Gorgon Gas Development and Jansz Feed Gas Pipeline:

Coastal and Marine Baseline State and Environmental Impact Report Appendices

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Appendices

Appendix 1 Identification and Risk Assessment of Marine Matters of National Environmental Significance (NES)

Chevron

Gorgon Gas Development and Jansz Feed Gas Pipeline:

Appendix: Identification of Marine Matters of National Environmental Significance (NES) and their Habitat

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1.0 Environment Protection and Biodiversity Conservation Act (Cth) Listed Species

A number of marine species that occur in Barrow Island waters in the vicinity of the Marine Facilities of the Gorgon Gas Development and Jansz Feed Gas Pipeline are protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Cth). EPBC Act listed species were identified in the Draft Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) (Chevron Australia 2005) and were reviewed during the preparation of the Public Environmental Review (PER) (Chevron Australia 2008) for the Revised and Expanded Gorgon Gas Development. The marine species identified to date fall within a number of different protection categories under the EPBC Act; however, only those listed as threatened fauna species or listed as migratory species are identified in this Appendix. The threatened species categories, as stated in section 179 of the EPBC Act are:

- Extinct
- Extinct in the wild
- Critically endangered
- Endangered
- Vulnerable
- Conservation dependent.

There are 81 marine species that may occur in the waters surrounding the Gorgon Gas Development and Jansz Feed Gas Pipeline Marine Facilities on the east and west coasts of Barrow Island and that are listed under the EPBC Act as either threatened and/or migratory species. The 81 protected species include nine species of marine mammals, six species of marine reptiles, three species of fish, and 63 species of birds. These species have been identified via a review of journal articles, survey reports, the Draft EIS/ERMP (Chevron Australia 2005), the PER (Chevron Australia 2008) and searches of the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC; formerly the Department of Environment, Water, Heritage and the Arts [DEWHA]) current EPBC Act List of Threatened Fauna Species (DEWHA 2009), List of Migratory Species (DEWHA 2009a) and Species Profile and Threats (SPRAT) Database (DEWHA 2010).

The EPBC Act listed threatened fauna species and listed migratory species that may occur within the vicinity of the Marine Facilities are listed in Table 1.1 and described in Section 1.1 (marine mammals), Section 1.2 (marine reptiles), Section 1.3 (fish) and Section 1.4 (avifauna). Section 2.0 describes the risk assessment process used to determine which listed threatened fauna species and listed migratory species and their habitat, are at risk of Material or Serious Environmental Harm from construction and operation of the Marine Facilities.

Table 1.1 EPBC Act Listed Threatened Fauna Species and Listed Migratory Species that may occur in the vicinity of the Marine Facilities, Barrow Island

Species	Scientific Name	EPBC Act (Cth) Status
Marine Mammals		
Humpback Whale	*Megaptera novaeangliae*	Vulnerable, Migratory
Blue Whale	*Balaenoptera musculus*	Endangered, Migratory
Bryde’s Whale	*Balaenoptera edeni*	Migratory
Killer Whale	*Orcinus orca*	Migratory
Dusky Dolphin	*Lagenorhynchus obscurus*	Migratory
Irrawaddy Dolphin	*Orcaella heinsohni*	Migratory
Indo-Pacific Humpback Dolphin	*Sousa chinensis*	Migratory

Species	Scientific Name	EPBC Act (Cth) Status
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations)	*Tursiops aduncus* (Arafura/Timor Sea populations)	Migratory
Dugong	*Dugong dugon*	Migratory
Marine Reptiles		
Olive Ridley Turtle	*Lepidochelys olivacea*	Endangered, Migratory
Loggerhead Turtle	*Caretta caretta*	Endangered, Migratory
Leatherback Turtle	*Dermochelys coriacea*	Vulnerable, Migratory
Hawksbill Turtle	*Eretmochelys imbricata*	Vulnerable, Migratory
Flatback Turtle	*Natator depressus*	Vulnerable, Migratory
Green Turtle	*Chelonia mydas*	Vulnerable, Migratory
Fish		
Whale Shark	*Rhincodon typus*	Vulnerable, Migratory
Great White Shark	*Carcharodon carcharias*	Vulnerable, Migratory
Grey Nurse Shark	*Carcharias taurus*	Vulnerable
Marine Avifauna		
Anatidae (ducks, geese and swans)		
Black Swan	*Cygnus atratus*	Migratory
Australian Wood Duck	*Chenonetta jubata*	Migratory
Grey Teal	*Anas gibberifrons*	Migratory
Procellariidae (shearwaters)		
Wedge-tailed Shearwater	*Puffinus pacificus*	Migratory
Diomedeidae (albatrosses)		
Yellow-nosed Albatross	*Diomedea chlororhynchos*	Migratory
Hydrobatidae (storm-petrels)		
Wilson's Storm Petrel	*Oceanites oceanicus*	Migratory
Sulidae (gannets and boobies)		
Masked Booby	*Sula dactylatra*	Migratory
Brown Booby	*Sula leucogaster*	Migratory
Fregatidae		
Lesser Frigatebird	*Fregata ariel*	Migratory
Ardeidae (herons and egrets)		
Eastern Reef Egret	*Ardea (Egretta) sacra*	Migratory
Great Egret	*Ardea (Egretta) alba*	Migratory
Accipitridae (kites, hawks and eagles)		
Osprey	*Pandion haliaetus*	Migratory
Black-shouldered Kite	*Elanus notatus*	Migratory
Square-tailed Kite	*Lophoictinia isura*	Migratory
Black-breasted Buzzard	*Hamirostra melanosternon*	Migratory
Whistling Kite	*Haliastur sphenurus*	Migratory
Brahminy Kite	*Haliastur indus*	Migratory
White-bellied Sea-eagle	*Haliaeetus leucogaster*	Migratory
Spotted Harrier	*Circus assimilis*	Migratory
Wedge-tailed Eagle	*Aquila audax*	Migratory
Falconidae (falcons)		
Brown Falcon	*Falco berigora*	Migratory
Australian Hobby	*Falco longipennis*	Migratory
Nankeen Kestrel	*Falco cenchroides*	Migratory

Species	Scientific Name	EPBC Act (Cth) Status
Scolopacidae (sandpipers)		
Black-tailed Godwit	*Limosa limosa*	Migratory
Bar-tailed Godwit	*Limosa lapponica*	Migratory
Little Curlew	*Numenius minutus*	Migratory
Whimbrel	*Numenius phaeopus*	Migratory
Eastern Curlew	*Numenius madagascariensis*	Migratory
Marsh Sandpiper	*Tringa stagnatalis*	Migratory
Common Greenshank	*Tringa nebularia*	Migratory
Wood Sandpiper	*Tringa glareola*	Migratory
Terek Sandpiper	*Xenus cinerea (Tringa terek)*	Migratory
Common Sandpiper	*Tringa hypoleucos*	Migratory
Grey-tailed Tattler	*Tringa brevipes*	Migratory
Ruddy Turnstone	*Arenaria interpres*	Migratory
Great Knot	*Calidris tenuirostris*	Migratory
Red Knot	*Calidris canutus*	Migratory
Sanderling	*Calidris alba*	Migratory
Red-necked Stint	*Calidris ruficollis*	Migratory
Sharp-tailed Sandpiper	*Calidris acuminata*	Migratory
Curlew Sandpiper	*Calidris ferruginea*	Migratory
Recurvirostridae (stilts and avocets)		
Black-winged Stilt	*Himantopus himantopus*	Migratory
Banded Stilt	*Cladorhynchus leucocephalus*	Migratory
Charadriidae (lapwings and plovers)		
Pacific Golden Plover	*Pluvialis fulva*	Migratory
Grey Plover	*Pluvialis squatarola*	Migratory
Red-capped Plover	*Charadrius ruficapillus*	Migratory
Lesser Sand Plover	*Charadrius mongolus*	Migratory
Greater Sand Plover	*Charadrius leschenaultia*	Migratory
Oriental Plover	*Charadrius veredus*	Migratory
Glareolidae (waders)		
Oriental Pratincole	*Glareola maldivarum*	Migratory
Laridae (gulls and terns)		
Lesser Crested Tern	*Sterna bengalensis*	Migratory
Roseate Tern	*Sterna dougallii*	Migratory
Common Tern	*Sterna hirundo*	Migratory
Little Tern	*Sterna albifrons*	Migratory
Bridled Tern	*Sterna anaethetus*	Migratory
Caspian Tern	*Sterna caspia*	Migratory
White-winged Black Tern	*Chlidonias leucoptera*	Migratory
Sternidae (terns)		
Australian Lesser Noddy	*Anous tenuirostris melanops*	Vulnerable
Cuculidae (cuckoos)		
Oriental Cuckoo	*Cuculus saturatus*	Migratory
Strigidae (hawk-owls)		
Southern Boobook Owl	*Ninox novaeseelandiae*	Migratory
Apodidae (swifts)		
Fork-tailed Swift	*Apus pacificus*	Migratory
White-throated Needletail	*Hirundapus caudacutus*	Migratory

Species	Scientific Name	EPBC Act (Cth) Status
Motacillidae (pipits and true wagtails)		
Yellow Wagtail	*Motacilla flava*	Migratory

Sources: Chevron Australia (2005, 2008), DEWHA (2009, 2009a, 2010).

1.1 Threatened and Migratory Marine Mammals and Habitat

The Pilbara region supports migratory, transient and resident marine mammals such as whales, dolphins and dugong (Chevron Australia 2005). There are nine species of marine mammals that are listed as threatened fauna species and/or migratory species under the EPBC Act and under the Convention on Migratory Species (CMS) (Bonn Convention) that are likely to be found in the vicinity of the Marine Facilities (Table 1.1). These are the Humpback Whale (*Megaptera novaeangliae*), Blue Whale (*Balaenoptera musculus*), Bryde's Whale (*Balaenoptera edeni*), Killer Whale (*Orcinus orca*), Dusky Dolphin (*Lagenorhynchus obscures*), Irrawaddy Dolphin (*Orcaella heinsohni*), Indo-Pacific Humpback Dolphin (*Sousa chinensis*), Spotted Bottlenose Dolphin (*Tursiops aduncus*) (the Arafura/Timor Sea populations only), and Dugong (*Dugong dugon*). All of these species are listed as migratory species (Table 1.1), with the exception of the Blue Whale, which is also listed as Endangered, and the Humpback Whale, which is also listed as Vulnerable.

The regional distribution of many whale species is not well understood and while many species may occur in the Pilbara region, most are likely to be transient (Chevron Australia 2005). The Blue Whale and the Bryde's Whale are generally more abundant in deeper waters and are expected to be rare visitors to the shallow, inshore waters in the vicinity of the Marine Facilities on the east or west coasts of Barrow Island (Chevron Australia 2005). Humpback Whales are regular visitors moving through Barrow Island waters between June and October on their annual migration between their feeding grounds in Antarctic waters and their calving grounds in Pilbara and Kimberley waters (Chevron Australia 2005). Humpback Whales are more common in waters on the west coast of Barrow Island but do visit the east coast of the Island (Chevron Australia 2005).

Dolphins may occasionally visit the subtidal marine areas associated with the Marine Facilities (Chevron Australia 2005). Similar to whales, the regional distribution of most dolphin species is poorly known and while many species may occur in the Pilbara region, most are likely to be transient (Chevron Australia 2005). In Australia, Killer Whales are generally most often seen in relatively deeper waters along the continental slope and on the continental shelf, particularly near seal colonies (DEWHA 2010). Indo-Pacific Humpback Dolphins have resident populations within the shallow waters of the inner Rowley Shelf, including Barrow Island (Chevron Australia 2005). Irrawaddy Dolphins mainly occur in shallow coastal or estuarine waters (Beasley *et al.* 2002), which suggest they are more likely to occur in the waters between the east coast of Barrow Island and the mainland, rather than in the vicinity of the Marine Facilities on the west coast of Barrow Island. Dusky Dolphins are not well surveyed in Australian waters and are known from only 13 reports since 1828, with two sightings in the early 1980s (DEWHA 2009a). The Dusky Dolphin occurs mostly in temperate and sub-Antarctic waters, primarily inhabiting inshore waters (Ross 2006). As their distribution in Australia is uncertain, they may occur in the vicinity of the Marine Facilities during construction and operation of the Gorgon Gas Development, although this is considered unlikely. The Spotted Bottlenose Dolphin inhabits warmer coastal areas, in waters less than 10 m (Bannister *et al.* 1996). The populations of Spotted Bottlenose Dolphins in the Arafura/Timor Sea are listed in Appendix II of the Bonn Convention. Since the Arafura/Timor Sea populations are listed as migratory and their distribution is thought to extend as far south as Exmouth, they may occur in Barrow Island waters.

Dugongs occur throughout the shallow waters between the Pilbara offshore islands and the mainland (Chevron Australia 2005). Dugongs are generally associated with shallow seagrass meadows on which they feed and have been observed in the shallow waters over the Barrow

Shoals, along the east coast of Barrow Island, and over the Lowendal Shelf (Chevron Australia 2005). They are likely to be occasional visitors to any area of subtidal seagrass in the vicinity of the Gorgon Gas Development Marine Facilities (Chevron Australia 2005).

1.2 Threatened and Migratory Marine Reptiles and Habitat

Six species of marine turtle occur in Western Australian waters, all of which are listed as threatened and migratory species under the EPBC Act (Table 1.1). These are the Green Turtle (*Chelonia mydas*), Flatback Turtle (*Natator depressus*), Olive Ridley Turtle (*Lepidochelys olivacea*), Loggerhead Turtle (*Caretta caretta*), Hawksbill Turtle (*Eretmochelys imbricata*) and Leatherback Turtle (*Dermochelys coriacea*). Of these species, only Flatback Turtles, Green Turtles and Hawksbill Turtles have been recorded in Barrow Island waters and on Barrow Island beaches (Chevron Australia 2009). Barrow Island is a regionally important nesting area for Green Turtles and Flatback Turtles, whilst Hawksbill Turtles nest at low densities around the Island (Chevron Australia 2005).

Flatback Turtles nest only in northern Australia and the rookeries at Mundabullangana Station, Barrow Island, Lacepede Islands, Dampier Archipelago, Port Hedland, the Montebello Islands and the Lowendal Islands are considered regionally important (Chevron Australia 2005). The annual mean reproductive population of Flatback Turtles tagged nesting at Barrow Island is currently estimated to be 1397 (Pendoley Environmental 2009), which is comparable to the rookery at Mundabullangana on the Western Australian mainland, which is estimated to be 1700 (Pendoley *et al.* 2011) and is smaller than the rookery at Cape Domett in far north-western Australia, which supports approximately 3250 nesting females per year (Whiting *et al.* 2008). Flatback Turtle nesting on Barrow Island is concentrated on the mid-east coast on deep sandy, low sloped beaches with wide shallow intertidal zones (Pendoley 2005). The highest average number of tracks per night occurs on Mushroom Beach, approximately 2 km from Town Point (Chevron Australia 2009). The majority of nesting on these beaches occurs between November and February (Pendoley 2005).

Flatback Turtle hatchlings emerge from their nests six to eight weeks after eggs are laid and are present on the beaches and in the waters around the nesting beaches between December and April (Chevron Australia 2008). Little is known about the behaviour of Flatback Turtle hatchlings after they leave their natal beaches (Chevron Australia 2009); however, it is known that they grow to maturity in shallow coastal waters close to their natal beaches, remaining within the continental shelf waters (Musick and Limpus 1996). Flatback Turtles are carnivorous and forage primarily on soft-bodied invertebrates such as soft corals, sea pens, and holothurians (Chevron Australia 2008).

The north-western Australian population of Green Turtles is considered regionally important due to high predation pressures on nesting and internesting turtles in other parts of the Indo-Pacific region (Chevron Australia 2005). The estimated size of the Green Turtle reproductive population at Barrow Island is approximately 20 000 females, which may therefore represent a substantial component of the Pilbara region population (Prince 1994). However, this is less substantial than the Lacepede Island rookery, where nightly nesting effort is known to number in the thousands (Chevron Australia 2009). Green Turtles tend to nest on the west and north-east coasts of Barrow Island where beaches are high energy, deep, steeply sloped, sandy, and have an unobstructed foreshore approach (Pendoley 2005). The nesting period for Green Turtles on the west coast of Barrow Island is between November and February (Pendoley 2005).

Green Turtle hatchlings emerge from their nests after eggs are laid and are present on the beaches and in the waters around the nesting beaches between October and May (Chevron Australia 2009). After the hatchling stage, juvenile Green Turtles typically use a number of nursery habitats located away from their natal beach (Musick and Limpus 1996). Green Turtles are herbivorous and graze on algae growing on intertidal rock platforms on the west coast of Barrow Island (Chevron Australia 2008, 2009).

Barrow Island is not considered a regionally important nesting site for Hawksbill Turtles. The estimated size of the Hawksbill Turtle reproductive population at Barrow Island is 100 per year, which is smaller than the reproductive populations at the Lowendal Islands and the Montebello Islands (1000 and 1300 respectively) (Pendoley 2005). Hawksbill Turtle nesting on Barrow Island typically occurs in low numbers on beaches that are small, shallow and characterised by coarse-grained sand or coral grit interspersed with rocks and beach wrack (Pendoley 2005).

1.3 Threatened and Migratory Fish and Habitat

Numerous species of shark are present in the offshore waters of the North West Shelf; however, only the Whale Shark (*Rhincodon typus*), the Grey Nurse Shark (*Carcharias taurus*), and the Great White Shark (*Carcharodon carcharias*) are listed as threatened and/or migratory species under the EPBC Act (Table 1.1). To date, none of these species has been recorded during baseline marine surveys conducted since 2007 in the vicinity of the Marine Facilities (Chevron Australia 2011).

Whale Sharks have a broad distribution in tropical and warm temperate seas (Chevron Australia 2005). They congregate annually off Ningaloo Reef, approximately 150 km south-west of Barrow Island between March and April (Chevron Australia 2005). Whale Sharks leave Ningaloo Reef between May and June, travelling north-east along the continental shelf (Wilson *et al.* 2006). Whale Sharks may pass through the deeper waters off Barrow Island occasionally; however, they do not aggregate there (Woodside Energy 2008).

Grey Nurse Sharks have a broad inshore distribution around Australia (Environment Australia 2002). The Grey Nurse Shark has been recorded as far north as the North West Shelf in Western Australia; however, distribution is generally confined to predominantly the coastal waters of the south-west (Environment Australia 2002).

Great White Sharks have a distribution from the southern coastline of Australia to the Northwest Cape and have been recorded just north of Exmouth (Commonwealth Scientific and Industrial Research Organisation [CSIRO] 2006). Barrow Island is the northern extreme of the documented distribution for Great White Sharks (Chevron Australia 2005). Great White Sharks are highly mobile, but generally more abundant in temperate waters and around seal and sea lion colonies of which there are none in the Barrow Island area (Chevron Australia 2005). Great White Sharks are unlikely to be encountered in the vicinity of the Marine Facilities, except on rare occasions (Chevron Australia 2005).

1.4 Threatened and Migratory Marine Avifauna and Habitat

Numerous species of littoral birds (or shorebirds), migratory seabirds, and raptors are found on Barrow Island (Chevron Australia 2005). There are 63 species of marine avifauna (Table 1.1) that may be present from time to time near the Marine Facilities, all of which are listed as migratory species under the EPBC Act.

Migratory shorebird abundances increase on Barrow Island as the birds arrive from the north during September and December (Chevron Australia 2005). The abundances of some migratory shorebirds continue to increase during January and February, suggesting local movements of birds from the mainland to Barrow Island (Chevron Australia 2005). Abundances decrease as the migratory species leave the region to return north at the end of summer (Chevron Australia 2005).

Barrow Island is both a staging site and an important non-breeding site for migratory shorebirds (Chevron Australia 2005). The greatest abundances of shorebirds on Barrow Island (over two-thirds of records for most species) are associated with the south-eastern and southern coasts of the Island, from the existing Chevron camp to Bandicoot Bay (Chevron Australia 2005). These concentrations appear to be associated with the extensive tidal mudflats in these areas (Chevron Australia 2005). North Whites Beach on the west coast of Barrow Island (where the Feed Gas Pipeline Shore Crossing is located) does not provide significant shorebird habitat and abundances are generally low in these areas (Chevron Australia 2005).

The Montebello/Lowendal/Barrow Island region has significant rookeries of a number of migratory species, including the Wedge-tailed Shearwater (*Puffinus pacificus*), the Bridled Tern (*Sterna anaethetus*) and the Roseate Tern (*Sterna dougallii*) (Chevron Australia 2005). Double Island, approximately 5 km north of Town Point off the east coast of Barrow Island, is a regionally significant rookery for Bridled Terns and a locally significant rookery for Wedge-tailed Shearwaters (Chevron Australia 2005). However, the Wedge-tailed Shearwater rookery is small compared to other rookeries in the immediate region (Chevron Australia 2005). Other species that may nest on Double Island from time to time include the Caspian Tern (*Sterna caspia*), Roseate Tern, and Lesser Crested Tern (*Sterna bengalensis*) (A. Burbidge pers. comm. 2008, cited in Chevron Australia 2009a).

The Red-necked Stint (*Calidris ruficollis*), Grey-tailed Tattler (*Tringa brevipes*), Ruddy Turnstone (*Arenaria interpres*), Bar-tailed Godwit (*Limosa lapponica*), Lesser Sand Plover (*Charadrius mongolus*), Greater Sand Plover (*Charadrius leschenaultia*), and the Common Tern (*Sterna hirundo*) are the most abundant migratory species of shorebirds that forage at Town Point on the east coast of Barrow Island (Chevron Australia 2005). Other migratory species, such as the Red-capped Plover (*Charadrius ruficapillus*), the Caspian Tern (*Sterna caspia*) and the Osprey (*Pandion haliaetus*), may nest in the general area, but were not observed to nest there during surveys conducted in 2003/2004 for the Draft EIS/ERMP (Chevron Australia 2005). Town Point is not considered of local importance to any EPBC Act listed migratory species of shorebird (Chevron Australia 2005).

Ruddy Turnstones are seasonally abundant on Barrow Island and the Island is an internationally important site for this species (Chevron Australia 2005). While Ruddy Turnstones are one of the more abundant species at Town Point during spring and summer, their densities in the vicinity of the Marine Facilities are much lower than in the south and south-eastern areas of Barrow Island (Chevron Australia 2005). These are highly mobile birds that are not restricted to any of the habitats near Town Point on the east coast of Barrow Island (Chevron Australia 2005).

2.0 Marine Matters of National Environmental Significance – Risk Assessment

2.1 Overview

A number of environmental risk assessments have been completed and are reported for the Gorgon Gas Development. A strategic risk assessment was undertaken during the preparation of the Draft EIS/ERMP to determine the environmental acceptability of the Gorgon Gas Development and identify the key areas of risk requiring mitigation (Chevron Australia 2005). This Draft EIS/ERMP assessment was reviewed as part of the development of the PER for the Revised and Expanded Proposal (Chevron Australia 2008), in light of the changes to the Gorgon Gas Development. The outcomes of these assessments have been reviewed and considered during the preparation of this Appendix.

A summary of the risk assessments that have been undertaken to date and that have provided input into this Appendix and the documents that support it, are provided in Table 2.1.

Table 2.1 Risk Assessments Relevant to this Appendix

Scope of Risk Assessment	Method(s)	Documentation	Year
Entire Scope of the Approved Development	AS/NZS 4360:2004	Draft EIS/ERMP (Chevron Australia 2005)	2005
Entire Scope of the Revised and Expanded Proposal	AS/NZS 4360:2004	Gorgon Gas Development PER (Chevron Australia 2008)	2008
Long-term Marine Turtle Management Plan Risk Assessment	RiskMan2	Long-term Marine Turtle Management Plan (Chevron Australia 2009)	2009
State Marine Facilities Construction Environmental Management Plan (EMP) Risk Assessment	RiskMan2	State Marine Facilities Construction EMP (Chevron Australia 2011)	2009
Dredge and Spoil Disposal Management and Monitoring Plan Risk Assessment	RiskMan2	Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011a)	2009
Horizontal Directional Drilling (HDD) Management and Monitoring Plan Risk Assessment	RiskMan2	HDD Management and Monitoring Plan (Chevron Australia 2011b)	2010
Offshore Feed Gas Pipeline System Risk Assessment	RiskMan2	Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)	2010

2.2 Methodology

The methodology for the environmental risk assessments undertaken during the EIS/ERMP and PER assessment processes is documented in Chapter 9 of the Draft EIS/ERMP and Chapter 5 of the PER, respectively (Chevron Australia 2005, 2008). The EIS/ERMP and PER risk assessments were undertaken in accordance with the following standards:

- Australian Standard/New Zealand Standard (AS/NZS) 4360:2004 Risk Management (Standards Australia/Standards New Zealand 2004)
- AS/NZS Handbook 203:2006 Environmental Risk Management – Principles and Process (Standards Australia/Standards New Zealand 2006)
- AS/NZS 3931:1998 Risk Analysis of Technological Systems – Application Guide (Standards Australia/Standards New Zealand 1998).

The main components of the RiskMan2 risk assessment methodology include:

- **Hazard Identification**: Identifying potential hazards that are applicable to Gorgon Gas Development activities and determining the hazardous events to be evaluated.
- **Hazard Analysis**: Determining the possible causes that could lead to the hazardous events identified; the consequences of the hazardous events; and the safeguards and controls currently in place to mitigate the events and/or the consequences.
- **Risk Evaluation**: Evaluating the risks using the Chevron Integrated Risk Prioritization Matrix. The risk ranking is determined by a combination of the expected frequency of the hazard occurring (likelihood) and the consequence of its occurrence. Note that when assessing the consequence no credit is given to the hazard controls; hazard controls are taken into account in determining the likelihood of the event.
- **Residual Risk Treatment**: Reviewing the proposed management controls for each of the risks identified and proposing additional controls or making recommendations, if required.

Using the Chevron Integrated Risk Prioritization Matrix, identified risks are categorised into four groups, which determine the level of response and effort in managing the risks. The risk-ranking categories have been used in the development of this Appendix to determine whether the residual risks were acceptable or whether further mitigation was required.

2.3 Risk Assessment Outcomes

The marine fauna listed as threatened fauna species and/or migratory species under the EPBC Act that were considered at risk of some level of impact from the Gorgon Gas Development were identified in the Draft EIS/ERMP (Chevron Australia 2005). Subsequent risk assessments have since been conducted (as described in Section 2.1). The risk profile of these species and their habitat has been updated based on the outcomes of these more recent risk assessments.

Of the species identified in Table 1.1, those that are considered to be at risk of impacts that are categorised as 'medium' (RiskMan2 residual risk ratings of 5 or 6) or 'high' (RiskMan2 residual risk ratings of 1 to 4) are listed in Table 2.2. Also included in the table are the stressors and a brief summary of the scenarios associated with the risk ratings.

No 'high' risks were identified for EPBC Act listed threatened and/or migratory species. A total of 12 'medium' risks are summarised in Table 2.2 comprising: five risks to whales, dolphins and dugong; five risks to Flatback Turtles, Green Turtles and Hawksbill Turtles; and two risks to migratory species of shorebirds, seabirds and raptors. These risks were all related to activities associated with construction and operation of the Marine Facilities on the east coast of Barrow Island. Given that no 'medium' or 'high' risks were identified for marine fish, and that none of the three species listed in Table 1.1 have been recorded in the vicinity of the Marine Facilities, marine fish are not at risk of Material or Serious Environmental Harm and are therefore not discussed further.

All of the risks identified for EPBC Act listed threatened and migratory marine fauna species that were associated with HDD activities conducted on the west coast of Barrow Island were rated as 'low' and are therefore not discussed further (Chevron Australia 2011b). Information on impacts associated with HDD activities is provided in the HDD Management and Monitoring Plan (Chevron Australia 2011b).

The potential for the risks summarised in Table 2.2 to result in Material or Serious Environmental Harm to EPBC Act listed threatened and/or migratory marine fauna is discussed in Section 2.4.

Table 2.2 Medium and High Risks to Threatened and Migratory Species from the Construction and Operation of the Marine Facilities

Fauna	Stressor	Context	Risk Rating (Sources)
Whales, Dolphins and Dugongs	Physical Interaction	• Changes in localised distribution of marine fauna due to vessel collision/strike on the east coast of Barrow Island. • Change in local abundance/distribution of mobile fauna through construction of Marine Facilities on the east coast of Barrow Island, causing localised changes in fauna behaviour/movement, i.e. restricting preferential patterns of movement or access to certain waters. • Marine fauna injuries or fatalities from vessel movements or waste generation, storage and disposal associated with installation of the Offshore Feed Gas Pipeline System	**Medium** Marine Facilities Construction EMP (Chevron Australia 2011) Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)
	Physical Presence	• Presence of the Materials Offloading Facility (MOF) and Liquefied Natural Gas (LNG) Jetty on the east coast of Barrow Island causes localised changes in fauna behaviour/movements, i.e. restricting preferential patterns of movement or access to certain waters.	**Medium** Marine Facilities Construction EMP (Chevron Australia 20011)
	Light Spill	• Change in local abundance/distribution of mobile marine fauna through either attraction or avoidance of development areas on the east coast of Barrow Island. • Increased feeding opportunities for adaptable species leading to reduced numbers of prey species attracted to light. • Increased incidents of marine fauna collisions/interactions with vessels and equipment (e.g. bottlenose dolphins known to congregate in lit areas at night to assist in hunting).	**Medium** Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011a) Marine Facilities Construction EMP (Chevron Australia 2011) Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)
	Noise and Vibration	• Vibration and noise emissions generated by construction and dredge vessels, rock armouring activities and land-based excavator movements on the east coast of Barrow Island results in avoidance behaviour. • Shock waves, noise and vibration from underwater blasting and drilling on the east coast of Barrow Island results in mortality or injury (permanent and/or temporary hearing loss). • Disturbance to noise-sensitive marine fauna during helicopter movements, vessel movements and general operation of vessels and equipment, associated with installation of the Offshore Feed Gas Pipeline System.	**Medium** Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011a) Marine Facilities Construction EMP (Chevron Australia 2011) Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)
	Marine Water and Sediment Quality	• Turbid plume generated by the dredging and spoil disposal program on the east coast of Barrow Island results in a reduction in water quality causing avoidance of the area by fauna and/or reduced health or	**Medium** Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia

Fauna	Stressor	Context	Risk Rating (Sources)
		mortality.	2011a)
Flatback Turtles, Green Turtles and Hawksbill Turtles	Physical Interaction	• Vessel strike during construction and operation of the Marine Facilities on the east coast of Barrow Island (Flatback Turtles and Green Turtles are considered at greater risk than Hawksbill Turtles). • Dredge-strike during construction and operation of the Marine Facilities on the east coast of Barrow Island (Flatback Turtles are considered at greater risk than Hawksbill Turtles and Green Turtles). • Marine fauna injuries or fatalities from vessel movements or waste generation, storage and disposal associated with installation of the Offshore Feed Gas Pipeline System.	**Medium** Long-term Marine Turtle Management Plan (Chevron Australia 2009) Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)

	Physical Presence	• Potential for the presence of the MOF and LNG Jetty on the east coast of Barrow Island for the duration of the Operations Phase to influence:
		  o nesting and mating adults and hatchlings on the beaches adjacent to Town Point, e.g. due to beach erosion/accretion (Flatback Turtles are considered at greater risk than Hawksbill Turtles and Green Turtles)
		  o foraging juveniles and adults of Flatback Turtles, Green Turtles and Hawksbill Turtles in the waters near Town Point.
			Medium
			Long-term Marine Turtle Management Plan (Chevron Australia 2009)

	Light Spill	• Impacts to turtle nesting, breeding, mating and hatching from marine vessels and equipment, and Terrestrial Facilities during the marine construction period on the east coast of Barrow Island. • Impacts to mating adults and hatchlings from marine vessels and impacts to nesting adults and hatchlings from Terrestrial Facilities during the Operations Phase on the east coast of Barrow Island (Flatback Turtles are considered at greater risk than Hawksbill Turtles). • Impacts to hatchlings from marine construction light sources during the construction period on the west coast of Barrow Island (Green Turtles and Hawksbill Turtles are considered at greater risk than Flatback Turtles).	**Medium** Long-term Marine Turtle Management Plan (Chevron Australia 2009) Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)
	Noise and Vibration	• Impacts to mating and foraging adults and juveniles from marine vessels, helicopters and general operation of vessels during the marine construction period on the west coast of Barrow Island (Green and Hawksbill Turtles are considered at greater risk than Flatback Turtles).	**Medium** Long-term Marine Turtle Management Plan (Chevron Australia 2009) Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)
	Blasting	• Impacts during the marine construction period on the east coast of	**Medium**

Fauna	Stressor	Context	Risk Rating (Sources)
		Barrow Island.	Long-term Marine Turtle Management Plan (Chevron Australia 2009)
	Liquid Waste Discharges	• Turbidity during marine construction activities on the east coast of Barrow Island impacts foraging juveniles and adults and breeding adults of Flatback Turtles and Green Turtles. Impacts considered here include disorientation due to low visibility, covering of foraging grounds, etc.	**Medium** Long-term Marine Turtle Management Plan (Chevron Australia 2009)
Migratory species of shorebirds, seabirds and/or raptors	Light Spill	• Attraction of insects to artificial lighting on the east coast of Barrow Island may result in changes to community composition (e.g. an increase in Silver Gulls), and competition with threatened or migratory species. • Increased incidents of avifauna collisions/interaction with vessels and equipment on the east coast of Barrow Island due to light attraction (e.g. juvenile Wedge-tailed Shearwaters known to be attracted to light). • Temporary displacement/attraction of avifauna due to temporary land-based lighting attracting insects at night on MOF and LNG Jetty. • Attraction of marine fauna to artificial lighting on vessels and equipment at night during installation of the offshore Feed Gas Pipeline System.	**Medium** Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011a) Marine Facilities Construction EMP (Chevron Australia 2011) Offshore Gas Pipeline Installation Management Plan (Chevron Australia 2011c)
	Noise and Vibration	• Vibration and noise emissions generated by construction and dredge vessels, rock armouring activities and land-based excavator movements on the east coast of Barrow Island results in avoidance behaviour. • Shock waves, noise and vibration from underwater blasting and drilling on the east coast of Barrow Island results in mortality or injury (permanent and/or temporary hearing loss).	**Medium** Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011a) Marine Facilities Construction EMP (Chevron Australia 2011)

2.4 Material or Serious Environmental Harm to Marine Matters of National Environmental Significance

2.4.1 Overview

The SEWPaC (formerly DEWHA and Department of Environment and Heritage [DEH]) provides guidance on the criteria used in determining whether certain activities are likely to have a Significant Impact on EPBC Act listed species (DEH 2006). The Significant Impact criteria for the listed threatened fauna species and listed migratory species that are relevant to this Appendix are provided in Table 2.3. These Significant Impact criteria were considered in conjunction with the outcomes of the risk assessments conducted (and summarised in Table 2.2), to determine whether any listed threatened fauna species and listed migratory species are at risk of Material or Serious Environmental Harm due to construction and operation of the Marine Facilities.

