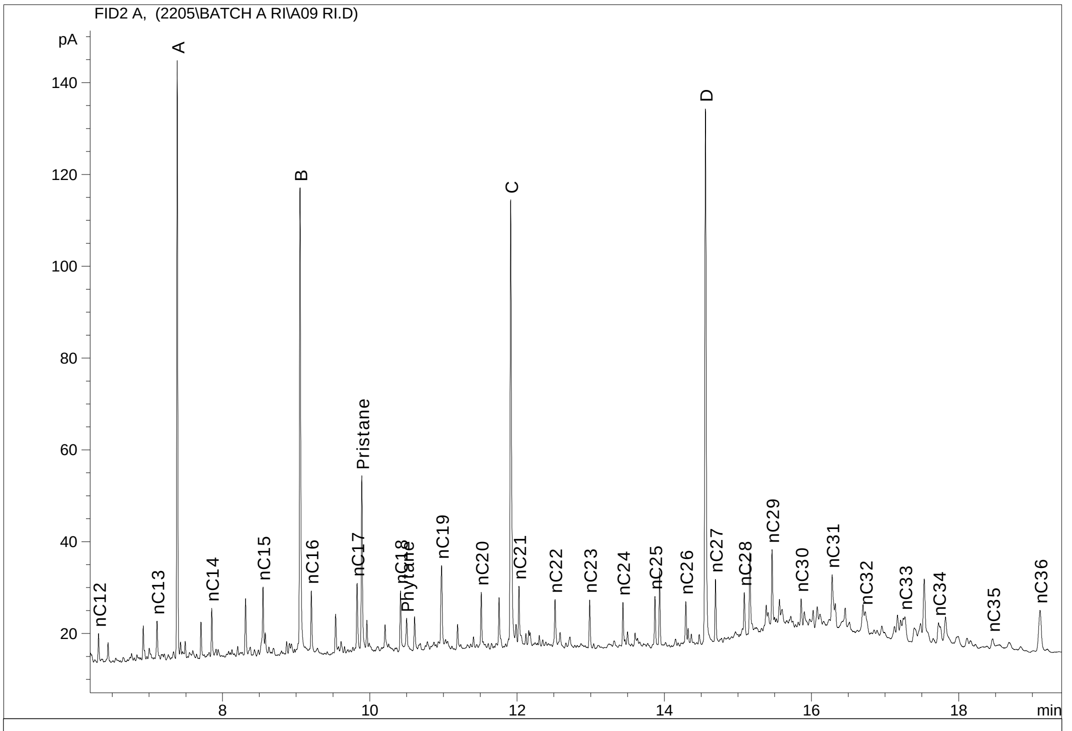
Station T5 – Sediment GC Trace



Station T8 – Sediment GC Trace

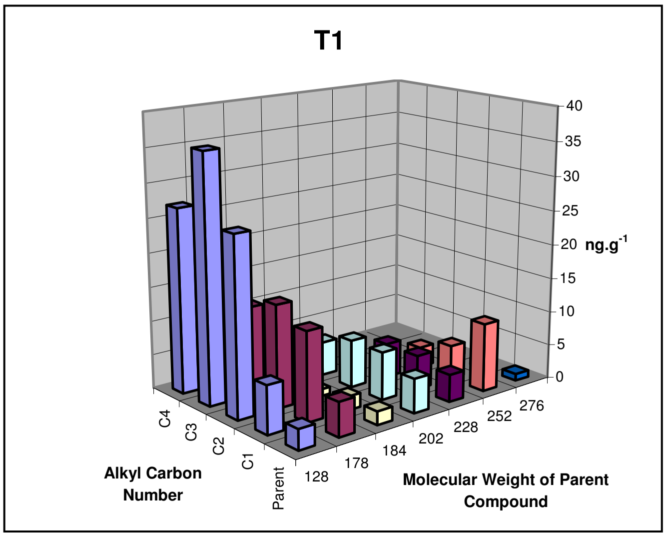


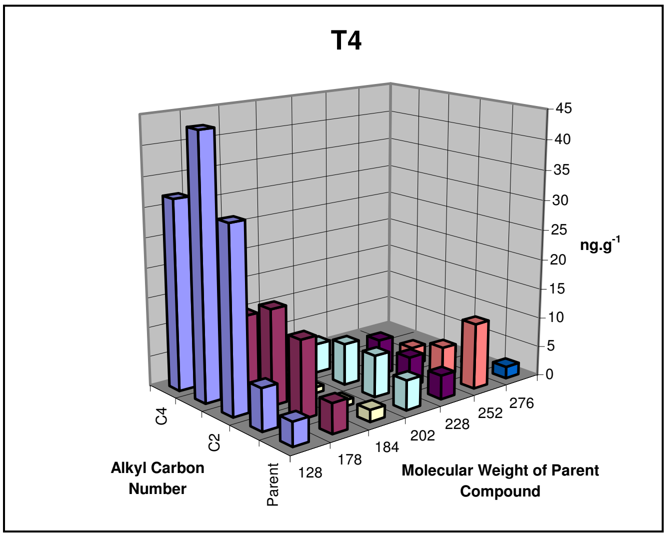
Station T9 – Sediment GC Trace

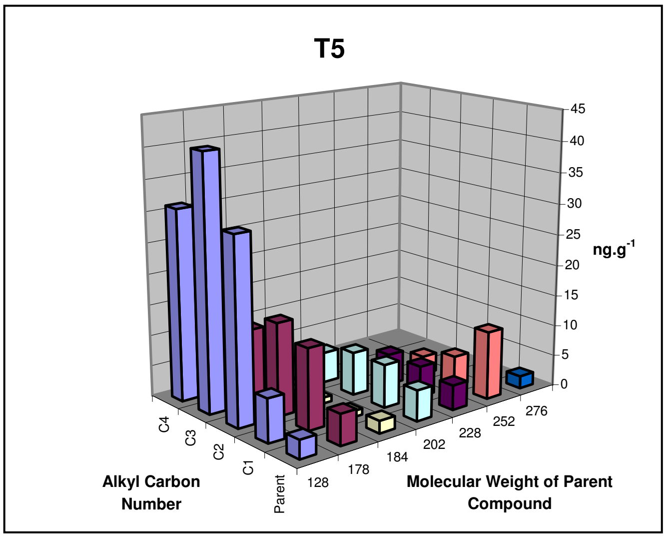


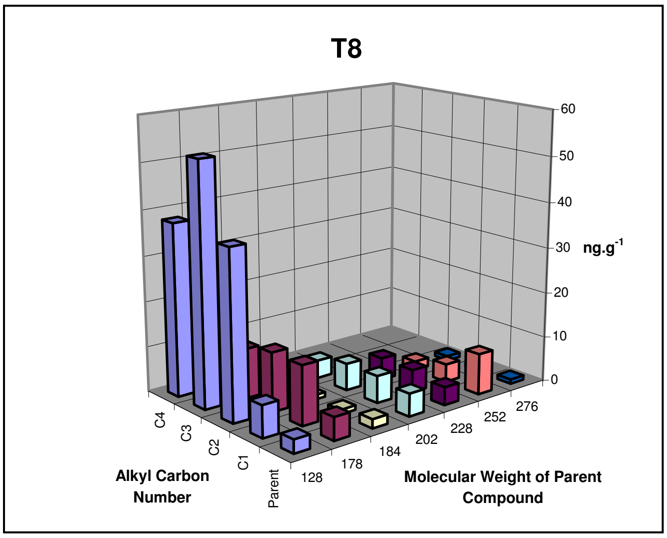
Station T10 – Sediment GC Trace

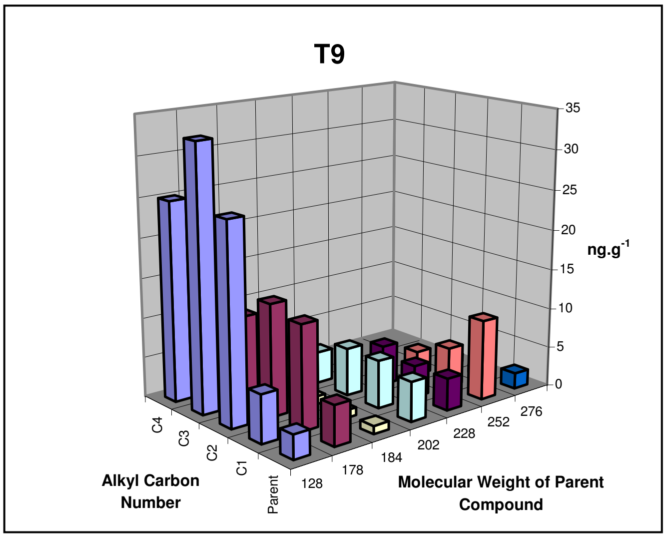
F.2 PARENT - ALKYL PAH GRAPHS

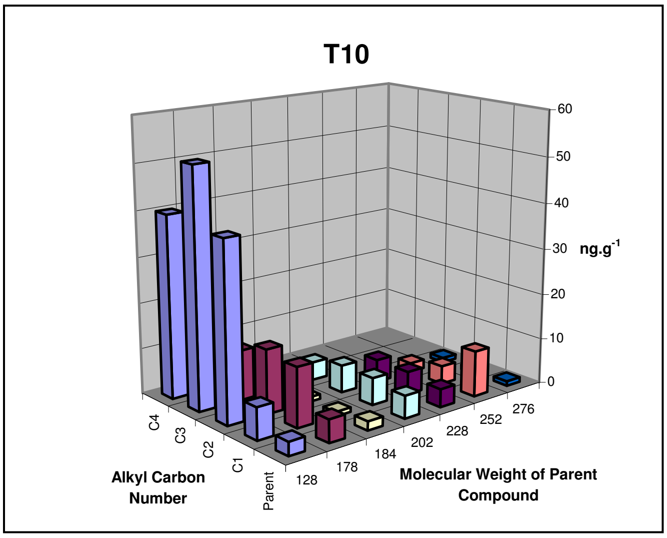

T1
40
35
30
25
20
15
10
5
0
ng.g-1
C4
C3
C2
C1
Parent
128
178
184
202
228
252
276
Alkyl Carbon Number
Molecular Weight of Parent Compound


T4
45
40
35
30
25
20
15
10
5
0
ng.g-1
C4
C2
Parent
128
178
184
202
228
252
276
Alkyl Carbon Number
Molecular Weight of Parent Compound


T5
45
40
35
30
25
20
15
10
5
0
ng.g-1
C4
C3
C2
C1
Parent
128
178
184
202
228
252
276
Alkyl Carbon Number
Molecular Weight of Parent Compound


T8
60
50
40
30
20
10
0
ng.g-1
C4
C3
C2
C1
Parent
128
178
184
202
228
252
276
Alkyl Carbon Number
Molecular Weight of Parent Compound


T9
35
30
25
20
15
10
5
0
ng.g-1
C4
C3
C2
C1
Parent
128
178
184
202
228
252
276
Alkyl Carbon Number
Molecular Weight of Parent Compound


T10
60
50
40
30
20
10
0
ng.g-1
C4
C3
C2
C1
Parent
128
178
184
202
228
252
276
Alkyl Carbon Number
Molecular Weight of Parent Compound

G. MACROFAUNA ANALYSIS

G.1 SAMPLE DATA

The following list of taxa excludes those that were merged for, or excluded from, statistical analysis

Taxa	Samples												Total
	T1-FA	T1-FB	T4-FA	T4-FB	T5-FA	T5-FB	T8-FA	T8-FB	T9-FA	T9-FB	T10-FA	T10-FB	
Nemertea													
Nemertea indet.								1					1
Sipuncula													
Annelida													
Abyssoninoe abyssorum				1		1	1						3
Ampharete sp. 1	6	4		1	2	6	2	4	4	3			32
Ampharetinae sp. 1												1	1
Amphitritinae sp. 1								2	1			1	4
Ancistrosyllis cf. *groenlandica*			1	1					1				3
Aphelochaeta sp. 3												2	2
Arabella iridicolor											2		2
Aricidea (Acesta) simplex							2		2			2	6
Aricidea (Allia) cf. *hartmani*				1									1
Aricidea (Allia) ramosa ?							1						1
Brada cf. *mammillata*											1		1
Chaetozone andersenensis ?		1	2	1		2	2				1		9
Chone sp. 2					1					1			2
Clymenura ? sp. 1	5	3											8
Clymenura sp. 2			1	1					2	1	1		6
Dodecaceria sp. 1				1	1								2
Euchone sp. 1									1				1
Euphionella patagonica								1					1
Eusamytha sp. 1												1	1
Galathowenia scotiae									1	3		3	7
Hyalopomatus macintoshi						1							1
Jasmineira sp. 2				1				1	1				3
Jasmineira sp. 3 [was fabriciinae sp. 3]											1		1
Jasmineira sp. 4 [was fabriciinae sp. 2]				1								1	2
Kesun sp. 1				1									1
Kinbergonuphis oligobranchiata						1							1
Leaena sp. 1		1				2							3
Levinsenia cf. *gracilis*				1						1		2	4
Lumbrineris sp. 1										2			2
Maldanidae sp. 1									1				1
Maldanidae sp. 2									1	2			3
Melinna sp. 1			1		2			1	1				5
Melinnopsis collaris	1		2			2		1					6
Myriochele riojai	3			2								2	7
Neoleanira magellanica		1											1
Nicon aestuariensis										1			1
Notomastus sp. 1								1					1
Onuphis pseudoiridescens	12	6	1	8	8	7	4	1	8	5	3	1	64
Paronuphis benthaliana										1	1	4	6
Phyllodocidae sp. 1						1							1
Pista mirabilis	1	1			1				2				5
Pista torquata ?				4	1			1					6
Polynoidae sp. 2			1										1
Samytha ? sp. 1									1				1
Samytha sp. 2												1	1
Samythella ? sp. 1				1									1
Scalibregma inflatum						1				1			2
Spiochaetopterus typicus		2		1							1	1	5
Spiophanes cf. *duplex*					3	1							4
Spiophanes sp. 1			1	1				1	4	1			8
Sternaspis sp. 1	2	5		2	4	3			4				20
Tauberia cf. *gracilis*			1										1
Tauberia cf. *oligobranchiata*				1									1