It should be noted that in the guidance on Significant Impact criteria (DEH 2006), ‘habitat’ that is considered critical to the survival of a threatened fauna species refers to areas that are necessary for:

- activities such as foraging, breeding, roosting, or dispersal
- the long-term maintenance of the species (including the maintenance of species essential to the survival of the species, such as pollinators)
- maintaining genetic diversity and long-term evolutionary development
- the reintroduction of populations or recovery of the species.

Table 2.3 Significant Impact Criteria

EPBC Act (Cth) Category	Significant Impact Criteria
Threatened (Endangered) species	An action is likely to have a Significant Impact on a Critically Endangered or Endangered species if there is a real chance or possibility that it will: • lead to a long-term decrease in the size of a population • reduce the area of occupancy of the species • fragment an existing population into two or more populations • adversely affect habitat critical to the survival of a species • disrupt the breeding cycle of a population • modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline • result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species’ habitat • introduce disease that may cause the species to decline • interfere with the recovery of the species.
Threatened (Vulnerable) species	An action is likely to have a significant impact on a Vulnerable species if there is a real chance or possibility that it will: • lead to a long-term decrease in the size of an important population of a species • reduce the area of occupancy of an important population • fragment an existing important population into two or more populations • adversely affect habitat critical to the survival of a species • disrupt the breeding cycle of an important population • modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline • result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species’ habitat • introduce disease that may cause the species to decline

EPBC Act (Cth) Category	Significant Impact Criteria
	• interfere substantially with the recovery of the species.
Migratory species	An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will: • substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy, or isolate an area of important habitat for a migratory species • result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species • seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Source: DEH (2006).

2.4.2 Material or Serious Environmental Harm Impacts to Threatened and Migratory Marine Mammals

EPBC Act listed threatened fauna species and/or listed migratory species of whales, dolphins and dugongs are not at risk of Material or Serious Environmental Harm from the stressors and associated risks identified in Table 2.2. All these species are listed as migratory species (Table 1.1), with the exception of the Blue Whale, which is also listed as Endangered, and the Humpback Whale, which is also listed as Vulnerable.

When considering the Significant Impact criteria in Table 2.3 in conjunction with the risks in Table 2.2, the Blue Whale and the Humpback Whale are not at risk of Material or Serious Environmental Harm from noise and vibration during construction activities such as drilling and blasting, vessel and helicopter movements, light spill to the marine environment, changes to marine water and sediment quality during dredging, or the physical presence of the MOF and LNG Jetty. These risks are associated with temporary construction activities, with the exception of the permanent presence of the MOF and LNG Jetty. However, Blue Whales and Humpback Whales are unlikely to occur in significant numbers in the vicinity of the east coast Marine Facilities; therefore, the presence of the MOF and LNG Jetty are unlikely to obstruct their movements to such a degree that would result in Material or Serious Environmental Harm to those species.

The risks presented in Table 2.2 would not result in any long-term decreases in the size of the Blue Whale or the Humpback Whale populations, would not fragment the existing populations, or reduce the area of occupancy of the species since they are mobile marine fauna. There is no habitat critical to the survival of the species that would be disturbed due to construction and operation of the Marine Facilities on the east coast of Barrow Island, and the potential impacts are not anticipated to disrupt the breeding cycle of their populations. Furthermore, these risks should not result in the introduction of invasive species or diseases that would result in adverse impacts to these species. The risks presented in Table 2.2 are unlikely to interfere with the recovery of the Blue Whale and the Humpback Whale.

The remaining seven species of whales, dolphins and the Dugong are listed as migratory species. The risks identified in Table 2.2 should not result in Material or Serious Environmental Harm to these species. The marine habitats in the vicinity of the Marine Facilities are not known to represent important habitat for the Bryde's Whale, the Killer Whale, the Dusky Dolphin, the Irrawaddy Dolphin, the Indo-Pacific Humpback Dolphin, the Spotted Bottlenose Dolphin, or the Dugong. Furthermore, the risks identified in Table 2.2 should not result in the introduction of invasive species or diseases that would result in adverse impacts to these species. The populations of these species present in the vicinity of the Marine Facilities on the east coast of Barrow Island during construction and operation do not represent ecologically significant proportions, and therefore, impacts to breeding, feeding, migration, or resting behaviours would be limited to individuals of these species.

2.4.3 Material or Serious Environmental Harm to Threatened and Migratory Marine Turtles

All six species of marine turtles are listed as migratory, with Olive Ridley Turtles and Loggerhead Turtles also listed as Endangered, and Leatherback, Hawksbill, Flatback and Green Turtles also listed as Vulnerable under the EPBC Act. Of the six species, the Flatback Turtle is considered at risk of Material or Serious Environmental Harm from construction and operation of the Marine Facilities on the east coast of Barrow Island, and Green Turtles are considered to be at risk of Material or Serious Environmental Harm from construction of the Marine Facilities on the west coast of Barrow Island.

The Olive Ridley Turtle and Leatherback Turtle have not been recorded and the Loggerhead Turtle has rarely been seen in Barrow Island waters and on Barrow Island beaches and these species are therefore not at risk of Material or Serious Environmental Harm from the construction and operation of the Marine Facilities. When considering the Significant Impact criteria in Table 2.3 in conjunction with the risks in Table 2.2, the Hawksbill Turtle is also not at risk of Material or Serious Environmental Harm. The risks in Table 2.2 are unlikely to lead to long-term decreases in the size of the Hawksbill Turtle population, would not fragment the existing population, and are unlikely to reduce the area of occupancy of this species since they are only found in low numbers on Barrow Island and in surrounding waters. There is no habitat critical to the survival of Hawksbill Turtles that would be disturbed due to construction and operation of the Marine Facilities, and the potential impacts should not disrupt the breeding cycle of their population. Furthermore, these risks are unlikely to result in the introduction of invasive species or diseases that would result in adverse impacts or declines in this species. The risks presented in Table 2.2 are unlikely to interfere with the recovery of the Hawksbill Turtle and would not seriously disrupt the lifecycle (breeding, feeding, migration, or resting behaviour) of an ecologically significant proportion of the population of the species.

As Barrow Island is considered a regionally important nesting site for Flatback Turtles, Material or Serious Environmental Harm to their breeding activity has the potential to affect the Western Australian population of this species. The beaches either side of Town Point where the MOF and LNG Jetty are located (Terminal Beach and Bivalve Beach), are important components of the Barrow Island rookery, with almost 30% of Flatback Turtle tracks occurring on these beaches (Chevron Australia 2005). The risks identified in Table 2.2 may disrupt the breeding cycle of Flatback Turtles and there is a chance that the physical presence of the MOF and the LNG Jetty could lead to a decrease in the size of the rookery over the longer term. The risk also exists (and is identified in Table 2.2) that changes to the beach profile or sediment characteristics arising from the physical presence of the MOF and LNG Jetty could lead to a decrease in the availability or quality of nesting habitat for Flatback Turtles. It is for these reasons that Flatback Turtles and their habitat (the nesting beaches adjacent to Town Point at Terminal Beach and Bivalve Beach) are considered at risk of Material or Serious Environmental Harm during construction and operation of the Marine Facilities on the east coast of Barrow Island.

Similar to Flatback Turtles, the north-western Australian population of Green Turtles is considered regionally important. According to Prince (2004), the estimated size of the Green Turtle reproductive population at Barrow Island may represent a substantial component of the Pilbara region population, despite this rookery being smaller than the rookery at the Lacepede Islands. Therefore, Material or Serious Environmental Harm to breeding activity of the Barrow Island rookery has the potential to affect the Pilbara region population of this species. Green Turtle nesting on Barrow Island is concentrated on the west and north-east coasts of Barrow Island (Pendoley 2005); therefore, although nesting activities are unlikely to be disrupted as a result of construction and operation of Marine Facilities on the east coast of Barrow Island, construction on the west coast of Barrow Island does have the potential to cause Material or Serious Environmental Harm to the population. The shore crossing at North Whites Beach is not a locally important Green Turtle nesting site because the shallow sand and limestone reef, including a large limestone shelf along the waterline, make the beach unsuitable for nesting (Pendoley 2005, Pendoley Environmental 2008). However, injuries or fatalities to turtles from vessel movements or waste generation, storage and disposal; the potential impact of light spill on Green Turtle hatchlings and potential impacts on mating and foraging adults and juveniles from vessel and helicopter-related noise and vibration during construction (Table 2.2) were recognised as potential threats during the west coast construction period (Chevron Australia 2009, 2011c) that may cause Material or Serious Environmental Harm to the Green Turtle population.

In terms of habitat for Green Turtles, the national Recovery Report for Marine Turtles in Australia (Environment Australia 2003) identifies Barrow Island and waters within a 20 km radius of the Island as critical (Chevron Australia 2005). This is most likely due to their utilisation of this habitat for foraging and mating (Chevron Australia 2009). Whilst the physical presence of the MOF (Table 2.2) will result in the loss of an area of macroalgae-dominant limestone reef, this will not significantly reduce the feeding and pre-nesting areas for Green Turtles as data indicates that Green Turtles mate in greatest numbers in the shallow nearshore waters off the west coast of Barrow Island (Pendoley 2005). The waters off the west coast will not be affected by construction and operation of the MOF, the LNG Jetty, or by activities associated with the Dredge Spoil Disposal Ground, and baseline marine surveys show that macroalgae-dominant limestone reef habitat is extensive in the region (Chevron Australia 2008, 2010). The benthic habitats used by Green Turtles are well represented around Barrow Island and in the broader region; therefore, the disturbance of the habitat associated with the MOF and LNG Jetty is unlikely to lead to a decline in the Green Turtle population at Barrow Island. The habitat of Green Turtles is therefore not considered at risk of Material or Serious Environmental from construction and operation of the Marine Facilities.

2.4.4 Material or Serious Environmental Harm to Threatened and Migratory Marine Avifauna

Of the marine avifauna listed as threatened fauna species and/or migratory species in Table 1.1, the Wedge-tailed Shearwater and the Bridled Tern are considered at risk of Material or Serious Environmental Harm from construction and operation of the Marine Facilities. This is because Double Island, off the east coast of Barrow Island, is a regionally significant rookery for Bridled Terns and a locally significant rookery for Wedge-tailed Shearwaters (Chevron Australia 2005). Whilst the Wedge-tailed Shearwater rookery is small compared to other rookeries in the region (Chevron Australia 2005), fledging Wedge-tailed Shearwaters have been documented as being attracted to the night lighting of the Gas Treatment Plant on nearby Varanus Island (Nicholson 2002). Therefore, this species has the potential to be impacted by lighting associated with construction and operation of the Marine Facilities on the east coast of Barrow Island.

Whilst Barrow Island is considered an important non-breeding site for many species of migratory shorebirds, the highest abundances (over two-thirds of records for most species) are associated with the south-eastern and southern coasts of the Island (Chevron Australia 2005). Therefore, whilst the risks presented in Table 2.2 may have some impact on migratory species of shorebirds, seabirds and raptors, the impacts are not anticipated to result in modification or disturbance of important habitat, nor are they expected to result in the introduction of a harmful invasive species. The potential impacts are also not expected to impact the breeding, feeding, migration, and resting behaviours of an ecologically significant proportion of the populations of these migratory species of shorebirds, seabirds, and raptors.

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Appendix 2 Barrow Island Habitat Classification Scheme

Physical Factors		Biological Factors			Biological Factors	
Relief	**Substrate Type**	**Dominant Ecological Element**	**Dominant Taxa or physical descriptor**	**Cover**	**Sub-Dominant Taxa or physical descriptor**	**Cover**
R0 Flat/micro-ripples (<0.5m height)	S01 Sand	H01 **Macroalgae**	*Sargassum*	C0 Unknown density	*Sargassum*	C0 Unknown density
R1 Gently sloping (5 - 35 deg)	S02 Silt		*Padina*	C1 Sparse (5-25%)	*Padina*	C1 Sparse (5-25%)
R2 Steeply sloping (35 - 70 deg)	S03 Mud		*Caulerpa*	C2 Medium (25-75%)	*Caulerpa*	C2 Medium (25-75%)
R3 Vertical wall (70-90 deg) and caves/overhangs	S04 Gravel		*Cladophora*	C3 Dense (> 75%)	*Cladophora*	C3 Dense (> 75%)
R4 Macro-ripples (>0.5m height)	S05 Rubble		Mixed Rhodophyta		Mixed Rhodophyta	
	S06 Consolidated rubble		Mixed Chlorophyta		Mixed Chlorophyta	
	S07 Limestone pavement		Mixed Phaeophyceae		Mixed Phaeophyceae	
	S08 Limestone pavement w/ shallow sand veneer		Mixed turfing algae		Mixed turfing algae	
	S09 Boulders		Unidentified Rhodopyhta		Unidentified Rhodopyhta	
	S10 Reef - low profile		Unidentified Chlorophyta		Unidentified Chlorophyta	
	S11 Reef - high profile		Unidentified Phaeophyceae		Unidentified Phaeophyceae	
	S12 Sand with Shell fragments		Unidentified turfing algae		Unidentified turfing algae	
	S13 Silt with Shell fragments		Unidentified macroalgae		Unidentified macroalgae	
		H02 **Seagrass**	*Halophila*	C0 Unknown density	*Halophila*	C0 Unknown density
			Heterozostera	C1 Sparse (5-25%)	*Heterozostera*	C1 Sparse (5-25%)
			Syringodium	C2 Medium (25-75%)	*Syringodium*	C2 Medium (25-75%)
			Thallasodendron	C3 Dense (> 75%)	*Thallasodendron*	C3 Dense (> 75%)
			Unidentified seagrass		Unidentified seagrass	
		H03 **Non-coral benthic invertebrates**	Crinoids (sea, brittle and feather stars)	Present	Crinoids (sea stars, brittle and feather stars)	Present
			Sea pens, whips and fans		Sea pens, whips and fans	
			Gorgonians		Gorgonians	
			Sea Urchins		Sea Urchins	
			Sponges		Sponges	
			Ascidians		Ascidians	
			Holothurians		Holothurians	
			Bivalaves		Bivalaves	
			Bryozoans		Bryozoans	
		H04 **Coral - hard and soft**	A *Acropora*	C2 Medium (10-50%)	*Acropora*	C0 Unknown density
			P Coral bombora - *Porites*	C3 Dense (51-75%)	Coral bombora - *Porites*	C1 Sparse (<10%)
			N Coral bombora - non-*Porites*	CV Very Dense (>75%)	Coral bombora - non-*Porites*	
			I Bombora - invert/macroalgae dominated		Bombora - invert/macroalgae dominated	
			M Mixed coral community		Mixed coral community	
		H05 **Mangroves**	*Avicennia*	Present	*Avicennia*	Present
			Rhizophora		*Rhizophora*	
			Ceriops		*Ceriops*	
			Brugeiera		*Brugeiera*	
			Aegialitis		*Aegialitis*	
			Aegiceras		*Aegiceras*	
			Acanthus		*Acanthus*	
			Unidentified mangrove		Unidentified mangrove	
		H06 **Unvegetated**	Undisturbed flat	C0 Unknown density	Undisturbed flat	C0 Unknown density
			Undisturbed micro-ripples (<0.5m height)	C1 Sparse (5-25%)	Undisturbed micro-ripples (<0.5m height)	C1 Sparse (5-25%)
			Bioturbated (mounds and burrows)	C2 Medium (25-75%)	Bioturbated (mounds and burrows)	C2 Medium (25-75%)
			Drift macroalgae	C3 Dense (> 75%)	Drift macroalgae	C3 Dense (> 75%)
			Drift seagrass	C4 Bare	Drift seagrass	C4 Bare

Public

Appendix 3 Coral Species List

Scleractinian species and their abundance scale recorded from 12 Rapid Visual Assessment (RVA) Surveys at Barrow Island.

Abundance scale	No. of colonies
1	1 to 2
2	3 to 5
3	6 to 20
4	21 to 50
5	51+

Legend

- Genus (yellow)
- New record for Australia (cyan)
- New record for WA (magenta)
- New record for North West Shelf (light green)

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
ORDER SCLERACTINIA												
Family Acroporidae Verrill, 1902												
Genus *Acropora* Oken, 1815												
Acropora aculeus (Dana, 1846)			1									
Acropora acuminata (Verrill, 1864)					1	2	2					
Acropora anthocercis (Brook, 1893)				1								
Acropora austera (Dana, 1846)	1				5	5	2			1		1
Isopora brueggemanni (Brook, 1893)		1				3		1				
Acropora cerealis (Dana, 1846)		2			1							1
Acropora cytherea (Dana, 1846)						1						
Acropora digitifera (Dana, 1846)						1		3				1
Acropora divaricata (Dana, 1846)	3	3	3	3	2	1	3	1	3	2		3
Acropora donei Veron and Wallace, 1984						1				1		
Acropora florida (Dana, 1846)			2	2	3	3	2		1	3	1	3
Acropora gemmifera (Brook, 1892)					2	1				1		
Acropora glauca (Brook, 1893)					1	1					1	2

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Acropora grandis (Brook, 1892)					2	2				1		1
Acropora horrida (Dana, 1846)					1							
Acropora humilis (Dana, 1846)		1			1		1					
Acropora hyacinthus (Dana, 1846)		1			3		1					1
Acropora insignis Nemenzo, 1967	1						1			1		
Acropora intermedia		2			4	5				2		
Acropora latistella (Brook, 1891)	1						1	1				
Acropora listeri (Brook, 1893)		1										
Acropora loripes (Brook, 1892)		2										1
Acropora lovelli Veron and Wallace, 1984					1	1						1
Acropora lutkeni Crossland, 1952					1	1	1					1
Acropora microclados (Ehrenberg, 1834)						1						
Acropora microphthalma (Verrill, 1859)		1			2							
Acropora millepora (Ehrenberg, 1834)	1	2			2	4				2		3
Acropora muricata	2	2	1	2	4	3			1	3		2
Acropora nasuta (Dana, 1846)	2	2			3	3	2	4	1		1	2
Acropora palmerae Wells, 1954					1							
Acropora polystoma (Brook, 1891)						1				1		
Acropora pulchra (Brook, 1891)					2	2						
Acropora robusta (Dana, 1846)		1			1							
Acropora samoensis (Brook, 1891)	1		1		1	2	1		1	2		2
Acropora sarmentosa (Brook, 1892)					1							
Acropora secale (Studer, 1878)					1	2		1				
Acropora selago (Studer, 1878)		1			1							1
Acropora solitaryensis Veron and Wallace, 1984					1	1						1
Acropora spicifera (Dana, 1846)					3	1	1	2			2	
Acropora subulata (Dana, 1846)		1				1						
Acropora tenuis (Dana, 1846)		2	1		1	2	2		2	1	1	
Acropora valenciennesi (Milne Edwards and Haime,1860)			1		1	1	1					
Acropora valida (Dana, 1846)			1		2		1					

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Acropora verweyi Veron and Wallace, 1984					1							
Acropora willisae Veron and Wallace, 1984		2	2									
Acropora yongei Veron and Wallace, 1984					1							
Acropora cf. *arafura* (Wallace in prep.)			2		3	3	3		2		1	2
Genus *Montipora* Blainville, 1830												
Montipora aequituberculata Bernard, 1897					2	2	1			3		
Montipora crassituberculata Bernard, 1897						2				2		
Montipora danae (Milne Edwards and Haime, 1851)				1		1			1	1		
Montipora digitata (Dana, 1846)					1							
Montipora efflorescens Bernard, 1897		1			1		1			1		
Montipora foliosa (Pallas, 1766)						1						
Montipora grisea Bernard, 1897						2		1				
Montipora hispida (Dana, 1846)		1	1		1	2				1		
Montipora informis Bernard, 1897										1		
Montipora mollis Bernard, 1897					1					1		
Montipora monasteriata (Forskäl, 1775)			1								1	
Montipora peltiformis Bernard, 1897						1	1			2		
Montipora tuberculosa (Lamarck, 1816)	1	1					2			1		2
Montipora turgescens Bernard, 1897				1	2		1			2		
Montipora turtlensis Veron and Wallace, 1984										1		
Montipora undata Bernard, 1897		1				1	2					
Montipora verrucosa (Lamarck, 1816)			1	1					1			
Genus *Astreopora* Blainville, 1830												
Astreopora gracilis Bernard, 1896												2
Astreopora listeri Bernard, 1896							1	1				
Astreopora myriophthalma (Lamarck, 1816)					2	1	1				1	3
Family Faviidae Gregory, 1900												
Genus *Platygyra* Ehrenberg, 1834												
Platygyra acuta Veron, 2000	1	1	1				1	1		1	1	1
Platygyra daedalea (Ellis and Solander, 1786)	2	2		2	2		2		1	1	3	2

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Platygyra lamellina (Ehrenberg, 1834)		1			1			2	1		2	1
Platygyra pini Chevalier, 1975	3	1	3	3	1		2	3	3	2	3	2
Platygyra ryukyuensis Yabe and Sugiyama, 1936			2	1	1				1	1		
Platygyra sinensis (Milne Edwards and Haime, 1849)	1	1	1	2	1		1	1	1	1	2	1
Platygyra yaeyamaensis							1					
Genus *Favia* Oken, 1815												
Favia favus (Forskål, 1775)			2				1					
Favia helianthoides Wells, 1954	1									1		
Favia laxa (Klunzinger, 1879)					1							
Favia maritima (Nemenzo, 1971)		1										1
Favia matthaii Vaughan, 1918		2									2	1
Favia maxima Veron, Pichon & Wijsman-Best, 1972		1										
Favia pallida (Dana, 1846)	2	2	3	2			2	3	2		2	1
Favia rotumana (Gardiner, 1899)								1		1		1
Favia rotundata Veron, Pichon & Wijsman-Best, 1972	1		1				1		1	1	1	1
Favia speciosa Dana, 1846		2	3	2	1			1	1		3	
Favia stelligera (Dana, 1846)								2			2	
Favia veroni Moll and Borel-Best, 1984					1		1				1	
Genus *Goniastrea* Milne Edwards and Haime, 1848												
Goniastrea aspera Verrill, 1905			1					3			1	
Goniastrea australensis (Milne Edwards and Haime, 1857)			1		2		1	2	1	1	1	2
Goniastrea edwardsi Chevalier, 1971								1			2	1
Goniastrea favulus (Dana, 1846)				2				3				2
Goniastrea pectinata (Ehrenberg, 1834)	2		2	1		1	1	2	1	3	3	3
Goniastrea retiformis (Lamarck, 1816)		2	1		1		2	4	1		3	
Genus *Favites* Link, 1807												
Favites abdita (Ellis and Solander, 1786)			1	1	2		2		2	2	1	1
Favites acuticollis (Ortmann, 1889)								2				
Favites chinensis (Verrill, 1866)											1	1
Favites complanata (Ehrenberg, 1834)									1	1	1	

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Favites flexuosa (Dana, 1846)							1				1	
Favites halicora (Ehrenberg, 1834)	1	2			2	2	1	3	2	1	3	2
Favites pentagona (Esper, 1794)		1			1				2			2
Favites russelli (Wells, 1954)		1			1						1	
Favites stylifera (Yabe and Sugiyama, 1937)		1					1			1		
Genus *Echinopora* Lamarck, 1816												
Echinopora ashmorensis Veron, 1990										1	3	2
Echinopora lamellosa (Esper, 1795)		2	2		1	1	2	3	1	2	5	3
Genus *Cyphastrea* Milne Edwards and Haime, 1848												
Cyphastrea chalcidium (Forskål, 1775)		1					1	2			1	
Cyphastrea microphthalma (Lamarck, 1816)		1	1	1		1	3	3	1	1	2	1
Cyphastrea serailia (Forskål, 1775)							1				2	
Genus *Montastrea* Blainville, 1830												
Montastrea colemani Veron, 2000							1		1			
Montastrea curta (Dana, 1846)		1		1	1	1	2	2	1			1
Montastrea salebrosa (Nemenzo, 1959)							1					
Genus *Diploastrea* Matthai, 1914												
Diploastrea heliopora (Lamarck, 1816)		4	1						1	1		
Genus *Leptastrea* Milne Edwards and Haime, 1848												
Leptastrea pruinosa Crossland, 1952						1						
Leptastrea purpurea (Dana, 1846)		1			1	1	1		1			
Leptastrea transversa Klunzinger, 1879					1		1					
Genus *Caulastrea* Dana, 1846												
Caulastrea curvata Wijsmann-Best, 1972								1	1		1	3
Genus *Oulophyllia* Milne Edwards and Haime, 1848												
Oulophyllia bennettae (Veron & Pichon, 1977)											1	1
Oulophyllia crispa (Lamarck, 1816)					1		1			1		
Genus *Leptoria* Milne Edwards and Haime, 1848												
Leptoria phrygia (Ellis and Solander, 1786)	1						1		1		2	
Genus *Plesiastrea* Milne Edwards and Haime, 1848												

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Plesiastrea versipora (Lamarck, 1816)				1	1			1				
Genus *Moseleya* Quelch, 1884												
Moseleya latistellata Quelch, 1884		1										
Family Poritidae Gray, 1842												
Genus *Porites* Link, 1807												
Porites annae Crossland, 1952			2	2	2		2	2	2	2	2	1
Porites australiensis Vaughan, 1918	2	4	4	4	1	2	4	2	3	2		
Porites cylindrica Dana, 1846	4		3	4	2		4	2	2		3	2
Porites lichen Dana, 1846	3		2	2			3				2	
Porites lutea Milne Edwards & Haime, 1851	5	2	5	5	3	2	5	2	5	3	3	3
Porites nigrescens Dana, 1846	3		3				3	2	2	2	3	
Porites rus (Forskål, 1775)	3			2	1			3		3		
Porites solida (Forskål, 1775)			2									1
Genus *Goniopora* Blainville, 1830												
Goniopora burgosi											1	
Goniopora lobata Milne Edwards and Haime, 1860		1	1				1		1	1	1	2
Goniopora stokesi Milne Edwards and Haime, 1851		1		1								
Goniopora tenuidens (Quelch, 1886)							1				1	
Family Pectiniidae Vaughan and Wells, 1943												
Genus *Pectinia* Oken, 1815												
Pectinia lactuca (Pallas, 1766)	1	2	2	2	2		1	2	2	3	5	
Pectinia paeonia (Dana, 1846)	1		1	1	1					2	4	
Genus *Oxypora* Saville-Kent, 1871												
Oxypora glabra Nemenzo, 1959			1				3		1	1	2	2
Oxypora lacera Verrill, 1864	1	2	1	2			2		1	2	3	1
Genus *Echinophyllia* Klunzinger, 1879												
Echinophyllia aspera (Ellis and Solander, 1788)	1	2				1	1	1		1	2	
Echinophyllia orpheensis Veron and Pichon, 1980		2								1	1	2
Genus *Mycedium* Oken, 1815												
Mycedium elephantotus (Pallas, 1766)			1	1			2				2	
Family Mussidae Ortmann, 1890												

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Genus *Lobophyllia* Blainville, 1830												
Lobophyllia corymbosa (Forskål, 1775)		1	2	2	2	1	2		1	1	2	2
Lobophyllia diminuta Veron, 1985		3			1					1	1	2
Lobophyllia hemprichii (Ehrenberg, 1834)	2	2	3	3	1	2	2	2	3	2	2	3
Lobophyllia flabelliformis		1		1								
Lobophyllia robusta Yabe and Sugiyama, 1936		2								1		1
Genus *Acanthastrea* Milne Edwards and Haime, 1848												
Acanthastrea echinata (Dana, 1846)		1					1		1	1	1	1
Acanthastrea hemprichii (Ehrenberg, 1834)		1			1							
Acanthastrea subechinata Veron, 2000											1	
Genus *Symphyllia* Milne Edwards and Haime, 1848												
Symphyllia radians Milne Edwards and Haime, 1849							1		1	1		
Symphyllia recta (Dana, 1846)					1			1		1		1
Genus *Blastomussa* Wells, 1961												
Blastomussa merleti Wells, 1961							1		1			
Genus *Scolymia* Haime, 1852												
Scolymia australis (Milne Edwards and Haime, 1849)							1					
Family Merulinidae Verrill, 1866												
Genus *Hydnophora* Fischer de Waldheim, 1807												
Hydnophora exesa (Pallas, 1766)		2	2	2		1	2		2	2	2	1
Hydnophora grandis Gardiner, 1904				1			2		2	1		
Hydnophora pilosa Veron, 1985			1	1	1		3	3	1	1		2
Hydnophora rigida (Dana, 1846)				1						1	2	1
Genus *Merulina* Ehrenberg, 1834												
Merulina ampliata (Ellis and Solander, 1786)		2	2	2	2		3	3	1	2	5	2
Merulina scabricula Dana, 1846				1			1	2	1	1	3	
Family Pocilloporidae Gray, 1842												
Genus *Pocillopora* Lamarck, 1816												
Pocillopora damicornis (Linnaeus, 1758)	2	1	2	2	2	2	2	3	2	2	3	3
Pocillopora verrucosa (Ellis and Solander, 1786)				2	2	1	1	1				