Taxa	Samples												Total
	T1-FA	T1-FB	T4-FA	T4-FB	T5-FA	T5-FB	T8-FA	T8-FB	T9-FA	T9-FB	T10-FA	T10-FB	
Terebellides stroemi var. *kerguelensis* ?										1			1
Tharyx sp. 1							1				1		2
Crustacea													
Amphipoda sp. 1					2						1		3
Amphipoda sp. 2					2								2
Ampelisca sp. 2		2											2
Harpinia sp. 1									1				1
Harpinia sp. 2		4				1				2	1	2	10
Harpinia sp. 3								2					2
Haustoriidae sp. 1	10	10		9	4	9	5	4	9	2		5	67
Orchomenella sp.1											2		2
Phoxcephalidae sp.1		1				1	1						3
Phoxcephalidae sp.2				1									1
Tryphosella? sp.										1			1
Cirolanidae sp.1	1					2						2	5
Eugerda sp. 1		1											1
Ilyarachna sp. 1	1								2				3
Leptanthura sp. 1				1		2				2		1	6
Serolis sp.1							1						1
Sphaeromatidae sp. 1												1	1
Leptognathia sp.		1				1							2
Tanaidae indet.					1								1
Diastylis sp. 1									1				1
Nannastacidae sp.	1			2									3
Mollusca													
Chaetoderma sp	2			1						1			4
Prochaetoderma sp.				1		1				1			3
Nucula falklandica	1	1		2	2	2		1	1	1			11
Yoldiella sp.					1		1			3			5
Limatula sp										1			1
Thyasira falklandica					1								1
Thyasira subovata	2			5		1				1		2	11
Axinulus cf croulinensis	1			5		2			1		2		11
Thyasiridae sp. 1		3			1				1				5
Astarte longirostris										1			1
Eulima sp.	1		1	1							1		4
Acirsa sp						1							1
Xymenopsis sp					1								1
Chlanidota sp										1			1
Marginella warreni		1											1
Philine falklandica						1							1
Cylichna sp.									1				1
Pulsellum falklandicum				2					3	3			8
Echinodermata													
Ctenodiscus australis	2		1			1	3		3		3		13
Brisaster antarcticus			1										1
Molpadia cf. *musculus*									2				2
Amphiura eugeniae										1			1
Amphiura joubini				1	1					1			3
Amphiura sp. 1				1	1	1	1		2			1	7
Ophiogona doederleini							1				1		2
Number of Taxa	17	18	12	32	20	26	14	14	28	28	16	20	102
Abundance	52	48	14	63	40	54	26	22	62	45	23	36	485

The following taxa (regular type) were merged (bold type) for statistical analysis

Taxa	Samples												Total
	T1-FA	T1-FB	T4-FA	T4-FB	T5-FA	T5-FB	T8-FA	T8-FB	T9-FA	T9-FB	T10-FA	T10-FB	
Sipuncula indet.				1							1		2
Sipuncula sp. 1		1											1
Sipuncula		**1**		**1**							**1**		**3**

Number of Taxa		1		1							1		2
Abundance		1		1							1		3

The following taxa were excluded from statistical analysis

Taxa	Samples												Total
	T1-FA	T1-FB	T4-FA	T4-FB	T5-FA	T5-FB	T8-FA	T8-FB	T9-FA	T9-FB	T10-FA	T10-FB	
Juvenile													
Neogastropod egg capsule												3	3
Brisaster sp. juv.								1					1
Schizasteridae indet. juv.												1	1
Amphiura sp. juv.	2			1		1				2	1	1	8
Amphiuridae indet. juv.												2	2
Ophiuridae indet. juv.	1					3			1	1		2	8
Indeterminate / Damaged													
Polynoinae indet.					1	1							2
Spionidae indet.							1						1
Terebellinae indet.	1	1					1						3
Sabellidae indet.					1								1
Amphipoda damaged indet.	1						1			2			4

Number of Taxa	4	1	0	1	2	3	3	1	1	3	1	5	11
Abundance	5	1	0	1	2	5	3	1	1	5	1	9	34

G.2 STATION DATA

The following list of taxa excludes those that were merged for, or excluded from, statistical analysis

Taxa	Samples						Total
	T1	T4	T5	T8	T9	T10	
Nemertea							
Nemertea indet.				1			1
Sipuncula							
Annelida							
Abyssoninoe abyssorum		1	1	1			3
Ampharete sp. 1	10	1	8	6	7		32
Ampharetinae sp. 1						1	1
Amphitritinae sp. 1				2	1	1	4
Ancistrosyllis cf. *groenlandica*		2			1		3
Aphelochaeta sp. 3						2	2
Arabella iridicolor						2	2
Aricidea (Acesta) simplex				2	2	2	6
Aricidea (Allia) cf. *hartmani*		1					1
Aricidea (Allia) ramosa ?				1			1
Brada cf. *mammillata*						1	1
Chaetozone andersenensis ?	1	3	2	2		1	9
Chone sp. 2			1		1		2
Clymenura ? sp. 1	8						8
Clymenura sp. 2		2			3	1	6
Dodecaceria sp. 1		1	1				2
Euchone sp. 1					1		1
Euphionella patagonica				1			1
Eusamytha sp. 1						1	1
Galathowenia scotiae					4	3	7
Hyalopomatus macintoshi			1				1
Jasmineira sp. 2		1		1	1		3
Jasmineira sp. 3 [was fabriciinae sp. 3]						1	1
Jasmineira sp. 4 [was fabriciinae sp. 2]		1				1	2
Kesun sp. 1		1					1
Kinbergonuphis oligobranchiata			1				1
Leaena sp. 1	1		2				3
Levinsenia cf. *gracilis*		1			1	2	4
Lumbrineris sp. 1					2		2
Maldanidae sp. 1					1		1
Maldanidae sp. 2					3		3
Melinna sp. 1		1	2	1	1		5
Melinnopsis collaris	1	2	2	1			6
Myriochele riojai	3	2				2	7
Neoleanira magellanica	1						1
Nicon aestuariensis					1		1
Notomastus sp. 1				1			1
Onuphis pseudoiridescens	18	9	15	5	13	4	64
Paronuphis benthaliana					1	5	6
Phyllodocidae sp. 1			1				1
Pista mirabilis	2		1		2		5
Pista torquata ?		4	1	1			6
Polynoidae sp. 2		1					1
Samytha ? sp. 1					1		1
Samytha sp. 2						1	1
Samythella ? sp. 1		1					1
Scalibregma inflatum			1		1		2
Spiochaetopterus typicus	2	1				2	5
Spiophanes cf. *duplex*			4				4
Spiophanes sp. 1		2		1	5		8
Sternaspis sp. 1	7	2	7		4		20
Tauberia cf. *gracilis*		1					1
Tauberia cf. *oligobranchiata*		1					1
Taxa	Samples						Total
	T1	T4	T5	T8	T9	T10	

Terebellides stroemi var. *kerguelensis* ?					1		1
Tharyx sp. 1				1		1	2
Crustacea							
Amphipoda sp. 1			2			1	3
Amphipoda sp. 2			2				2
Ampelisca sp. 2	2						2
Harpinia sp. 1					1		1
Harpinia sp. 2	4		1		2	3	10
Harpinia sp. 3				2			2
Haustoriidae sp. 1	20	9	13	9	11	5	67
Orchomenella sp.1						2	2
Phoxcephalidae sp.1	1		1	1			3
Phoxcephalidae sp.2		1					1
*Tryphosella? s*p.					1		1
Cirolanidae sp.1	1		2			2	5
Eugerda sp. 1	1						1
Ilyarachna sp. 1	1				2		3
Leptanthura sp. 1		1	2		2	1	6
Serolis sp.1				1			1
Sphaeromatidae sp. 1						1	1
Leptognathia sp.	1		1				2
Tanaidae indet.			1				1
Diastylis sp. 1					1		1
Nannastacidae sp.	1	2					3
Mollusca							
Chaetoderma sp	2	1			1		4
Prochaetoderma sp.		1	1		1		3
Nucula falklandica	2	2	4	1	2		11
Yoldiella sp.			1	1	3		5
Limatula sp					1		1
Thyasira falklandica			1				1
Thyasira subovata	2	5	1		1	2	11
Axinulus cf croulinensis	1	5	2		1	2	11
Thyasiridae sp. 1	3		1		1		5
Astarte longirostris					1		1
Eulima sp.	1	2				1	4
Acirsa sp			1				1
Xymenopsis sp			1				1
Chlanidota sp					1		1
Marginella warreni	1						1
Philine falklandica			1				1
Cylichna sp.					1		1
Pulsellum falklandicum		2			6		8
Echinodermata							
Ctenodiscus australis	2	1	1	3	3	3	13
Brisaster antarcticus		1					1
Molpadia cf. *musculus*					2		2
Amphiura eugeniae					1		1
Amphiura joubini		1	1		1		3
Amphiura sp. 1		1	2	1	2	1	7
Ophiogona doederleini				1		1	2

Number of Taxa	30	39	40	26	48	33	103
Abundance	100	77	94	48	107	59	485

The following taxa (regular type) were merged (bold type) for statistical analysis

Taxa	Samples						Total
	T1-FA	T4-FA	T5-FA	T8-FA	T9-FA	T10-FA	
Sipuncula indet.		1				1	2
Sipuncula sp. 1	1						1
Sipuncula	**1**	**1**				**1**	**3**
Number of Taxa	1	1				1	2
Abundance	1	1				1	3

The following taxa were excluded from statistical analysis

Taxa	Samples						Total
	T1-FA	T4-FA	T5-FA	T8-FA	T9-FA	T10-FA	
Juvenile							
Neogastropod egg capsule						3	3
Brisaster sp. juv.				1			1
Schizasteridae indet. juv.						1	1
Amphiura sp. juv.	2	1	1		2	2	8
Amphiuridae indet. juv.						2	2
Ophiuridae indet. juv.	1		3		2	2	8
Indeterminate / Damaged							
Polynoinae indet.			2				2
Spionidae indet.				1			1
Terebellinae indet.	2			1			3
Sabellidae indet.			1				1
Amphipoda damaged indet.	1			1	2		4
Number of Taxa	4	1	4	4	3	5	11
Abundance	6	1	7	4	6	10	34

H. CORRELATIONS

H.1 TOROA SITE

Variables	Depth	Sorting	Mean (phi)	% Sand	% Fines	F.O.C. %	^LOI % @ 450C	THC	UCM	n-alkn C12-20	n-alk nC21-36	n-alk nC12-36	cpi nC12-20	cpi nC21-36	cpi nC12-36
Depth															
Sorting	-0.360														
Mean (phi)	-0.069	0.040													
% Sand	0.091	0.037	-0.995												
% Fines	-0.091	-0.037	0.995	-1.000											
F.O.C. %	-0.937	0.191	0.170	-0.211	0.211										
^LOI % @ 450C	-0.569	-0.105	0.269	-0.328	0.328	0.812									
THC	-0.497	0.164	0.243	-0.252	0.252	0.354	0.148								
UCM	-0.462	0.239	-0.002	-0.001	0.001	0.292	0.082	0.961							
n-alk nC12-20	0.248	-0.417	0.522	-0.544	0.544	-0.234	-0.054	0.602	0.471						
n-alk nC21-36	-0.624	0.129	0.162	-0.180	0.180	0.467	0.180	0.976	0.935	0.492					
n-alk nC12-36	-0.494	-0.019	0.270	-0.294	0.294	0.368	0.163	0.976	0.903	0.660	0.978				
cpi nC12-20	-0.119	-0.425	-0.698	0.657	-0.657	-0.029	-0.261	0.181	0.283	-0.015	0.315	0.282			
cpi nC21-36	0.202	0.217	0.068	-0.046	0.046	-0.005	0.231	-0.810	-0.798	-0.631	-0.833	-0.868	-0.634		
cpi nC12-36	0.279	0.124	0.029	-0.011	0.011	-0.072	0.195	-0.862	-0.847	-0.611	-0.884	-0.905	-0.582	0.994	
Pristane	0.189	-0.241	0.891	-0.897	0.897	-0.115	0.060	0.367	0.141	0.836	0.257	0.424	-0.447	-0.241	-0.245
Phytane	-0.146	-0.488	-0.319	0.261	-0.261	0.106	0.122	0.624	0.680	0.513	0.649	0.687	0.709	-0.810	-0.779
Pr:Ph ratio	0.132	0.355	0.734	-0.686	0.686	-0.079	-0.062	-0.311	-0.478	-0.053	-0.374	-0.338	-0.824	0.554	0.517
Total 2-6 ring PAH	0.814	-0.380	0.209	-0.207	0.207	-0.579	-0.068	-0.683	-0.720	0.095	-0.801	-0.669	-0.481	0.608	0.668
NPD	0.838	-0.276	0.081	-0.067	0.067	-0.635	-0.167	-0.767	-0.765	-0.048	-0.878	-0.773	-0.456	0.670	0.728
4-6 ring PAH	-0.378	-0.422	0.597	-0.658	0.658	0.474	0.534	0.645	0.455	0.713	0.651	0.753	0.018	-0.512	-0.524
NPD / 4-6 ring ratio	0.791	-0.027	-0.175	0.211	-0.211	-0.676	-0.345	-0.848	-0.771	-0.331	-0.937	-0.900	-0.366	0.727	0.775
Aluminium AR	-0.146	-0.421	-0.763	0.717	-0.717	0.082	-0.113	-0.219	-0.115	-0.397	-0.042	-0.107	0.883	-0.219	-0.164
Arsenic AR	0.455	-0.873	-0.196	0.146	-0.146	-0.451	-0.343	-0.040	-0.077	0.470	-0.003	0.129	0.650	-0.493	-0.396
Barium AR	0.802	-0.583	-0.521	0.510	-0.510	-0.753	-0.504	-0.635	-0.540	-0.067	-0.642	-0.567	0.380	0.133	0.236
Chromium AR	-0.014	0.412	-0.113	0.144	-0.144	0.124	0.174	-0.755	-0.700	-0.844	-0.729	-0.830	-0.482	0.940	0.917
Copper AR	-0.656	-0.179	0.575	-0.622	0.622	0.706	0.511	0.330	0.109	0.187	0.441	0.459	-0.022	-0.198	-0.230
Iron AR	0.184	-0.602	-0.502	0.467	-0.467	-0.304	-0.478	-0.088	-0.061	0.063	0.035	0.065	0.879	-0.495	-0.417
Lead AR	-0.278	-0.168	0.579	-0.592	0.592	0.208	-0.079	0.188	-0.045	0.275	0.277	0.330	0.030	-0.278	-0.287
Nickel AR	-0.007	0.456	0.001	0.034	-0.034	0.129	0.207	-0.707	-0.671	-0.774	-0.705	-0.795	-0.598	0.955	0.924
Vanadium AR	0.018	-0.287	-0.945	0.917	-0.917	-0.110	-0.238	-0.198	-0.006	-0.401	-0.075	-0.153	0.868	-0.220	-0.165
Zinc AR	0.148	-0.284	-0.275	0.275	-0.275	-0.294	-0.593	-0.365	-0.397	-0.230	-0.228	-0.232	0.538	-0.129	-0.077
Aluminium HF	-0.271	-0.484	0.017	-0.064	0.064	0.217	-0.067	-0.028	-0.159	0.004	0.148	0.167	0.546	-0.317	-0.282
Barium HF	0.870	-0.301	-0.043	0.059	-0.059	-0.709	-0.308	-0.832	-0.814	-0.123	-0.917	-0.824	-0.316	0.632	0.701
Cadmium HF	0.102	0.298	0.626	-0.582	0.582	-0.228	-0.280	0.637	0.534	0.721	0.495	0.574	-0.369	-0.443	-0.484
Chromium HF	0.320	-0.121	0.054	-0.026	0.026	-0.447	-0.681	-0.431	-0.520	-0.129	-0.362	-0.332	0.145	0.054	0.092
Copper HF	-0.872	0.428	0.402	-0.401	0.401	0.766	0.330	0.454	0.325	-0.117	0.561	0.470	-0.089	-0.175	-0.258
Iron HF	-0.290	-0.476	0.465	-0.514	0.514	0.331	0.180	0.057	-0.172	0.228	0.178	0.247	0.156	-0.202	-0.186
Lead HF	-0.444	0.099	0.346	-0.340	0.340	0.244	-0.235	0.370	0.211	0.152	0.479	0.464	0.213	-0.460	-0.489
Nickel HF	-0.484	0.401	0.136	-0.104	0.104	0.196	-0.377	0.441	0.369	0.000	0.534	0.461	0.244	-0.483	-0.531
Vanadium HF	0.068	-0.291	-0.333	0.326	-0.326	-0.317	-0.633	0.347	0.366	0.315	0.420	0.441	0.806	-0.807	-0.765
Zinc HF	0.865	-0.312	-0.382	0.408	-0.408	-0.958	-0.830	-0.307	-0.213	0.199	-0.377	-0.294	0.313	-0.153	-0.073