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Genus *Seriatopora* Lamarck, 1816												
Seriatopora caliendrum Ehrenberg, 1834	2	1	3			1	3					1
Genus *Stylophora* Schweigger, 1819												
Stylophora pistillata Esper, 1797	2				1	1	1				2	3
Stylophora subseriata (Ehrenberg, 1834)							1					
Family Fungiidae Dana, 1846												
Genus *Fungia* Lamarck, 1801												
Fungia corona Döderlein, 1901											2	
Fungia fungites (Linneaus, 1758)											3	
Fungia repanda Dana, 1846	1				1	2	1	3	2		3	
Genus *Lithophyllon* Rehberg, 1892												
Lithophyllon undulatum Rehberg, 1892		2		1	1	2	2		1	1		1
Genus *Podabacia* Milne Edwards and Haime, 1849												
Podabacia crustacea (Pallas, 1766)	2	1		1	1		3		1		1	
Genus *Herpolitha* Eschscholtz, 1825												
Herpolitha limax (Houttuyn, 1772)	1		1	1		1	1			1	2	
Genus *Halomitra* Dana, 1846												
Halomitra pileus (Linnaeus, 1758)											1	
Family Agariciidae Gray, 1847												
Genus *Pachyseris* Milne Edwards and Haime, 1849												
Pachyseris rugosa (Lamarck, 1801)	2		1	2			1			1		2
Pachyseris speciosa (Dana, 1846)	2	4	2	2			3		2	2		2
Genus *Pavona* Lamarck, 1801												
Pavona clavus (Dana, 1846)							1				1	
Pavona decussata (Dana, 1846)	1						1	2	1		1	
Pavona duerdeni Vaughan, 1907										1		
Pavona explanulata (Lamarck, 1816)			1						2			
Pavona maldivensis (Gardiner, 1905)							1					
Pavona varians Verrill, 1864							1	2				
Pavona venosa (Ehrenberg, 1834)				1								
Genus *Leptoseris* Milne Edwards and Haime, 1849												

Species	Zones of High Impact	Zones of Moderate Impact			Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
Leptoseris explanata Yabe and Sugiyama, 1941							1					
Leptoseris mycetoseroides Wells, 1954							1					
Family Oculinidae Gray, 1847												
Genus *Galaxea* Oken, 1815												
Galaxea astreata (Lamarck, 1816)	1	2	2	3	2	2	2		3	3	3	2
Galaxea fascicularis (Linnaeus, 1767)	1			2	2	2	3		2	2	1	1
Family Dendrophylliidae Gray, 1847												
Genus *Turbinaria* Oken, 1815												
Turbinaria bifrons Brüggemann, 1877								1				1
Turbinaria mesenterina (Lamarck, 1816)	1	1	2	3	2						2	
Turbinaria patula (Dana, 1846)	1				1							
Turbinaria peltata (Esper, 1794)		1			1							
Turbinaria reniformis Bernard, 1896	3	1	2	1			3		2	1		2
Family Siderastreidae Vaughan and Wells, 1943												
Genus *Psammocora* Dana, 1846												
Psammocora contigua (Esper, 1797)			2	3		1	1		2	2	2	3
Psammocora digitata Milne Edwards and Haime, 1851			1	1	1				1		1	
Psammocora nierstraszi van der host, 1921							1					
Psammocora obtusangula (Lamarck, 1816)							1					
Psammocora superficialis Gardiner, 1898				1			1					
Genus *Coscinaraea* Milne Edwards and Haime, 1848												
Coscinaraea columna (Dana, 1846)				1			1		1			1
Family Euphyllidae Veron, 2000												
Genus *Euphyllia* Dana, 1846												
Euphyllia ancora Veron and Pichon, 1979			1				1					
Euphyllia glabrescens (Chamisso and Eysenhardt, 1821)							1					
Genus *Plerogyra* Milne Edwards and Haime, 1848												
Plerogyra sinuosa (Dana, 1846)		1								1		
Genus *Physogyra* Quelch, 1884												

Species	Zones of High Impact	Zones of Moderate Impact		Zones of Influence		Reference			Regionally Significant Area		
	LNG0	MOF1	LNG1	LONE	ANT	LOW	AHC	BIG	LNG3	DUG	BAT	SBS
*Physogyra lichtensteini (*Milne Edwards and Haime, 1851)		1					1					
ORDER ALCYONACEA												
Family Alcyoniidae												
Genus *Sinularia*	2		1				3	3	2			
Genus *Lobophytum*				2			2	3				
Genus *Sarcophyton*			2				2	3	1		1	
Genus *Alcyonium*									1			
Family Nephtheidae												
Genus *Nephthea*							1		1			
Genus *Dendronephthya*				1			1			1	1	
Family Xeniidae												
Genus *Xenia*									1			
ORDER HYDROZOA												
Family Milleporidae												
Genus *Millepora*	5									1	1	

Appendix 4 Macroalgae Species List

Macroalgae Species	Site													
	NEBWI 1	BR	TP2	TP4	TP5	TP6	TP7	TP9	TP10	DI1	DS1	DSS1	TPC1	LC1
Acrochaetium sp.		X												
Aglaothamnion cordatum	X													
Amphiroa fragilissima														
Anotrichium tenue		X			X									
Asparagopsis taxiformis	X		X											
Avrainvillea obscura														
Bornetella oligospora														
Calothrix sp.		X												
Caulerpa brachypus			X											X
Caulerpa cactoides			X	X	X					X				
Caulerpa corynephora	X	X												
Caulerpa cupressoides	X	X												X
Caulerpa cupressoides var. *mamillosa*									X					
Caulerpa lentillifera					X	X								
Caulerpa racemosa var. *lamourouxii*														
Caulerpa serrulata					X									
Caulerpa sp.								X						
Centroceras clavulatum									X					
Champia parvula	X	X												
Champia sp.	X	X												
Chondria sp.		X												
Chondrophycus sp.		X			X									
Cladophora catenata														
Cladophora vagabunda		X												
Codium dwarkense														
Coelarthrum cliftoni	X													

Macroalgae Species	Site													
	NEBWI 1	BR	TP2	TP4	TP5	TP6	TP7	TP9	TP10	DI1	DS1	DSS1	TPC1	LC1
Coelothrix irregularis					X									
Corallinaceae		X		X				X				X		
Cottoniella filamentosa		X												
Cystoseira trinodis														
Dasya sp.		X												
Desikacharyella indica		X												
Dictyopteris australis			X		X			X						
Dictyopteris serrata	X													
Dictyopteris sp.				X	X	X		X						
Dictyopteris woodwardii	X	X								X				
Dictyota sp.		X	X		X	X		X		X				
Encyothalia cliftoni		X												
Feldmannia sp.		X												
Galaxaura rugosa	X		X		X									
Galaxaura sp.		X		X				X				X		
Gayliella flaccida		X			X									
Griffithsia sp.		X												
Halimeda cf. *cuneata*		X						X	X					
Halimeda cf. *discoidea*	X													
Halimeda cuneata														
Halimeda discoidea						X								X
Halimeda lacunalis														X
Halimeda macroloba												X	X	X
Halimeda sp.			X							X				
Haliptilon roseum		X												
Herposiphonia secunda		X												
Heterosiphonia callithamnion	X	X												
Heterosiphonia crassipes														X
Hincksia mitchelliae	X	X												

Macroalgae Species	**Site**													
	NEBWI 1	**BR**	**TP2**	**TP4**	**TP5**	**TP6**	**TP7**	**TP9**	**TP10**	**DI1**	**DS1**	**DSS1**	**TPC1**	**LC1**
Hormophysa cuneiformis														
Hydroclathrus clathratus	X													
Hypnea pannosa					X									
Jania rosea	X	X												
Jania sp.		X				X								
Laurencia sp.														
Leveillea jungermannoides	X													
Lobophora variegata														
Lophocladia sp.	X													
Padina australis					X									
Padina boryana					X									
Padina sp.	X	X	X			X		X	X	X				
Penicillus nodulosus														
Penicillus sp.				X	X	X							X	X
Phaeophyceae sp. (turf)		X	X	X	X	X				X	X	X		
Placophora binderi	X													
Platysiphonia delicata	X													
Polysiphonia sp.	X	X			X									
Sargassum carpophyllum					X									
Sargassum decurrens	X	X			X		X							
Sargassum oligocystum	X				X									
Sargassum peronii														
Sargassum sp.			X	X		X		X		X	X			
Sargassum sp.1	X	X												
Sargassum sp.2							X							
Sargassum sp.3														X
Spatoglossum macrodontum	X													
Sphacelaria rigidula	X	X			X									
Sporochnus comosus	X													

Macroalgae Species	Site													
	NEBWI 1	BR	TP2	TP4	TP5	TP6	TP7	TP9	TP10	DI1	DS1	DSS1	TPC1	LC1
Spyridia filamentosa		X							X					
Tolypiocladia glomerulata		X		X										
Udotea argentea				X		X	X		X					
Udotea flabellum														X
Udotea glaucescens												X		X
Udotea orientalis					X									
Udotea sp.			X							X	X	X	X	X

Macroalgae Species	Site					
	TPC3	LNGI2	LNGI1	LNGR2	LNGR3	LC4
Acrochaetium sp.						
Aglaothamnion cordatum						
Amphiroa fragilissima		X				
Anotrichium tenue						
Asparagopsis taxiformis						
Avrainvillea obscura	X					
Bornetella oligospora	X					
Calothrix sp.						
Caulerpa brachypus						
Caulerpa cactoides						
Caulerpa corynephora					X	
Caulerpa cupressoides	X					
Caulerpa cupressoides var. *mamillosa*						
Caulerpa lentillifera	X				X	
Caulerpa racemosa var. *lamourouxii*			X			

Macroalgae Species	Site					
	TPC3	LNGI2	LNGI1	LNGR2	LNGR3	LC4
Caulerpa serrulata					X	
Caulerpa sp.						
Centroceras clavulatum						
Champia parvula						
Champia sp.						
Chondria sp.						
Chondrophycus sp.						
Cladophora catenata					X	
Cladophora vagabunda						
Codium dwarkense	X				X	
Coelarthrum cliftoni						
Coelothrix irregularis						
Corallinaceae		X	X		X	
Cottoniella filamentosa						
Cystoseira trinodis			X		X	
Dasya sp.						
Desikacharyella indica						
Dictyopteris australis						
Dictyopteris serrata						
Dictyopteris sp.		X	X		X	
Dictyopteris woodwardii						
Dictyota sp.		X	X		X	
Encyothalia cliftoni						
Feldmannia sp.						
Galaxaura rugosa	X	X			X	
Gayliella flaccida						
Griffithsia sp.						
Halimeda cf. *cuneata*						
Halimeda cf. *discoidea*						

Macroalgae Species	Site					
	TPC3	LNGI2	LNGI1	LNGR2	LNGR3	LC4
Halimeda cuneata						X
Halimeda discoidea	X				X	
Halimeda lacunalis						
Halimeda macroloba	X					
Halimeda sp.			X			
Haliptilon roseum						
Herposiphonia secunda						
Heterosiphonia callithamnion						
Heterosiphonia crassipes						
Hincksia mitchelliae						
Hormophysa cuneiformis			X	X		
Hydroclathrus clathratus						
Hypnea pannosa						
Jania rosea						
Jania sp.						
Laurencia sp.		X				
Leveillea jungermannoides						
Lobophora variegata					X	
Lophocladia sp.						
Padina australis						
Padina boryana					X	
Padina sp.					X	
Penicillus nodulosus	X					
Penicillus sp.			X			
Phaeophyceae sp.(turf)	X	X	X		X	
Placophora binderi						
Platysiphonia delicata						
Polysiphonia sp.						
Sargassum carpophyllum						

Macroalgae Species	Site					
	TPC3	LNGI2	LNGI1	LNGR2	LNGR3	LC4
Sargassum decurrens			X		X	
Sargassum oligocystum						
Sargassum peronii				X		
Sargassum sp.						
Sargassum sp.1				X	X	
Sargassum sp.2			X	X		
Sargassum sp.3	X					
Spatoglossum macrodontum						
Sphacelaria rigidula						
Sporochnus comosus						
Spyridia filamentosa						
Tolypiocladia glomerulata						
Udotea argentea						
Udotea flabellum	X					
Udotea glaucescens						
Udotea orientalis	X				X	
Udotea sp.			X			

Appendix 5 Seagrass Species List

Seagrass Species	Site											
	BR	TP2	TP4	TP5	TP9	TP10	DI1	DS1	DS2	DSS1	TPC1	LC1
Cymodocea serrulata					X		X					
Halophila ovalis		X	X	X	X	X	X	X	X	X	X	X
Halophila spinulosa		X	X				X	X		X		X
Halophila decipiens		X	X				X					X
Syringodium isoetifolium	X	X	X				X					X

Seagrass Species	Site									
	LC2	DSR1	DSR3	TPC2	TPC3	LNGR1	LNGI1	LNGR2	DGIO	DSR5
Cymodocea serrulata										
Halophila ovalis	X	X	X	X	X	X	X	X	X	X
Halophila spinulosa	X	X			X	X				
Halophila decipiens			X		X		X			
Syringodium isoetifolium						X	X	X		

Appendix 6 Baseline Fish Survey: September 2010

CENTRE FOR MARINE FUTURES

THE UNIVERSITY OF WESTERN AUSTRALIA

BARROW ISLAND – BASELINE FISH SURVEY (STEREO BRUV)

FISH ASSEMBLAGES ASSOCIATED WITH THE MATERIALS OFFLOADING FACILITY, LNG JETTY AND DREDGE SPOIL DISPOSAL GROUND

Dianne Watson, Peter Barnes, Kris Waddington, Euan Harvey and Jessica Meeuwig

FINAL REPORT

CENTRE FOR MARINE FUTURES CMF_ 2010_06

PRODUCED FOR RPS/Chevron

Perth

4 SEPTEMBER 2010

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1. EXECUTIVE SUMMARY

In accordance with Condition 14.8.iii, Ministerial Implementation Statement (MIS) No. 800, a comprehensive field survey was conducted to benchmark the distribution, relative abundance and size structure of existing fish assemblages in the waters surrounding Barrow Island. Researchers from the Centre for Marine Futures, University of Western Australia (UWA) and RPS conducted the surveys in October 2008 and March 2009. Surveys of demersal fish assemblages were conducted across key habitats around Barrow Island including; coral, macroalgae, sand and sessile invertebrates. In addition, fish assemblages were benchmarked across a range of potential impact and reference sites within each habitat class such that, with repeated sampling, potential impacts of construction and dredging and spoil disposal activities may be detected.

A non-destructive, fishery independent sampling technique was chosen to conduct these surveys, namely baited remote underwater stereo-video (stereo BRUV). The stereo configuration of the systems enables very accurate and precise measures of fish length. Furthermore, the use of bait facilitates sampling of a diverse range of fish species with sufficient power to detect change in assemblage structure over time.

The results of this benchmark fish survey are significant, highlighting distinct assemblages in key habitats surrounding Barrow Island. Assemblages in coral habitats were the most diverse comprising many small pomacentrids, scarids and large lutjanid and serranid predators. Habitats dominated by macroalgae had high abundances of small nemipterids and juvenile lethrinids, siganids and labrids. Macroalgae appears to be an important nursery ground for a diverse range of fish families. Stereo BRUVs deployed in bare sandy areas were often visited by large transient predators including carangids and scombrids. Also high in abundance in sandy areas were small-bodied monacanthids, nemipterids and tetraodontids. In contrast, fish assemblages in sand areas with high sessile invertebrate coverage had high abundances of lethrinids, nemipterids and carangids. In general, fish assemblages in sand and sessile invertebrate habitats were less diverse than those in coral or macroalgae habitats.

At present there are no differences in the structure of fish assemblages at sites within the different Zones of Impact (Zones of High Impact, Zones of Moderate Impact and Zones of Influence) and Reference areas. Therefore, any change in fish assemblages as a result of construction and dredging activites should be detectable in future surveys, subject to ensuring sufficient replication temporally and spatially.

2. INTRODUCTION

The Ministerial Conditions for the Gorgon Gas Development relating to the fish assemblages have the following requirements:

i. Record the demersal fish assemblages that characterise the hard and soft coral, macroalgae, non-coral benthic invertebrate, seagrass and mangrove communities (Condition 14.8.iii of Statement No. 800).

ii. Describe demersal fish within the Zones of High Impact and Zones of Moderate Impact and representative areas in the Zones of Influence associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal required for Marine Facilities listed in Condition 14.3 (i-iii) of Statement No. 800 (MOF, LNG Jetty and Dredge Spoil Disposal Ground).

iii. Describe demersal fish of reference sites which are not at risk of Material or Serious Environmental Harm due to construction and operation of Marine Facilities listed in Condition 14.3 of Statement No. 800 (MOF, LNG Jetty and Dredge Spoil Disposal Ground).

This report specifically analyses the baseline data associated with the Materials Offloading Facility (MOF), LNG Jetty and Dredge Spoil Disposal Ground. A second report will address the conditions associated with the Offshore Feed Gas Pipeline System and Domestic Gas Pipeline. No data are presented for the WAPET Landing as this area was not surveyed using the stereo BRUV technique. This baseline survey program includes a comprehensive survey of the demersal fish in Barrow Island waters. 'Demersal' refers to those fish species that live at, or near the seabed. These species are often strongly associated with benthic habitats. Survey sites were selected using ground-truth data to reflect the range of major benthic habitats known to exist in Barrow Island waters (coral, macroalgae and sand/benthic invertebrates) and potential levels of impacts from dredging and construction of marine facilities. The demersal fish surveys were conducted by the Centre for Marine Futures, University of Western Australia (UWA) and RPS using baited remote underwater stereo-video systems (stereo BRUV), a non-destructive, fishery-independent sampling technique (Harvey et al. 2001).

Stereo BRUV allowed the collection of diversity, relative abundance and length information on a broad range of fish species across habitat classes and zones of potential impact at Barrow Island. Stereo BRUVs were chosen to survey fish assemblages as they are non-destructive and provide measures of relative abundance and diversity as well as very accurate and precise measures of fish length (Harvey et al. 2001, 2002a, 2004; Watson et al. 2005). The use of stereo BRUV to survey demersal fish assemblages has undergone expansion in recent years with the technique now widely employed across Australia (e.g. Broome (Newman unpubl. data.), Ningaloo Reef (Fitzpatrick unpubl. data), the Great Barrier Reef (Cappo unpubl. data), and in southwestern Australia from the Houtman Abrolhos Islands to Esperance (Watson et al. 2005, 2007, 2009; Marine Futures unpubl. data). Stereo BRUVs can be deployed from 3 to 500 m depth and are particularly useful as they overcome or minimise sampling limitations related to (1) safety and field logistics as divers are not required, (2) observer experience, (3) intra- and inter-observer variability, and (4) fish/diver interactions (Harvey et al. 2001a, 2001b, 2004; Cappo et al. 2002). Many of these limitations and biases hamper more traditional survey techniques such as Underwater Visual Census (UVC) by SCUBA divers. The collection of high-definition video that can be repetitively viewed at any stage permits more accurate identification of fish to species level using image libraries in laboratory. The use of stereo BRUV to survey fish assemblages around Barrow Island waters also facilitated an increased sampling capability as it removed the limitations of dive time (decompression limits).

The use of bait in stereo BRUVs increases the abundance and diversity of fishes observed, particularly species of interest to fishery or park managers, such as piscivores, without precluding the sampling of prey or herbivorous fish species (Watson et al. 2005; Harvey et al. 2007). Furthermore, bait entices cryptic species out of crevices and into view (e.g. moray eels, *Gymnothorax* spp) and draws in pelagic and transient species (e.g. mackerel, Scombridae spp) (Watson et al. 2007). An additional advantage of stereo BRUVs is that they provide highly accurate measurements of length, which, where length/weight relationships exist, can be used to estimate weight. Equipped with lights, stereo BRUVs can be deployed at night time to obtain a diurnal representation of the fish assemblage. Night sampling was not conducted here for two reasons; 1) recent work has revealed very low species richness and abundance at night (Watson and Harvey unpubl data) and 2) difficulty in comparing day and night fish assemblages given the varying behaviour of fish to different coloured lights.

2.1. CURRENT KNOWLEDGE OF NORTH-WEST AUSTRALIAN FISH FAUNA

Survey work to date on the fish fauna of north-western Australia has revealed a species-rich assemblage (e.g. Travers et al. 2006; Hutchins 2004; Fox and Beckley 2005). However, the degree of endemism in the fish fauna of the North West Shelf is low when compared to the temperate waters of southern Western Australia (Fox and Beckley 2005).

The Montebello/Barrow Islands region supports a rich fish fauna with 456 species from 75 families recorded during a Western Australian Museum survey in 1993 (Allen 2000). The fish fauna of the Montebello/Barrow Islands is considered to be closely related to that of the Dampier Archipelago, where 650 species were recorded during another Western Australian Museum survey (Hutchins 2004).

2.2. CURRENT KNOWLEDGE OF DREDGING IMPACTS ON FISH ASSEMBLAGES

Dredging and dredge spoil disposal will be undertaken at Barrow Island as part of the proposed Gorgon Gas Development. Dredging activities can have a range of effects on fish through increasing turbidity and suspended sediment concentrations (Hovenkamp-Obbema and Fieggen 1992; Clarke and Wilber 2000; Au et al. 2004). These include physically disturbing fish habitat by elevated sedimentation rates (Rhoades and Germano 1986), interfering with recruitment or migratory behaviours (Thrush et al. 2002), and hydraulically entraining demersal fish species in dredging equipment (Harvey and Lisle 1998; Reine and Clarke 1998; Reine et al. 1998). Of these effects, sediment resuspension is the impact most widely cited in the literature (see Anchor 2003 for a review) and likely to be most widespread. For instance, Au et al. (2004) examined the influence of suspended sediments on the estuary cod (*Epinephelus coioides*), finding that prolonged exposure to suspended solids can cause sub-lethal stress and compromise health. Thrush et al. (2002) showed strong links between habitat structure and juvenile pink snapper (*Pagrus auratus*) distribution, suggesting that where dredging results in habitat removal, consequences may be severe for certain species.

Effects of dredging activities on fish assemblages in an area will vary depending on local environmental conditions, larger scale environmental conditions and the size and frequency of dredging operations (Blanchard and Feder 2003). Furthermore, dredging activities will likely illicit different responses among different fish species and even within a species depending upon their life history stage and habitat preferences.

2.3. IMPORTANCE OF BASELINE FISH ASSEMBLAGE DATA

The baseline fish surveys conducted at Barrow Island were designed to be robust, repeatable and provide sufficient data on fish populations to enable subsequent determination of potential impacts associated with dredging and construction in accordance with Condition 14.8.iii, Ministerial Implementation Statement (MIS) No. 800. To enable detection of potential impacts and change in a fish assemblage, the appropriate population parameters must be assessed. There have been numerous studies of the impacts on fish assemblages from disturbance including crown of thorns (Sano 2000), coral bleaching (Kokita and Nakazono 2001) and storms (Halford et al. 2004). These studies reported little or no impact on fish assemblages. Bellwood et al. (2006) suggested that failure to detect impacts can be related to the selection of inappropriate metrics or population parameters - highlighting the need for information on fish assemblage structure (composition, abundance, diversity, fish size). This baseline demersal fish survey has been designed to determine information on the composition of fish assemblages, as well as traditional metrics such as species richness, relative abundance and fish length.

Change in the size structure of fish assemblages and species is widely used as an indicator of disturbance and is typically quantified in terms of fish length (Graham et al, 2005; Jennings et al. 2002). Changes in size at the assemblage level reflect changes in trophic structure (Jennings et al. 2002; Pauly 2007), while changes in size structure at the species level reflect changes in recruitment to commercial and recreational fisheries as well as changes in reproductive potential (Lucero 2008). Where relationships exist between weight and length, fish length measurements can also be converted to biomass which also may be used as an indicator of disturbance (Casatti et al. 2006; Duplisea and Kerr 1995; Clarke and Warwick 2001). However, it should be noted that biomass can be a less sensitive indicator of change than length due to intrinsic error associated with equations that estimate an unknown (e.g. weight) from a known (length).

3. METHODS

3.1. STUDY SITE

Barrow Island is located approximately 70 kilometres off the Pilbara coast of Western Australia (20° 47' S, 115° 24' E) (Figure 1). Barrow Island was gazetted as a class A nature reserve in 1910 after a range of unique flora and fauna were identified. The State waters surrounding Barrow Island are part of the Barrow-Montebello Islands Marine Conservation Reserve (Department of Conservation and Land Management, 2007) and are encompassed by the Barrow Island Marine Management Area, which includes the Barrow Island Marine Park (sanctuary zone) on the west coast and a conservation area, Bandicoot Bay, on the south coast of Barrow Island. The Barrow Island Port Area on the east coast of Barrow Island is excluded from the Marine Management Area and contains most of the Gorgon Project Marine Facilities proposed for the eastern side of Barrow Island. Barrow Island is also home to Australia's largest operating oilfield. This study focussed on the fish assemblages that occupied major abiotic and biotic habitats (e.g. coral, macroalgae, sand and sessile invertebrates) in the waters surrounding Barrow Island.

3.2. SAMPLING DESIGN

Demersal fish surveys were conducted in the waters surrounding Barrow Island from the 20^{th}-29^{th} October, 2008 and from the 16^{th}-27^{th} March, 2009 (Figure 1, Figure 2). Multiple surveys were conducted to assess fish assemblage structure in different seasons, to provide additional power to detect potential impacts and to ensure good coverage of habitats within each of the Zones of Influence. The majority of sites surveyed in October 2008 were re-surveyed in 2009 where additional sites were added to provide sufficient statistical power (Table 1). The surveys were conducted to benchmark the fish assemblages across a broad spectrum of habitats in depths ranging between 1 m and 25 m. The following criteria were used to ensure that fish assemblage data would provide an adequate benchmark and allow for testing of potential impacts (Green 1979, Underwood 1992):

- Sites were chosen to represent the four major habitats (strata) identified in the study area: (1) corals (soft and hard); (2) macroalgae dominated; (3) bare sand and (4) sand with sessile invertebrates (Figure 3; see Appendix II for detailed maps of the distribution of sampling sites with respect to particular habitat types).

- Sites were chosen to represent four Zones of Impact: (1) Zones of High Impact; (2) Zones of Moderate Impact; (3) Zones of Influence and; (4) Reference. The Zones of Impact were derived from the hydrodynamic dredge plume modeling outputs together with cumulative coral threshold criteria. The Zones of Impact include areas of predicted impact to corals from sedimentation and turbidity. Corals are considered to be the most sensitive ecological element within these zones so impacts to other benthic ecological elements such as seagrass and macroalgae are predicted to be less or more short term than impacts to coral. There is no predicted measurable impact upon marine benthic primary producers within the Zones of Influence. Therefore, for the present analyses examination of reference areas also included data obtained from sites within the Zones of Influence. For future analyses fish assemblages within the Zones of Influence will be compared to those in reference areas to ensure similar fish assemblages exist in both zones before they are considered together.
- Sites were chosen for each of these habitat types and impact levels in relation to the footprints of the MOF and LNG Jetty, and the Dredge Spoil Disposal Ground.
- Replicate sites were chosen for each habitat/impact/activity combination. Replication at the level of sites was to some degree constrained by available sites (e.g. a limited number of coral habitats are located within the study area).
- Within each site, stereo BRUV cameras were deployed at five ‘drops’, with each drop (deployment) at least 250 m apart.

The location and dominant habitat of all sites surveyed for every Impact Level is presented in Table 1. Following analysis of video images from the October 2008 survey – some changes were made to site names and locations for the March 2009 survey. These changes were made to 1) include additional reference sites so that sufficient power is attained to enable statistical detection of potential impacts in the future and 2) to simplify site names for reporting and recording purposes.

3.3. EQUIPMENT AND LOGISTICS

Demersal fish assemblages were surveyed using baited remote underwater stereo-video systems (stereo BRUVs) (Harvey et al. 2002a; and Watson et al. 2005, 2007; Figure 4). Information on the design, measurement and calibration procedures are presented in Harvey and Shortis (1996, 1998). The stereo BRUVs in this study used two SONY HDR-CX7 and CX12 handycams in water proof housings. The housings were mounted 0.7 m apart on a base bar inwardly converged at 8 degrees to gain an optimized field of view with visibility of 8 m distance (Harvey and Shortis 1996; Figure 4). A synchronising diode and bait basket was positioned in the field of view of both cameras (Figure 4).

Each stereo BRUV system was deployed by boat and left to film on the sea floor for a period of at least one hour. Ten stereo BRUVs were deployed synchronously (2 sites), maximising sampling efficiency. Previous research has shown that a filming time of at least 36 minutes is essential to maximise measures of diversity and that it is advisable that 60 minutes is recorded and analysed to obtain measures of numerous targeted fish species (Watson 2006). Exactly 60 minutes bottom-time was analysed for all video recordings. Stereo BRUVs were baited with 800 grams of pilchards placed in a lobster bait basket. The bait basket was centrally suspended 1.2 m in front of the two cameras using a piece of conduit. The pilchards were crushed to maximise dispersal of the fish oil. Adjacent deployments were separated by at least 250 m to avoid overlap of bait plumes and reduce the likelihood of fish moving between deployments within the sampling period.

Stereo BRUVs were deployed and retrieved from the Calypso. The stereo BRUV team consisted of six people, comprising a skipper and five field crew members. Of the field crew, one operated the winch, a second prepared the cameras for deployment and recorded the deployment times and positions, and the remainder set and loaded the cameras, baited the stereo BRUV, and assisted with deployment and retrieval of the stereo BRUVs. The second crew member also recorded the numbers of the cameras that were deployed, while the skipper operated the positioning software (ARC PAD) which had all the sampling sites loaded into it in advance. For both sampling occasions, the teams were mobilised from Perth to Exmouth, then transported to Barrow Island aboard the Calypso. The field team and crew remained onboard the boat during the entire sampling period, with sampling occurring on a daily basis subject to weather, tidal conditions and visibility. As collection proceeded, high definition stereo BRUV footage was downloaded from internal memory cards to hard drives, with data backed-up to separate hard drives on a daily basis.

3.4. IMAGE ANALYSIS

In the laboratory, high definition stereo BRUV footage was downloaded from internal memory cards to hard drives and converted from .m2ts to .mpeg format using Elecard Converter Studio AVC HD V 3.0. EventMeasure (SeaGIS Pty Ltd 2008) was used to view and analyse all footage for measures of relative abundance for all fish species. This software program was purpose built for analysis of fish assemblages and includes a built-in movie player, extensive fish reference library and the ability to zoom in on targets. Identification of fish to species level from high definition video was aided by relevant literature (Randall et al. 1997; Allen et al. 1998; Lieske and Myers 2001; Randall 2002; Allen et al. 2003; Hutchins 2003; Allen 2004). Relative abundance counts were obtained as the maximum number of fish belonging to each species, present in the field of view of the stereo BRUV at one time (MaxN; Priede et al. 1994; Cappo et al. 2004). This measure avoids repeated counts of the same individual and provides a conservative measure of relative abundance, as on occasion only a portion of the total number of individuals in the area may be viewed at one time.

PhotoMeasure (SeaGIS Pty Ltd 2008) was used to make length measurements from the left and right stereo pair of images (Figure 5). To avoid making repeated measurements of the same individuals, measures of length (snout to fork, FL) were made at the time of MaxN determined using EventMeasure. This MaxN 'time' is not instantaneous; rather it corresponds to the amount of time all individuals remained in the field of view of the stereo BRUV. To ensure good measurement accuracy and precision, measures of fish length were limited to those individuals within a maximum distance of 7 m from the cameras (Harvey et al. 2002b). After this point measurement accuracy can deteriorate. The software calculates both distance from the cameras and length at the same time, allowing measurements of individuals further than 7 m from the cameras to be discarded. With improvements to camera technology it is likely that accurate measurements are obtainable to distances of 10 m, however this is currently being tested (Harvey et al. in prep).