Variables	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)														
% 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	0.011													
Pr:Ph ratio	0.478	-0.867												
Total 2-6 ring PAH	0.270	-0.401	0.394											
NPD	0.122	-0.475	0.386	0.982										
4-6 ring PAH	0.685	0.508	-0.078	-0.220	-0.399									
NPD / 4-6 ring ratio	-0.184	-0.580	0.337	0.839	0.926	-0.715								
Aluminium AR	-0.665	0.402	-0.668	-0.312	-0.258	-0.184	-0.131							
Arsenic AR	0.185	0.555	-0.430	0.189	0.129	0.251	-0.016	0.515						
Barium AR	-0.258	0.074	-0.269	0.589	0.643	-0.462	0.671	0.466	0.677					
Chromium AR	-0.480	-0.811	0.462	0.329	0.432	-0.639	0.597	-0.053	-0.608	0.031				
Copper AR	0.417	0.049	0.229	-0.372	-0.494	0.749	-0.681	0.013	0.014	-0.580	-0.183			
Iron AR	-0.226	0.464	-0.518	-0.167	-0.152	-0.027	-0.115	0.819	0.849	0.608	-0.426	0.016		
Lead AR	0.527	-0.128	0.428	-0.237	-0.319	0.499	-0.445	0.000	0.244	-0.291	-0.268	0.805	0.280	
Nickel AR	-0.377	-0.848	0.545	0.363	0.454	-0.588	0.594	-0.189	-0.671	-0.044	0.990	-0.167	-0.537	-0.259
Vanadium AR	-0.786	0.458	-0.796	-0.259	-0.168	-0.389	0.021	0.921	0.438	0.562	-0.054	-0.347	0.726	-0.342
Zinc AR	-0.207	-0.112	0.013	-0.086	-0.030	-0.261	0.080	0.636	0.543	0.473	-0.017	0.130	0.811	0.534
Aluminium HF	0.045	0.160	-0.074	-0.298	-0.343	0.329	-0.401	0.613	0.554	0.097	-0.240	0.664	0.721	0.781
Barium HF	0.019	-0.472	0.335	0.939	0.979	-0.500	0.951	-0.106	0.223	0.753	0.431	-0.531	0.016	-0.278
Cadmium HF	0.744	0.039	0.348	-0.095	-0.158	0.355	-0.260	-0.740	-0.106	-0.419	-0.530	0.056	-0.321	0.273
Chromium HF	0.070	-0.426	0.416	0.143	0.192	-0.296	0.268	0.241	0.374	0.390	0.093	0.100	0.538	0.616
Copper HF	0.122	-0.136	0.276	-0.708	-0.743	0.400	-0.723	-0.081	-0.438	-0.846	0.005	0.791	-0.198	0.637
Iron HF	0.431	0.025	0.232	-0.126	-0.235	0.606	-0.429	0.215	0.404	-0.144	-0.235	0.874	0.383	0.908
Lead HF	0.293	-0.033	0.253	-0.568	-0.601	0.344	-0.596	0.109	0.125	-0.397	-0.322	0.684	0.334	0.907
Nickel HF	0.066	-0.046	0.159	-0.729	-0.703	0.096	-0.572	0.098	-0.075	-0.450	-0.259	0.433	0.253	0.679
Vanadium HF	-0.022	0.550	-0.468	-0.443	-0.433	0.085	-0.372	0.534	0.691	0.292	-0.698	0.015	0.848	0.355
Zinc HF	-0.042	0.102	-0.174	0.430	0.493	-0.460	0.558	0.185	0.611	0.841	-0.235	-0.696	0.535	-0.220

Variables	Nickel AR	Vanadium AR	Zinc AR	Aluminium HF	Barium HF	Cadmium HF	Chromium HF	Copper HF	Iron HF	Lead HF	Nickel HF	Vanadium HF
Depth												
Sorting												
Mean (phi)												
% 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	-0.184											
Zinc AR	-0.113	0.456										
Aluminium HF	-0.315	0.281	0.787									
Barium HF	0.430	-0.024	0.155	-0.228								
Cadmium HF	-0.425	-0.671	-0.298	-0.279	-0.233							
Chromium HF	0.047	0.070	0.898	0.608	0.340	-0.020						
Copper HF	0.026	-0.324	0.052	0.403	-0.761	0.178	0.051					
Iron HF	-0.250	-0.169	0.510	0.882	-0.204	-0.042	0.480	0.513				
Lead HF	-0.331	-0.159	0.566	0.727	-0.526	0.319	0.579	0.750	0.721			
Nickel HF	-0.273	-0.050	0.486	0.502	-0.615	0.365	0.486	0.734	0.401	0.920		
Vanadium HF	-0.768	0.507	0.652	0.559	-0.288	0.161	0.459	0.000	0.265	0.541	0.567	
Zinc HF	-0.274	0.369	0.420	-0.066	0.602	0.082	0.448	-0.777	-0.289	-0.207	-0.151	0.510

H.2 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

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Appendix E – IUCN Red List Aves

Source: BirdLife International –

http://www.birdlife.org/datazone/species/index.html?action=SpcHTMFindResults.asp&hdnAction=SEARCH&hdnPageMode=0&cboFamily=-2&txtGenus=&txtSpecies=&txtCommonName=&cboRegion=11&cboCountry=69&chkEX=1&chkEW=1&chkCR=1&chkEN=1&chkVU=1&chkNT=1&chkDD=1&chkLC=1

Viewed on 18th June 2009.

Species	Category
Coscoroba Swan *Coscoroba coscoroba*	LC
Black-necked Swan *Cygnus melancoryphus*	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
Mallard *Anas platyrhynchos*	LC
Cinnamon Teal *Anas cyanoptera*	LC
Red Shoveler *Anas platalea*	LC
White-cheeked Pintail *Anas bahamensis*	LC
Speckled Teal *Anas flavirostris*	LC
Yellow-billed Pintail *Anas georgica*	LC
Silver Teal *Anas versicolor*	LC
Rosy-billed Pochard *Netta peposaca*	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 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
Snow Petrel *Pagodroma nivea*	LC
Blue Petrel *Halobaena caerulea*	LC
Broad-billed Prion *Pachyptila vittata*	LC
Antarctic Prion *Pachyptila desolata*	LC
Thin-billed Prion *Pachyptila belcheri*	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
Magellanic Diving-petrel *Pelecanoides magellani*	LC
Common Diving-petrel *Pelecanoides urinatrix*	LC
White-tufted Grebe *Rollandia rolland*	LC
Great Grebe *Podiceps major*	LC
Silvery Grebe *Podiceps occipitalis*	LC
Maguari Stork *Ciconia maguari*	LC
Buff-necked Ibis *Theristicus caudatus*	LC
Black-crowned Night-heron *Nycticorax nycticorax*	LC
Cattle Egret *Bubulcus ibis*	LC
Cocoi Heron *Ardea cocoi*	LC
Great Egret *Casmerodius albus*	LC
Imperial Shag *Phalacrocorax atriceps*	LC
Rock Shag *Phalacrocorax magellanicus*	LC
Turkey Vulture *Cathartes aura*	LC
Crested Caracara *Caracara cheriway*	LC
Striated Caracara *Phalcoboenus australis*	NT
American Kestrel *Falco sparverius*	LC
Peregrine Falcon *Falco peregrinus*	LC
Cinereous Harrier *Circus cinereus*	LC

Sharp-shinned Hawk *Accipiter striatus*	LC
Red-backed Hawk *Buteo polyosoma*	LC
Plumbeous Rail *Pardirallus sanguinolentus*	LC
Yellow-legged Gallinule *Porphyrio martinica*	LC
White-winged Coot *Fulica leucoptera*	LC
Red-gartered Coot *Fulica armillata*	LC
Red-fronted Coot *Fulica rufifrons*	LC
Snowy Sheathbill *Chionis albus*	LC
Blackish Oystercatcher *Haematopus ater*	LC
Magellanic Oystercatcher *Haematopus leucopodus*	LC
Black-necked Stilt *Himantopus mexicanus*	LC
Two-banded Plover *Charadrius falklandicus*	LC
Rufous-chested Plover *Charadrius modestus*	LC
South American Snipe *Gallinago paraguaiae*	LC
Fuegian Snipe *Gallinago stricklandii*	NT
Hudsonian Godwit *Limosa haemastica*	LC
Whimbrel *Numenius phaeopus*	LC
Ruddy Turnstone *Arenaria interpres*	LC
Sanderling *Calidris alba*	LC
White-rumped Sandpiper *Calidris fuscicollis*	LC
Baird's Sandpiper *Calidris bairdii*	LC
Stilt Sandpiper *Calidris himantopus*	LC
Dolphin Gull *Leucophaeus scoresbii*	LC
Grey Gull *Larus modestus*	LC
Kelp Gull *Larus dominicanus*	LC
Brown-hooded Gull *Larus maculipennis*	LC
Franklin's Gull *Larus pipixcan*	LC
Common Tern *Sterna hirundo*	LC
Arctic Tern *Sterna paradisaea*	LC
Antarctic Tern *Sterna vittata*	LC
Southern Skua *Catharacta antarctica*	LC
South Polar Skua *Catharacta maccormicki*	LC
Parasitic Jaeger *Stercorarius parasiticus*	LC
Long-tailed Jaeger *Stercorarius longicaudus*	LC
Eared Dove *Zenaida auriculata*	LC
Austral Parakeet *Enicognathus ferrugineus*	LC
Dark-billed Cuckoo *Coccyzus melacoryphus*	LC
Barn Owl *Tyto alba*	LC
Short-eared Owl *Asio flammeus*	LC
White-collared Swift *Streptoprocne zonaris*	LC
Sick's Swift *Chaetura meridionalis*	LC

White-crested Elaenia *Elaenia albiceps*	LC
Patagonian Negrito *Lessonia rufa*	LC
Dark-faced Ground-tyrant *Muscisaxicola maclovianus*	LC
White-browed Ground-tyrant *Muscisaxicola albilora*	LC
Black-billed Shrike-tyrant *Agriornis montanus*	LC
Fire-eyed Diucon *Xolmis pyrope*	LC
Great Kiskadee *Pitangus sulphuratus*	LC
Eastern Kingbird *Tyrannus tyrannus*	LC
Blackish Cinclodes *Cinclodes antarcticus*	LC
Chilean Swallow *Tachycineta meyeni*	LC
Southern Rough-winged Swallow *Stelgidopteryx ruficollis*	LC
Barn Swallow *Hirundo rustica*	LC
Cliff Swallow *Petrochelidon pyrrhonota*	LC
Sedge Wren *Cistothorus platensis*	LC
Cobb's Wren *Troglodytes cobbi*	VU
Patagonian Mockingbird *Mimus patagonicus*	LC
Austral Thrush *Turdus falcklandii*	LC
House Sparrow *Passer domesticus*	LC
Correndera Pipit *Anthus correndera*	LC
Black-chinned Siskin *Carduelis barbata*	LC
Long-tailed Meadowlark *Sturnella loyca*	LC
White-bridled Finch *Melanodera melanodera*	LC

Appendix F – IUCN Red List Cetaceans and Fish

Scientific Name	Common Name	IUCN Categorry
	Cetaceans	
Balaenoptera borealis	Sei whale	**Endangered**
Balaenoptera musculus	Blue whale	**Endangered**
Berardius arnuxii	Arnoux's beaked whale	Low Risk/Cons. Dependant
Cephalorhynchus commersonii	Commerson's dolphin	Data Deficient
Eubalaena australis	Southern right whale	Low Risk/Cons. Dependant
Hyperoodon planifrons	Southern bottlenose whale	Low Risk/Cons. Dependant
Lagenorhynchus australis	Peale's dolphin	Data Deficient
Lagenorhynchus obscurus	Dusky dolphin	Data Deficient
Lissodelphis peronii	Southern right whale	Data Deficient
Megaptera novaeangliae	Humpback whale	Vulnerable
Mesoplodon grayi	Gray's beaked whale	Data Deficient
Mesoplodon hectori	Hector's beaked whale	Data Deficient
Mesoplodon layardi	Layard's beaked whale	Data Deficient
Orcinus orca	Killer whale	Low Risk/Cons. Dependant
Phocoena dioptrica	Spectacled porpoise	Data Deficient
Physeter macrocephalus	Sperm whale	Vulnerable
Ziphius cavirostris	Cuvier's beaked whale	Data Deficient
	Fish	
Carcharhinus longimanus	Oceanic whitetip shark	Vulnerable
Cetorhinus maximus	Basking shark	Vulnerable

Appendix G: Cuttings Modelling – The BMT PROTEUS Model

G.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.

G.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.

G.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)).

G.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.

G.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.

G.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.

G.7 Model output

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.

G.8 Input parameters

The parameters input into the PROTEUS model for the Loligo and Toroa exploration wells were as follows:

Loligo well input parameters

Section Size (inches)	Operation		Cuttings		Muds			Depth of Discharge (m)
	Duration (days)	Interval (days)	Density (sg)	Volume Discharged (m^3)	Density (sg)	Continuous Volume Discharged (m^3)	Batch Volume Discharged (m^3)	
42	1	1	2.6	84.7	1.5	55.65	0	Seabed
26	4	1	2.6	216.5	1.14	208.3	0	Seabed
17 ½	10	2	2.6	141.6	1.38	1285.4	0	10
12 ¼	11.5	2	2.6	83.0	1.74	777.1	0	10
8 ½	5.5	2	2.6	17.5	1.92	297.9	0	10

All used automatic cuttings and mud PSDs.

Toroa well input parameters

Section Size (inches)	Operation		Cuttings		Muds			Depth of Discharge (m)
	Duration (days)	Interval (days)	Density (sg)	Volume Discharged (m^3)	Density (sg)	Continuous Volume Discharged (m^3)	Batch Volume Discharged (m^3)	
42	1	1	2.6	84.7	1.44	55.65	0	Seabed
17 ½	3.5	1	2.6	56.2	1.44	208.3	0	10
12 ¼	9	2	2.6	69.9	1.14	1285.4	0	10
8 ½	6.5	2	2.6	25.7	1.32	583.5	0	10

All used automatic cuttings and mud PSDs.

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).

Blanket current speed and direction data used for the model run at the discharge location for the Loligo and Toroa exploration wells are shown in Table F.1.