In addition to information on the fish assemblage, the stereo BRUV images were used to verify habitat type and to estimate visibility. Visibility was generally good throughout the study averaging >6 m on the eastern side of Barrow Island, despite a coral spawning event during the second (2009) survey and no samples were excluded from either survey on the basis of poor visibility (e.g. <2 m). All species identifications, counts and measurements were made by experienced analysts.

3.5. STATISTICAL ANALYSIS

The overall fish assemblage was first described in terms of number of species, abundance of species, and their commonality (number of sites) and size structure.

Sampling was designed to examine differences in fish assemblage structure (composition, richness, abundance, size) across habitats and Zones of High Impact, Zones of Moderate Impact and Zones of Influence for the MOF and LNG Jetty and the Dredge Spoil Disposal Ground. For this report, the MOF and LNG Jetty are considered together as a single impact. An initial two factor multivariate analysis was conducted to ascertain overall habitat effects on fish assemblages at Barrow Island. The two factors were: Habitat (four levels, fixed: coral, macroalgae, sand, sessile invertebrates), and Site (nested in Habitat, random with varying levels). The multivariate abundance data set was analysed using permutational multivariate analysis of variance with 9999 permutations (PERMANOVA; Anderson 2001) in the Primer-E software package. This permutational approach was used for analyses because the relative abundances of fish were highly skewed and contained many zero counts (non-normal data). The multivariate analysis was conducted using the Modified Gower log base 10 dissimilarity matrix (see Anderson et al. 2006) on raw untransformed relative abundance data. Univariate analysis for species richness was analysed using the Euclidean Distance dissimilarity measure. Where significant relationships were evident, similarity percentages (SIMPER; Clarke and Warwick 2001), on fourth-root transformed data, were used to examine which individual species contributed to any observed differences in assemblage composition by identifying those with a ratio of dissimilarity to standard deviation greater than 1.

For the two types of impact 1) MOF/LNG Jetty and 2) Dredge Spoil Disposal Ground, a three factor multivariate analysis was conducted to determine whether any differences exist in fish assemblages across the different Zones of Impact (High, Moderate, Zones of Influence) and across habitats at Barrow Island. The three factors were: Level of Impact (three levels, fixed: high, moderate, zones of influence), Habitat (four levels, fixed: coral, macroalgae, sand, sessile invertebrates), and Site (nested in Level of Impact x Habitat, random with varying levels). Fish assemblages at sites within the Zones of Influence were also compared to those at Reference sites. As no difference currently exists, Zone of Influence sites could be considered together with Reference sites when describing fish assemblages at Reference sites at Barrow Island. The multivariate data set and univariate species richness data set were then analysed using the same PERMANOVA model (see previous paragraph).

Patterns in the size structure of assemblages were compared using length-frequency histograms and tested using a Kolmogorov-Smirnov distribution test. Graphs of mean lengths and tables of length-specific data are also presented.

4. RESULTS

4.1. FISH ASSEMBLAGE STRUCTURE

Across the two surveys, a total of 24,838 individuals from 321 species and 63 families were recorded from the MOF, LNG and Dredge Spoil Disposal Ground Zones of High Impact, Zones of Moderate Impact and Zones of Influence sites and Reference areas to the east of Barrow Island. A small number of species were grouped to the level of genus or family as species could not be consistently identified from video. These were *Sillago* spp (whitings), *Nemipterus* spp (threadfin-breams), Platycephalidae spp (flatheads), *Pseudorhombus* spp (flounders) and Scombridae spp (mackerels) (APPENDIX I).

In the first survey in October 2008, a total of 11,393 individuals from 248 species and 52 families were recorded from 150 stereo BRUV deployments (see APPENDIX I for full species list). On average, 17.5 ± 0.8 SE species were observed on each deployment. The highest species richness recorded for a single deployment was 49 species at a coral site within the Dredge Spoil Disposal Ground Zone of Influence (CNR4; see Figure 1 and Table 1 for site location and information). Numbers recorded in the second survey in March 2009 were very similar with a total of 13,440 individuals from 247 species and 54 families recorded from 183 stereo BRUV deployments (see APPENDIX I for full species list). In 2009, 17 ± 0.8 SE species, on average, were observed on each deployment. The highest species richness recorded for a single deployment was 50 species at a reference coral site (CFR4; see Figure 2 and Table 1 for site location and information).

The most diverse family recorded at Barrow Island was the labrids (31 species in 2008; 29 species in 2009), followed by the pomacentrids (25 and 26 species, respectively), serranids (14 and 16 species), carangids (13 and 15 species), and chaetodontids (13 and 15 species)

(APPENDIX I). The 20 most common fish species (observed on the greatest number of stereo BRUV deployments) for 2008 and 2009 surveys are listed in Table 2. Of these, the most common species were the mackerel (Scombridae spp), northwest threadfin bream (*Pentapodus porosus*), blue tuskfish (*Choerodon cyanodus*), and blackspot tuskfish (*Choerodon schoenlenii).* While the scope of the project was only to examine demersal fish species, transient species were included in the analyses as a number of species were consistently common and abundant for both survey periods (e.g. mackerel, trevally species). Their abundance was not variable between sampling times. The decision to include transient species may be re-examined for surveys post-dredging and construction if there is any suggestion that their presence may be influenced by other factors such as season. From these surveys we suggest this is unlikely. Here, the high abundance and commonality of transient species to both sampling occasions and their strong links to particular habitat types around Barrow Island warranted their inclusion in the data set and analyses.

Across both survey times the lengths of 13,482 individuals from 302 species were measured from stereo-imagery pairs. In October 2008, 6408 individuals from 221 species were measured with sizes ranging from a 21.9 mm meteor cardinalfish (*Apogon selas)* to a 2.78 m great hammerhead shark (*Sphyrna mokarran).* In March 2009, 7074 individuals from 233 species were measured. The smallest individual was a 24.2 mm juvenile swarth-headed goatfish (*Parupeneus barberinoides*) and the largest a 2.62 m great hammerhead shark (*Sphyrna mokarran*).

An unusual observation of an albino leopard shark (*Stegastoma fasciatum)* was made in 2008 at DSFR3/DGNR3 (see Figure 6 and Table 1 for site information). This individual was 1.17 m in length. In 2009, another albino leopard shark was sighted but this time at site SIFR3 and was 1.65 m in size. Despite the relatively rare occurrence of these colour morphs, these were likely different individuals based on the difference in size and growth rates (the size difference would assume an 8% increase in length per month over the five month period).

4.2. FISH ASSEMBLAGES THAT CHARACTERISE OBSERVED HABITATS

The habitats surveyed during this study were primarily coral, macroalgae, sand and sessile invertebrates. A sparse covering of seagrass (*Halophila* spp*)* was observed at a few sessile invertebrate sites (DSI1, DSI2; 2008 and 2009; see Figure 3D) and SIN7 (2009). There was a slightly higher coverage of *Halophila* spp in 2008 at DSI1 and DSI2 than in 2009, reflecting seasonal changes in the cover of this species (Gary Kendrick pers comm). Despite sparse presence of seagrass, it was quite patchy and these sites remained classed as 'sessile invertebrates' given the presence of sea whips, sea fans, sponges and hydroids.

The relative abundance and composition of fish assemblages differed across the four habitats surveyed in 2008 and in 2009 (Table 3; Figure 7). Pairwise tests showed that fish assemblages were distinct at each of the four habitats (all $t > 1.7$, $p < 0.05$). The species characterising coral, macroalgae, sand and sessile invertebrate-dominated habitats are described below.

The size structure of fish assemblages varied across four habitat categories studied (Komolgorov-Smirnov tests (K-S tests), $p < 0.05$; Figure 8). The only exception was for macroalgae and sessile invertebrate habitats were fish assemblages were of similar size structure. Species driving the observed differences are described below.

4.2.1. Coral sites

Coral sites possessed significantly higher species richness than all other habitat types (all $p < 0.5$) in 2008 (193 species) and in 2009 (183 species) (Table 6). On average, 28.4 ± 1.5 SE species were viewed on each stereo BRUV deployment in coral in 2008 and 30.6 ± 1.4 SE in 2009.

Coral habitats were typified by a high abundance of small-bodied pomacentrids (e.g. *N. filamentosus, A. bengalensis*) and common occurrence of larger serranids, labrids, lutjanids and lethrinids (Table 4, Table 5). During both surveys, coral sites had a higher abundance of many fish species compared to other habitats including *Thalassoma lunare, Abudefduf bengalensis, Lutjanus carponotatus, Acanthurus grammoptilus, Pomacanthus sexstriatus, Neopomacentrus filamentosus, Lethrinus atkinsoni, Pterocaesio digramma* and *Caesio cuning.* Many other species had similar abundances in coral and macroalgal habitats – but were far more abundant in these habitats than in sand and sessile invertebrate habitats. These species included *Choerodon schoenleinii, Choerodon cyanodus, Choerodon cauteroma, Plectropomus maculatus, Pentapodus emeryii,* and *Scarus schlegeli.* Further information on fish species in coral habitats is presented in Section 4.6 for Indicator Species.

A number of fish species were more abundant on coral reefs during the October 2008 survey as compared to the March 2009 survey, including *Thalassoma lunare, Epinephelus bilobatus, Hemigymnus melapterus* and *Naso unicornis.* Conversely more abundant in 2009 than in 2008 were *Lutjanus carponotatus, Choerodon cauteroma, Carangoides fulvoguttatus, Epinephelus fasciatus, Epinephelus polyphekadion, Neopomacentrus filamentosus* and *Pomacanthus sexstriatus.*

The size structure of fish assemblages on coral reefs differed to all other habitats (all K-S tests, $p < 0.05$). These coral sites comprised a greater proportion of larger-bodied individuals >240 mm FL than any other habitat type (Figure 8). This reflects the higher abundance and commonality of many lethrinids, lutjanids and serranids on coral reefs.

4.2.2. Macroalgae sites

Macroalgal-dominated sites had higher species richness than sand and sessile invertebrate habitats (all $p < 0.05$; 2008 and 2009). A total of 84 species were observed in 2008 with an average of 14.9 ± 0.8 SE species per stereo BRUV deployment (Table 6). A higher number of species were observed in this habitat in 2009 at 110 species and an average of 19.6 ± 0.7 SE viewed on each stereo BRUV deployment (Table 6).

For both sampling times, macroalgal habitats were typified by a high abundance of juveniles – in particular, *Lethrinus* sp and various *Choerodon* spp (Figure 9). *Plectropomus maculatus* juveniles were observed in March 2009 but not in October 2008. Figure 9 illustrates the presence of juveniles in 2009 compared to 2008 by a large difference in mean lengths. Also high in abundance and commonality were small nemipterids (*Pentapodus porosus, Pentapodus vitta)* (Table 4, Table 5). Compared to coral, macroalgal, sessile invertebrates and sand habitats had increased abundances of *Lethrinus* sp and *Siganus fuscenscens. Choerodon cauteroma* was also present in higher abundances at macroalgal sites than coral sites. Other species present in higher abundances at macroalgae habitats than at sessile invertebrates and sand sites were also abundant at coral sites and are listed in Section 4.3.1.

There was a noticeable difference in the abundance of many fish species present in macroalgal habitats between the October 2008 survey and the March 2009 survey. While the species observed on both occasions were very similar, abundances were higher in March 2009. More abundant, on average, at this time were *Acanthurus grammoptilus, Carangoides* *fulvoguttatus, Choerodon cauteroma, Choerodon cyanodus, Choerodon schoenleinii, Epinephelus rivulatus, Lethrinus genivittatus, Parupeneus indicus, Pentapodus emeryii, Pentapodus porosus, Pentapodus vitta, Plectropomus maculatus, Scarus schlegeli, Scolopsis monogramma, Siganus fuscescens* and *Symphorus nematophorus.* A greater number of juveniles were observed in March 2009 compared to October 2008. These species, including *Plectropomus maculatus, Siganus fuscescens* and *Pentapodus porosus* were absent or present in very low numbers during October 2008.

The size structure of fish assemblages in macroalgal beds differed to most other habitats (all K-S tests, $p < 0.05$) with the exception of sessile invertebrates (Figure 8). Macroalgal sites comprised a high proportion of individuals in the 80-200 mm FL range. This size range reflects the higher abundance of nemipterids and juvenile *Lethrinus* and *Choerodon* species at these sites (Figure 9).

4.2.3. Sand sites

Bare sand sites had lower species richness than coral and macroalgal sites (all $p < 0.05$) but similar species richness to sessile invertebrate sites. In 2008, a total of 33 species were observed in bare sand habitats across 18 sites with an average of 10.4 ± 0.5 SE viewed on each stereo BRUV deployment. In 2009, a total of 75 species (64 sites) were recorded with an average of 9.1 ± 0.4 SE observed on each stereo BRUV deployment (Table 6).

Assemblages in bare sand habitats were quite uniform with high abundances of *Selaroides leptolepis, Pentapodus porosus, Pentapodus vitta, Nemipterus* spp and Scombridae spp observed on both sampling occasions (Table 4; Table 5). Small individuals such as *Paramonacanthus choirocephalus* and *Upeneus tragula* were common and abundant as were larger individuals such as *Echeneis naucrates.* The high prevalence of small-bodied individuals over sand habitats is reflected in the size-frequency histograms (Figure 8).

Highly abundant in 2008 but absent in 2009 were an unidentified herring species, *Herklotsichthys* sp. During October 2008, this species was recorded in large schools (100-500 individuals) at nine sites. The greater abundance of this species in 2008 is reflected in the size frequency histogram for this year with a peak at 80-200 m FL (Figure 8). In contrast, large schools of *Atule mate* were observed in March 2009, but only a small number of individuals were observed in October 2008. Generally, fish assemblages over bare sand habitats appeared quite similar across the sampling locations.

4.2.4. Sessile invertebrates sites

In 2008, a total of 102 fish species were observed associated with sessile invertebrates and an average of 10.3 ± 0.9 SE species per stereo BRUV deployment (Table 6). In 2009, a total of 62 species were observed and an average of 9.3 ± 0.6 SE per stereo BRUV deployment (Table 6).

Sessile invertebrate habitats were characterised by high abundances and commonality of *Pentapodus porosus, Selaroides leptolepis, Pentapodus vitta* and *Nemipterus* spp*,* Scombridae spp (Table 4; Table 5). Compared to bare sand habitats, sessile invertebrates had higher abundances of *Pentapodus porosus* and various lethrinids associated with them. Fish assemblage structure in sessile invertebrate habitats tended not to be as uniform as bare sand habitats, as illustrated by lower commonality percentages for the 10 most common species in Table 5.

In October 2008, higher average abundances of *Abalistes stellatus* and *Atule mate* were observed compared to March 2009 (SIMPER Diss/SD > 1). Conversely, species present in higher mean abundance in 2009 included *Carangoides fulvoguttatus, Diagramma labiosum, Pentapodus porosus, Pentapodus vitta* and *Symphomorus nematophorus.*

Sessile invertebrate habitats possessed fish assemblages of a similar size structure to macroalgal habitats, despite comprising different species (Figure 8). Fish assemblages in sessile invertebrate habitats comprised a large proportion of individuals in the size range 120-240 mm FL. Individuals within this size range and common in sessile invertebrate habitats were *Pentapodus porosus, Selaroides leptolepis* and *Nemipterus* spp*.*

4.3. FISH ASSEMBLAGES ASSOCIATED WITH THE MATERIALS OFFLOADING FACILITY AND LNG JETTY

Prior to commencement of dredging and construction activities for the Materials Offloading Facility and LNG Jetty, no differences in the species richness, relative abundance and composition of fish assemblages existed between Zone of High Impact, Zone of Moderate

Impact and Zone of Influence for both sampling times (2008 & 2009, $p > 0.05$; Figure 10). There were, however, some minor differences in the structure of fish assemblages between the Zones of Impact. These are described in sections below. Furthermore, fish assemblage structure varied across the different habitat types and sites (Figure 11) as described below.

4.3.1. Size structure of fish assemblages across different Zones of Impact

Considering each habitat type separately, there were some differences observed in the size structure of fish assemblages across the Zones of Impact. In 2008, the only coral site surveyed within the Zone of High Impact (CI1) has a different size structure to coral sites surveyed within each of the other zones (Moderate, Zone of Influence and Reference; K-S tests, $p < 0.05$). This was likely due to the presence of schooling *Pterocaesio tile* at CI1. A similar result was observed in 2009 with site CI1 having a different size structure to coral sites within the Zone of Moderate Impact, Zone of Influence and Reference sites. This was due to a greater proportion of individuals in the size category of 200-280 mm FL at this single site, reflecting the presence of schooling *Glaucosoma magnificum.*

For macroalgal habitats, the size structure of fish assemblages differed between all of the zones for each sampling time. In 2008, sites within the Zone of Moderate Impact (MI1, MI2) had a higher proportion of individuals 160-200 mm FL than sites in other Zones due to high numbers of small *Lethrinus* sp. Macroalgal reference sites had a higher proportion of small 40-80 mm FL individuals (*Pomacentrus coelestis* and *Neopomacentrus filamentosus*) than sites in other zones. In 2009, the presence of high numbers of juveniles across a range of species at macroalgal sites within the Zone of Influence meant that these sites had a higher proportion of individuals 81-120 mm than sites in Moderate Zones of Impact and Reference sites where lower numbers of these juveniles were measured. Larger individuals of the same species (*Siganus fuscenscens, Lethrinus* sp*, Pentapodus porosus)*, 181-200 mm FL, were observed at sites within the Zone of Moderate Impact (MI1 and MI2) compared to sites within the Zone of Influence and Reference sites.

In 2008, there was no difference in the size structure of fish assemblages in sessile invertebrate sites across the different Zones of Impact. No sand sites were surveyed for the MOF/LNG Jetty in 2008. In 2009, the size structure of sessile invertebrate sites within the Zone of Influence differed to Reference sites. Within the Zone of Influence a higher abundance of *Pterocaesio digramma* and *Thalassoma lunare* were measured resulting in a higher proportion of individuals 81-121 mm FL than at Reference Sites. More *Lethrinus* sp*,* *Nemipterus* spp and various carangid species were measured at sessile invertebrate Reference sites giving them a higher proportion of individuals measured 161-280 mm FL than sites within the Zone of Influence. In 2009, the sand site within the Zone of High Impact (SI2) had a similar size structure to the sand site within the Zone of Influence (SIN1) but both had different size structures to the site within the Zone of Moderate Impact (SI1) and Reference sites. Site SI2 and SIN1 both had higher proportions of their assemblages in the 81-120 mm FL category than SI1 and Reference sites. Site SI1 and Reference sites had a higher proportion of their assemblage in the 121-160 mm FL category. While species were similar at all sites, they were slightly larger at SI1 and Reference sites (*Selaroides leptolepis* and various nemipterid species).

4.3.2. Zone of High Impact

In October 2008, a single coral site of High Impact was surveyed: CI1. This coral site was re-surveyed in March 2009 in addition to a second high impact site on sand: SI2 (Table 1).

4.3.2.1. Coral site

In 2008 a total of 343 individuals from 65 species were recorded from site CI1 (Table 6). On average 25.4 ± 5 SE species were observed per stereo BRUV deployment. In 2009, 695 individuals from 80 species were observed at the same site with an average of 31.2 ± 3.9 SE species per stereo BRUV deployment. Several large schools (200) of threadfin pearl perch (*Glaucosoma magnificum)* were seen in March 2009 but not in October 2008, accounting for the disparity in numbers between the two sampling occasions. Species commonly observed at coral site CI1 are presented in Table 7. As coral sites are quite diverse, many other species were also common (>60% deployments), These include *Pomacanthus sexstriatus, Epinephelus bilobatus, Scarus schlegeli, Chaetodontoplus duboulayi,* Scombridae spp*, Siganus doliatus, Lutjanus carponotatus, Carangoides fulvoguttatus and Thalassoma lunare* in 2008 and *Parupeneus indicus, Pomacanthus sexstriatus, Abudefduf bengalensis, Chaetodon marginalis, Lethrinus nebulosus, Scarus ghobban, Scarus rivulatus, Scarus schlegeli,, Scolopsis monogramma, Symphomorus nematophorus* and *Thalassoma lunare* in 2009.

4.3.2.2. Sand site

A total of 376 individuals from 20 species were recorded at bare sand site SI2 in March 2009 (Table 6). A mean of 11.6 ± 0.2 SE individuals were observed on each stereo BRUV deployment at this site. The site comprised a fish assemblage considered typical of a bare sand habitat with low numbers of species and high uniformity across deployments. The most common fish species recorded at this site are shown in Table 7.

4.3.3. Zone of Moderate Impact

In 2008 and in 2009, two coral and macroalgal sites were assessed within the Zone of Moderate Impact (CI2, CI3, MI1, MI2) along with a single sand/sessile invertebrates site (SII1) (Table 1). In October 2008, site SII1 had sessile invertebrates present (and a small amount of seagrass). However in March 2009 sessile invertebrate cover was very sparse and the site was classed as sand. The absence of sessile invertebrates at this site in 2009 may be due to their removal by a storm event over the summer, seasonal changes, and/or extreme patchiness in cover.

4.3.3.1. Coral sites

Species richness information for these coral sites is presented in Table 6. At coral site CI2, a total of 507 individuals from 69 species were observed in 2008 and 750 individuals from 78 species in 2009. At site CI3, 410 individuals from 61 species were recorded in 2008 and 691 individuals from 69 species in 2009. These coral sites were characterised by families possessing a diverse range of species. The most species-rich families included the labrids, pomacentrids, chaetodontids and scarids. Species most common to both sites and sampling occasions include *Plectropomus maculatus, Thalassoma lunare, Choerodon schoenleinii, Lutjanus carponotatus, Acanthurus grammoptilus, Epinephelus bilobatus, Abudefduf bengalensis, Neopomacentrus filamentosus, Caesio cuning, Choerodon cyanodus, Choerodon cauteroma* and *Pomacanthus sexstriatus.* Present in high abundances at these coral sites were *Caesio cuning, Neopomacentrus filamentosus* and *Pterocaesio* spp*.* For both sampling occasions, CI2 had higher abundances of *Lethrinus nebulosus, Heniochus acuminatus, Symphorus nematophorus, Choerodon cauteroma* and *Scarus rivulatus* than site CI3 (SIMPER Diss/SD >1). More abundant at site CI3 compared to CI2 were *Pomacentrus nigromanus, Neopomacentrus filamentosus, Lethrinus atkinsoni* and *Abudefduf bengalensis.*

4.3.3.2. Macroalgae sites

At macroalgae site MI1, a total of 325 individuals from 35 species were recorded in October 2008 and 326 individuals from 48 species in March 2009. At macroalgae site MI2, 388 individuals from 31 species were observed in 2008 and 322 individuals from 35 species in 2009. High abundances of juvenile labrids, lethrinids, siganids, serranids and nemipterids were characteristic of macroalgal sites. The most common fish species observed at both sites and on both sampling occasions included *Choerodon cauteroma, Pentapodus emeryii, Lethrinus* sp.*, Parupeneus barberinoides, Parupeneus indicus, Plectropomus maculatus, Lethrinus laticaudis, Siganus fuscescens, Pentapodus porosus* and *Pentapodus vitta.* Juvenile *Plectropomus maculatus* was seen more regularly on macroalgal deployments in 2009 than in 2008. The most abundant species at macroalgal sites MI2 and MI3 were *Lethrinus* sp and *Pentapodus vitta.* Species present in higher average abundance at site MI1 than at MI2 were *Choerodon schoenleinii* and *Lutjanus carponotatus.* Conversely more abundant at site MI2 were *Lethrinus genivittatus, Lethrinus* sp and *Parupeneus barberinoides.*

4.3.3.3. Sand/Sessile invertebrate site

In 2008 a total of 388 individuals from 11 species were observed at site SII1, while in 2009 a total of 322 individuals from 17 species were recorded (Table 6). With habitat differences observed for this site between 2008 and 2009, there were also some differences in the fish assemblages. In 2008 the most common fish species observed included *Nemipterus* sp (100% of deployments), Scombridae spp (60%), *Lagocephalus lunaris* (67%), *A. mate* (67%), *S. leptolepis* (67%) and *P. porosus* (67%). In 2009 the most common species were *P. choirocephalus* (100%), *S. leptolepis* (100%), Synodontidae spp (100%), *U. tragula* (100%), *E. naucrates* (80%), *T. pallimaculatus* (80%), *Nemipterus* sp (60%) and Scombridae spp (60%). For both occasions the most abundant species were *S. leptolepis* and *Nemipterus* sp, however *S. leptolepis* were much more abundant in March 2009 (mean 41.8 ± 16 SE) than in October 2008 (9.7 ± 5 SE).

4.3.4. Zone of Influence

In 2008, sites surveyed within the Zone of Influence included four coral sites (CFR1, CNR1, CNR2, CNR3), four macroalgal sites (MNR1, MNR2, MNR3, MNR4), and four sessile invertebrates sites (SINR1, SINR2, SINR3, SIN4). The same coral sites were surveyed again in March 2009 (CFR1, CN1, CN2, CN3). However, macroalgal site MNR4 was not surveyed in March 2009 when instead MFR4 was added to the sampling design (Table 1). Sites SIN1, SIN2, SIN3 were again surveyed in 2009, however at this time SIN1 was bare sand and the other sites remained sessile invertebrates. SINR4 was not surveyed in March 2009 with site SIFR5 surveyed instead. Site SIFR5 was predicted to be sessile invertebrates but was in fact macroalgal-dominated and was therefore analysed as such. Species richness information pertaining to sites within the Zones of Influence is presented in Table 6.

4.3.4.1. Coral sites

A total of 1578 individuals from 122 species were observed across the four coral sites in October 2008. At this time, mean species richness per site ranged from 23.2 ± 2 SE at site CFR1 to mean 34.6 ± 4.4 SE at site CNR3. In March 2009, a total of 2374 individuals from 134 species were recorded. Species richness was similar across the four coral sites ranging from a mean of 30.4 ± 2.86 SE (CN2, CN3) to 33.8 ± 1.7 SE at site CN1.

Fish assemblages at coral sites within the Zone of Influence were not significantly different to those surveyed at coral sites in Zones of High and Moderate Impact (Sections 4.3.2.1 and 4.3.3.1; $p > 0.05$). Large serranids and lethrinids and small pomacentrids were common. Species-rich families at coral sites within the Zone of Influence included labrids, pomacentrids, serranids, scarids and chaetodontids.

The most common fish species observed at coral sites within the Zone of Influence (>70% of deployments) were common to both sampling occasions and included *Choerodon schoenleinii, Plectropomus maculatus, Choerodon cyanodus, Lutjanus carponotatus, Pentapodus emeryii, Lethrinus atkinsoni, Thalassoma lunare* and *Pomacanthus sexstriatus.* The most abundant fish species at coral sites were *Thalassoma lunare, Pterocaesio digramma, Caesio cuning, Neopomacentrus filamentosus, Siganus doliatus, Lethrinus atkinsoni* and *Lutjanus carponotatus.*

4.3.4.2. Macroalgae sites

A total of 1010 individuals from 65 species were observed across the four macroalgae sites in October 2008 (MNR1→4). At this time, mean species richness per site ranged from 9.4 ± 3.2 SE at site MNR1 to mean 19.6 ± 2.1 SE at site MNR3. Site MNR1 had much lower species richness than the other three sites.. In March 2009, a total of 1653 individuals from 77 species were recorded from the five sites (MFR4, MNR1→3 and SIFR5). At this time, species richness was very similar across sites ranging from a mean of 17.6 ± 2.4 SE at site MN2 to 21.3 ± 5 SE at site MN1.

Macroalgae-dominated habitats were characterised by high abundances of lethinrids, labrids, siganids and nemipterids. Tuskfish species (*Choreodon* spp) were very common with many juveniles observed (*Choreodon cauteroma, Choreodon cyanodus, Choreodon schoenleinii* at >70% drops). Also common were *Pentapodus emeryii, Pentapodus pororus, Lethrinus laticaudis* and juveniles of *Plectropomus maculatus, Siganus fuscenscens* and *Parupeneus indicus.* Juvenile *Plectropomus maculatus* were only observed in March 2009.

4.3.4.3. Sand site

A single sand site (SIN1) was surveyed in 2009. A total of 353 individuals were recorded from 21 species from the five stereo BRUV deployments for this site. The most common species included Synodontidae spp (100% drops), *Echeneis naucrates* (80%), Scombridae spp (80%), *Torquigener pallimaculatus* (80%), *Upeneus tragula* (80%), *Paramonacanthus choirocephalus* (60%), *Pentapodus vitta* (60%) and *Selaroides leptolepis* (60%).

4.3.4.4. Sessile invertebrate sites

Four sessile invertebrate sites were surveyed in October 2008 (SINR1 → 4) yielding a total of 1088 individuals from 73 species. Mean species richness per site ranged from 4.2 ± 1.4 SE at site SINR1 to 15 ± 1.6 SE at site SINR4. Two sessile invertebrate sites were surveyed in March 2009 (SIN2, SIN3) yielding a total of 438 individuals from 29 species. Site SIN2 had a mean species richness of 10.6 ± 0.7 SE and site SIN3 of 7.8 ± 1.4 SE.

Families characterising sessile invertebrate habitats within the Zones of Influence were the nemipterids, scombrids, mullids and labrids. Common fish species included Scombridae spp, *Penatpodus porosus, Upeneus tragula, Cheorodon cauteroma* and *Nemipterus* spp*.*

4.4. FISH ASSEMBLAGES ASSOCIATED WITH THE DREDGE SPOIL DISPOSAL GROUND

There were insufficient sites to test for any prior differences in species richness and relative abundance between Zones of Impact associated with the Dredge Spoil Disposal Ground (High, Moderate and Zones of Influence) (Table 1). No sites were located within the Zone of Moderate Impact (Table 1). Only the survey in 2008 facilitated testing the effects of habitat when the single coral bommie in the area was surveyed. This result needs to be interpreted carefully as the sample size is small but recognising that the entire population of one bommie was sampled (see Figure 12). In 2008, four sites associated with the Dredge Spoil Disposal Ground were surveyed (DSI1, DSI2, CNR4/DSNR1 and DSNR2) and a further four sites were surveyed in 2009 (DSI1, DSI2, DSN1 and DSN3; Table 1). Species richness information pertaining to sites associated with each level of impact for the Dredge Spoil Disposal Ground is presented in Table 6.

4.4.1. Size structure of fish assemblages across different Zones of Impact

The size structure of fish assemblages could be compared across the different Zones of Impact for sessile invertebrate habitats only. In 2008, site SINR5 within the Zone of Influence had a different size structure to sites DSI1 and DSI2 in the Zone of High Impact and to Reference sites. Site SINR5 had a higher proportion of its population in the size category 161-200 mm FL than other sessile invertebrate sites. This reflects higher abundances of *Pentapodus pororus* measured at this site. No differences existed in the size structure of fish assemblages in 2009.

4.4.2. Zone of High Impact

The Zone of High Impact within the Dredge Spoil Disposal Ground were classed as the habitat 'sessile invertebrates' as they comprised large sea-fans, sea-whips and the occasional sponge and hydroid. Seagrass was observed at both sites and in higher cover in October 2008 than in March 2009.

At High Impact site DSI1, species richness was much higher in 2008 with 240 individuals recorded from 33 species compared to 187 individuals from 17 species in 2009. Species common to this site on both sampling occasions are listed in Table 8. Common in October 2008 but not viewed in March 2009 were *Gnathodon speciosus* and *Neopomacentrus filamentosus.* Common in 2009 but not viewed in 2008 was *Pentapodus vitta.* In general, the majority of species recorded at site DSI1 were observed on both sampling occasions and were typical of sessile invertebrate habitats (see Section 4.2.4).

The second High Impact site DSI2 possessed higher species richness in March 2009 with 217 individuals recorded from 33 species compared to 221 individuals from 21 species observed in 2008. In contrast to site DSI1, there were fewer species that were very common to the majority of replicate stereo BRUV deployments at this site (Table 8). *Pentapodus porosus, Abalistes stellatus,* Scombridae spp and *Carangoides fulvoguttatus* and *Diagramma labiosum* were reasonably common across stereo BRUV deployments and to both sampling locations (Table 8). Viewed regularly in October 2008 (>60% drops) but not viewed at this site in March 2009 were *Choerodon schoenleinii* and *Echeneis naucrates.* No species were common in 2009 that were not viewed in 2008.