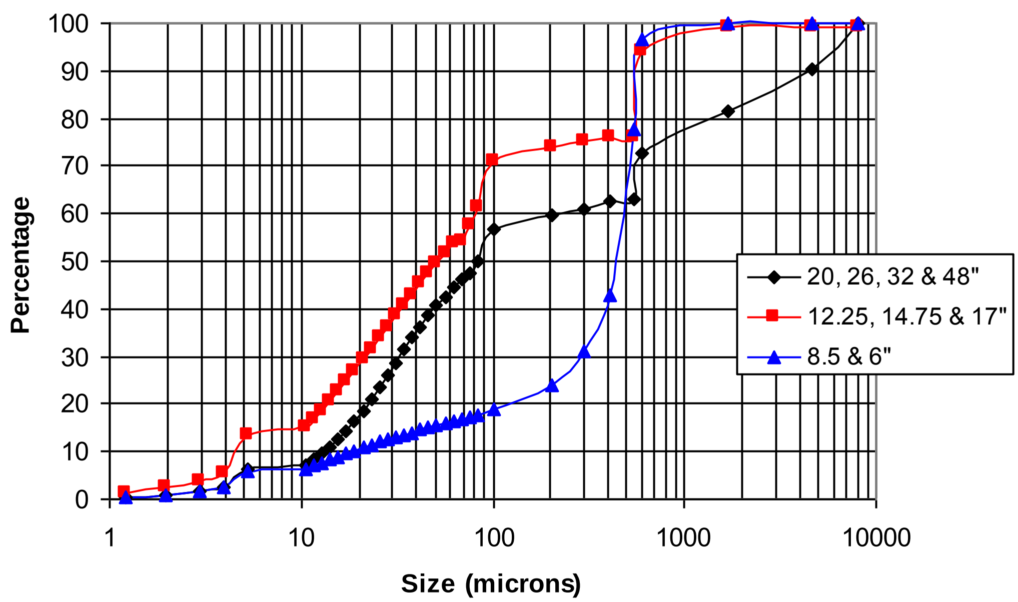

Figure G.1. Particle Size Distributions (PSD) for drill cuttings from a toothed drill bit used in the modelling. Plot shows the cumulative distribution of solids (by diameter) within the drill cuttings.

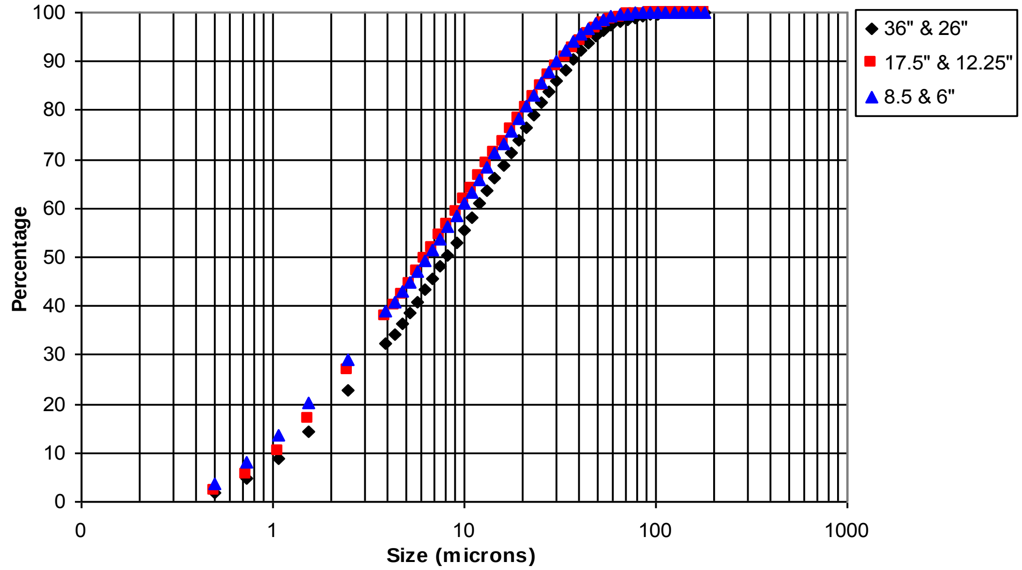

Figure G.2. Particle Size Distribution (PSD) for solid particles within drilling muds used in the modelling. Plot shows the cumulative distribution of solids by diameter.

Table G.1. Blanket (current override) current speed and direction input data for the Loligo and Toroa exploration well models.

	Loligo	Toroa
Current Speed	0.01 (minimum observed)	0.01 (estimated minimum observed)
Current Direction	041° (residual direction)	012° (observed direction)

Appendix H: Oil Spill Modelling – The BMT OSIS Model

H.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 BHPBP(F)C 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[1].

The following sections detail the prevailing met-ocean conditions in the vicinity of the proposed drilling locations and the likely trajectories of spills associated with the proposed operations. 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 Toroa and Loligo well locations.

H.2 Metocean Data

H.2.1 Currents

Outside the continental shelf, tidal influences are negligible and any water movement may be regarded as being from 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.

The predominant current south of the Falkland Islands, between December and February, is in a north, north east direction, which occurs up to 50% of the time in the range of 0.5 to 1 knot. From June to August, currents are directed in a north easterly direction, with strengths of 1-1.5 knots and occur in this manner for approximately 75 percent or more of the time[2]. There is also a weaker current occurring less than 50 % of the time in a north, north westerly direction.

H.2.2 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.

H.2.3 Wind

Mean wind directions tend to be similar to that of the prevailing wave movements and as such are predominantly from a south-westerly to north-westerly direction throughout the year, with mean wind speeds typically varying from 15 to 17 knots. The number of days a month where gale force winds occur is roughly the same throughout the year ranging between 4 - 5 days, with a total of approximately 55 days a year experiencing such conditions.

H.2.4 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^{o}C while in August it is relatively lower, ranging between 2 to 6 ^{o}C.

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[1] *United Kingdom Hydro-graphic Office, (2008) Admiralty Sailing Directions, South America Pilot, Volume II, NP 6.*

[2] Page 16 of *UKHO (2008)*

H.3 Spill Modelling

H.3.1 Modelling Scenarios

The drilling programme will target an ITOPF category medium crude reservoir (18^{o} API crude with a specific gravity of 0.947) and, therefore, the main spill risk associated with drilling operations would be derived from a loss of reservoir hydrocarbons associated with a loss of well control or accidental hydrocarbon releases, mainly from fuel bunkering of diesel. Modelling was carried out using the BMT OSIS 4.0 model and the following was determined:

1. the weathering of a partial inventory loss (100 tonnes) instantaneous crude spill with a constant 16 knot onshore wind (trajectory) from the Toroa well location;
2. the weathering of a partial inventory loss (100 tonnes) instantaneous crude spill with a constant 16 knot onshore wind (trajectory) from the Loligo well location;
3. the weathering of a spill plume of 6,110 tonnes derived from a well blowout event lasting two days (where 20,000 BOPD release over two days) under 'prevailing' currents and 'typical' weather conditions (stochastic) from the Toroa well location;
4. the weathering of a spill plume of 6,110 tonnes derived from a well blowout event lasting two days (where 20,000 BOPD release over two days) under 'atypical' currents and 'typical' weather conditions (stochastic) from the Toroa well location;
5. the weathering of a spill plume of 6,110 tonnes derived from a well blowout event lasting two days (where 20,000 BOPD release over two days) under 'prevailing' currents and 'typical' weather conditions (stochastic) from the Loligo well location;
6. the weathering of a spill plume of 6,110 tonnes derived from a well blowout event lasting two days (where 20,000 BOPD release over two days) under 'atypical' currents and 'typical' weather conditions (stochastic) from the Loligo well location.

The results of the modelling are shown in the Table H.1 below.

Table H.1. OSIS Modelling Results

Oil Type	Spill Size	Scenario	Met-ocean Conditions	Fate of Spill
18°API crude	100 t (Instantaneous Release)	Partial inventory loss from the Toroa well	Trajectory 16 knot onshore wind	The spill plume makes contact with the south coast of the Falkland Islands shore after approximately 80 hours (Figure H.1).
18°API crude	100 t (Instantaneous Release)	Partial inventory loss from the Loligo well	Trajectory 16 knot onshore wind	The spill plume makes contact with the east coast of the Falkland Islands shore after approximately 160 hours (Figure H.2).
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Toroa well	Stochastic Typical weather conditions with 'prevailing' currents	Under typical conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching (Figure H.3).
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Toroa well	Stochastic Typical weather conditions with 'atypical' currents	Under typical weather and atypical current conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching (Figure H.4).
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Loligo well	Stochastic Typical weather conditions with 'prevailing' currents	Under typical conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching (Figure H.5).
18°API crude	6,110 t (released over 48 hours)	Well blowout from the Loligo well	Stochastic Typical weather conditions with 'atypical' currents	Under typical weather and atypical current conditions the oil would disperse offshore with a 0.0 percent chance of the spill beaching (Figure H.6).

Trajectory and stochastic modelling simulations were undertaken to predict the worst possible case and expected behaviour of spill plumes derived from the proposed well locations. The simulations were run using the 'Alba' oil type which is an 18° API oil similar to the expected reservoir fluids from the proposed well locations. The modelling simulations were undertaken for the month of July where sea surface temperatures are expected to be at their lowest and would therefore not be conducive to the rapid breakdown of spilled crude, also representing a worst case scenario. Mean wind speeds and general directions are roughly similar throughout the year and therefore this was not a deciding factor for when to simulate the modelling.

Two trajectory modelling scenarios were undertaken from both the proposed Toroa and Loligo well locations. The trajectory simulations provide an indication of how a potential spill may behave under absolute worst case met-oceanic conditions. An instantaneous 100 tonne spill of crude from the Toroa well, under a constant 16 knot onshore wind and 0.5 knot current, directed towards the Falkland Islands (atypical conditions) resulted in the spill beaching on the coast after 80 hours (Figure H.1). The same modelling scenario was run for the Loligo well location and the output from the modelling run suggested that the spill would beach after approximately 160 hours (Figure H.2).

Several stochastic modelling runs were undertaken to model the behaviour of spilled crude from both the proposed well locations. Two stochastic modelling simulations were specifically run for the proposed Toroa well as there are two currents that have the potential to impact the behaviour of the spilled crude.

Of the two currents that could impact on the behaviour of crude spilled from the Toroa well, the predominant and stronger current (1.5 knots) is orientated in a north-easterly direction away from the Falkland Islands while the less frequent, weaker current (0.5 knot) is directed towards the Islands. The modelling results suggested that under typical wind conditions with both the predominant and atypical currents there would be a zero percent probability of a spill beaching on the Falklands or anywhere else. The data suggested that the spills would likely disperse offshore, although under typical current conditions, the area of sea surface affected by such a spill would be significantly greater than that under atypical current conditions (Figures H.3 and H.4).

The modelling data from the Loligo well also suggested that there would be a zero percent probability of a spill beaching (Figure H.5).

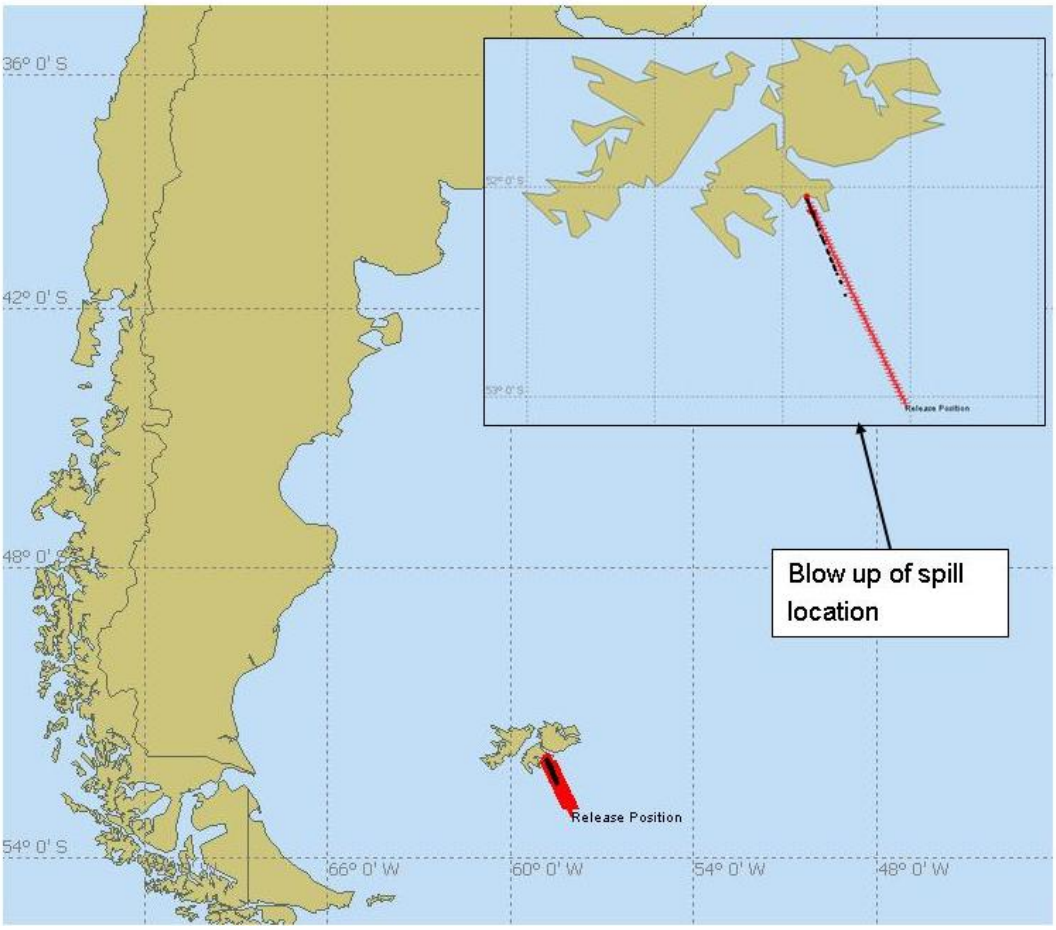
Furthermore, the wind rose data from the *United Kingdom Hydro-graphic Office, (2008)* used in the stochastic modelling suggests that wind will only blow in the direction of the Falkland Islands from the Toroa well for approximately 37.2 hours and from the Loligo well for 15 hours in the month of July. These time frames even were they to be continuous are considerably less than the 80 and 160 hours required for a spill to reach the coast of the Falkland Islands from the Toroa or Loligo well locations.

H.3.2 Modelling Conclusions

In conclusion, under typical or atypical met-ocean conditions, it is not expected that a spill from the proposed Toroa or Loligo wells would beach on the Falkland Islands or on any of the landmasses in the general area.

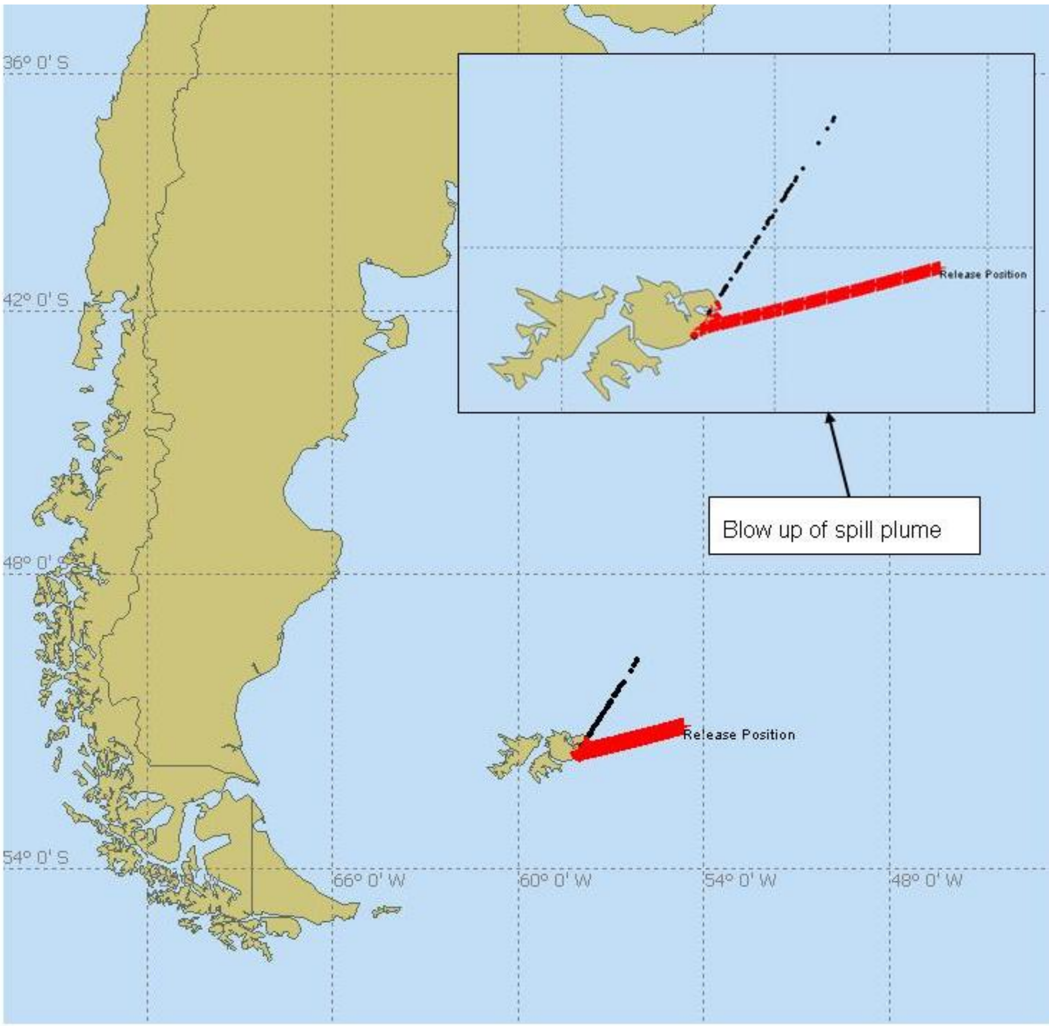
The trajectory modelling data suggested that under worst case conditions of a constant 30 knot onshore wind, the minimum time for a spill to beach from proposed well locations is approximately 80 hours. In practice, if such a spill was to occur, the BHPBP(F)C in-house emergency response system would be activated and specialist responders would be deployed to address the situation. Typically, Oil Spill Response (OSR) or similar contractors offer such services. Preliminary discussions with OSR suggest that appropriate shoreline or offshore spill response equipment could be onsite within 24 hours which would be sufficient to respond to possible shoreline threats.

Figure H.1. 100 tonne 18°API crude spill from the Toroa well modelled using a trajectory simulation



Note: Red line displays the main slick path, that is, the red line is a series of crosses that mark the location of the spill centroid (mean position of bulk of slick) at intervals (in this case, one third of an hour). Black dots indicate general direction of oil slick dispersion. The current moves the sea continually and the oil takes the resultant of the current and wind velocities.

Figure H.2. 100 tonne 18^{o}API crude spill from the Loligo well modelled using a trajectory simulation



Note: Red line displays the main slick path, that is, the red line is a series of crosses that mark the location of the spill centroid (mean position of bulk of slick) at intervals (in this case, one third of an hour). Black dots indicate general direction of oil slick dispersion. The current moves the sea continually and the oil takes the resultant of the current and wind velocities.

Figure H.3. 6,110 tonne 18^{o}API crude spill from the Toroa well modelled using a trajectory simulation under prevailing currents

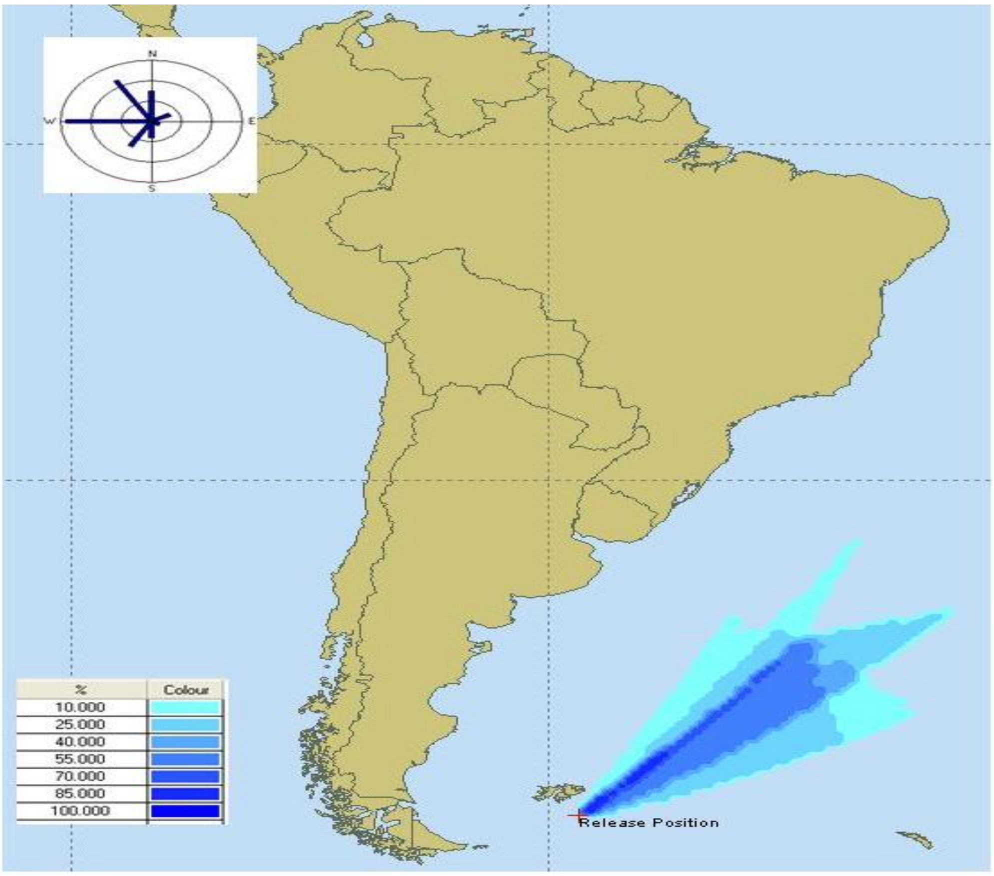


Figure H.4. 6,110 tonne 18°API crude spill from the Toroa well modelled using a trajectory simulation under atypical currents

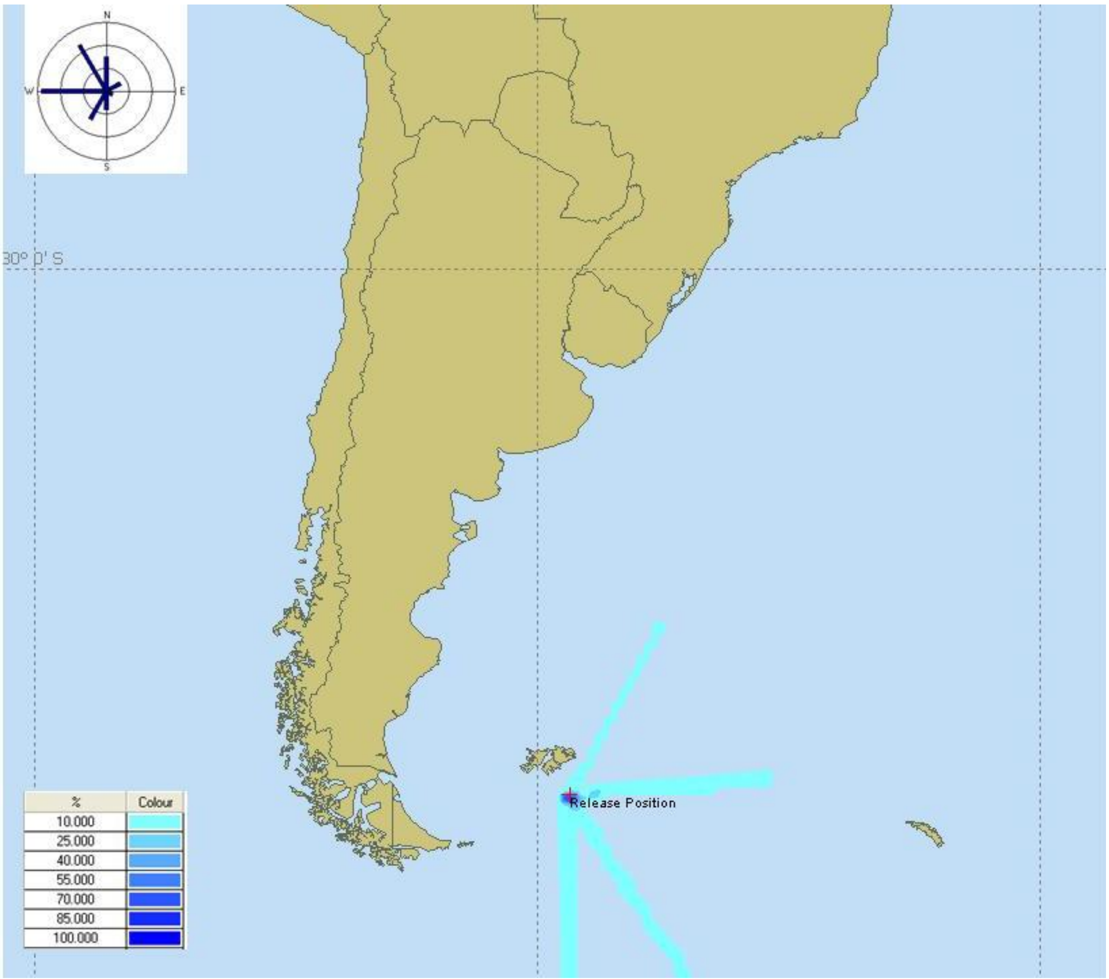


Figure H.5. 6,110 tonne 18°API crude spill from the Loligo well modelled using a stochastic simulation under prevailing currents

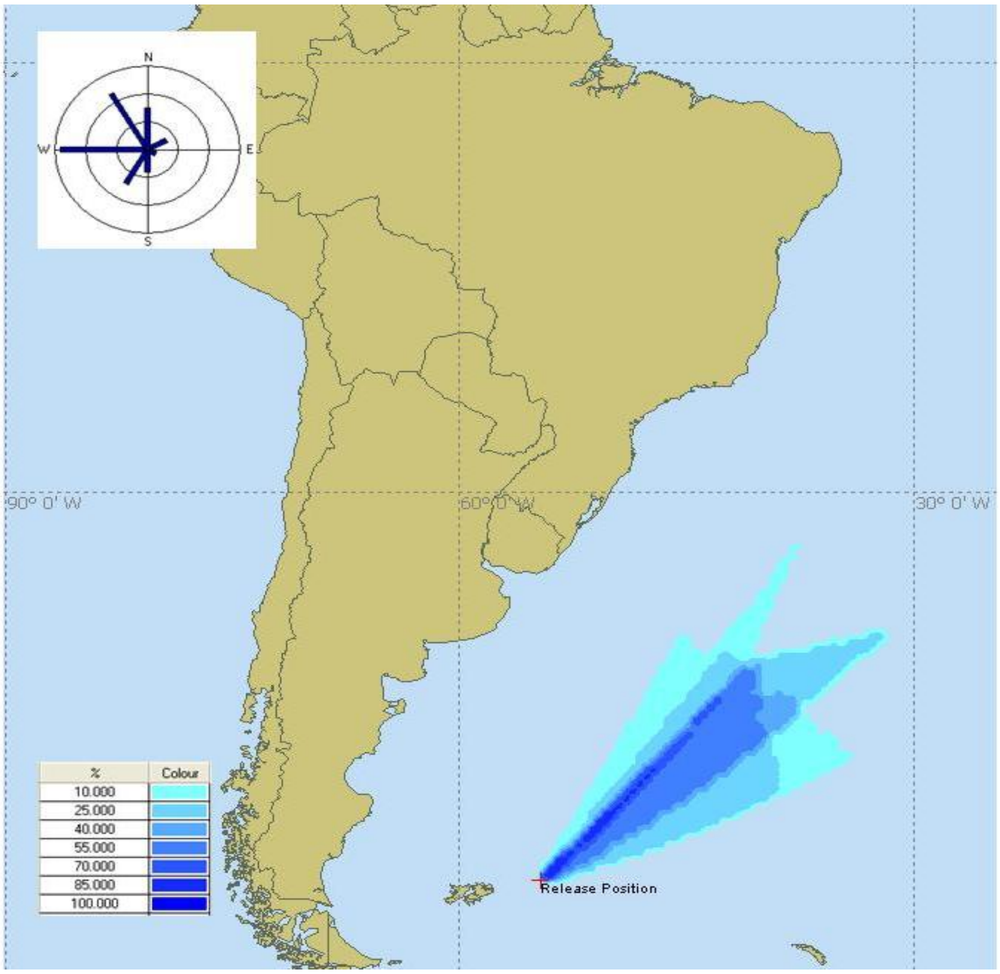
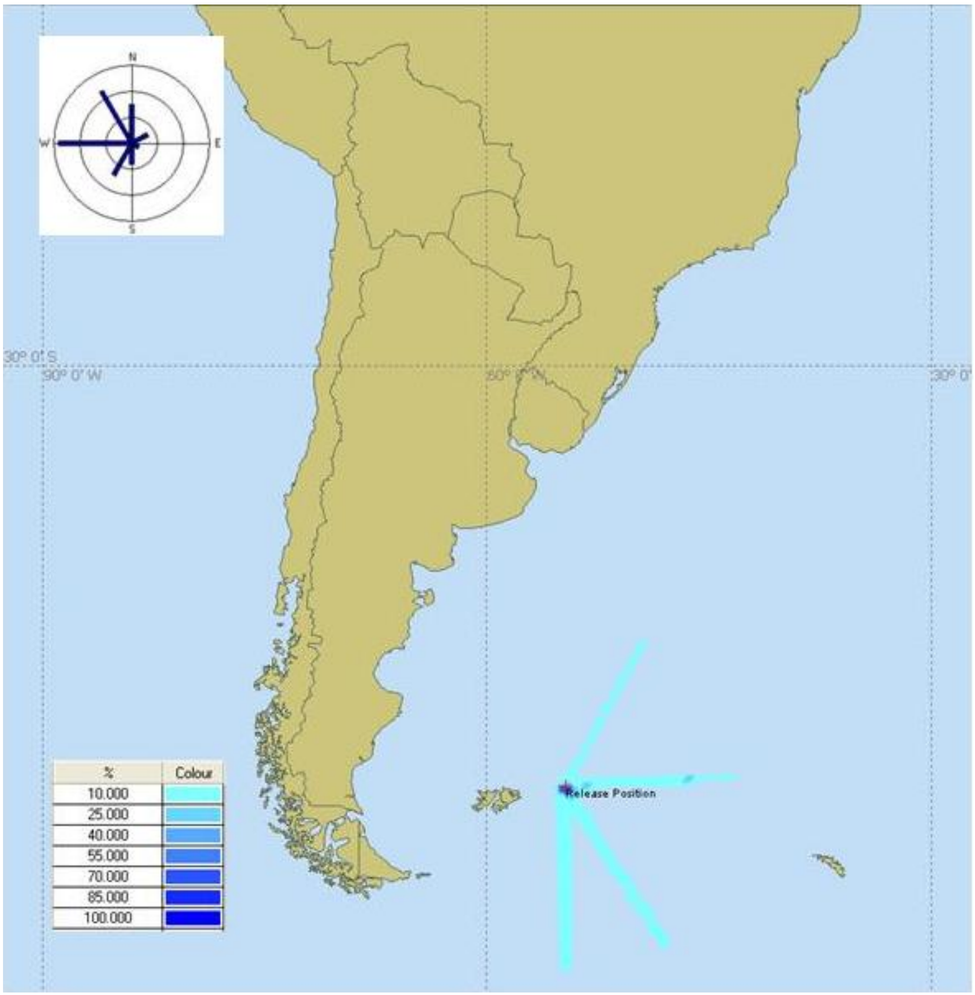


Figure H.6. 6,110 tonne 18^{o}API crude spill from the Loligo well modelled using a trajectory simulation under atypical currents



Appendix I: Management Systems

I.1 BHP Billiton Charter

BHP BILLITON CHARTER

WE ARE BHP BILLITON, A LEADING GLOBAL RESOURCES COMPANY.