The most common and abundant fish species observed at High Impact Sites DSI1 and DSI2 were *Pentapodus porosus* (mean 26.4 ± 13.8 SE) and *Carangoides fulvoguttatus* (mean 2.8 ± 0.5 SE).

4.4.3. Zone of Moderate Impact

There are no sites located within the Zone of Moderate Impact associated with the Dredge Spoil Disposal Ground.

4.4.4. Zone of Influence

The two habitat types surveyed within the Zone of Influence for the Dredge Spoil Disposal Ground were coral (CNR4/DNSR1 in 2008) and sand (DSNR2 in 2008 and DSN1, DSN3 in 2009). A single site was surveyed on both sampling occasions (DSNR2 which became DSN1 in 2009 in the process of simplifying site names).

The only coral site surveyed within the Zone of Influence for the Dredge Spoil Disposal Ground was very small in area and comprised a coral bommie. The size of the area permitted only two replicate stereo BRUV deployments. Despite the small sampling effort, the site possessed quite high species richness with 262 individuals recorded from 62 species. The fish assemblage was characteristic of coral reefs with high diversity and the occurrence of serranids, lutjanids, pomacentrids, labrids, chaetodontids and scarids. This was the only site where manta rays, *Manta birostris*, were recorded during the study.

Sand site DSNR2 (2008) was re-surveyed in 2009 as DSN1. In 2008, 260 individuals from 17 species were recorded while in 2009 a total of 157 individuals from 24 species were observed. Differences in the total numbers of individuals were driven by higher abundances of *P. vitta* at this site in 2008 (total 106 individuals) compared to 2009 (9 individuals). Numbers of another common species, *Pentapodus porosus*, also differed across the sampling times with much higher abundances observed in 2009 (total 72 individuals) than in 2008 (total 8 individuals). The fish assemblages surveyed at this sand site were characteristic of sand assemblages as described in Section 4.2.3. Common species were *Carangoides fulvoguttatus,* Scombridae spp, *Nemipterus* spp*, Scomberoides commersonnianus* and

Pentapodus vitta. Regularly observed in 2008 (>75% drops) but not viewed in 2009 were *Selaroides leptolepis* and *Upeneus tragula.*

The second sand site surveyed in 2009, DSN3, had lower abundances and species richness than DSNR2/DSN1 with a total of 105 individuals from 14 species. *Pentapodus porosus* (total 43) was the most abundant and common fish species at this site while *Nemipterus* spp were also common but less abundant. The majority of fish species observed at site DSN3 were nemipterids, caragids, lethrinids and scombrids.

4.5. REFERENCE AREAS

Data from the 2008 and 2009 surveys suggest that fish assemblages at reference locations around Barrow Island do not differ to fish assemblages in Zones of High Impact, Zones of Moderate Impact or Zones of Influence ($p > 0.05$; 2008 and 2009). As there is no predicted measurable impact upon marine benthic primary producers within the Zones of Influence, sites in this area were considered together with reference areas for the assemblage descriptions provided below.

Reference sites around Barrow Island covered all four habitat types (coral, macroalgae, sand, sessile invertebrates). Each habitat type had distinct fish assemblages (2008: d.f. = 3, 25.6; MS = 5.9; Pseudo-F = 6.4, $p < 0.01$; 2009: d.f. = 3, 28.4; MS = 5.8; Pseudo-F = 5.1, $p < 0.01$; Pairwise tests all $p < 0.05$). This distinction in fish assemblage structure is illustrated by clear separation of points in Figure 13. The only similar fish assemblages were in reference sand and sessile invertebrates sites in March 2009. The fish assemblages associated with each habitat type are described below. Species richness information pertaining to reference sites is presented in Table 6.

4.5.1. Size structure of fish assemblages at Reference sites

The size structure of fish assemblages differed across the majority of habitat types, particularly in the 2008 survey (Figure 14). In October 2008, each of the four habitats had a unique size structure (Figure 14 A; all K-S tests, $p < 0.05$). Sand assemblages comprised a very high proportion of individuals between 80 and 200 mm FL, representing the large schools of *Herklotsichthys* spp and *Pentapodus* spp observed associated with these habitats. This peak was not as prominent in the March 2009 survey (Figure 14 B) due to the absence of schooling *Herklotsichthys* spp. Coral assemblages comprised the highest proportion of large individuals (240 – 400 mm FL) encompassing the larger serranids and lethrinids observed in this habitat. Macroalgal and sessile invertebrate assemblages had a bimodal frequency pattern with peaks at 80-120 mm and 160-240 mm FL likely reflecting high abundances of small *Pentapodus porosus* (sessile invertebrates) and juveniles (macroalgae) with larger lethrinids.

4.5.2. Coral sites

In October 2008, a total of 3476 individuals from 174 species were recorded at reference coral sites to the east of Barrow Island. A total of 3527 individuals from 162 species were recorded in March 2009. Coral habitats were characterised by high species richness with the most species-rich families being the labrids, pomacentrids, lethrinids, scarids, serranids and chaetodontids. The most common fish species observed at reference coral sites was *Choerodon schoenleinii,* followed by *Plectropomus maculatus, Choerodon cyanodus, Thalassoma lunare* and *Lutjanus carponotatus.* These species were common to both sampling occasions. The most abundant fish species were *Pterocaesio digramma, Caesio cuning, Neopomacentrus filamentosus, Thalassoma lunare* and *Lutjanus carponotatus.* As no differences exist between these coral reef assemblages and those observed in high and moderate zones of impact ($p > 0.05$), additional information can be found in Sections 4.2.1 and 4.6.

4.5.3. Macroalgae sites

A total of 1498 individuals from 81 species were recorded in October 2008 and 2759 individuals from 109 species in March 2009. The most common and species-rich families at macroalgal reference sites were the labrids, nemipterids and lethrinids. The five most common species were *Choerodon cyanodus, Choerodon cauteroma, Pentapodus emeryii, Choerodon schoenleinii* and *Lethrinus laticaudis* (2008)/ *Plectropomus maculatus* (2009). The five most abundant species at macroalgal reference sites in 2008 were *Lethrinus* sp*, Atule mate, Upeneus tragula, Pentapodus vitta* and *Pentapous emeryii.* In 2009, the five most abundant were *Siganus fuscenscens, Pentapodus vitta, Lethrinus* sp*, Pentapodus porosus* and *Lethrinus genivittatus.* Differences in abundance between sampling times may reflect seasonal variation. As no differences exist between these macroalgal assemblages and those recorded in high and moderate zones of impact, additional information can be found in Section 4.2.2.

4.5.4. Sand sites

In October 2008, a total of 2206 individuals from 33 species were recorded from 18 stereo BRUV deployments in reference sand sites. A total of 2411 individuals from 67 species were recorded from 54 stereo BRUV deployments in sand sites in 2009. Families characteristic of sand reference sites were the nemipterids, carangids and scombrids. The five most common species were similar for both survey times and were *Nemipterus* spp (2008)/Scombridae spp (2009), *Paramonacanthus choirocephalus, Pentapodus vitta, Selaroides leptolepis* and *Pentapodus porosus.* The five most abundant species in 2008 were *Herklotsichthys* spp*, Pentapodus vitta, Selaroides leptolepis, Nemipterus* spp and *Pentapodus porosus.* The five most abundant species in 2009 were similar: *Selaroides leptolepis, Pentapodus porosus, Atule mate, Pentapodus vitta* and *Gnathodon speciosus.* As no differences exist between these sand assemblages and those recorded in high and moderate zones of impact, additional information can be found in Section 4.2.3.

4.5.5. Sessile invertebrate sites

A total of 1696 individuals from 95 species were recorded from 33 sessile invertebrate stereo BRUV deployments in 2008. In 2009, a total of 786 individuals from 50 species were recorded from 18 deployments. The five most common species recorded at sessile invertebrate reference sites in 2008 were Scombridae spp, *Pentapodus porosus, Parapercis nebulosa, Upeneus tragula* and *Choerodon cyanodus.* The most common species differed slightly during the 2009 survey: *Pentapodus porosus,* Scombridae spp, *Nemipterus* spp*, Carangoides fulvoguttatus* and *Pentapodus vitta.* The five most abundant species recorded at reference sessile invertebrate sites in 2008 were *Pentapodus porosus, Selaroides leptolepis, Torquigener pallimaculatus, Lethrinus* sp and *Siganus fuscenscens.* In 2009, the five most abundant species were *Pentapodus porosus, Selaroides leptolepis, Pentapodus vitta, Gnathodon speciosus* and *Upeneus tragula.* Differences may be a result of variable sampling effort and/or seasonal shifts in assemblages.

4.6. INDICATOR SPECIES FOR CORAL HABITATS

Here we provide a list of potential 'indicator' species for coral habitats around Barrow Island (Table 10) as this habitat will potentially be impacted by construction and dredging activities. Indicator species are commonly identified as a component of monitoring programs where change in indicator species (distribution, abundance, size) is expected to be linked to environmental condition (Zacharias and Roff 2001). The challenge in choosing indicator species is that the relationship between the species and environment needs to be understood and the degree to which the indicator species is representative of other species also requires clarification. Typically, our understanding of marine ecosystems, with some exceptions (e.g. corallivorous butterflyfish and coral health; piscivores and fishing), hampers the choice of indicator species. This lack of knowledge has, in part, driven the development of multivariate “indicators” where changes in the assemblage as a whole are monitored (Warwick 1998; Clarke and Warwick 2001).

For this benchmark study, indicator species were chosen if they fulfilled at least one of the following criteria:

1. Common (present at more than 40% of coral sites)

Species common to coral sites provide added power to statistical tests for potential impacts as their occurrence is not likely attributed to chance observation on a stereo BRUV deployment. Commoness is a better criterion than abundance as the latter is biased towards schooling species which do not necessarily characterise the habitats.

2. Possess life-history characteristics that make them vulnerable

These species are typically large, predatory species that are long-lived and slow-growing. These life-history characteristics make the species vulnerable to impacts such as fishing and dredging (where suspended sediments compromise their health). As these species may be affected by fishing in reference areas, estimates of effects of construction/dredging on these species are likely to be conservative.

3. Corallivores

Those species that feed directly on coral polyps (e.g. many chaetodontids) rely heavily on healthy coral reef environments. Any change to the coral habitat may be detected by a change in the abundance, size and distribution of these species.

4. Site attached

Territorial species (e.g. many *Pomacentrus* spp) with small home ranges are more likely to be impacted by construction/dredging activities where they are unable to relocate. While vagile species (e.g. *Choerodon* spp*, Lethrinus* spp*, Acanthurus* spp*)* may be impacted to a lesser extent by construction/dredging activities - any impact will be detectable by comparing changes in the abundance and size of individuals in impacted areas relative to reference areas, before and after commencement of construction/dredging activities.

Chosen indicator species are presented in Table 9 and Table 10. Note that there are many more species that could have been included on this list however they were not selected as they were less common and iconic. This list may be changed at any stage in the future to suit reporting requirements as relative abundance and length data is retained for all fish species viewed on stereo BRUV footage. These indicator species are useful as they enable scientists to directly examine any effect of construction and dredging of their abundance and size and to articulate this effect clearly. However, examination of change in the structure of fish assemblages over coral reefs as a whole should be the primary focus as this facilitates a better understanding of impacts on ecosystem function.

5. DISCUSSION

The spatial distribution of fishes is influenced by habitat, largely through the provision of shelter and food (Parrish 1989; Beukers and Jones 1997). Occupation of different habitats can also vary depending on fish age and ontogeny (Forrester 1991; Clements and Choat 1993; McCormick 1998; St John 1999). This was clearly evident at Barrow Island with the presence of markedly different fish assemblages across coral, macroalgae, sand and sessile invertebrate habitats. Coral habitats were characterised by high species richness and the presence of many small pomacentrids, schooling caesionids, labrids and large serranids and lethrinids. In contrast, macroalgae habitats were characterised by high abundances of lethrinids, nemipterids and labrids and also by the presence of juveniles of many different fish species. Measurments of fish length from stereo-video imagery clearly highlighted the presence of juveniles in this habitat. Macroalgal habitats at Barrow Island therefore appear to act as nursery grounds for numerous fish species, including those where adults were observed in different habitats (e.g. *Plectropomus leopardus* on coral). Assessment of size structure in fish assemblages is very important because when linked to the biology of a species it can provide estimates of biomass, reproductive capacity and recruitment. While initially considered a single habitat – sand and sessile invertebrate habitats comprised quite distinct fish assemblages, warranting separate consideration and increased sampling in

2009. While different to each other, fish assemblages were uniform in both habitat types. This uniformity likely reflects lower habitat complexity. Knowledge of the different habitats around Barrow Island and the different fish assemblages that characterise them is critical for continuing a monitoring program that is designed to robustly assess any potential impacts of dredging, construction and dredge spoil disposal.

There was no difference in the composition of assemblages and the relative abundances of fish species across Zones of High and Moderate Impact, Zones of Influence and Reference Sites. Following dredging, construction and dredge spoil disposal activities, any change in fish assemblages at impacted sites not mirrored in Reference sites may be attributed to these potential impacts. Minor differences in the size structure of fish assemblages across the different Zones reflected high abundances of particular species at certain sites. These differences will be re-asessed and should still be evident post-contruction and dredging activites. The present study therefore acts as a reasonable baseline with which future data may be compared.

Some differences in fish assemblage structure were noted between the surveys conducted in October 2008 and March 2009. These differences were largely due to the presence/absence of schooling species (e.g. *Herklotsichthys* spp in 2008 but not 2009), the varying habitat locations of schooling species (e.g. *Atule mate* in sessile invertebrate habitats in 2008 and in sand in 2009*)* and the varying presence of juveniles. For example, many juvenile bar-cheek coral trout *Plectropomus leopardus* were observed in macroalgal habitats in March 2009 but not in October 2008. The observation of some seasonal shifts in habitat cover and fish assemblage structure warrants a strong baseline study that is temporally replicated, both seasonally and annually. Without knowledge of the seasonal and interannual variability in fish assemblage structure at Barrow Island prior to construction and dredging works, the impacts of these projects on fish assemblage structure may not be comprehensively assessed.

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TABLES

Table 1: Location and dominant habitat of each site surveyed in 2008 and 2009 for Zones related to the MOF and Dredge Spoil Disposal Ground Facilities.

Oct 2008 Site name	**Mar 2009** Site name	**Dominated Habitat 2008**	**Dominated Habitat 2009**	**Depth 2008**	**Depth 2009**	**Zone**	**Impact Type**	**Location** Latitute-Longitude
DSI1	DSI1	Sessile	Sessile	16	16.2	High	Dredge Spoil Disposal Ground	-20.87066; 115.538988361111
DSI2	DSI2	Sessile	Sessile	17.1	16.1	High	Dredge Spoil Disposal Ground	-20.89087; 115.538792894444
DSNR2	DSN1	Sand	Sand	14.3	15.6	Zone of Influence	Dredge Spoil Disposal Ground	-20.86541; 115.568862275
-	DSN3	-	Sand		15	Zone of Influence	Dredge Spoil Disposal Ground	-20.90996; 115.531880047222
CNR4/DSNR1		Coral	-	13.9		Zone of Influence	Dredge Spoil Disposal Ground	-20.86039; 115.532360161111
CI1	CI1	Coral	Coral	3.9	6.1	High	MOF	-20.80035; 115.479806663889
-	SI2	-	Sand			High	MOF	-20.81704; 115.490851661111
CI2	CI2	Coral	Coral	6.8	6.6	Moderate	MOF	-20.80415; 115.482689163889
CI3	CI3	Coral	Coral	8.6	9	Moderate	MOF	-20.83169; 115.506300697222
MI1	MI1	Macroalgae	Macroalgae	3.5	4.5	Moderate	MOF	-20.78677; 115.478453808333
MI2	MI2	Macroalgae	Macroalgae	4.1	4.6	Moderate	MOF	-20.80355; 115.472982508333
SII1	SI1	Sessile	Sand	10.2	8.7	Moderate	MOF	-20.80363; 115.494107347222
CFR1	CFR1	Coral	Coral	4.9	4.7	Zone of Influence	MOF	-20.70946; 115.481483297222
CNR1	CN1	Coral	Coral	7.2	5.6	Zone of Influence	MOF	-20.86401; 115.468739808333
CNR2	CN2	Coral	Coral	8.1	8.2	Zone of Influence	MOF	-20.84133; 115.501612269444
CNR3	CN3	Coral	Coral	5.3	9.3	Zone of Influence	MOF	-20.78635; 115.506680041667
-	MFR4	-	Macroalgae			Zone of Influence	MOF	-20.68784; 115.479087391667
MNR1	MN1	Macroalgae	Macroalgae	5.9	3.6	Zone of Influence	MOF	-20.77021; 115.482528952778
MNR2	MN2	Macroalgae	Macroalgae	4.2	2.9	Zone of Influence	MOF	-20.81711; 115.468445627778
MNR3	MN3	Macroalgae	Macroalgae	5	3.7	Zone of Influence	MOF	-20.75743; 115.48727605
-	SIFR5	-	Macroalgae		13.3	Zone of Influence	MOF	-20.74233; 115.504194205556

Oct 2008 Site name	**Mar 2009** Site name	**Dominated Habitat 2008**	**Dominated Habitat 2009**	**Depth 2008**	**Depth 2009**	**Zone**	**Impact Type**	**Location** Latitute-Longitude
SINR1	SIN1	Sessile	Sand	6.1	8.3	Zone of Influence	MOF	-20.79424; 115.505074980556
SINR2	SIN2	Sessile	Sessile	11.4	12.2	Zone of Influence	MOF	-20.83487; 115.488463966667
SINR3	SIN3	Sessile	Sessile	12	12.6	Zone of Influence	MOF	-20.7662; 115.495679180556
MNR4		Macroalgae	-	5		Zone of Influence	MOF	-20.85288; 115.469208119444
SINR4		Sessile	-	12.8		Zone of Influence	MOF	-20.85009; 115.483997047222
CFR2	CFR2	Coral	Coral	4.8	5.9	Reference	Reference	-20.90386; 115.464288591667
CFR3	CFR3	Coral	Coral	5.8	4.3	Reference	Reference	-20.95713; 115.482478638889
CFR4	CFR4	Coral	Coral	7.4	9.2	Reference	Reference	-20.50618; 115.568506886111
MFR1	MFR1	Macroalgae	Macroalgae	4.4	4.3	Reference	Reference	-20.97563; 115.472914541667
MFR3	MFR3	Macroalgae	Macroalgae	4.2	5	Reference	Reference	-20.55171; 115.558156277778
	MFR5		Macroalgae		4.9	Reference	Reference	-20.56948; 115.567313302778
DGI3	DGI3	Sand	Sand	15	15	Reference	Reference	-20.93081; 115.571789958333
DSFR3/DGNR3	SAFR1	Sand	Sand	15.5	14.8	Reference	Reference	-20.90878; 115.592091844444
DSFR1/DGFR1	SAFR2	Sand	Sand	16.7	15.8	Reference	Reference	-20.81389; 115.573615219444
DSFR2/DGFR2	SAFR3	Sand	Sand	15.8	15.7	Reference	Reference	-20.82353; 115.538696022222
	SAN1		Sand		15.2	Reference	Reference	-20.95664; 115.581344630556
SIFR3/DGFR5	SIFR3	Sessile	Sand	15.4	14.8	Reference	Reference	-20.99354; 115.541220575
	SIFR4		Sand		15.3	Reference	Reference	-20.96339; 115.561267172222
	SIN6		Sand		15	Reference	Reference	-20.88812; 115.477617477778
SIFR2	SIFR2	Sessile	Sessile	16.2	15	Reference	Reference	-20.9353; 115.499314077778
DSFR4/DGNR4	SIN7	Sessile	Sessile	16.9	16.2	Reference	Reference	-20.96216; 115.5596248
CNR5		Coral	-	6.7		Reference	Reference	-20.86222; 115.489161377778
SINR5		Sessile	-	15.5		Reference	Reference	-20.86101; 115.512874080556

Table 2: The 20 most common fish species recorded on stereo BRUV deployments in 2008 and in 2009 with a rank of 1 indicating the most common. Numbers in brackets were not within the 'top 20' for that year however their rank for that year is still presented. Those with an '*' are targeted by commercial and/or recreational fishers.

		2008		2009	
Species	**Common name**	**Rank**	**Total #**	**Rank**	**Total #**
*Carangoides fulvoguttatus**	gold-spotted trevally	20	172	7	216
Chaetodontoplus duboulayi	scribbled angelfish	10	63	(26)	56
*Choerodon cauteroma**	bluespotted tuskfish	6	117	6	195
*Choerodon cyanodus**	blue tuskfish	1	182	3	240
*Choerodon schoenleinii**	blackspot tuskfish	2	122	4	128
Echeneis naucrates	sharksucker	(25)	58	12	79
*Lethrinus atkinsoni**	yellowtail emperor	19	108	(34)	150
*Lethrinus laticaudis**	grass emperor	9	95	11	91
Lethrinus sp*	blue-lined emperor	13	810	(25)	316
*Lutjanus carponotatus**	stripey snapper	8	172	10	296
Nemipterus spp	treadfin bream species	(22)	194	17	114
Paramonacanthus choirocephalus	pigface leatherjacket	(37)	60	16	161
Parupeneus indicus	yellowspot goatfish	12	100	15	125
Pentapodus emeryii	purple threadfin bream	5	162	9	250
Pentapodus porosus	northwest threadfin bream	4	939	2	1048
Pentapodus vitta	western butterfish	16	579	8	607
*Plectropomus maculatus**	barcheek coral trout	7	128	5	170
Pomacanthus sexstriatus	sixband angelfish	18	53	(22)	54
Scarus schlegeli	schlegel's parrotfish	15	72	14	108
Scolopsis monogramma	rainbow monocle bream	17	52	20	65
Scombridae spp*	mackeral species	3	130	1	233
Selaroides leptolepis	yellowstripe scad	(29)	577	18	1036
*Symphorus nematophorus**	chinaman fish	14	51	13	72
Thalassoma lunare	moon wrasse	11	283	19	209

Table 3: PERMANOVA based on Modified Gower log base 10 dissimilarities of relative abundances in response to factors habitat and site.

Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perms)**	**perms**
2008						
Habitat	3	28.39	9.46	8.42	<0.01	9887
Site (Hab x Zone)	35	40.04	1.14	2.63	<0.01	9373
Residual	144	62.56	0.43			
Total	182	132.5				
2009						
Habitat	3	23.00	7.66	8.53	<0.01	9896
Site (Hab x Zone)	32	29.89	0.93	2.08	<0.01	9375
Residual	114	51.09	0.45			
Total	149	106.04				

Table 4: Top ten species by numerical abundance for each habitat type and their percentage of the total abundance observed for that habitat.

Year	Corals			Macroalgae			Sand			Sessile invertebrates		
	Species	**Tot**	**%Tot**	**Species**	**Tot**	**%Tot**	**Species**	**Tot**	**%Tot**		**Tot**	**%Tot**
2008	*Pterocaesio digramma*	755	16%	*Lethrinus* sp	629	28%	*Herklotsichthys* sp	1016	46%	*Pentapodus porosus*	784	35%
	Caesio cuning	422	9%	*Pentapodus vitta*	115	5%	*Pentapodus vitta*	413	19%	*Selaroides leptolepis*	198	9%
	Neopomacentrus filamentosus	273	6%	*Upeneus tragula*	97	4%	*Selaroides leptolepis*	379	17%	*Torquigener pallimaculatus*	162	7%
	Thalassoma lunare	257	5%	*Siganus fuscescens*	94	4%	*Nemipterus* spp	89	4%	*Lethrinus* sp	142	6%
	Siganus doliatus	154	3%	*Pentapodus emeryii*	84	4%	*Pentapodus porosus*	62	3%	*Nemipterus* spp	105	5%
	Lutjanus carponotatus	138	3%	*Lethrinus genivittatus*	82	4%	*Paramonacanthus choirocephalus*	42	2%	Scombridae spp	77	3%
	Caesio caerulaurea	100	2%	*Atule mate*	76	3%	*Upeneus tragula*	41	2%	*Siganus fuscescens*	71	3%
	Choerodon cyanodus	98	2%	*Choerodon cyanodus*	69	3%	*Sillago* spp	33	1%	*Upeneus tragula*	58	3%
	Lethrinus atkinsoni	98	2%	*Pentapodus porosus*	64	3%	*Parapercis nebulosa*	18	1%	*Carangoides fulvoguttatus*	45	2%
	Plectropomus maculatus	98	2%	*Neopomacentrus filamentosus*	57	3%	Scombridae spp	18	1%	*Pentapodus vitta*	41	2%
2009	*Pterocaesio digramma*	731	13%	*Siganus fuscescens*	552	16%	*Selaroides leptolepis*	931	30%	*Pentapodus porosus*	481	40%
	Caesio cuning	577	10%	*Pentapodus vitta*	293	8%	*Pentapodus porosus*	322	10%	*Selaroides leptolepis*	79	7%
	Neopomacentrus filamentosus	506	9%	*Lethrinus* sp	257	7%	*Pentapodus vitta*	251	8%	*Carangoides fulvoguttatus*	63	5%
	Glaucosoma magnificum	275	5%	*Pentapodus porosus*	220	6%	*Atule mate*	203	7%	*Pentapodus vitta*	62	5%
	Lutjanus carponotatus	255	5%	*Pentapodus emeryii*	173	5%	*Gnathanodon speciosus*	194	6%	*Gnathanodon speciosus*	55	5%
	Thalassoma lunare	157	3%	*Lethrinus genivittatus*	166	5%	*Torquigener pallimaculatus*	143	5%	*Upeneus tragula*	49	4%
	Pterocaesio chrysozona	112	2%	*Choerodon cyanodus*	147	4%	*Paramonacanthus choirocephalus*	132	4%	*Lethrinus genivittatus*	35	3%
	Lethrinus atkinsoni	108	2%	*Choerodon cauteroma*	126	4%	Scombridae spp	122	4%	Scombridae spp	34	3%
	Plectropomus maculatus	108	2%	*Gnathanodon speciosus*	117	3%	*Upeneus tragula*	98	3%	*Chromis fumea*	32	3%
	Acanthurus grammoptilus	96	2%	*Upeneus tragula*	64	2%	*Nemipterus* spp	83	3%	*Nemipterus* spp	31	3%

Table 5: Top ten species by commonality for each habitat type. The percent of deployments at which each species was recorded at, for each habitat type is presented.

Year	**Coral**		**Macroalgae**		**Sand**		**Sand with sessile inverts**	
	Species	**%**	**Species**	**%**	**Species**	%	**Species**	%
2008	*Choerodon schoenleinii*	94%	*Choerodon cyanodus*	89%	*Nemipterus* spp	100%	Scombridae spp	82%
	Choerodon cyanodus	88%	*Pentapodus emeryii*	84%	*Pentapodus vitta*	100%	*Pentapodus porosus*	80%
	Plectropomus maculatus	88%	*Choerodon cauteroma*	78%	*Selaroides leptolepis*	100%	*Nemipterus* spp	40%
	Lutjanus carponotatus	78%	*Lethrinus* sp	68%	*Paramonacanthus choirocephalus*	89%	*Abalistes stellatus*	33%
	Thalassoma lunare	78%	*Choerodon schoenleinii*	57%	*Pentapodus porosus*	89%	*Carangoides fulvoguttatus*	31%
	Pentapodus emeryii	70%	*Lethrinus laticaudis*	57%	Scombridae spp	67%	*Echeneis naucrates*	31%
	Lethrinus atkinsoni	66%	*Lutjanus carponotatus*	49%	*Parapercis nebulosa*	56%	*Atule mate*	29%
	Pomacanthus sexstriatus	64%	*Parupeneus indicus*	49%	*Upeneus tragula*	56%	*Chaetodontoplus duboulayi*	29%
	Abudefduf bengalensis	62%	*Pentapodus porosus*	49%	*Sillago* spp	50%	*Parapercis nebulosa*	29%
	Hemigymnus melapterus	62%	*Plectropomus maculatus*	46%	*Herklotsichthys* sp	44%	*Selaroides leptolepis*	29%
2009	*Plectropomus maculatus*	*93%*	*Choerodon cyanodus*	98%	Scombridae spp	91%	*Pentapodus porosus*	96%
	Choerodon cyanodus	*89%*	*Choerodon cauteroma*	93%	*Paramonacanthus choirocephalus*	67%	Scombridae spp	71%
	Choerodon schoenleinii	*87%*	*Pentapodus emeryii*	91%	*Selaroides leptolepis*	63%	*Carangoides fulvoguttatus*	64%
	Lutjanus carponotatus	*84%*	*Plectropomus maculatus*	78%	*Pentapodus vitta*	56%	*Nemipterus* sp	54%
	Pomacanthus sexstriatus	*82%*	*Choerodon schoenleinii*	74%	*Nemipterus* spp	53%	*Pentapodus vitta*	43%
	Thalassoma lunare	*71%*	*Pentapodus porosus*	67%	*Parapercis nebulosa*	52%	*Diagramma labiosum*	39%
	Pentapodus emeryii	*67%*	*Parupeneus indicus*	59%	*Synodontidae* spp	48%	*Symphorus nematophorus*	29%
	Choerodon cauteroma	*60%*	*Pentapodus vitta*	57%	*Torquigener pallimaculatus*	48%	*Echeneis naucrates*	25%
	Scarus schlegeli	*60%*	*Symphorus nematophorus*	57%	*Pentapodus porosus*	45%	*Parapercis nebulosa*	25%
	Abudefduf bengalensis	*58%*	*Lethrinus* sp	54%	*Echeneis naucrates*	44%	*Abalistes stellatus*	21%

Table 6: Species richness information pertaining to the different types of potential impacts, Zone of Impact and habitats to the east of Barrow Island.

2008			Coral			Macroalgae			Sand			Sessile Inverts		
	Type of Impact	**Zones of Impact**	**# drops**	**# spp**	**Mean spp**	**# drops**	**# spp**	**Mean spp**	**# drops**	**# spp**	**Mean spp**	**# drops**	**# spp**	**Mean spp**
	MOF/LNG Jetty	Zone of High Impact	5	65	25.4 ± 5	-	-	-	-	-	-	-	-	-
		Zone of Moderate Impact	9	88	31.9 ± 2.9	10	45	14.3 ± 1.1	-	-	-	3	11	13.2 ± 1.2
		Zone of Influence	16	122	28.9 ± 2.2	19	65	15 ± 1.4	-	-	-	19	73	10.5 ± 1.3
	Dredge Spoil Disposal Ground	Zone of High Impact	-	-	-	-	-	-	-	-	-	9	37	11.1 ± 1.5
		Zone of Moderate Impact	-	-	-	-	-	-	-	-	-	-	-	-
		Zone of Influence	2	62	39 ± 10	-	-	-	4	17	9.3 ± 1.3	-	-	-
	Reference		36	174	28 ± 1.9	27	81	15.1 ± 1.1	18	33	10.4 ± 1.3	33	95	10.4 ± 0.9
	TOTAL		50	193	28.4 ± 1.5	37	84	14.9 ± 0.8	18	33	10.4 ± 0.5	45	102	10.3 ± 0.9
2009			**Coral**			**Macroalgae**			**Sand**			**Sessile Inverts**		
	Type of Impact	**Zone**	**# drops**	**# spp**	**Mean spp**	**# drops**	**# spp**	**Mean spp**	**# drops**	**# spp**	**Mean spp**	**# drops**	**# spp**	**Mean spp**
	MOF/LNG Jetty	Zone of High Impact	5	80	31.2 ± 3.9	-	-	-	5	20	11.6 ± 0.2	-	-	-
		Zone of Moderate Impact	8	104	32.1 ± 3.3	10	53	19.1 ± 1.6	5	17	8.8 ± 0.6	-	-	-
		Zone of Influence	20	134	31.3 ± 1.9	22	77	19.1 ± 0.8	5	21	9.4 ± 1	8	29	8.9 ± 1
	Dredge Spoil Disposal Ground	Zone of High Impact	-	-	-	-	-	-	-	-	-	10	35	9 ± 1.4
		Zone of Moderate Impact	-	-	-	-	-	-	-	-	-	-	-	-
		Zone of Influence	-	-	-	-	-	-	9	30	6.7 ± 1.1	-	-	-
	Reference		32	162	30.1 ± 1.8	36	109	19.7 ± 1	54	67	8.9 ± 0.4	18	50	9.4 ± 0.8
	TOTAL		45	183	30.6 ± 1.4	46	110	19.6 ± 0.7	64	75	9.1 ± 0.4	28	62	9.3 ± 0.6

Table 7: Most common fish species and their mean relative abundance per stereo BRUV deployment in Zone of High Impact sites associated with the Materials Offloading Facility and LNG Jetty.