Our purpose is to create long-term value through the discovery, development and conversion of natural resources, and the provision of innovative customer and market-focused solutions.

To prosper and achieve real growth, we must:

- actively manage and build our portfolio of high quality assets and services,
- continue the drive towards a high performance organisation in which every individual accepts responsibility and is rewarded for results,
- earn the trust of employees, customers, suppliers, communities and shareholders by being forthright in our communications and consistently delivering on commitments.

We value:

- **Safety and the Environment** – An overriding commitment to health, safety, environmental responsibility and sustainable development.
- **Integrity** – Including doing what we say we will do.
- **High Performance** – The excitement and fulfilment of achieving superior business results and stretching our capabilities.
- **Win-Win Relationships** – Having relationships which focus on the creation of value for all parties.
- **The Courage to Lead Change** – Accepting the responsibility to inspire and deliver positive change in the face of adversity.
- **Respect for Each Other** – The embracing of diversity, enriched by openness, sharing, trust, teamwork and involvement.

We are successful in creating value when:

- our shareholders are realising a superior return on their investment.
- our customers and suppliers are benefiting from our business relationships.
- the communities in which we operate value our citizenship.
- every employee starts each day with a sense of purpose and ends each day with a sense of accomplishment.

Marius Kloppers

Marius Kloppers
Chief Executive Officer

October 2007

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I.2 BHP Billiton's Sustainable Development Policy

OUR APPROACH TO HEALTH, SAFETY, ENVIRONMENT AND THE COMMUNITY

BHP BILLITON'S SUSTAINABLE DEVELOPMENT POLICY

At BHP Billiton our objective is to be the company of choice – creating sustainable value for our shareholders, employees, contractors, suppliers, customers, business partners and host communities.

We aspire to Zero Harm to people, our host communities and the environment and strive to achieve leading industry practice. Sound principles to govern safety, business conduct, social, environmental and economic activities are integral to the way we do business.

Wherever we operate we will develop, implement and maintain management systems for sustainable development that drive continual improvement and ensure we:

- do not compromise our safety values, and seek ways to promote and improve the health of our workforce and the community
- identify, assess and manage risks to employees, contractors, the environment and our host communities
- uphold ethical business practices and meet or, where less stringent than our standards, exceed applicable legal and other requirements
- understand, promote and uphold fundamental human rights within our sphere of influence, respecting the traditional rights of Indigenous peoples and valuing cultural heritage
- encourage a diverse workforce and provide a work environment in which everyone is treated fairly, with respect and can realise their full potential
- set and achieve targets that promote efficient use of resources and include reducing and preventing pollution
- enhance biodiversity protection by assessing and considering ecological values and land-use aspects in investment, operational and closure activities
- engage regularly, openly and honestly with people affected by our operations, and take their views and concerns into account in our decision-making
- develop partnerships that foster the sustainable development of our host communities, enhance economic benefits from our operations and contribute to poverty alleviation
- work with those involved through the lifecycles of our products and by-products to promote their responsible use and management
- regularly review our performance and publicly report our progress.

In implementing this Policy, we will engage with and support our employees, contractors, suppliers, customers, business partners and host communities in sharing responsibility for meeting our requirements.

We will be successful when we achieve our targets towards Zero Harm, are valued by our host communities, and provide lasting social, environmental and economic benefits to society.

Marius Kloppers

Marius Kloppers
Chief Executive Officer

1 October 2007

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I.3 Health, Safety and Environment Management System

PETROLEUM

HEALTH, SAFETY AND ENVIRONMENT MANAGEMENT SYSTEM

AUGUST 2009

resourcing the future

Zero Harm

OUR COMMITMENT

Zero Harm is achievable and a core BHP Billiton Petroleum value.

We all have an obligation to identify and reduce risks, safeguard people and protect the environment and the communities where we operate. Working together in this way, we can make informed business decisions and maintain a safe work environment.

We can build on our current efforts, learn from health, safety and environment (HSE) incidents, and continually improve performance to achieve our goal of Zero Harm by focusing on three main areas:

- Our people.
- Our systems.
- Our equipment.

The implementation of effective HSE controls, visible leadership and application of HSE excellence will truly make our business a success.

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INTRODUCTION

The BHP Billiton Petroleum HSE Management System defines performance criteria to drive our commitment to Zero Harm. BHP Billiton has established a number of mandatory areas of performance, and the criteria to meet that performance are noted in the Group Level Documents (GLDs). Implementation of the BHP Billiton Petroleum HSE Management System will assure compliance with the HSE GLD criteria and other Petroleum specific requirements.

The Petroleum HSE Management System document resides on the Petroleum Portal where links are provided to related additional performance criteria.

Consistent with the principles of continuous improvement, the Petroleum HSE Management System and the related additional performance criteria will be periodically updated.

All Petroleum sites and activities must maintain up-to-date practices that adhere to the current criteria contained in the Petroleum HSE Management System, and personnel must go about their work in accordance with these practices.

Success in our exploration, development and production activities is underpinned by effective HSE management alongside technical excellence, integrity and meeting stakeholder expectations.

J. Michael Yeager

Chief Executive, Petroleum

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Purpose

BHP Billiton Petroleum activities range from exploration programs in remote and diverse locations, through to development of new projects, upstream operations and closure. Our activities are supported by a diverse workforce working in culturally varied locations worldwide.

Petroleum is committed to implementing systems and practices throughout its business for the activities it can control or have some influence over. These systems aim to maximize productivity by adopting sound technical standards and the principles of Zero Harm to people, the environment and the local communities. The HSE Management System sets the framework for continual improvement through the application of consistent performance standards across all aspects of Petroleum activities, including:

- Identification of statutory obligations and commitments and the implementation of systems to ensure our license to operate is maintained.
- Development and implementation of Petroleum risk management processes, including the Safety Case requirements.
- Establishment of competencies for personnel and provision of training to promote expected behaviors and HSE leadership.
- Control and management of all contractors and suppliers of Petroleum goods and services.
- Conduct of reviews including self assessments, audits and compliance evaluations, and the reporting of outcomes from these reviews.

Scope

The scope of the Petroleum HSE Management System covers Petroleum activities that affect or have the potential to affect, beneficially or adversely, the health, safety and security of people, the physical environment and protection of assets. In particular, the scope covers systems to manage:

- Health – promoting and improving the health of Petroleum's workforce and host communities.
- Safety – ensuring that safety values are not compromised, personnel are protected and a workplace is provided where people are able to work without being injured.
- Environment – promoting the efficient use of resources, reducing and preventing pollution and enhancing biodiversity protection.
- Community – engaging the external community, managed through the Petroleum External Affairs Function.
- Asset protection – prevention of harm to and protection of personnel, physical and financial assets, and intellectual property.

Application

The Petroleum HSE Management System applies to Petroleum controlled activities and to Petroleum employees and contractors performing controlled activities.

It applies to the entire lifecycle of Petroleum's activities, processes and products, including exploration and planning, development, operation, closure (decommissioning, remediation and rehabilitation), marketing and acquisitions and divestments.

Petroleum monitored activities should have equivalent systems in place that meet the intent of this document. Partners, suppliers and contractors are encouraged to adopt the intent and nature of the performance requirements in this document.

Responsibility

Unless otherwise stated, managers and supervisors responsible for controlled activities are accountable for the implementation of the performance requirements outlined in this document.

Personnel must comply with the letter and spirit of the performance requirements in the Petroleum HSE Management System including associated documentation.

Petroleum HSE Management System

This document defines the elements of the Petroleum HSE Management System and provides direction to related Petroleum documentation and associated performance criteria.

The Petroleum HSE Portal must be used to access the most current version of the related documentation.

There are 16 Elements which make up the Petroleum HSE Management System. Each Element contains an overall intent statement and a set of specific expectations.

The remainder of this document describes the intent of each Element and provides a set of corresponding mandatory performance requirements.

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ELEMENT 1

LEADERSHIP AND ACCOUNTABILITY

INTENT

Petroleum managers, employees and contractors understand their accountabilities and demonstrate leadership and commitment to sustainable development through effective management.

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PERFORMANCE REQUIREMENTS

Visible Leadership

1.1 Managers must complete an Annual HSE Leadership Action Plan. The objectives and deliverables of these plans must be cascaded throughout their organization to ensure alignment with Petroleum CSG level HSE Objectives and local level HSE goals and targets.

1.2 Managers must:

- Promote HSE initiatives.
- Conduct frequent site inspections, reviews and behavioral observations.
- Lead incident investigations.
- Drive the implementation of and compliance with Petroleum HSE Policies, Standards and Procedures.
- Provide methods to identify and control the risks in their areas.

1.3 Petroleum HR systems must include HSE leadership and performance as prerequisites for promotion.

Reward, Recognition and Behavior

1.4 HSE reward and recognition processes must be developed and implemented for each site, and be aligned to Petroleum CSG level HSE Objectives and expected behaviors.

HSE Management System

1.5 Petroleum sites must implement and maintain a local level HSE Management System appropriate to the risk of the controlled activities. The local level HSE Management System must be aligned to this document and Petroleum HSE Controls and Procedures.

1.6 Local level HSE Management Systems for Petroleum sites must conform to ISO 14001 and to OHSAS 18001. Petroleum owned and operated production facilities must also obtain certification to ISO14001 within 12 months of commissioning, and maintain certification for the life of the operation.

Resources

1.7 Petroleum sites must identify minimum manning levels and other resources (e.g. equipment, controls, personal protection equipment, etc.) to manage the HSE risks of these operations, comply with relevant HSE legal and other requirements and maintain the license to operate. Assessment of manning levels must specifically address both quantity and competency of resources required.

1.8 Manning levels and resources must be reviewed annually and included in the annual budget.

1.9 All levels of Petroleum must provide safe and healthy working conditions for all personnel in accordance with local laws. This includes the provision of personal protective equipment (PPE) in accordance with the Petroleum PPE procedure.

Roles and Accountabilities

1.10 Position descriptions must be developed for, and communicated to, all employees. Position descriptions must be endorsed by managers, and include relevant HSE responsibilities and accountabilities commensurate with the requirements of the roles.

1.11 Managers must consult with employees to establish relevant individual HSE key performance indicators each year.

1.12 An assessment of employees' performance against the HSE responsibilities defined in the position descriptions and the annual HSE KPIs must be included in their annual performance evaluation process.

1.13 HSE responsibilities for contractors must be defined and communicated by the manager responsible for the contractor.

1.14 Personnel are responsible for HSE management as defined in their position description and must consistently deliver on their HSE accountabilities.

1.15 Personnel must participate in HSE programs at their locations.

Right to Stop Work

1.16 Personnel are obliged to challenge or stop work or an activity where there is concern that continuation of the activity may lead to an uncontrolled HSE hazard.

1.17 Where work or an activity has been stopped for this reason, the relevant manager must verify the hazard or concern is adequately assessed and controlled before the work or activity can re-commence.

ELEMENT 2

LEGAL AND OTHER REQUIREMENTS

INTENT

Relevant legal and other requirements are identified, accessible, understood and complied with. Systems are in place to assure compliance through periodic evaluations.

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PERFORMANCE REQUIREMENTS

Compliance

2.1 Petroleum sites must identify and access applicable HSE legal and other requirements. These requirements include relevant local laws, license conditions, permit obligations, consents, regulations, joint venture commitments, contracts, agreements, environmental and community commitments.

2.2 Where there is a conflict between local legislation and the requirements in Petroleum HSE Policies, Standards and Procedures, the more stringent requirement prevails, subject to applicable law.

Compliance and Commitments Register

2.3 Identified legal and other requirements must be summarized in a Compliance and Commitments Register that is maintained and up to date.

2.4 The Compliance and Commitments Register must identify the person(s) accountable for establishing, maintaining and verifying compliance for each specific requirement.

Communication and Responsibilities

2.5 Managers must ensure that applicable HSE legal and other requirements are communicated to and understood by affected personnel.

Reviews

2.6 Compliance with HSE legal and other requirements must be assessed at least annually, or when new or changed requirements have the potential to impact the license to operate.

2.7 The annual or periodic review must ensure that any changes in regulations, legislation or other requirements are captured in relevant HSE documentation and communicated to affected personnel.

ELEMENT 3

HAZARDS AND RISKS

INTENT

Hazards are identified and associated risks assessed and managed.

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PERFORMANCE REQUIREMENTS

Hazard Identification, Risk Assessment and Risk Management

3.1 Hazards and risks associated with Petroleum activities and sites must be identified, assessed and managed in accordance with the appropriate Petroleum risk management procedures. These include procedures relating to:

- Case to Operate.
- Environmental and Social Impact Assessments.
- Health and Hygiene Management.
- Job Risk Assessments.
- Management of Change.
- Permit to Work.
- Safe Travel Procedures.
- Safety Cases.

3.2 Hazard identification and risk assessments must provide evidence that justify commencement of, or continuation of operations.

3.3 The outcome of risk assessments, including the identified hazards and controls must be appropriately documented and the quality of close-out of findings/actions assured.

Risk Recording and Review

3.4 Divisional, operational and project risks must be documented in a controlled risk register that is maintained and up to date.

3.5 Risks must be reviewed and updated at least annually or more often if the nature of the risk requires. Risks must also be reviewed following a significant incident, to capture learnings from incidents or when change occurs.

Consultation and Involvement

3.6 Hazard identification and HSE risk assessments must ensure adequate breadth of technical and functional representation to cover all anticipated risks.

3.7 The HSE hazard identification and risk assessment process must involve relevant personnel to provide the knowledge, competency and experience of both risk assessment and the activity/subject under review to ensure adequate evaluation of risk and effective identification of controls.

Hierarchy of Controls

3.8 All HSE risk controls must be tested against the hierarchy of controls and wherever practicable, the most effective control should be used.

3.9 Criteria specified in HSE Controls must be applied, as appropriate to the assessed risks.

Risk Tolerability and Control Effectiveness

3.10 Residual HSE risk must be tolerable as defined in the relevant risk management procedures.

3.11 Managers are accountable for ensuring that residual HSE risks are tolerable and have been reduced to as low as reasonably practicable (ALARP).

3.12 HSE risk controls must be approved by the responsible line manager and endorsed by the site manager.

3.13 The effectiveness of HSE risk controls must be verified by the responsible line manager at a frequency commensurate with the risk. Where change is required, a formal review (e.g. Management of Change or Case to Operate as required) must be undertaken to determine that risks remain at tolerable levels.

3.14 Documented HSE plans including environmental plans and Safety Cases must provide the clear identification of all critical controls and associated Performance Standards.

ELEMENT 4

PLANNING, GOALS AND TARGETS

INTENT

Petroleum goals and targets are established as an integral part of the business planning process and set to drive continual improvement in performance.

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PERFORMANCE REQUIREMENTS

Petroleum Alignment Process

4.1 Petroleum CSG level HSE objectives must be established by the Petroleum Leadership Team.

HSE Goals and Targets

4.2 Petroleum sites must establish, document and communicate HSE goals and targets that are aligned with Petroleum CSG level HSE Objectives. For Production Division, this includes setting process safety goals and targets.

4.3 When establishing HSE goals and targets, leading as well as lagging metrics should be identified.

4.4 Goals and targets must be structured to deliver continual improvement, reduce the HSE risk profile and must contribute to the achievement of Petroleum's CSG level HSE Objectives.

4.5 Goals, targets and the related leading and lagging metrics must be developed for each financial year and included in the Petroleum budget process.

HSE Performance

4.6 Petroleum sites must monitor, track for compliance and formally record, report and communicate progress on goals and targets on a monthly basis, in accordance with Petroleum HSE reporting requirements.

4.7 The results from monthly HSE performance tracking must be used to identify trends and any areas that require improvement. This includes an assessment on the suitability of the leading and lagging metrics.

4.8 Where HSE performance trends indicate that inadequate or ineffective HSE risk controls are in place, those risks must be reported to the relevant manager and be re-assessed and revised controls must be implemented.

HSE Plans

4.9 Petroleum sites must establish HSE action plans that contain the means, timeframe and assigned responsibilities for achieving HSE goals and targets.

4.10 Plans commensurate with the risk, must be established as appropriate to achieve compliance with Petroleum HSE Controls. HSE plans include:

- Health Surveillance plans.
- Environmental Management plans.
- Safety Management plans.
- Construction plans.
- Commissioning plans.
- Closure plans.

ELEMENT 5

AWARENESS, COMPETENCY AND BEHAVIOR

INTENT

Employees, contractors and visitors are aware of relevant requirements, hazards, risks and controls, and are competent to conduct their activities and behave in a responsible manner.

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PERFORMANCE REQUIREMENTS

HSE Awareness and Competency

5.1 Hazards and controls, expected behaviors, Petroleum Policies, Standards and Procedures, and HSE competencies must be understood by the relevant Petroleum personnel.

HSE Induction Process

5.2 HSE inductions must be conducted for new employees, contractors and visitors arriving at any Petroleum location. Inductions must be appropriate to the nature and risks of the Petroleum location.

5.3 Records of inductees and induction assessments results must be maintained.

5.4 The induction processes must be reviewed for currency and relevance at least annually, or in the event of material change to hazards, risks and controls.

5.5 Each site must determine the frequency with which personnel are required to undertake refresher inductions. The frequency must be based on the HSE risks and endorsed by the relevant site manager.

Competency Assurance and Training

5.6 Role specific HSE competencies must be established and maintained for all Petroleum positions.

5.7 The HSE competencies must be used to conduct a training needs analysis for each employee. The outcome of the analysis must be documented in a training plan which includes timeframes to develop role specific competencies, certification/re-certification requirements and expected performance outcomes. These plans must include training in applicable Petroleum HSE competencies.

5.8 Personnel involved with controlled activities at Petroleum sites must undertake competency based HSE training and assessment that is relevant and appropriate to their roles. Where applicable, this includes compliance with the Petroleum Competency Assurance Training requirements.

5.9 The management of competency assessments including expiration dates, records and results, must, as a minimum, be maintained in a local HSE training database.

Behavioral-Based Observation System

5.10 Petroleum sites must adopt the Petroleum Behavioral-Based Observation System for making and reporting observations of safe and unsafe conditions and behaviors.

5.11 Detailed information from the Behavioral-Based Observation System must be recorded in a common database and reported monthly at each site.

5.12 Observations must be analyzed by appropriately trained personnel to develop trends and identify focus areas for HSE improvement initiatives.

ELEMENT 6

COMMUNICATION, CONSULTATION AND PARTICIPATION

INTENT

Effective, transparent and open communication and consultation is maintained with stakeholders associated with Petroleum's activities. Stakeholders are encouraged to contribute and participate in performance improvement initiatives.

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PERFORMANCE REQUIREMENTS

Stakeholder Management

6.1 Petroleum sites must identify relevant internal and external stakeholders and document their HSE needs in a stakeholder management plan.

6.2 The stakeholder management plan must comply with the relevant requirements defined by the Petroleum External Affairs Function.

Stakeholder Consultation and Participation

6.3 Managers responsible for Petroleum sites must consult with affected stakeholders and communicate relevant HSE issues.

6.4 Systems must be established to facilitate participation of personnel and external stakeholders, as appropriate, in HSE meetings, development of HSE programs and assessment of HSE performance.

6.5 A record of stakeholder consultations and participation, including attendees, issues discussed and outcomes/actions must be maintained and formally communicated to all relevant stakeholders.

Stakeholder Communication Processes

6.6 Petroleum sites must ensure that HSE information communicated to personnel is accurate and current.

6.7 Methods for communicating HSE information must include, as a minimum, inductions, training, Petroleum HSE portal, HSE alerts and regular HSE meetings.

6.8 Petroleum sites must document all communications with (to and from) stakeholders and ensure that complaints are managed and formally closed-out.

6.9 HSE information including learnings from significant incidents, reviews and audits, must be shared with appropriate stakeholders in accordance with the Petroleum Information Sharing and Communication Procedure.

ELEMENT 7

DESIGN, CONSTRUCTION AND COMMISSIONING

INTENT

Management of risks and opportunities is an integral part of all projects through design, approval, procurement, construction and commissioning.

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PERFORMANCE REQUIREMENTS

HSE Management

7.1 Development activities for new projects, facilities modifications and engineering change must assure adequacy of HSE design requirements and must comply with the relevant requirements of the HSE Management System, Safety Case, Central Engineering requirements and other HSE Controls. A project specific HSE plan that describes how these HSE requirements are managed, must be established and maintained.

7.2 Where activities require management of specific HSE risks and impacts, these must be assessed using risk management procedures to ensure minimum mandatory controls are in place.

HSE and Technical Criteria

7.3 Projects must ensure relevant technical and Performance Standards, including all Petroleum HSE Controls, are adopted for the design and selection of plant, equipment and processes.

7.4 The Project Director is accountable for the inclusion of HSE risk and life of asset assessment processes as part of the design and selection criteria.

7.5 Operating parameters must be specified during the design phase and approved by the relevant Petroleum technical authority.

Incorporation of HSE Learnings

7.6 HSE learnings, including those from previous projects and significant incidents, must be included within the project development processes, utilizing relevant information from First Priority (FPe) and other relevant sources (e.g. Post Implementation Reviews, etc).

Project Review and Tollgating

7.7 Tollgate peer reviews must be conducted in accordance with the Independent Peer Review Procedure and include, where appropriate, review of projects against Performance Standards and Central Engineering Requirements.

7.8 Projects must be assessed against the requirements defined in Safety Case procedures and commitments identified during any environmental and social impact assessments in accordance with Environment Controls.

7.9 Central Engineering must review projects against identified Performance Standards and Central Engineering Requirements (e.g. Petroleum Maintenance and Integrity Management requirements).

7.10 Pre-startup and post-startup reviews for newly installed and modified plant and equipment must be conducted.

7.11 Reviews must involve HSE personnel and assess the adequacy, quality, status and suitability of HSE requirements and performance.

7.12 Learnings from pre-startup and post-startup reviews must be shared within Petroleum via the Central Engineering department.

Critical Equipment, Systems and Procedures

7.13 Projects must define and document the criteria for identifying and validating critical equipment, systems and procedures.

7.14 Critical equipment, systems and procedures must be documented and included in the Development and Design Safety Cases and in relevant environment plans.

Commissioning Plans

7.15 Commissioning plans must be established for projects and must include the controls identified in the commissioning HSE risk assessment, and clearly define the required competencies and responsibilities of personnel.

Handover

7.16 Projects must plan for timely handover and acceptance of all relevant drawings, manuals, procedures and other documentation for critical equipment and systems prior to commissioning.

7.17 A formal and documented handover process between the Project Director and the Production Unit Manager must be carried out upon completion of the project execution, and where relevant, before the introduction of hydrocarbons. The handover process must include key hold points and an agreed handover date.

7.18 Completion of the handover phase must be acknowledged by a written agreement between the Project Director and the Production Unit Manager.

ELEMENT 8

OPERATIONS AND MAINTENANCE

INTENT

All plant and equipment is operated, maintained, inspected and tested using systems and procedures that manage risks.

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PERFORMANCE REQUIREMENTS

Operating Systems and Procedures

8.1 Procedures for operating and maintenance of critical plant and equipment must be documented.

Safe Systems of Work

8.2 Petroleum safe systems of work that comply with relevant aspects of the Global Operations requirements (e.g. Permit to Work, Isolations, etc.), risk management procedures, HSE Controls, and Performance Standards must be implemented and maintained.

Design Data and Operating Criteria

8.3 Petroleum design information and operating limits must be included in Operations Safety Case documentation.

8.4 Plant and equipment must be operated and maintained according to design data and operating criteria, Performance Standards, manufacturer and vendor specifications, Petroleum HSE Controls and Global Operations requirements.

8.5 Operating parameters must be formally reviewed to ensure that they remain effective, safe and valid, based on operational requirements. This review must be conducted annually, or in the event of a material change, at a frequency commensurate with the identified HSE risk.

8.6 Deviation from specified parameters can only be authorized through formal Management of Change process and the Case to Operate process.

Operating Parameters and Reliability Criteria

8.7 Petroleum sites must ensure that relevant operating parameters, equipment performance and reliability criteria are established, documented and monitored in accordance with requirements detailed in the facility's Safety Case, Performance Standards and local level maintenance systems. The frequency of monitoring, testing and verification must be defined in the local level maintenance systems.

8.8 Information on excursions outside defined operating parameters, equipment performance and equipment reliability must be recorded and reported to the relevant manager.

Equipment Integrity and Maintenance Criteria

8.9 Petroleum sites must assess the integrity of equipment and facilities in accordance with the Petroleum Maintenance and Integrity Management requirements.

8.10 Records of integrity audits, regulatory inspections and equipment certification must be recorded, maintained and reported to the site manager by the appointed system custodian.

Critical Systems and Procedures

8.11 Operating procedures and Performance Standards for critical equipment and systems must be established, assessed and verified in accordance with the requirements of the Safety Case and applicable regulatory requirements.

Simultaneous Operations Criteria

8.12 Petroleum sites must implement and maintain systems that define the approval and control processes necessary for simultaneous operations.

8.13 Simultaneous operations risks must be managed in accordance with the risk performance requirement in Element 3 of this document.

8.14 HSE risk controls associated with simultaneous operations must be tested against the hierarchy of controls.

8.15 Bridging documentation that defines the interfaces for simultaneous operations involving concurrent activities on a controlled site must be developed, as required. Bridging documentation must be formally approved by the site manager and issued to all parties prior to commencement of simultaneous operations.

ELEMENT 9

DOCUMENTS AND RECORDS

INTENT

An effective HSE document control system is in place and records are properly managed.

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PERFORMANCE REQUIREMENTS

Document Control

9.1 HSE documents must be readily available and understood.

9.2 The Petroleum HSE Management System must provide a centralized process for the control and management of Petroleum HSE documentation, including Polices, Standards, Procedures, Guidelines, forms, training materials and templates.

9.3 The initiation, development, authorization, control and review cycle for Petroleum CSG level HSE documents must be in accordance with the Petroleum HSE Document and Records Management Procedure.

9.4 Petroleum sites must implement a process that uses Documentum for controlling HSE related local level documentation. This process must ensure that controlled documents are current, traceable to the activities involved, can be located, uniquely identified, periodically reviewed and authorized. The process must also specify the method for the prompt removal of obsolete versions.

9.5 Documents from external sources necessary for the planning and operation of Petroleum activities must be maintained on a register and current.

Records Management

9.6 HSE records must be managed using Documentum as appropriate, to ensure their identification, maintenance, safe storage, retrieval and disposal complies with the requirements of the HSE Document and Records Management Procedure.

9.7 Retention times must be established and all HSE records managed in accordance with the HSE Document and Records Management Procedure.

9.8 Access to records must be controlled to ensure authorized access, security of information and relevant levels of confidentiality.

HSE Management System Documentation

9.9 Petroleum sites must describe their local level HSE Management System, including references and directions to related documents and records, in a controlled manual. This manual must also describe the interrelation between the local level HSE Management System and the Petroleum HSE Management System document.

ELEMENT 10

SUPPLIERS, CONTRACTORS AND PARTNERS

INTENT

The contracting of services, the purchase, hire or lease of equipment and materials, and activities with partners, are carried out so as to minimize any adverse HSE consequences.

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PERFORMANCE REQUIREMENTS

Risk Assessment of Goods and Services

10.1 Contract owners must identify and assess the level of HSE risk associated with services, contracts, agreements or partnerships.

10.2 HSE risks must be assessed and ranked in accordance with the requirements of the Petroleum risk management procedures and the Contractor and Supplier HSE Management Procedure.

Evaluation of Suppliers, Contractors and Partners

10.3 As part of the broader Petroleum supplier engagement process, an HSE evaluation of suppliers, partners and contractors must be conducted in accordance with the Petroleum Contractor and Supplier HSE Management Procedure. The HSE evaluation must be conducted prior to approval for award of a new contract or agreement.

10.4 The selection and evaluation process must include representation from HSE, the requesting group and Petroleum Supply function.

10.5 The evaluation must include a review of the suppliers', partners' or contractors' management systems against Petroleum HSE Management System requirements, identification of controls to ensure alignment with Petroleum HSE requirements and previous HSE performance.

HSE Contractual Requirements

10.6 Petroleum contracts and agreements must contain relevant HSE obligations and requirements, including, but not limited to, the requirement to comply with Petroleum Policies, Standards, Procedures and relevant legislation, and for the disclosure of information relating to hazards, previous HSE performance and learnings from such performance.

Contract Ownership

10.7 All contracts and agreements must have a single designated contract sponsor who is accountable for ensuring compliance with the HSE requirements of the contract.

HSE Management Processes and Interfacing

10.8 Bridging documentation commensurate with the nature of the contract must be established, approved, in place and formally communicated to relevant parties prior to execution of the services in the contract.

10.9 Where there is a conflict between the Petroleum HSE Management System Performance Requirements and those normally used by contractors or suppliers, the higher level performance requirements must be applied and implemented.

10.10 Contractor activities must be monitored and inspected to ensure compliance with relevant Petroleum HSE Policies, Standards, Procedures and agreed HSE performance requirements. The contract sponsor must ensure that appropriate personnel carry out contractor monitoring and inspection activities.

Suitability and Approval of Equipment and Materials

10.11 Equipment and materials used in Petroleum activities must be fit for purpose, inspected and approved for use by technically competent personnel and compliant with HSE requirements. Inspections and approvals must be documented (e.g. audits and inspection reports) and completed prior to purchase or lease, as appropriate.

Local Suppliers and Contractors

10.12 Petroleum contract specialists must coordinate the identification and assessment of local providers to confirm capability of providing the requisite equipment, supplies or services and meeting Petroleum HSE requirements for inclusion on Suppliers, Contractor and Tender Listings. Approved local providers must be included in the tendering process.