2008: High Impact Coral Site CI1			**2009: High Impact Coral Site CI1**			**2009: High Impact Sand Site SI2**		
	% drops	Mean MaxN (± SE)		% drops	Mean MaxN (± SE)		% drops	Mean MaxN (± SE)
Scolopsis monogramma	100	1.2 ± 0.2	*Chaetodontoplus duboulayi*	100	1.4 ± 0.24	*Paramonacanthus choirocephalus*	100	9.2 ± 1
Parupeneus indicus	100	3 ± 0.3	*Choerodon cyanodus*	100	2.4 ± 0.5	*Parapercis nebulosa*	100	2 ± 0.3
Pentapodus emeryii	100	3.2 ± 0.7	*Choerodon schoenleinii*	100	2.6 ± 0.5	*Pentapodus vitta*	100	11.8 ± 3
Abudefduf bengalensis	80	1.8 ± 0.7	*Lutjanus carponotatus*	100	8 ± 0.6	Scombridae spp	100	1.6 ± 0.2
Choerodon schoenleinii	80	1.4 ± 0.4	*Pentapodus emeryii*	100	3.6 ± 1.6	*Selaroides leptolepis*	100	21 ± 1.5
Plectropomus maculatus	80	1.8 ± 0.6	*Plectropomus maculatus*	100	3 ± 0.6	*Torquigener pallimaculatus*	100	3 ± 1.1
Choerodon cauteroma	80	1.2 ± 0.4	*Acanthurus grammoptilus*	80	4.4 ± 1.7	Synodontidae spp	80	1.6 ± 0.5
Choerodon cyanodus	80	2 ± 0.6	*Carangoides fulvoguttatus*	80	1.4 ± 0.4	*Upeneus tragula*	80	7 ± 3.8
Hemigymnus melapterus	60	0.8 ± 0.4	*Choerodon cauteroma*	80	2.2 ± 1	*Echeneis naucrates*	60	0.8 ± 0.4
Naso unicornis	60	2.4 ± 1.3	*Lethrinus laticaudis*	80	2 ± 0.6	*Nemipterus* spp	60	0.8 ± 0.4

Table 8: Most common fish species and their mean relative abundance per stereo BRUV deployment in the Zone of High Impact associated with the Dredge Spoil Disposal Ground.

2008: High Impact Sessile invertebrates site DSI1			**2009: High Impact Sessile invertebrates site DSI1**		
	% drops	Mean MaxN (± SE)		% drops	Mean MaxN (± SE)
Pentapodus porosus	100	24.4 ± 7	*Carangoides fulvoguttatus*	100	5 ± 0.3
Abalistes stellatus	80	1 ± 0.3	*Pentapodus porosus*	100	22.6 ± 4.7
Carangoides fulvoguttatus	80	2.2 ± 0.8	Scombridae spp	100	1.4 ± 0.2
Gnathanodon speciosus	80	3.4 ± 1.8	*Choerodon schoenleinii*	60	0.6 ± 0.2
Scombridae spp	80	1.6 ± 0.5	*Chromis fumea*	60	2.4 ± 1.1
Chaetodontoplus duboulayi	60	1 ± 0.4	*Diagramma labiosum*	60	0.8 ± 0.4
Choerodon schoenleinii	60	0.6 ± 0.2	*Pentapodus vitta*	60	0.8 ± 0.4
Chromis fumea	60	2.4 ± 1.3	*Abalistes stellatus*	40	0.6 ± 0.4
Neopomacentrus filamentosus	60	1.2 ± 0.7	*Chaetodontoplus duboulayi*	40	0.6 ± 0.4
Diagramma labiosum	40	0.4 ± 0.2	*Epinephelus coioides*	40	0.4 ± 0.2

2008: High Impact Sessile invertebrates site DSI2			**2009: High Impact Sessile invertebrates site DSI2**		
	% drops	Mean MaxN (± SE)		% drops	Mean MaxN (± SE)
Pentapodus porosus	100	37.5 ± 8.7	*Pentapodus porosus*	100	23.4 ± 4.8
Abalistes stellatus	75	1.3 ± 0.5	*Diagramma labiosum*	100	0.4 ± 0.2
Carangoides fulvoguttatus	75	2.3 ± 1.6	*Carangoides fulvoguttatus*	80	1.8 ± 0.9
Choerodon schoenleinii	75	0.8 ± 0.3	*Nemipterus* spp	60	1 ± 0.4
Echeneis naucrates	75	0.8 ± 0.3	*Symphorus nematophorus*	40	0.4 ± 0.2
Scombridae spp	75	1.5 ± 0.6	Scombridae spp	40	0.8 ± 0.6
Atule mate	50	2.8 ± 1.9	*Abalistes stellatus*	40	0.4 ± 0.2
Chaetodontoplus duboulayi	50	0.5 ± 0.3	Numerous spp recorded at 1 drop		
Diagramma labiosum	50	0.5 ± 0.3			
Lethrinus laticaudis	50	0.5 ± 0.3			

Table 9: Twenty selected 'indicator species' for coral habitats at Barrow Island - based on observations from stereo BRUV footage. Common species are those present at >40% of coral sites surveyed.

Family	Common name	Species	Relative abundance 2008	Relative abundance 2009	Common?	LHC make Vulnerable?	Corallivore?	Site attached?
Acanthuridae	ring-tailed surgeonfish	*Acanthurus grammoptilus*	1.58 ± 0.34	2.13 ± 0.4	Y	N	N	N
Chaetodontidae	golden-striped butterflyfish	*Chaetodon aureofasciatus*	0.72 ± 0.15	0.07 ± 0.07	Y	N	Y	Y
	margined coralfish	*Chelmon marginalis*	0.62 ± 0.12	0.82 ± 0.17	Y	N	Y	Y
Labridae	bluespotted tuskfish	*Choerodon cauteroma*	0.7 ± 0.12	0.02 ± 0.02	Y	Y	N	N
	blue tuskfish	*Choerodon cyanodus*	1.96 ± 0.18	1.22 ± 0.21	Y	Y	N	N
	blackspot tuskfish	*Choerodon schoenleinii*	1.66 ± 0.13	1.87 ± 0.15	Y	Y	N	N
	moon wrasse	*Thalassoma lunare*	5.14 ± 0.77	3.49 ± 0.58	Y	N	N	N
Lethrinidae	yellow-tailed emperor	*Lethrinus atkinsoni*	1.96 ± 0.34	0.56 ± 0.1	Y	Y	N	N
	spangled emperor	*Lethrinus nebulosus*	1.48 ± 0.44	2.4 ± 0.63	Y	Y	N	N
Lutjanidae	stripey seaperch	*Lutjanus carponotatus*	2.76 ± 0.77	5.67 ± 1.5	Y	Y	N	N
	chinaman fish	*Symphorus nematophorus*	0.74 ± 0.15	0.62 ± 0.16	Y	Y	N	N
Nemipteridae	purple threadfin-bream	*Pentapodus emeryii*	1.54 ± 0.23	1.69 ± 0.31	Y	N	N	N
Pomacanthidae	six-banded angelfish	*Pomacanthus sexstriatus*	0.92 ± 0.14	1.09 ± 0.12	Y	N	N	Y
Pomacentridae	narrow-banded sergeant major	*Abudefduf bengalensis*	1.9 ± 0.37	1.84 ± 0.36	Y	N	N	N
	brown demoiselle	*Neopomacentrus filamentosus*	5.46 ± 2.31	11.24 ± 3.03	Y	N	N	Y
Serranidae	barramundi cod	*Cromileptes altivelis*	0.18 ± 0.06	1.6 ± 0.15	N	Y	N	Y
	frostback cod	*Epinephelus bilobatus*	0.72 ± 0.15	0.29 ± 0.08	Y	Y	N	Y
	camouflage grouper	*Epinephelus polyphekadion*	0.18 ± 0.06	0.64 ± 0.19	N	Y	N	Y
	bar-cheeked coral trout	*Plectropomus maculatus*	1.96 ± 0.19	2.4 ± 0.21	Y	Y	N	Y
Siganidae	doublebar spinefoot	*Siganus doliatus*	3.08 ± 0.81	1.76 ± 0.5	Y	N	N	N

Table 10: Length information for the twenty selected 'indicator species' for coral habitats to the east of Barrow Island (see Table 9), listed by alphabetically by family then species. Note that numbers present indicate those that could be measured free from obstruction and are not indicative of abundance.

			2008			2009		
Family	**Common name**	**Species**	**Mean length mm ± SE (n)**	**Min (mm)**	**Max (mm)**	**Mean length mm ± SE (n)**	**Min (mm)**	**Max (mm)**
Acanthuridae	ring-tailed surgeonfish	*Acanthurus grammoptilus*	233 ± 5.8 (73)	109.26	345.26	219.6 ± 6.28 (81)	109.34	348.92
Chaetodontidae	golden-striped butterflyfish	*Chaetodon aureofasciatus*	86.7 ± 4.2 (22)	58.14	131.08	75.08 ± 5.08 (27)	47.01	155.41
	margined coralfish	*Chelmon marginalis*	123.9 ± 4.7 (22)	79.8	156.8	127.92 ± 6.49 (18)	56.51	166.03
Labridae	bluespotted tuskfish	*Choerodon cauteroma*	224.6 ± 9.3 (30)	120.35	310.41	233.19 ± 6.64 (35)	134.40	307.37
	blue tuskfish	*Choerodon cyanodus*	258.3 ± 8.5 (82)	76.45	473.44	261.11 ± 8.81 (62)	78.74	376.55
	blackspot tuskfish	*Choerodon schoenlienii*	390.6 ± 15.8 (76)	114.05	673.32	367.86 ± 18.27 (52)	80.63	713.07
	moon wrasse	*Thalassoma lunare*	109.1 ± 2.87 (161)	45.72	216.56	116.25 ± 4.08 (91)	70.74	325.59
Lethrinidae	yellow-tailed emperor	*Lethrinus atkinsoni*	269.7 ± 6.6 (72)	119.78	466.58	274.54 ± 6.82 (69)	156.92	408.80
	spangled emperor	*Lethrinus nebulosus*	359.4 ± 14.8 (59)	176.68	667.01	372.25 ± 13.2 (28)	227.65	537.26
Lutjanidae	stripey seaperch	*Lutjanus carponotatus*	263.4 ± 8.1 (96)	100.07	515.99	250.03 ± 4.95 (139)	117.54	403.35
	chinaman fish	*Symphorus nematophorus*	581.7 ± 40.8 (29)	198.63	975.89	496.28 ± 39.9 (20)	168.75	841.01
Nemipteridae	purple threadfin-bream	*Pentapodus emeryii*	215.9 ± 6.2 (65)	124.17	297.55	215.76 ± 6.79 (58)	98.83	344.92
Pomacanthidae	six-banded angelfish	*Pomacanthus sexstriatus*	208 ± 8.4 (37)	106.42	326.7	229.53 ± 11.07 (39)	101.05	447.55
Pomacentridae	narrow-banded sergeant major	*Abudefduf bengalensis*	135.1 ± 2.9 (77)	85.52	267.93	136.57 ± 2.65 (71)	72.25	224.81
	brown demoiselle	*Neopomacentrus filamentosus*	46 ± 1.8 (38)	33.16	83.48	43.85 ± 0.77 (108)	30.29	72.97
Serranidae	barramundi cod	*Cromileptes altivelis*	319.2 ± 31.9 (7)	172.95	360.61	412.43 ± 29.9 (10)	289.28	544.56
	frostback cod	*Epinephelus biolobatus*	294.6 ± 10.7 (23)	152.29	342.92	302.01 ± 12.4 (21)	116.84	367.13
	camouflage grouper	*Epinephelus polyphekadion*	506.95 ± 5.75 (6)	456.38	569.24	424.36 ± 12.99 (12)	344.82	495.23
	bar-cheeked coral trout	*Plectropomus maculatus*	353.6 ± 13.3 (73)	132.08	617.61	354.22 ± 16.97 (68)	47.68	939.38
Siganidae	doublebar spinefoot	*Siganus doliatus*	207.9 ± 4.3 (102)	102.17	410.94	199.29 ± 7.53 (48)	127.91	320.12

FIGURES

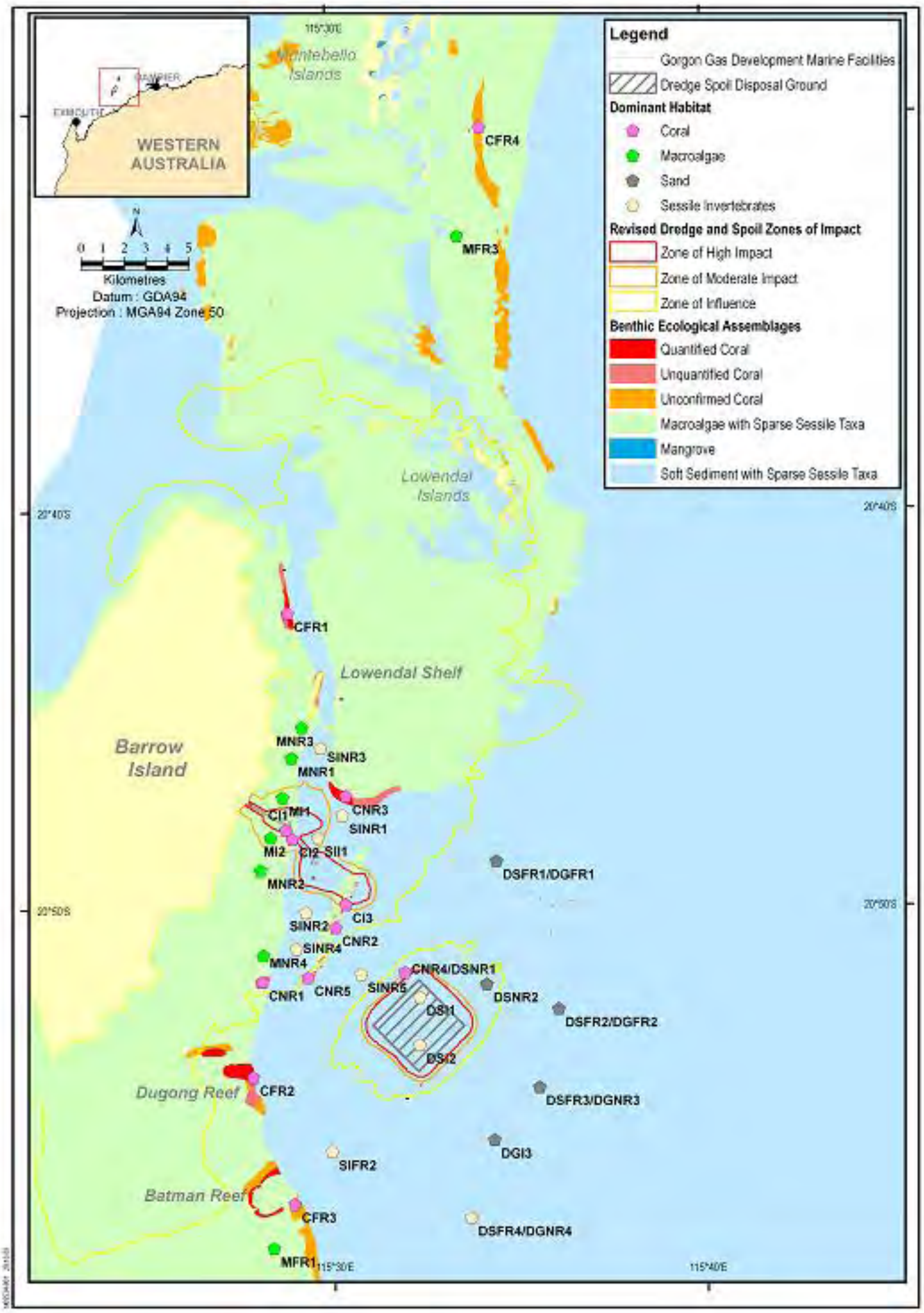


Figure 1: Map of sites surveyed in relation to the MOF, LNG and Dredge Spoil Disposal Ground in October 2008.

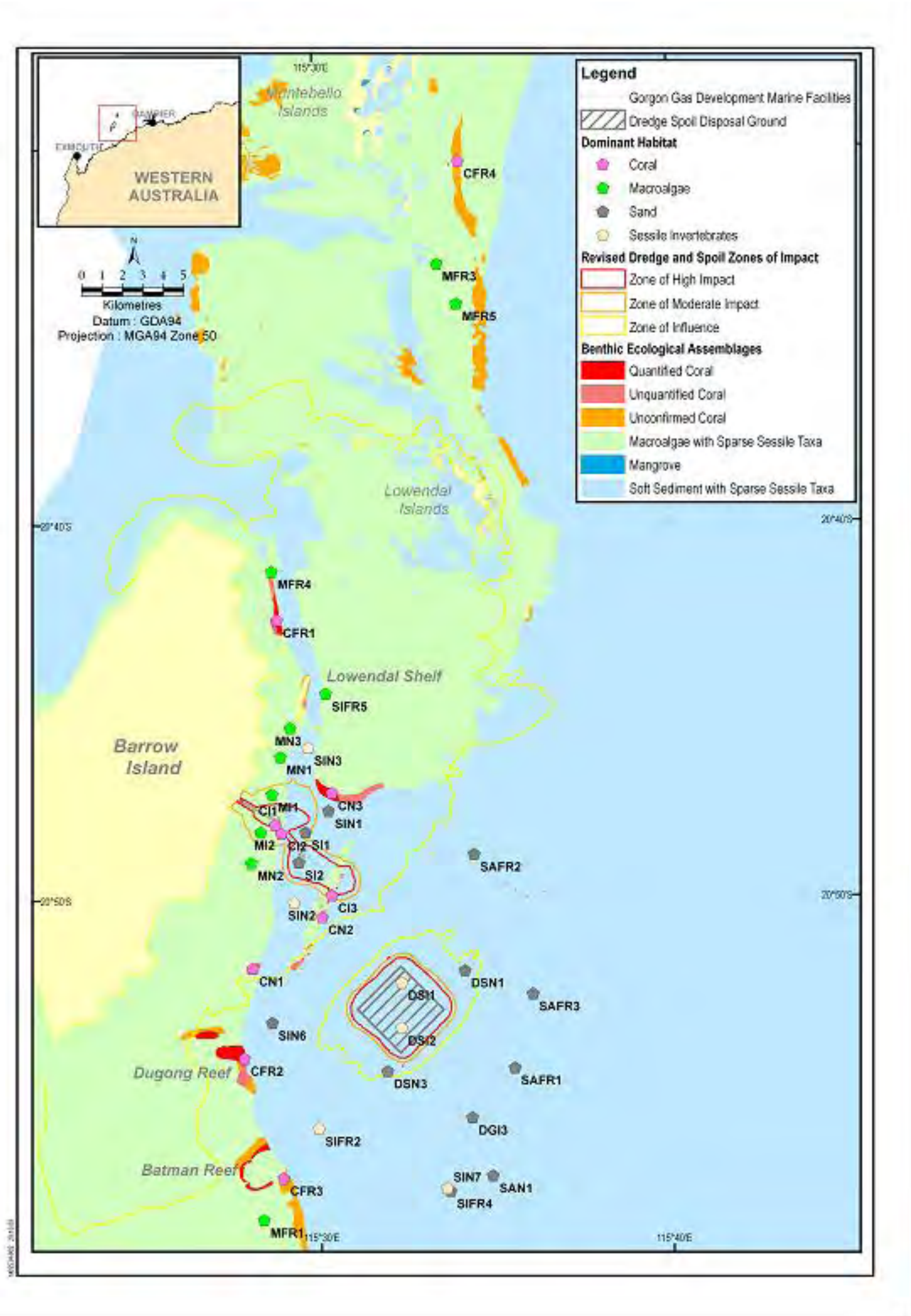


Figure 2: Map of sites surveyed in relation to the MOF, LNG and Dredge Spoil Disposal Ground in March 2009.

Figure 3: Habitat types surveyed at Barrow Island; A) coral, B) macroalgae, C) sand and D) sessile invertebrates.

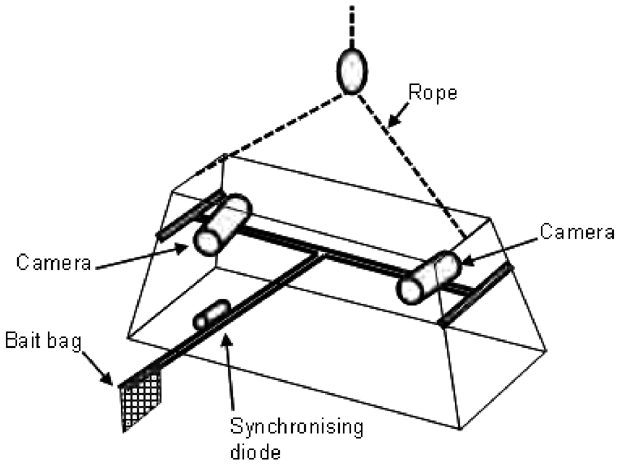


Figure 4: Baited remote underwater stereo-video system.

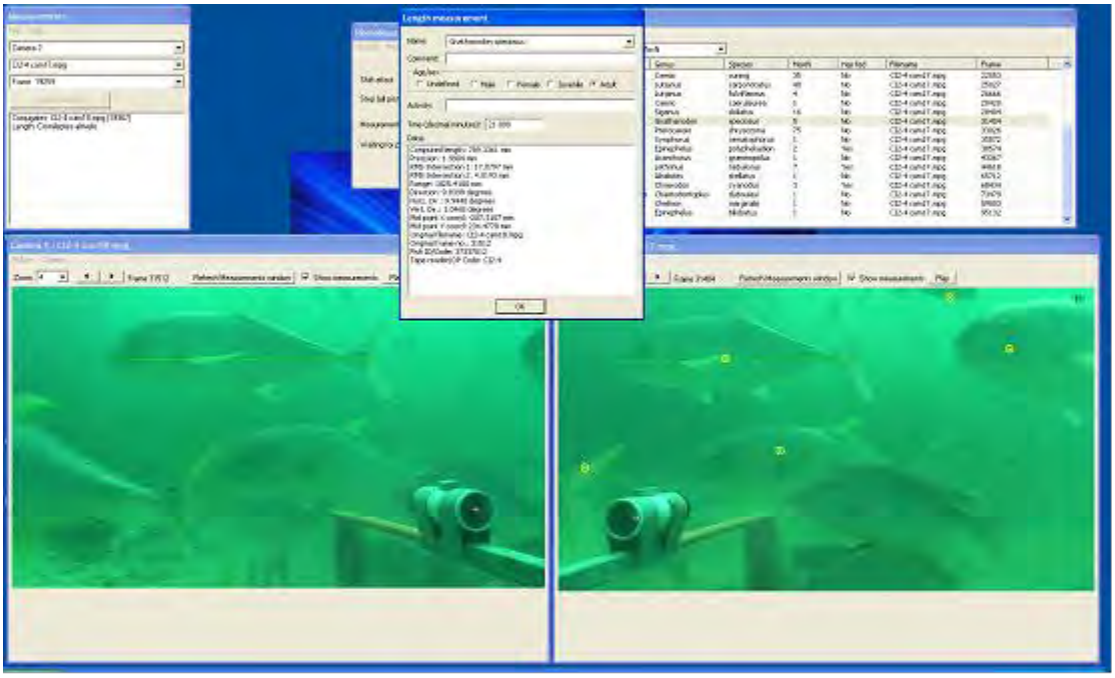
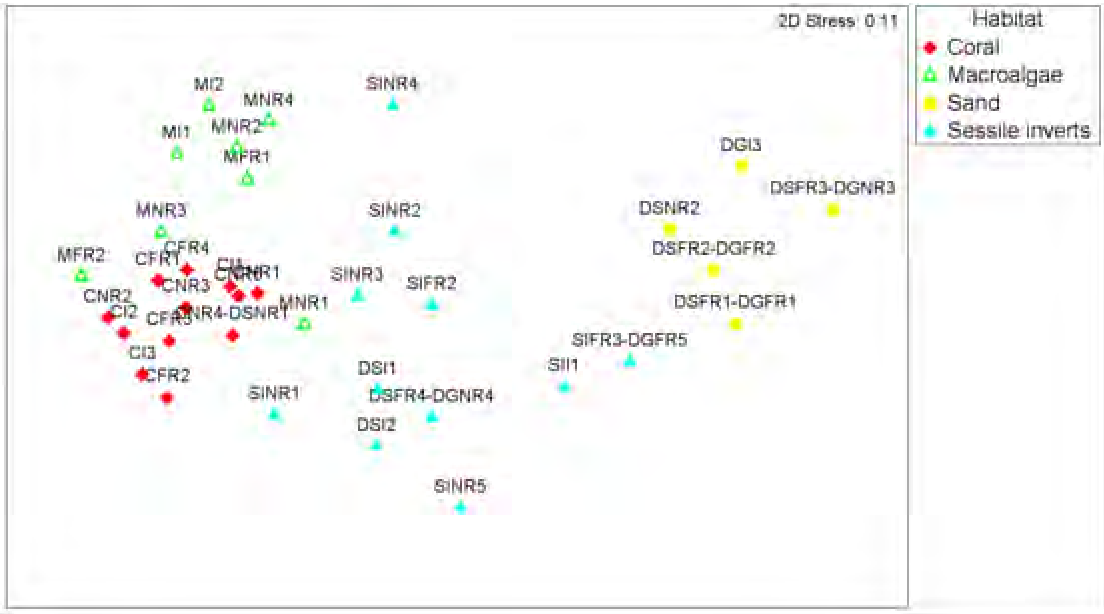


Figure 5: PhotoMeasure software used to measure lengths of individual fish. The golden trevally *Gnathanodon speciosus* is pictured here.

Figure 6: An albino leopard shark, *Stegastoma fasciatum,* measuring 1.18 m in length and observed at site DSFR3/DGNR3 in 2008 (site SAFR1 in 2009).



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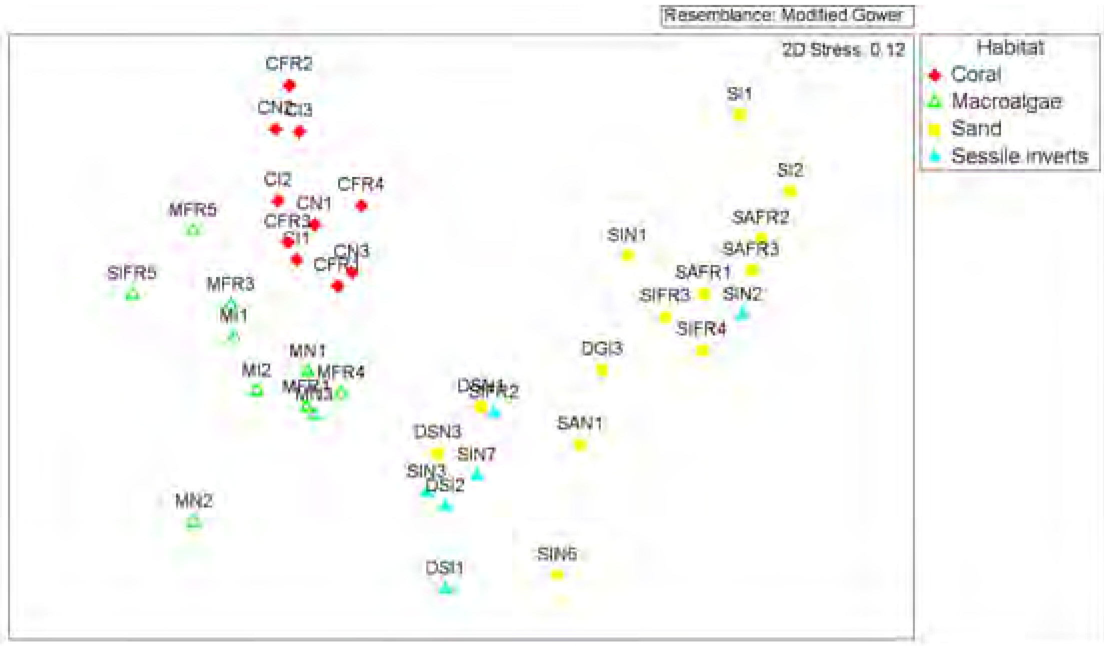
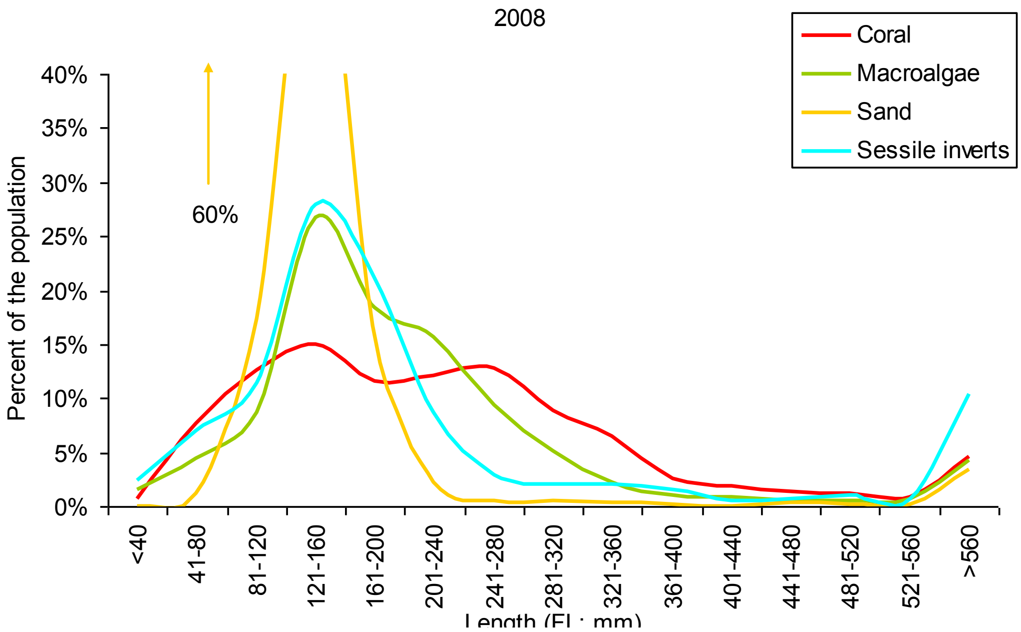


B

Figure 7: nMDS plots on the distances among centroids for each site - coded for the dominant habitat category for that site. A) Survey conducted in October 2008 and B) in March 2009. Separation of points illustrates the distinction in fish assemblages across different habitat types at Barrow Island.



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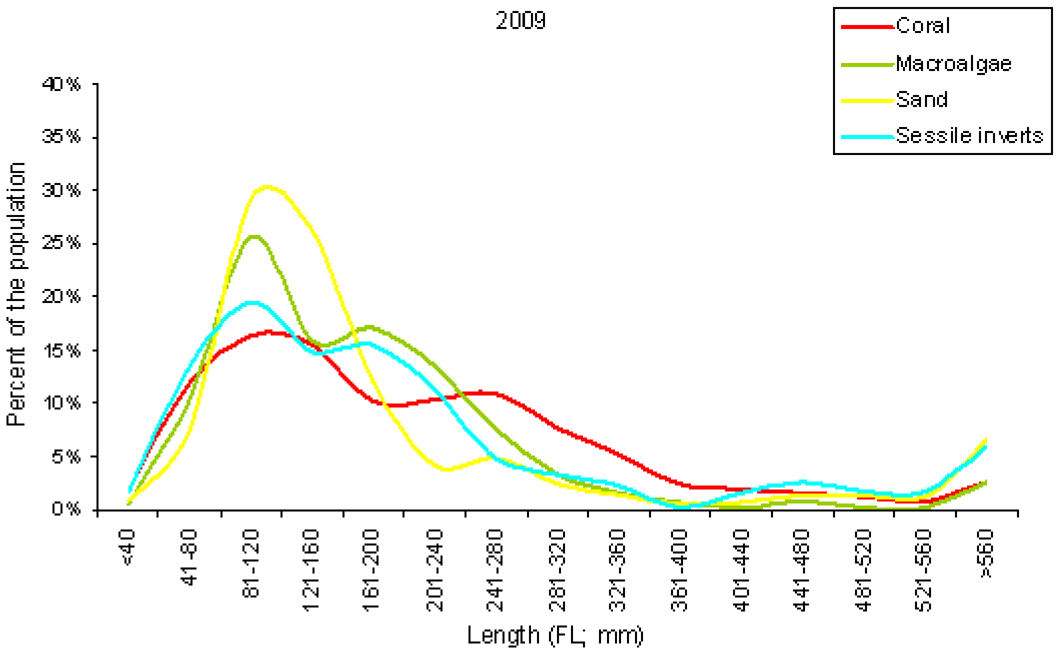


B

Figure 8: Size-structure of fish populations in each of four habitat categories surveyed around Barrow Island. A) October 2008: Coral n = 2660, macroalgae n = 1379, sand n = 1005, sessile inverts n = 1364; B) March 2009: Coral n = 3013, macroalgae n = 1971, sand n = 1417, sessile inverts n = 673).

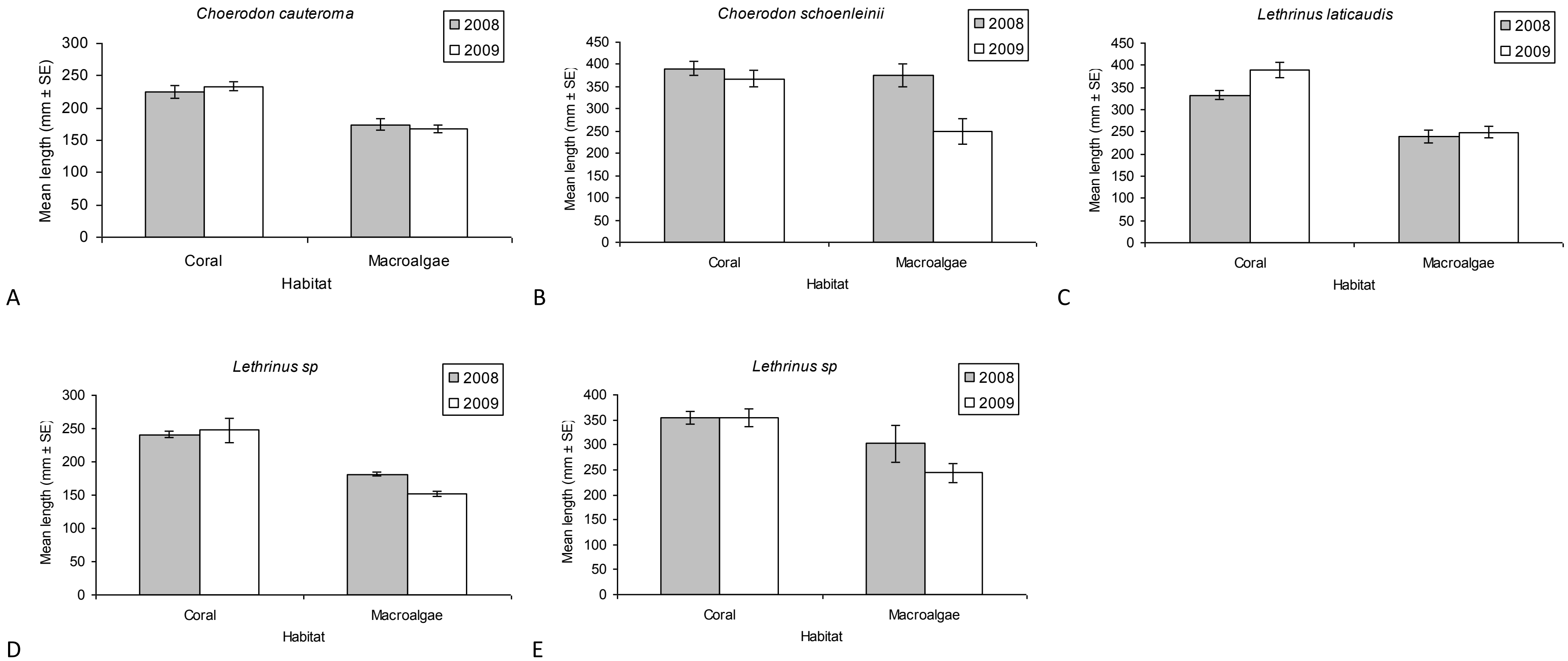
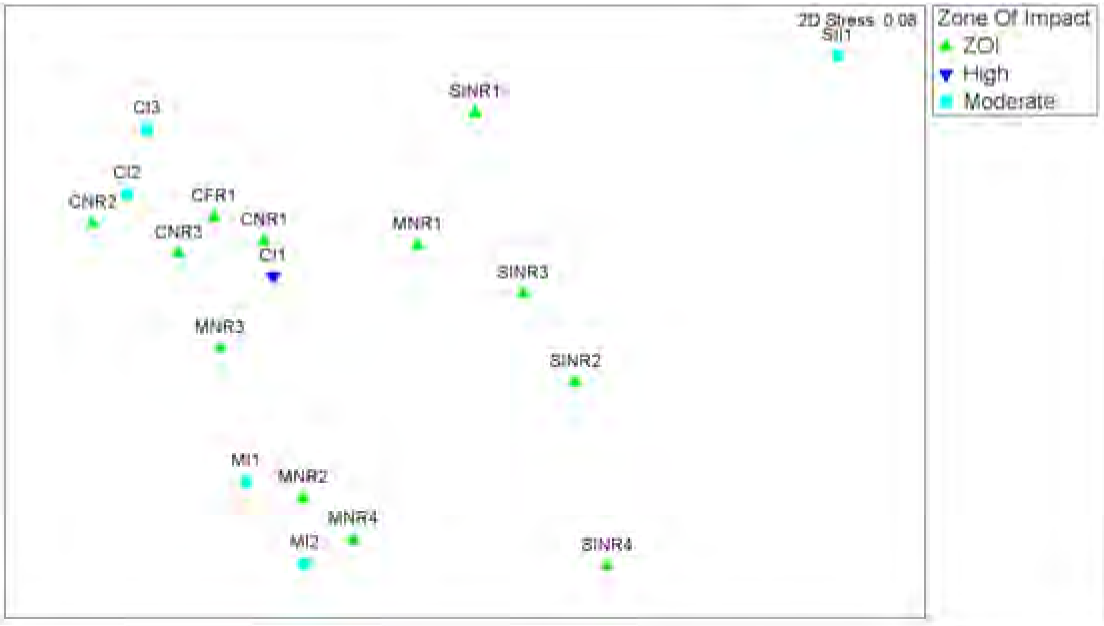


Figure 9: Mean length of fish species common to macroalgae and coral habitats. The graphs illustrate the presence of juveniles for each of these species in macroalgal habitats. A) bluespotted tuskfish; B) blackspot tuskfish; C) grass emperor; D) blue-lined emperor; E) bar cheek coral trout.



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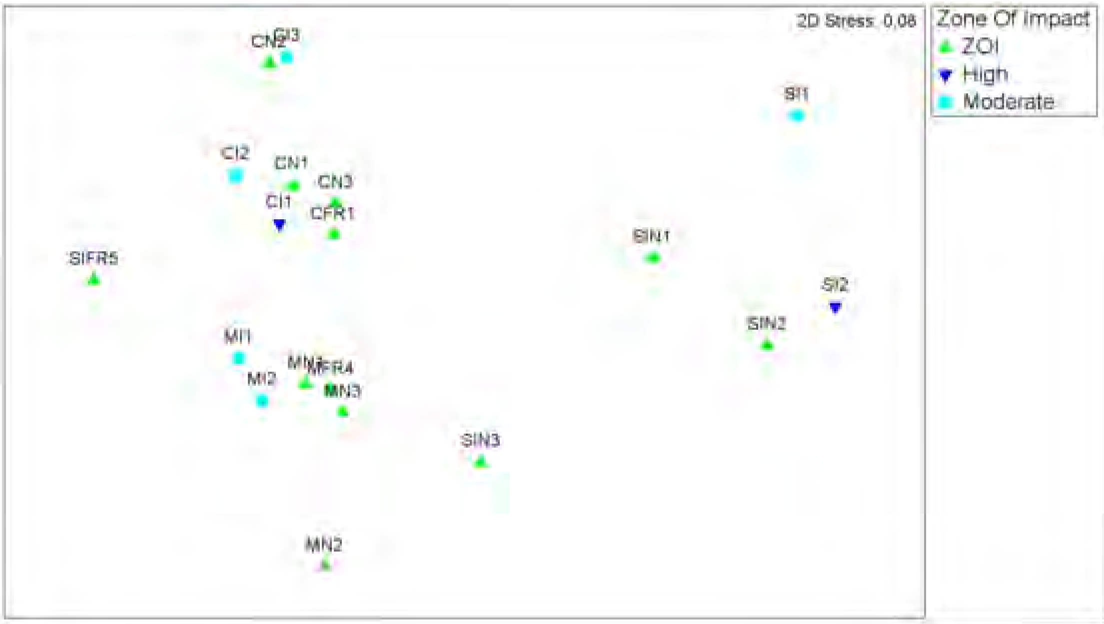
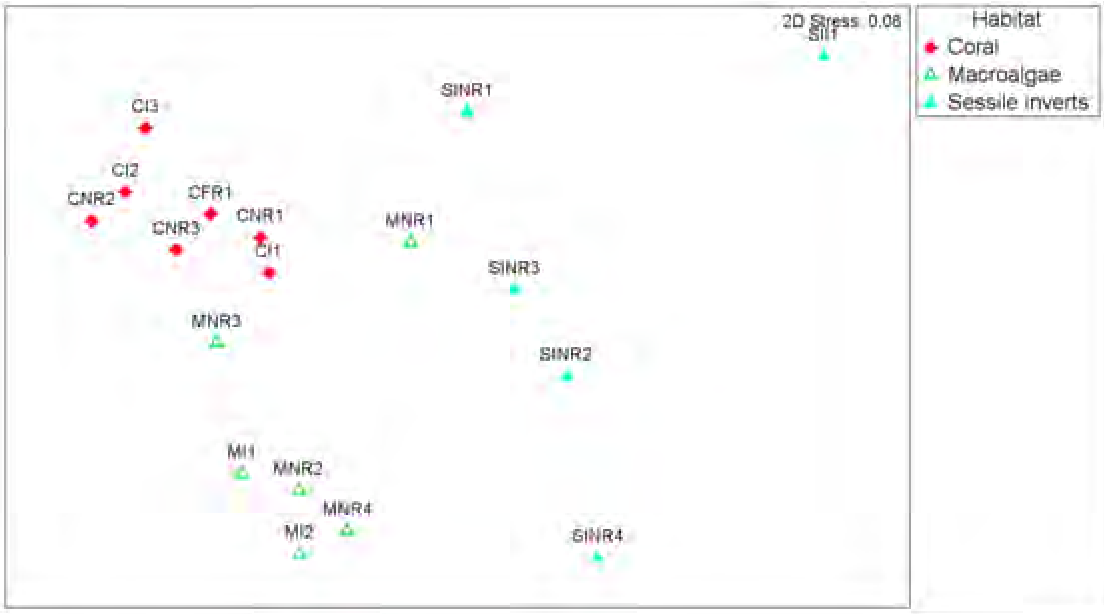


B

Figure 10: nMDS plots on the distances among centroids for each site - coded for Zones of Impact (Zone of Influence, High and Moderate) associated with the MOF and LNG Jetty. A) Survey conducted in October 2008 and B) in March 2009. No separation of points suggests similar fish assemblages exist within each of the zones prior to commencement of construction and dredging activities.



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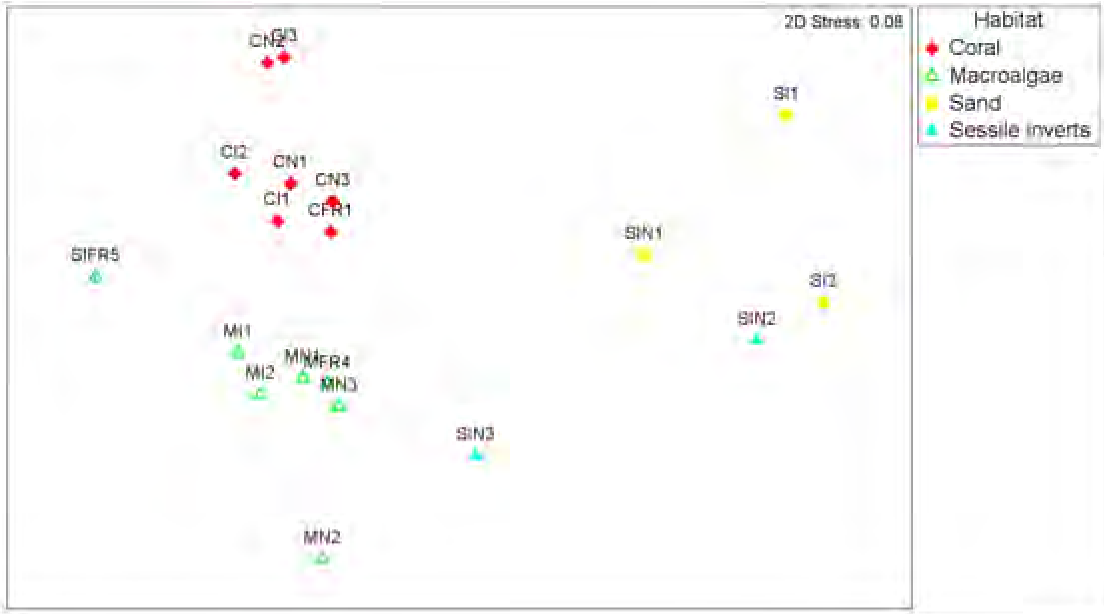
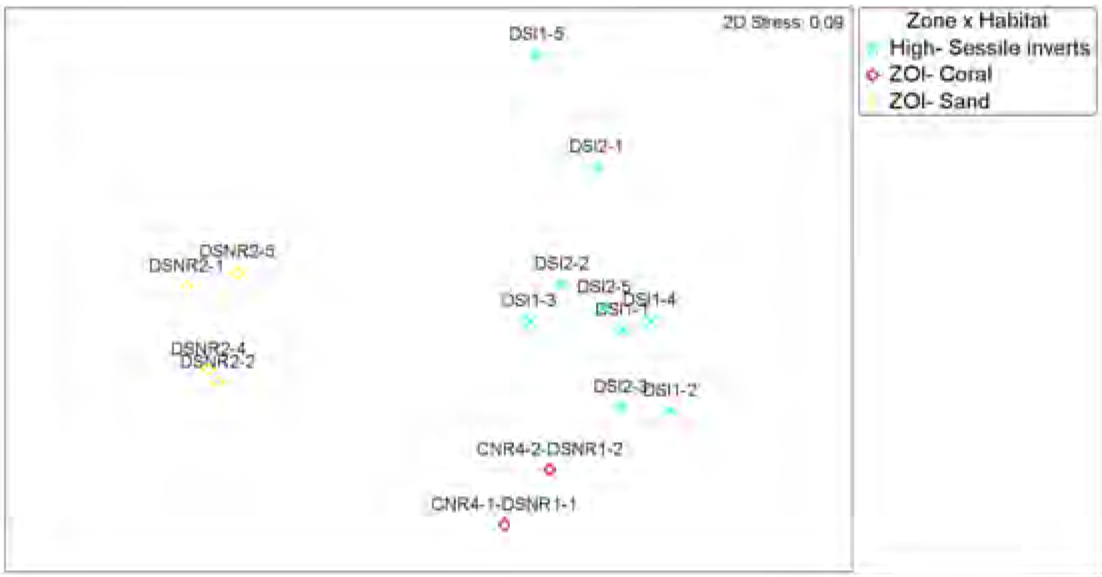


B

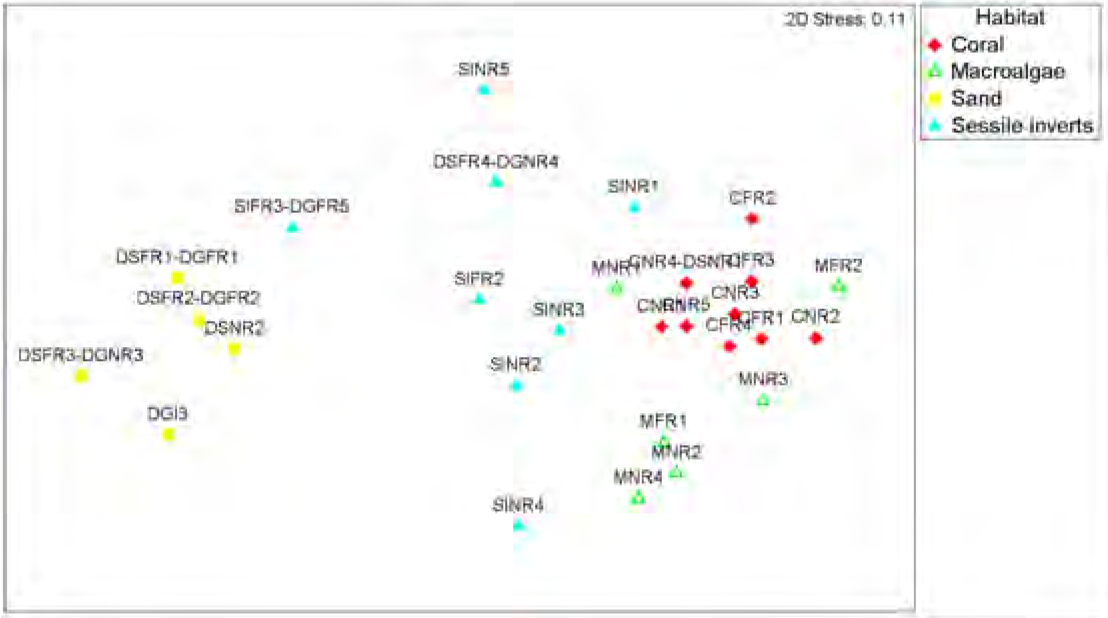
Figure 11: nMDS plots on the distances among centroids for each site - coded for Habitats associated with the MOF and LNG Jetty. A) Survey conducted in October 2008 and B) in March 2009. Clear separation of points illustrates distinct fish assemblages within each habitat prior to commencement of construction and dredging activities.



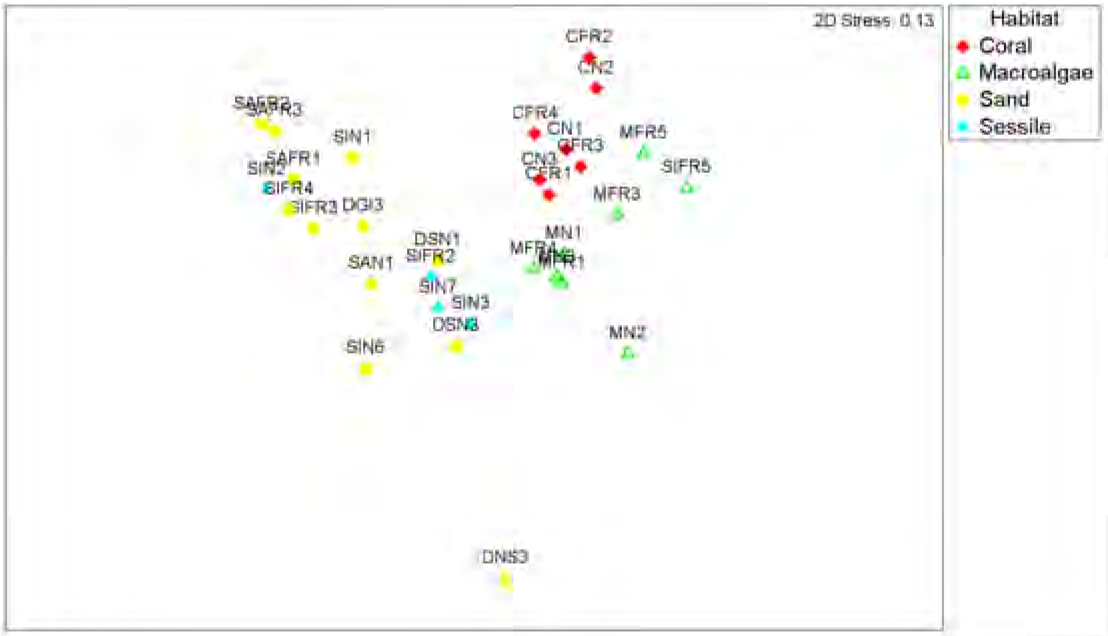
A

B

Figure 12: nMDS plots base on Modified Gower dissimilarity matrices for raw MaxN Data illustrating both Zone of Impact and habitat for each site associated with the Dredge Spoil Disposal Ground. A) Survey conducted in October 2008 and B) in March 2009.

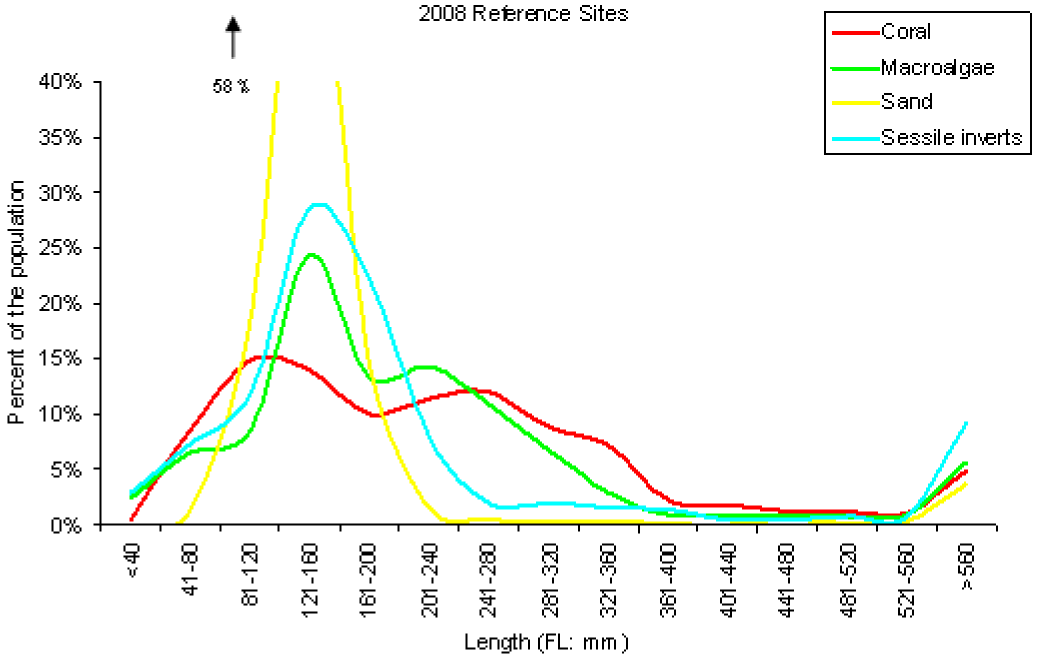


A



B

Figure 13: nMDS plots on the distances among centroids for each site - coded for Habitats associated with Reference sites around Barrow Island. A) Survey conducted in October 2008 and B) in March 2009. Clear separation of points illustrates distinct fish assemblages within each habitat.



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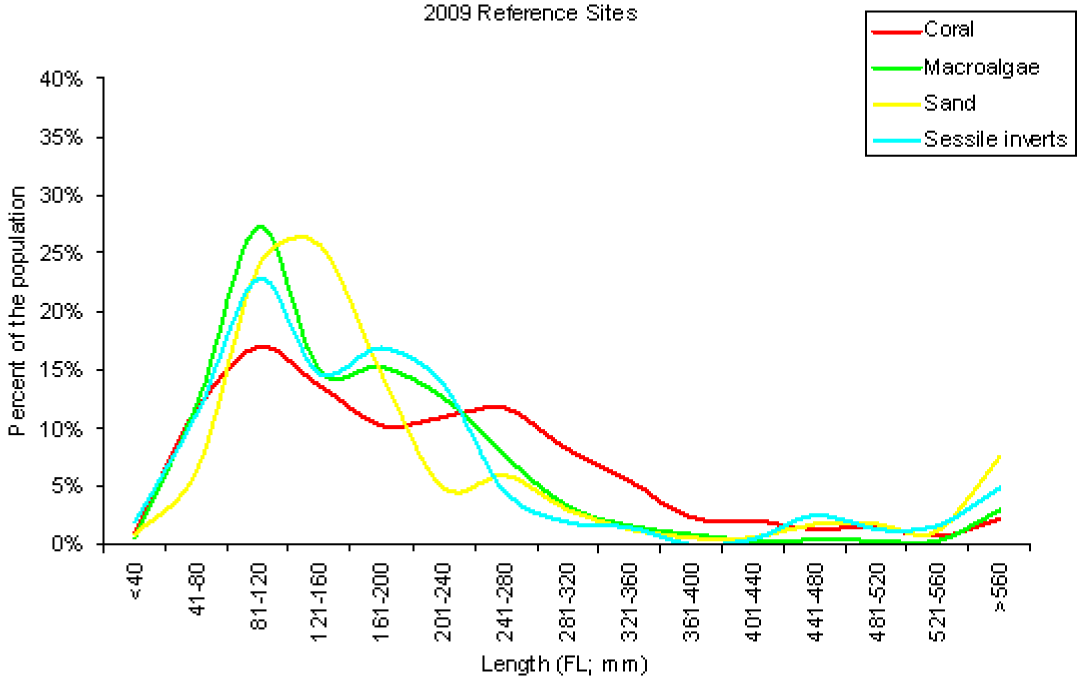


B

Figure 14: Size-structure of fish populations in each of four habitat categories surveyed at Reference sites to the east of Barrow Island. A) October 2008: Coral n = 1806, macroalgae n = 919, sand n = 817, sessile inverts n = 980; B) March 2009: Coral n = 1931, macroalgae n = 1589, sand n = 1093, sessile inverts n = 472).

8. APPENDIX I

List of families and species recorded at Barrow Island using stereo BRUVs in October 2008 and March 2009. Also presented is information on each species total abundance, % of sites at which they occurred, their rank based on how common they were (1 being the most common) and habitats with which they are associated (C = coral, M = macroalgae, S = bare sand, SI = sessile invertebrates). Species with an '*' are considered targeted by commercial and/or recreational fishers.