Monitored Activities and Joint Venture Partners

10.13 Where a JVOA (Joint Venture Operating Agreement) is to be agreed, appropriate HSE expectations must be included within the agreement.

10.14 This document and other applicable Petroleum documents must be made available to the operator of monitored activities and where Petroleum has an equity stake but does not have operational responsibility.

10.15 Managers responsible for monitored activities or a joint venture must encourage the operator to establish and maintain comparable management systems consistent with the Petroleum HSE Management System.

ELEMENT 11

INCIDENTS, EMERGENCIES AND SECURITY

INTENT

HSE incidents, emergencies and security risks are reported, investigated and analyzed. Corrective actions are taken and learnings shared. Procedures and resources are in place to effectively respond to crisis and emergency situations.

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PERFORMANCE REQUIREMENTS

Incident Reporting and Investigation

11.1 Petroleum sites must respond to, report and investigate incidents according to the Petroleum HSE Incident Management and Reporting procedures.

Business Continuity, Crisis and Emergency Management

11.2 Petroleum sites must develop and implement a Business Continuity Plan. This plan must be consistent with the Petroleum CSG Business Continuity Plan.

11.3 Petroleum sites must develop and implement a Crisis and Emergency Plan for foreseeable scenarios in accordance with the requirements of the Petroleum Crisis and Emergency Management Procedure. This plan must include the resources, response tasks and mitigation controls for each scenario.

11.4 These plans must be aligned with the Petroleum HSE Incident Management and Reporting procedures.

Security

11.5 A security threat risk assessment must be completed annually for each site or facility. The assessment must be reviewed following "any" significant security incident.

11.6 Security Controls must be in place to manage identified security risks at Petroleum sites and facilities in accordance with the Petroleum Security Controls and supporting procedures.

Corrective and Preventive Action Management

11.8 First Priority (FPe) must be used to track, and manage to closure, all corrective and preventive actions arising from incidents and emergencies.

11.9 Once corrective and preventive actions arising from incidents and emergencies have been implemented, their effectiveness must be verified and recorded by the responsible manager.

Communication

11.10 Information from incidents and emergencies must be analyzed to identify trends and learnings.

11.11 Learnings must be communicated to affected personnel and shared, where deemed applicable within Petroleum.

11.12 Information from exercises, drills and emergencies must be assessed and communicated to accountable personnel according to the requirements of the Petroleum Crisis and Emergency Management Procedure.

Significant Incidents and Emergencies

11.13 When a significant incident or emergency occurs at any Petroleum site, affected work must cease and not re-start until such time as the work areas affected have been risk assessed and the relevant manager has verified that effective controls, to prevent recurrence, are in place.

11.14 Managers must ensure that information received about a significant incident or an emergency is reviewed, and learnings are applied as appropriate, to prevent a recurrence at their site.

ELEMENT 12

MANAGEMENT OF CHANGE

INTENT

Planned and unplanned changes are identified and managed.

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PERFORMANCE REQUIREMENTS

Change Management

12.1 Where change occurs to equipment, operating processes, procedures or personnel, or where the potential for HSE impact from change exists, assessment of the change must be conducted utilizing the Petroleum management of change procedures, including formal approval of the change and implementation of effective change management controls.

12.2 A register must be used to record all engineering changes. The register must be maintained, current and be available to the Central Engineering function.

12.3 A risk assessment must be conducted where a change affects the design basis, operating parameters and controls, to verify that the change does not compromise the site's license to operate.

12.4 Managers must ensure that risks from a proposed change have been formally assessed and reviewed by competent technical and operational personnel.

12.5 Change requires formal approval by the responsible line manager, HSE, technically competent person(s), operationally competent person(s) and/or the Site Manager.

12.6 Where the potential exists for Petroleum-wide change requirements, the VP Engineering must approve such change.

Temporary Change Extension and Close Out

12.7 Where extension to approved durations for a temporary change is required, a formal review must be undertaken and approval obtained in accordance with the Petroleum management of change procedures.

12.8 Close out of a temporary change must be carried out in accordance with the Petroleum management of change procedures.

Change Authority Levels

12.9 Petroleum sites must establish and document approval authority levels commensurate with the HSE risk of the change.

Management of Change Processes

12.10 The management of change procedures must be used to assess changes including change to equipment, operations, personnel or business processes, and to identify controls required to manage the change, prior to approval.

Change Management Documentation

12.11 All changes must be documented in accordance with the requirements of the Petroleum management of change procedures and the site's document control procedures (see Element 9).

12.12 Managers must ensure that documents, plans and records are updated to reflect changes, and that changes to these documents, plans and records are clearly identified and formally communicated to all affected groups and stakeholders.

12.13 Where formal documentation changes have not been completed prior to implementation of a change, a record of the change (such as a red-line drawing) must be in place at the affected location, until the updated documentation is in place, to ensure accuracy and currency of documentation. Documentation (such as a red line drawing) must be updated before close out of the change record.

ELEMENT 13

HEALTH AND HYGIENE

INTENT

Employees and contractors are assessed for their fitness to work and are protected from health hazards associated with Petroleum activities.

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PERFORMANCE REQUIREMENTS

Qualitative Exposure Assessment

13.1 Assessment of employees must be conducted by a competent occupational hygiene professional and be completed in accordance with Petroleum Health and Hygiene Procedures. The assessment must include potential exposure to Similar Exposure Groups (SEGs).

13.2 Assessments must consider the work, environment, processes, tools, equipment and all credible occupational exposures for each SEG.

13.3 Exposure types must be ranked to prioritize the highest risks to the workforce, and be reviewed as a minimum every five years, or when change potentially affects the level of exposure.

Quantitative Exposure Assessment

13.4 A monitoring strategy based on the exposure profiles created during the qualitative assessment must be developed in accordance with Petroleum Health and Hygiene Procedures.

13.5 Monitoring must be supervised by a competent hygiene professional. Samples must be obtained using appropriately calibrated equipment and sent to a certified laboratory.

13.6 Monitoring data must be statistically analyzed to quantify the profile of all exposure groups.

Exposure Control Plan

13.7 When exposures exceed 50% of specified exposure limits, controls to mitigate exposure must be assessed for effectiveness, documented and actions assigned utilizing the requirements of the Petroleum Health and Hygiene Procedures.

Health Surveillance

13.8 Medical assessments must be undertaken for all Petroleum and contractor personnel in accordance with Petroleum Health Surveillance Procedures.

13.9 Biological monitoring must be implemented where exposures exceed 50% of limits.

13.10 Where noise exposure cannot be adequately controlled by elimination at source, PPE must be used and a hearing conservation program, including audiometry implemented.

13.11 Where respiratory hazard exposure cannot be adequately controlled by elimination at source, PPE must be used and a respiratory protection program implemented.

Fatigue Management

13.12 Fatigue management risk assessments must be conducted for all Petroleum controlled sites in accordance with Petroleum Fatigue Management Procedure. The risk assessment must be documented and reviewed at a minimum every five years or when schedules are changed.

13.13 Supervisors responsible for creating and implementing work/shift schedules must review and adjust schedules, and track/review overtime hours to ensure compliance with the Petroleum Fatigue Management Procedure.

13.14 Fatigue management requirements must be considered where company travel is required.

13.15 Risk controls for mitigating fatigue must be applied using the hierarchy of controls.

13.16 Training must be provided to assist employees in recognizing and managing fatigue. This training must also assist supervisors in recognizing and managing fatigue risks with their personnel.

Drug and Alcohol Program

13.17 Petroleum controlled locations and activities must implement a drug and alcohol testing program in accordance with the Petroleum Drug and Alcohol Procedure.

13.18 The program must provide awareness of the Employee Assistance Program (EAP) which can be used to provide support and rehabilitation for employees with drug and/or alcohol problems.

Reporting and Management Review

13.19 Results of monitoring and surveillance must be available to participating individuals.

13.20 Management review of all occupational health and hygiene programs, incidents and opportunities for improvement must be conducted annually.

ELEMENT 14

AVIATION AND MARINE OPERATIONS AND FATAL RISK CONTROLS

INTENT

Controls are identified and in place to manage occupational hazards arising from behaviors, procedures/practices, plant, equipment, workplace conditions and transportation.

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PERFORMANCE REQUIREMENTS

Aviation Operations

14.1 Aviation activities must be conducted in accordance with the Petroleum Aviation Operations Controls. The Aviation Controls include requirements for:

- Establishing a local level aviation management procedure.
- Defining roles, responsibilities and authority levels for aviation activities.
- Compliance with aviation regulatory and other requirements.
- Requirements to conduct aviation risk assessment, and the implementation of controls including a Journey Management Plan and Search and Rescue Plan.
- Formal evaluation and approval of suppliers of chartered aviation operators and related services, and format for written agreements with chartered aircraft operators.
- Chartered aircraft operating requirements including pilot qualifications and experience.

14.2 The Aviation Controls document must be reviewed at least annually against applicable international standards and regulations.

Marine Operations

14.3 Marine operations must be conducted in accordance with the Petroleum Marine Operations Controls. The Marine Operations Controls include requirements for:

- Establishing a local level marine operations management procedure.
- Defining roles, responsibilities and authority levels for marine operations.
- Compliance with marine operations regulatory and other requirements.
- Requirements to conduct marine operations risk assessment, and the implementation of controls.
- Formal evaluation and approval of suppliers of marine contractors, marine vessels and related services, and format for written agreements with marine operators.
- Requirements for marine operation equipment and services including qualifications and experience.

14.4 The Marine Operations Controls document must be reviewed at least annually against applicable international standards and regulations.

Fatal Risk Controls

14.5 Sites must implement the relevant requirements defined in the Petroleum Fatal Risk Controls to manage activities associated with:

- Company light vehicles used for transportation of personnel.
- Use of mobile equipment on Petroleum sites including inspection and maintenance programs.
- Handling, processing and loss of containment of process materials.
- Working with pressure, hydrogen sulphide (H_2S), explosives and other hazardous materials.
- Implementation of process safety controls such as isolation and permit to work, including the managing risks associated with confined spaces.
- Safeguarding of personnel from hazards relating to plant and equipment.
- Identification, assessment and management of risks from lifting operations, work at height and risks from dropped objects.
- Diving operations and activities.

14.6 The Fatal Risk Controls must be reviewed at least annually. This review must incorporate:

- Learnings from HSE performance and incidents.
- Emerging industry trends.
- Relevance and suitability of specifications for plant and equipment.
- Requirement for documented procedures.
- Outcomes of risk assessments.
- Training to manage hazards and eliminate at-risk behaviors.

ELEMENT 15

ENVIRONMENT

INTENT

The environmental impacts associated with activities, resources, materials, processes and products are identified, minimized and managed.

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PERFORMANCE REQUIREMENTS

Impacts Assessment

15.1 Petroleum sites including development activities must assess the environmental impacts for the following relevant aspects:

- Air emissions from combustion, flaring, venting, and fugitive gases.
- Greenhouse gas emissions.
- Energy efficiency and consumption.
- Protection of biodiversity values and sensitive areas.
- Discharges of drilling mud and cuttings and produced formation water.
- Disturbance of land, freshwater and marine areas, including facilities, storage tanks and pipelines.
- Water usage and impacts to surface and ground water.
- Waste generated from Petroleum operations.
- Noise and vibration.
- The environmental impacts associated with Petroleum products.

Environmental Controls

15.2 Sites and development activities must implement the relevant requirements defined in the Petroleum Environment Controls to manage environmental aspects of its activities.

15.3 The Environment Controls document must be reviewed at least annually against applicable international standards and regulations.

Management Plans

15.4 Sites and development activities must develop and implement documented management plans for the relevant environmental aspects listed in Element 15.1. Management plans must comply with the relevant requirements detailed in the Environment Controls, and be kept up to date.

ELEMENT 16

MONITORING, AUDITS AND REVIEWS

INTENT

HSE performance and systems are monitored, audited and reviewed to identify trends, measure progress, assess compliance and drive continual improvement.

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PERFORMANCE REQUIREMENTS

HSE Reporting

16.1 HSE performance is reported in accordance with the Petroleum HSE Reporting Procedure.

HSE Performance Data Reporting

16.2 Each site must have systems for the collection, storage and retrieval and verification of HSE performance data used for internal and external reporting. These systems must include processes to ensure HSE data is accurate and auditable back to source. Equipment used for measuring HSE data must be calibrated in accordance with the manufacturer's specifications and records of calibration must be retained. All HSE data used for reporting purposes must be authorized by the site manager prior to release.

16.3 HSE performance, including progress against HSE Objectives, goals, compliance with requirements in the Compliance and Commitments Register and status of HSE KPIs, must be regularly measured, monitored and recorded.

16.4 HSE performance results must be analyzed and trends developed and communicated.

HSE Inspections and Audits

16.5 HSE system audits and HSE inspections must be conducted for each Petroleum site at frequencies commensurate with the HSE risks.

16.6 An audit and inspection schedule must be developed by all sites. The schedule must include:

- Self assessment against the Petroleum HSE Management System.
- Self assessment against Petroleum HSE Controls.
- Reviews to evaluate compliance with the legal and other requirements in the Compliance and Commitments Register.
- ISO14001 and OHSAS 18001 compliance.
- A Petroleum tri-annual external (to the operation) compliance assessment.

HSE Self Assessments

16.7 Annual self-assessment against the Petroleum HSE Management System and Petroleum HSE Controls and Procedures, must be conducted in accordance with the audit and inspection schedule.

16.8 Audit/assessment teams must include relevant technical expertise and external (to the operation) participants as required. Team members must be independent from the area being audited. Approval for the team structure must be commensurate with the nature of audit/assessment.

Corrective and Preventive Action Management

16.9 First Priority (FPe) must be used to report and manage non-compliances, actions and improvement plans resulting from audits and inspections.

16.10 Progress against actions and improvement plans must be monitored and reported to the Site Manager monthly.

16.11 Once corrective and preventive actions have been implemented, their effectiveness must be verified by the responsible line manager and endorsed by the Site Manager.

Ownership, Accountability and Management Review

16.12 Site Managers with accountability for sites must conduct a formal annual management review to verify the implementation, adequacy and effectiveness of the HSE Management system. Information to be reviewed includes results of inspections, audits and self-assessments, incident reports, HSE performance, status of corrective and preventive actions and views of relevant stakeholders.

16.13 Management reviews including observations and recommended actions must be documented and implemented.

DEFINITIONS AND REFERENCES

Definitions

For general terms and definitions, refer to Glossary of BHP Billiton Terms and the Petroleum Glossary. Terms in the electronic version of HSE Management System available on the Petroleum HSE Portal, have hyperlinks to the definitions in either the Glossary of BHP Billiton Terms or the Petroleum Glossary.

References

For a complete and up-to-date list of the most current version of supporting references, refer to the electronic version of this document located on the Petroleum Portal.

Supporting reference documentation may include:

- Petroleum HSE Controls (Environment Controls, Health and Hygiene Controls, Fatal Risk Controls, Aviation Controls and Marine Controls).
- Petroleum HSE Management System documentation (via the Petroleum HSE Portal).
- Other Petroleum Documents (via the Petroleum Portal).
- External documents such as ISO14001 and OHSAS 18001.

BHP Billiton Petroleum supporting documentation will be made available to relevant external stakeholders such as suppliers, contractors and visitors as required and on a case-by-case basis.

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