				2008			2009			Habitat			
Family	**Genus species**	**Common name**	**Authority**	**Total #**	**% of drops**	**Rank**	**Total #**	**% of drops**	**Rank**	**C**	**M**	**S**	**SI**
Acanthuridae	*Acanthurus dussumieri*	pencil surgeonfish	Valenciennes, 1835	10	3.8	99	1	0.46	191	X			
	Acanthurus grammoptilus	ring-tailed surgeonfish	Richardson, 1843	88	22	25	149	18.35	26	X	X		X
	Acanthurus maculiceps	spotted-face surgeonfish	(Ahl, 1923)	1	0.6	185	3	0.46	192	X			
	Acanthurus nigricans	velvet surgeonfish	(Linnaeus, 1758)				2	0.46	193		X		
	Acanthurus triostegus	convict surgeonfish	(Linnaeus, 1758)	1	0.6	186				X			
	Ctenochaetus striatus	lined bristletooth	(Quoy & Gaimard, 1825)	3	1.9	139	20	6.42	61	X			
	Naso brevirostris	spotted unicornfish	(Valenciennes, 1835)	2	1.3	157	8	2.75	109	X			
	Naso fageni	horseface unicornfish	Morrow, 1954	13	3.8	97	16	3.21	103	X	X		
	Naso lituratus	clown unicornfish	(Forster, 1801)	3	1.3	151				X			
	Naso unicornis	bluespine unicornfish	(Forsskål, 1775)	43	10.7	52	16	5.5	72	X			
Apogonidae	*Apogon selas*	meteor cardinalfish	Randall & Hayashi, 1990	40	0.6	171					X		
	Apogon wassinki	kupang cardinalfish	Bleeker, 1861				45	0.46	196	X			
	Apogonidae sp1						7	0.92	162	X			
	Cheilodipterus artus	wolf cardinalfish	Smith, 1961				4	0.46	214	X			
Ariidae	*Arius thalassinus*	giant sea catfish	(Rüppell, 1837)				2	0.46	197				X
Balistidae	*Abalistes stellatus*	starry triggerfish*	(Anonymous, 1798)	31	15.1	41	38	11.93	38	X	X		X
	Odonus niger	redtooth triggerfish	(Rüppell, 1836)				1	0.46	234			X	
	Pseudobalistes fuscus	yellowspotted	(Bloch & Schneider,				1	0.46	242	X			

		triggerfish	1801)										
	Sufflamen fraenatum	bridled triggerfish	(Latreille, 1804)	1	0.6	187	1	0.46	254	X			
Belonidae	*Platybelone argalus*	flat-tail longtom	(Lesueur, 1821)	1	0.6	188				X			
	Tylosurus crocodilus	crocodile longtom	(Péron & Lesueur, 1821)	1	0.6	189				X			
	Blennidae sp1						2	0.92	163	X			X
Blenniidae	*Aspidontus dussumieri*	lance blenny	(Valenciennes, 1836)				1	0.46	199	X			
	Aspidontus taeniatus	false cleanerfish	Quoy & Gaimard, 1834	1	0.6	190	22	5.5	69	X			
	Cirripectes filamentosus	filamentous blenny	(Alleyne & Macleay, 1877)	1	0.6	191				X			
	Meiacanthus grammistes	linespot fangblenny	(Valenciennes, 1836)	1	0.6	192	13	5.5	71	X			
	Plagiotremus rhinorhynchos	bluestriped fangblenny	(Bleeker, 1852)				2	0.92	184		X	X	
Bothidae	*Bothidae sp1*	Flounder*					1	0.46	201			X	
	Engyprosopon grandisquama	spot-tail wide-eye flounder*	(Temminck & Schlegel, 1846)			1	0.46	0.46			X		
	Pseudorhombus sp			4	2.5	127						X	
Caesionidae	*Caesio caerulaurea*	goldband fusilier	Lacépède, 1801	100	0.6	170	72	2.29	116	X			
	Caesio cuning	yellowtail fusilier	(Bloch, 1791)	422	13.2	43	588	9.17	51	X			
	Caesio teres	blue fusilier	Seale, 1906	78	4.4	82				X	X		
	Pterocaesio chrysozona	yellowband fusilier	(Cuvier, 1830)				114	1.83	140	X			
	Pterocaesio digramma	doubleline fusilier	(Bleeker, 1865)	773	11.9	47	731	5.96	68	X	X		X
	Pterocaesio tile	neon fusilier	(Cuvier, 1830)	26	0.6	172				X			
Callionymidae	*Pseudocalliurichthys goodladi*	longspine dragonet	(Whitley, 1944)				1	0.46	243			X	
Carangidae	*Alectis ciliaris*	pennantfish	(Bloch, 1787)	1	0.6	193				X			
	Atule mate	barred yellowtail scad	(Cuvier, 1833)	118	11.3	50	252	9.63	47	X	X	X	X
	Carangoides chrysophrys	longnose trevally*	(Cuvier, 1833)	1	0.6	194	1	0.46	203	X			
	Carangoides fulvoguttatus	gold-spotted trevally*	(Forsskål, 1775)	179	25.8	14	245	41.28	4	X	X	X	X
	Carangoides gymnostethus	bludger trevally*	(Cuvier, 1833)	14	3.8	96	24	3.21	98	X		X	X
	Carangoides	bumpnose trevally*	(Whitley, 1934)				8	0.92	164				X

	hedlandensis												
	Carangoides orthogrammus	thicklip trevally*	(Jordan & Gilbert, 1882)	4	0.6	177	8	1.38	143				X
	Carangoides uii	Japanese trevally*	Wakiya, 1924				3	0.46	204			X	
	Caranx ignobilis	giant trevally*	(Forsskål, 1775)	5	1.9	135	3	0.92	165	X			
	Caranx sexfasciatus	bigeye trevally*	Quoy & Gaimard, 1825				1	0.46	205				X
	Caranx tille	tille trevally*	Cuvier, 1833	1	0.6	195						X	
	Decapterus russelli	indian scad	(Rüppell, 1830)				1	0.46	216			X	
	Gnathanodon speciosus	golden trevally*	(Forsskål, 1775)	119	23.3	21	485	19.27	23	X	X	X	X
	Pantolabus radiatus	fringefin trevally*	(Macleay, 1881)				7	0.92	181	X			X
	Scomberoides commersonnianus	giant queenfish*	Lacépède, 1801	9	5.7	76	5	1.38	158			X	X
	Scomberoides tol	needleskin queenfish*	(Cuvier, 1832)	1	0.6	196				X			
	Selaroides leptolepis	yellowstripe scad	(Kuhl & van Hasselt, 1833)	577	19.5	29	1190	24.31	15			X	X
	Seriolina nigrofasciata	blackbanded amberjack*	(Rüppell, 1829)	8	5	81	24	9.63	50			X	X
Carcharhinidae	*Carcharhinus amblyrhynchos*	grey reef shark*	(Bleeker, 1856)	1	0.6	197	1	0.46	206	X			
	Carcharhinus falciformis	silky shark*	(Bibron, 1839)				1	0.46	207			X	
	Carcharhinus leucas	bull shark*	(Valenciennes, 1839)	1	0.6	198							X
	Carcharhinus limbatus	common blacktip shark*	(Valenciennes, 1839)	1	0.6	199				X			
	Carcharhinus melanopterus	blacktip reef shark*	(Quoy & Gaimard, 1824)	10	6.3	71	5	2.29	117	X			X
	Carcharhinus plumbeus	sandbar shark*	(Nardo, 1827)	2	1.3	158	1	0.46	208	X			X
	Carcharhinus sorrah	spot-tail shark*	(Valenciennes, 1839)	1	0.6	200						X	
	Galeocerdo cuvier	tiger shark*	(Péron & Lesueur, 1822)	6	3.8	102	6	2.75	108	X	X	X	X
	Loxodon macrorhinus	sliteye shark*	Müller & Henle, 1839	37	11.9	48						X	X
	Negaprion acutidens	lemon shark*	(Rüppell, 1837)	3	1.9	140	6	2.75	111		X		
	Triaenodon obesus	whitetip reef shark*	(Rüppell, 1837)	6	3.8	103	11	5.05	80	X			
Chaetodontidae	*Chaetodon adiergastos*	philippine butterflyfish	Seale, 1910	1	0.6	201	2	0.92	166	X			
	Chaetodon	golden-striped	Macleay, 1878	38	13.2	46	52	11.01	43	X			X

	aureofasciatus	butterflyfish											
	Chaetodon auriga	threadfin butterflyfish	Forsskål, 1775	11	3.8	98	4	1.38	144	X			
	Chaetodon lineolatus	lined butterflyfish	Cuvier, 1831	18	6.9	62	22	5.05	75	X			
	Chaetodon lunula	racoon butterflyfish	(Lacépède, 1803)	2	0.6	181	3	0.92	167	X			
	Chaetodon lunulatus	pinstripe butterflyfish	Quoy & Gaimard, 1824	10	2.5	120	1	0.46	210	X			
	Chaetodon marginalis	margined coralfish	Richardson1842				1	0.46	211	X			
	Chaetodon plebeius	bluespot butterflyfish	Cuvier, 1831	3	1.9	141	7	2.29	119	X			
	Chaetodon speculum	ovalspot butterflyfish	Cuvier, 1831	1	0.6	202	1	0.46	212	X			
	Chelmon marginalis	margined coralfish	Richardson, 1842	44	18.2	35	40	11.47	41	X	X		X
	Coradion chrysozonus	orangebanded coralfish	(Cuvier, 1831)	4	1.9	136	12	3.21	99	X			X
	Heniochus acuminatus	longfin bannerfish	(Linnaeus, 1758)	41	14.5	42	47	11.01	44	X			X
	Heniochus monoceros	masked bannerfish	Cuvier, 1831				2	0.46	228	X			
	Heniochus singularius	singular bannerfish	Smith & Radcliffe, 1911	3	1.3	152	3	1.38	149	X			X
	Parachaetodon ocellatus	ocellate butterflyfish	(Cuvier, 1831)	29	6.3	67	30	5.96	66		X		X
Cirrhitidae	*Cirrhitichthys oxycephalus*	spotted hawkfish	(Bleeker, 1855)				1	0.46	215			X	
Clupeidae	*Herklotsichthys* sp			1016	5	77						X	
Dasyatidae	*Dasyatis kuhlii*	bluespotted maskray	(Müller & Henle, 1841)	13	8.2	58	3	1.38	146	X	X		X
	Himantura fai	pink whipray	Jordan & Seale, 1906				12	2.29	121	X	X	X	X
	Himantura granulata	mangrove whipray	(Macleay, 1883)				1	0.46	229				X
	Himantura jenkinsii	Jenkins' whipray	(Annandale, 1909)	1	0.6	203							X
	Himantura toshi	brown whipray	Whitley, 1939	3	1.9	142							X
	Himantura uarnak	reticulate whipray	(Forsskål, 1775)	1	0.6	204					X		
	Himantura undulata	leopard whipray	Manjaji-Matsumoto & Last, 2008	1	0.6	205						X	
	Pastinachus sephen	cowtail stingray	(Forsskål, 1775)	1	0.6	206	2	0.92	183	X			
	Taeniura lymma	bluespotted fantail ray	(Forsskål, 1775)	1	0.6	207	1	0.46	256	X			
	Taeniura meyeni	blotched fantail ray	Müller & Henle, 1841	1	0.6	208				X			
Echeneidae	*Echeneis naucrates*	sharksucker	Linnaeus, 1758	59	22	26	92	27.52	11	X	X	X	X
Elopidae	*Elops hawaiensis*	Hawaiian giant herring*	Regan, 1909	14	4.4	85	2	0.46	218	X	X		X

Ephippidae	*Platax batavianus*	humphead batfish	Cuvier, 1831	7	3.8	101	15	6.42	64	X	X		X
	Platax orbicularis	round batfish	(Forsskål, 1775)				1	0.46	237		X		
	Platax pinnatus	longfin batfish	(Linnaeus, 1758)				1	0.46	238			X	
	Platax teira	roundface batfish	(Forsskål, 1775)	1	0.6	209	12	3.67	96			X	
	Zabidius novemaculeatus	shortfin batfish	(McCulloch, 1916)				5	0.46	259	X			
Fistulariidae	*Fistularia commersonii*	smooth flutemouth	Rüppell, 1838	1	0.6	210	4	0.92	172	X			
Ginglymostomatidae	*Nebrius ferrugineus*	tawny shark	(Lesson, 1830)				6	2.75	110		X	X	
Glaucosomatidae	*Glaucosoma magnificum*	threadfin pearl perch*	(Ogilby, 1915)	4	1.3	149	303	2.29	120	X			
Gobbidae	*Gobbidae* sp1						3	0.92	173	X	X		
Grammistidae	*Diploprion bifasciatum*	barred soapfish	Cuvier, 1828	13	3.1	107	4	1.38	147	X			
Haemulidae	*Diagramma labiosum*	painted sweetlips*	Macleay, 1883	33	15.7	40	80	16.06	31	X	X		X
	Plectorhinchus albovittatus	giant sweetlips*	(Rüppell, 1838)	1	0.6	211					X		
	Plectorhinchus chaetodonoides	spotted sweetlips	Lacépède, 1801	2	1.3	159	10	4.13	91	X			
	Plectorhinchus gibbosus	brown sweetlips*	(Lacépède, 1802)	5	3.1	111	2	0.92	185	X	X		X
	Plectorhinchus multivittatus	manyline sweetlips	(Macleay, 1878)	2	1.3	160	5	1.83	139	X			
	Plectorhinchus picus	dotted sweetlips	(Cuvier, 1830)	6	0.6	176							X
	Plectorhinchus polytaenia	ribbon sweetlips	(Bleeker, 1852)				2	0.92	186	X			
	Plectorhinchus vittatus	oriental sweetlips	(Linnaeus, 1758)	2	1.3	161				X			
Hemigaleidae	*Hemigaleus australiensis*	weasel shark*	White, Last & Compagno, 2005	1	0.6	212							X
	Hemipristis elongata	fossil shark*	(Klunzinger, 1871)	4	2.5	125							X
Hemiscylliidae	*Chiloscyllium punctatum*	grey carpetshark	Müller & Henle, 1838	11	6.9	64	2	0.92	169	X	X		X
	Hemiscyllium trispeculare	speckled carpetshark	Richardson, 1843	1	0.6	213				X			
Holocentridae	*Myripristis violacea*	violet soldierfish	Bleeker, 1851				1	0.46	233	X			
	Sargocentron rubrum	red squirrelfish	(Forsskål, 1775)				31	2.75	114	X			
Labridae	*Anampses geographicus*	scribbled wrasse	Valenciennes, 1840	1	0.6	214				X			

	Anampses lennardi	blue-and-yellow wrasse	Scott, 1959	49	13.2	44	36	7.34	58	X	X	X	
	Anampses meleagrides	speckled wrasse	Valenciennes, 1840	8	3.8	100				X			
	Bodianus bilunulatus	saddleback pigfish*	(Lacépède, 1801)				1	0.46	200	X			
	Bodianus diana	diana's pigfish*	(Lacépède, 1801)	1	0.6	215				X			
	Cheilinus chlorourus	floral maori wrasse*	(Bloch, 1791)	1	0.6	216	2	0.92	168	X			
	Cheilinus fasciatus	redbreast maori wrasse*	(Bloch, 1791)	2	0.6	182					X		
	Cheilinus trilobatus	tripletail maori wrasse*	Lacépède, 1801	11	6.9	65	1	0.46	213	X	X		
	Cheilio inermis	sharpnose wrasse	(Forsskål, 1775)	9	5	78	18	6.88	59	X	X		
	Choerodon cauteroma	bluespotted tuskfish*	Gomon & Allen, 1987	125	44.7	5	197	35.78	7	X	X	X	X
	Choerodon cephalotes	purple tuskfish*	(Castelnau, 1875)	13	6.3	70	20	8.72	52			X	X
	Choerodon cyanodus	blue tuskfish*	(Richardson, 1843)	188	58.5	1	245	44.04	3	X	X	X	X
	Choerodon schoenleinii	blackspot tuskfish*	(Valenciennes, 1839)	123	49.1	4	129	37.61	5	X	X	X	X
	Choerodon vitta	redstripe tuskfish	Ogilby, 1910	2	1.3	162	47	4.13	89		X		X
	Cirrhilabrus cyanopleura	blueside wrasse	(Bleeker, 1851)	7	0.6	175							X
	Coris aygula	redblotched wrasse	Lacépède, 1801	5	3.1	112	11	3.21	100	X			
	Coris caudimacula	spot-tail wrasse	(Quoy & Gaimard, 1834)	6	3.8	104	18	5.05	76	X	X		X
	Coris pictoides	pixy wrasse	Randall & Kuiter, 1982	5	2.5	123	18	3.21	101	X	X		X
	Epibulus insidiator	slingjaw wrasse	(Pallas, 1770)	7	4.4	92	4	1.83	134	X			
	Gomphosus varius	birdnose wrasse	Lacépède, 1801	1	0.6	217				X			
	Halichoeres margaritaceus	pearly wrasse	(Valenciennes, 1839)	1	0.6	218				X			
	Halichoeres marginatus	dusky wrasse	Rüppell, 1835				1	0.46	227	X			
	Halichoeres melanochir	orangefin wrasse	Fowler & Bean, 1928	2	1.3	163	27	8.26	54	X			
	Halichoeres nebulosus	cloud wrasse	(Valenciennes, 1839)	9	4.4	87	21	5.96	65	X	X		X
	Hemigymnus fasciatus	fiveband wrasse	(Bloch, 1792)	1	0.6	219	3	1.38	148	X			
	Hemigymnus melapterus	thicklip wrasse	(Bloch, 1791)	45	19.5	31	32	9.63	49	X			
	Hologymnosus annulatus	ringed slender wrasse	(Lacépède, 1801)	1	0.6	220	1	0.46	230	X			
	Hologymnosus doliatus	pastel slender wrasse	(Lacépède, 1801)	1	0.6	221					X		

	Iniistius sp1						3	0.92	174			X	
	Labridae sp1						2	0.92	175	X	X		
	Labroides dimidiatus	common cleanerfish	(Valenciennes, 1839)	49	17.6	36	49	12.39	36	X	X		X
	Leptojulis cyanopleura	shoulderspot wrasse	(Bleeker, 1853)	3	0.6	179	55	2.29	122		X		
	Pseudodax moluccanus	chiseltooth wrasse	(Valenciennes, 1840)				1	0.46	245	X			
	Pteragogus cryptus	cryptic wrasse	Randall, 1981				3	1.38	154		X		
	Thalassoma lunare	moon wrasse	(Linnaeus, 1758)	283	28.9	11	209	20.18	20	X	X		X
	Thalassoma lutescens	green moon wrasse	(Lay & Bennett, 1839)	2	1.3	164	1	0.46	258	X			
	Xyrichtys sp			4	1.9	137	12	3.67	97			X	
Latidae	*Psammoperca waigiensis*	sand bass*	(Cuvier, 1828)				1	0.46	241	X			
Lethrinidae	*Gymnocranius sp*	*		1	0.6	222	1	0.46	226	X			
	Lethrinus atkinsoni	yellowtail emperor*	Seale, 1910	108	23.3	23	150	14.68	33	X	X		
	Lethrinus genivittatus	threadfin emperor*	Valenciennes, 1830	117	16.4	38	337	20.64	19	X	X	X	X
	Lethrinus laticaudis	grass emperor*	Alleyne & Macleay, 1877	95	30.8	10	96	26.15	12	X	X	X	X
	Lethrinus lentjan	redspot emperor*	(Lacépède, 1802)				15	1.38	150	X		X	
	Lethrinus microdon	smalltooth emperor*	(Valenciennes, 1830)				6	0.92	176	X			
	Lethrinus miniatus	redthroat emperor*	(Forster, 1801)	2	1.3	165				X			
	Lethrinus nebulosus	spangled emperor*	(Forsskål, 1775)	93	20.8	28	63	16.06	32	X	X		
	Lethrinus olivaceus	longnose emperor*	Valenciennes, 1830	5	3.1	113	2	0.92	177	X			
	Lethrinus sp	blue-lined emperor*		810	27.7	13	321	18.35	27	X	X	X	X
	Lethrinus variegatus	variegated emperor*	Valenciennes, 1830	20	4.4	84	33	6.42	63		X		X
Lutjanidae	*Lutjanus argentimaculatus*	mangrove jack*	(Forsskål, 1775)				2	0.92	178	X			
	Lutjanus bohar	red bass*	(Forsskål, 1775)	2	1.3	166	3	1.38	151	X			
	Lutjanus carponotatus	stripey snapper*	(Richardson, 1842)	172	36.5	8	296	28.44	9	X	X		X
	Lutjanus fulviflamma	blackspot snapper*	(Forsskål, 1775)				4	0.46	231	X			
	Lutjanus lemniscatus	darktail snapper*	(Valenciennes, 1828)	25	11.9	49	28	7.8	56	X			
	Lutjanus malabaricus	saddletail snapper*	(Bloch & Schneider, 1801)	8	0.6	174							X
	Lutjanus quinquelineatus	fiveline snapper*	(Bloch, 1790)	7	1.3	147	23	1.83	137	X			
	Lutjanus russellii	moses' snapper*	(Bleeker, 1849)	6	2.5	121	8	0.92	179	X			

	Lutjanus sebae	red emperor*	(Cuvier, 1828)				1	0.46	232	X			
	Lutjanus vitta	brownstripe snapper	(Quoy & Gaimard, 1824)	21	1.3	146	14	1.38	152		X		X
	Symphorus nematophorus	Chinamanfish*	(Bleeker, 1860)	51	25.8	15	73	24.31	16	X	X		X
Mobulidae	*Manta birostris*	manta ray	(Donndorff, 1798)	2	0.6	183				X			
Monacanthidae	*Acreichthys tomentosus*	bristle-tail leatherjacket	(Linnaeus, 1758)				2	0.46	194		X		
	Aluterus scriptus	scrawled leatherjacket	(Osbeck, 1765)	1	0.6	223				X			
	Anacanthus barbatus	bearded leatherjacket	Gray, 1831	1	0.6	224	3	0.92	161				X
	Chaetodermis penicilligera	tasselled leatherjacket	(Cuvier, 1817)	1	0.6	225						X	
	Monacanthus chinensis	fanbelly leatherjacket	(Osbeck, 1765)	3	1.9	143	14	4.59	83			X	X
	Paramonacanthus choirocephalus	pigface leatherjacket	(Bleeker, 1852)	65	18.2	33	170	24.77	14		X	X	X
	Pseudomonacanthus peroni	potbelly leatherjacket	(Hollard, 1854)				1	0.46	246			X	
Mullidae	*Parupeneus barberinoides*	bicolour goatfish	(Bleeker, 1852)	46	13.2	45	48	11.93	40	X	X		X
	Parupeneus chrysopleuron	rosy goatfish*	(Temminck & Schlegel, 1843)			10	0.46	0.46				X	
	Parupeneus cyclostomus	goldsaddle goatfish*	(Lacépède, 1801)	1	0.6	226				X			
	Parupeneus heptacanthus	opalescent goatfish*	(Lacépède, 1802)	14	2.5	119						X	X
	Parupeneus indicus	yellowspot goatfish*	(Shaw, 1803)	100	28.9	12	125	22.48	17	X	X		
	Parupeneus multifasciatus	banded goatfish	(Quoy & Gaimard, 1825)	1	0.6	227				X			
	Parupeneus spilurus	blacksaddle goatfish*	(Bleeker, 1854)	6	3.1	110	35	5.05	77	X	X		
	Upeneus moluccensis	goldband goatfish	(Bleeker, 1855)	17	3.1	106						X	X
	Upeneus tragula	bartail goatfish	Richardson, 1846	204	21.4	27	219	20.18	21		X	X	X
Muraenidae	*Gymnothorax flavimarginatus*	yellowmargin moray	(Rüppell, 1830)	8	4.4	89				X			
	Gymnothorax thrysoideus	greyface moray	(Richardson, 1845)	3	0.6	180				X			
	Gymnothorax undulatus	undulate moray	(Lacépède, 1803)	4	2.5	126	4	1.83	135	X			X

	Muraenidae sp1						3	1.38	153	X	X		
Nemipteridae	*Nemipterus sp*	*		212	23.9	19	141	28.44	10			X	X
	Pentapodus emeryii	purple threadfin bream	(Richardson, 1843)	162	42.1	6	250	34.4	8	X	X		X
	Pentapodus porosus	northwest threadfin bream	(Valenciennes, 1830)	1132	50.9	3	1348	50	2	X	X	X	X
	Pentapodus vitta	western butterfish	Quoy & Gaimard, 1824	579	24.5	16	615	4.59	84		X	X	X
	Scaevius milii	coral monocle bream	(Bory de Saint-Vincent, 1823)	3	1.3	153	37	2.29	126		X		X
	Scaevius vitta						14	3.21	104		X		
	Scolopsis affinis	bridled monocle bream	Peters, 1877				1	0.46	248		X		
	Scolopsis bilineata	two-line monocle bream	(Bloch, 1793)	55	8.2	57	32	6.88	60	X			
	Scolopsis monogramma	rainbow monocle bream	(Kuhl & van Hasselt, 1830)	52	23.9	20	65	19.72	22	X	X		X
	Scolopsis trilineata	threeline monocle bream	Kner, 1868				51	0.92	190			X	
Oneirodidae	*Oneirodes sp1*						1	0.46	235			X	
Orectolobidae	*Eucrossorhinus dasypogon*	tasselled wobbegong*	(Bleeker, 1867)	1	0.6	228				X			
	Orectolobus ornatus	banded wobbegong*	(De Vis, 1883)	2	1.3	167				X			
Ostraciidae	*Lactoria cornuta*	longhorn cowfish	(Linnaeus, 1758)	1	0.6	229					X		
	Ostracion cubicus	yellow boxfish	Linnaeus, 1758	5	3.1	114	5	2.29	123	X			
Pinguipedidae	*Parapercis nebulosa*	pinkbanded grubfish	(Quoy & Gaimard, 1825)	46	18.2	34	81	25.69	13	X		X	X
Platycephalidae	*Platycephalidae sp*	*		5	3.1	115	2	0.46	239	X		X	X
Plotosidae	*Paraplotosus butleri*	sailfin catfish	Allen, 1998	3	1.3	154	2	0.92	182	X			
Pomacanthidae	*Chaetodontoplus duboulayi*	scribbled angelfish	(Günther, 1867)	69	32.7	9	65	19.2	24	X	X	X	X
	Chaetodontoplus personifer	yellowtail angelfish	(McCulloch, 1914)	8	3.1	108	7	1.83	131	X		X	X
	Pomacanthus semicirculatus	blue angelfish	(Cuvier, 1831)	5	3.1	116	10	4.13	92	X			
	Pomacanthus sexstriatus	sixband angelfish	(Cuvier, 1831)	53	23.3	24	54	18.81	25	X	X		X

Pomacentridae	*Abudefduf bengalensis*	bengal sergeant	(Bloch, 1787)	109	23.3	22	94	14.22	34	X	X		X
	Abudefduf sexfasciatus	scissortail sergeant	(Lacépède, 1801)	49	1.9	130	58	4.13	87	X			
	Acanthochromis polyacanthus	spiny puller	(Bleeker, 1855)	3	1.3	155	3	1.38	142	X			
	Amblyglyphidodon batunai	batuna damsel	Allen, 1995	1	0.6	230				X			
	Amblyglyphidodon curacao	staghorn damsel	(Bloch, 1787)	1	0.6	231				X			
	Amphiprion clarkii	Clark's anemonefish	(Bennett, 1830)	1	0.6	232	1	0.46	195				X
	Chromis atripectoralis	blackaxil puller	Welander & Schultz, 1951				35	0.92	170	X			
	Chromis cinerascens	green puller	(Cuvier, 1830)				10	1.83	132	X			
	Chromis fumea	smoky puller	(Tanaka, 1917)	31	4.4	83	41	2.75	106	X			X
	Chromis viridis	blue-green puller	(Cuvier, 1830)	59	2.5	117	13	0.92	171	X	X		
	Chrysiptera glauca	grey demoiselle	(Cuvier, 1830)	1	0.6	233				X			
	Chrysiptera hemicyanea	azure demoiselle	(Weber, 1913)	1	0.6	234				X			
	Dascyllus reticulatus	headband humbug	(Richardson, 1846)	10	0.6	173	10	1.38	145	X			
	Dischistodus prosopotaenia	honeyhead damsel	(Bleeker, 1852)				1	0.46	217	X			
	Neoglyphidodon melas	black damsel	(Cuvier, 1830)	4	2.5	128	3	0.92	180	X			
	Neoglyphidodon nigroris	scarface damsel	(Cuvier, 1830)				11	2.75	112	X			
	Neopomacentrus azysron	yellowtail demoiselle	(Bleeker, 1877)				56	1.83	138	X			
	Neopomacentrus cyanomos	regal demoiselle	(Bleeker, 1856)	1	0.6	235					X		
	Neopomacentrus filamentosus	brown demoiselle	(Macleay, 1883)	351	18.2	32	516	11.47	42	X	X		X
	Pomacentrus amboinensis	ambon damsel	Bleeker, 1868	2	0.6	184	5	0.46	240	X			
	Pomacentrus bankanensis	speckled damsel	Bleeker, 1853				12	2.29	124	X	X		
	Pomacentrus coelestis	neon damsel	Jordan & Starks, 1901	47	1.3	145	13	0.92	187		X		
	Pomacentrus limosus	muddy damsel	Allen, 1992	95	16.4	39	32	4.13	93	X	X		X
	Pomacentrus milleri	Miller's damsel	Taylor, 1964	8	4.4	90	32	5.96	67	X	X		

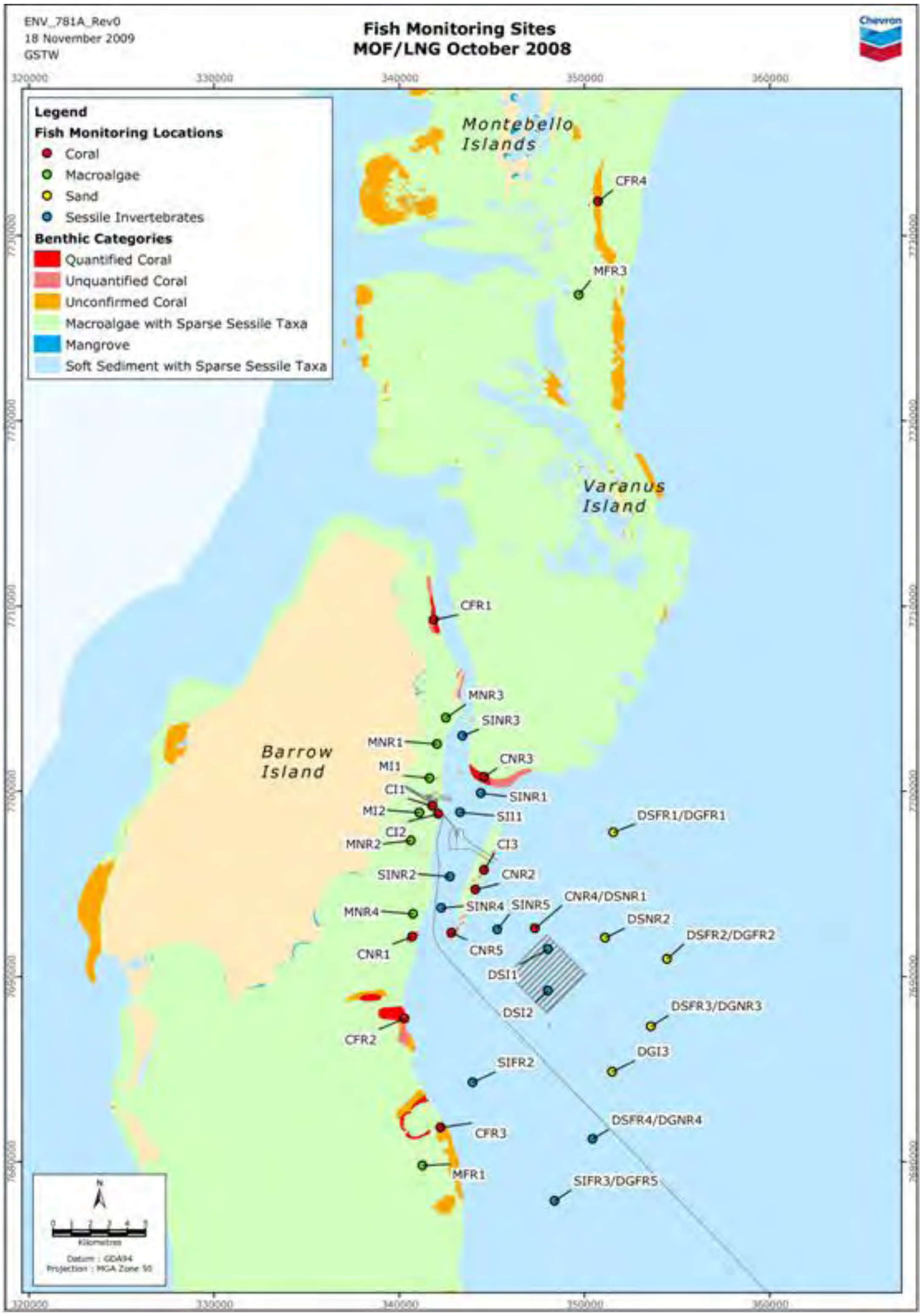
	Pomacentrus moluccensis	lemon damsel	Bleeker, 1853	11	1.9	131	33	4.59	85	X			
	Pomacentrus nigromanus	goldback damsel	Weber, 1913	77	10.1	53	86	5.5	73	X			
	Pomacentrus philippinus	Philippine damsel	Evermann & Seale, 1907	4	0.6	178	9	2.29	125	X			
	Pomacentrus sp1						38	7.8	57	X	X		
	Pomacentrus sp2						31	5.5	74	X	X	X	
	Pristotis obtusirostris	gulf damsel	(Günther, 1862)	22	2.5	118	96	4.13	94			X	X
	Stegastes fasciolatus	pacific gregory	(Ogilby, 1889)	4	1.9	138				X			
	Stegastes nigricans	dusky gregory	(Lacépède, 1801)	1	0.6	236				X			
	Stegastes obreptus	western gregory	(Whitley, 1948)	5	2.5	124	8	2.29	130	X			
	Stegastes sp1						7	1.38	159	X			
Priacanthidae	*Priacanthus hamrur*	lunartail bigeye	(Forsskål, 1775)	1	0.6	237	2	0.92	188				X
Pseudochromidae	*Labracinus lineatus*	lined dottyback	(Castelnau, 1875)	7	4.4	93	17	6.42	62	X	X		
	Pseudochromis fuscus	dusky dottyback	Müller & Troschel, 1849	13	6.9	63	9	4.13	95	X	X		
	Pseudochromis quinquedentatus	spotted dottyback	McCulloch, 1926				1	0.46	244	X			
	Pseudochromis wilsoni	yellowfin dottyback	(Whitley, 1929)	1	0.6	238				X			
Rachycentridae	*Rachycentron canadum*	cobia*	(Linnaeus, 1766)	7	1.9	132	48	2.75	113	X		X	X
Rhinidae	*Rhina ancylostoma*	shark ray	Bloch & Schneider, 1801	1	0.6	239							X
Rhinobatidae	*Rhinobatos typus*	giant shovelnose ray	Bennett, 1830				3	1.38	155			X	
	Rhynchobatus sp	giant guitarfish	(Forsskål, 1775)	10	6.3	72	11	5.05	78			X	X
Scaridae	*Cetoscarus bicolor*	bicolour parrotfish	(Rüppell, 1829)	1	0.6	240				X			
	Chlorurus bleekeri	bleeker's parrotfish	(de Beaufort, 1940)	1	0.6	241				X			
	Chlorurus microrhinos	steephead parrotfish	(Bleeker, 1854)	4	2.5	129	14	4.59	81	X			
	Chlorurus sordidus	greenfin parrotfish	(Forsskål, 1775)	7	3.1	109	75	5.5	70	X			
	Hipposcarus longiceps	longnose parrotfish	(Valenciennes, 1840)	13	5.7	74				X	X		X
	Scarus chameleon	chameleon parrotfish	Choat & Randall, 1986	6	2.5	122	22	1.38	156	X	X		
	Scarus flavipectoralis	yellowfin parrotfish	Schultz, 1958	5	1.3	148				X			
	Scarus frenatus	sixband parrotfish	Lacépède, 1802	2	1.3	168				X			
	Scarus ghobban	bluebarred parrotfish*	Forsskål, 1775	13	7.5	60	70	13.3	35	X	X		X
	Scarus prasiognathos	greencheek parrotfish	Valenciennes, 1840	1	0.6	242				X			

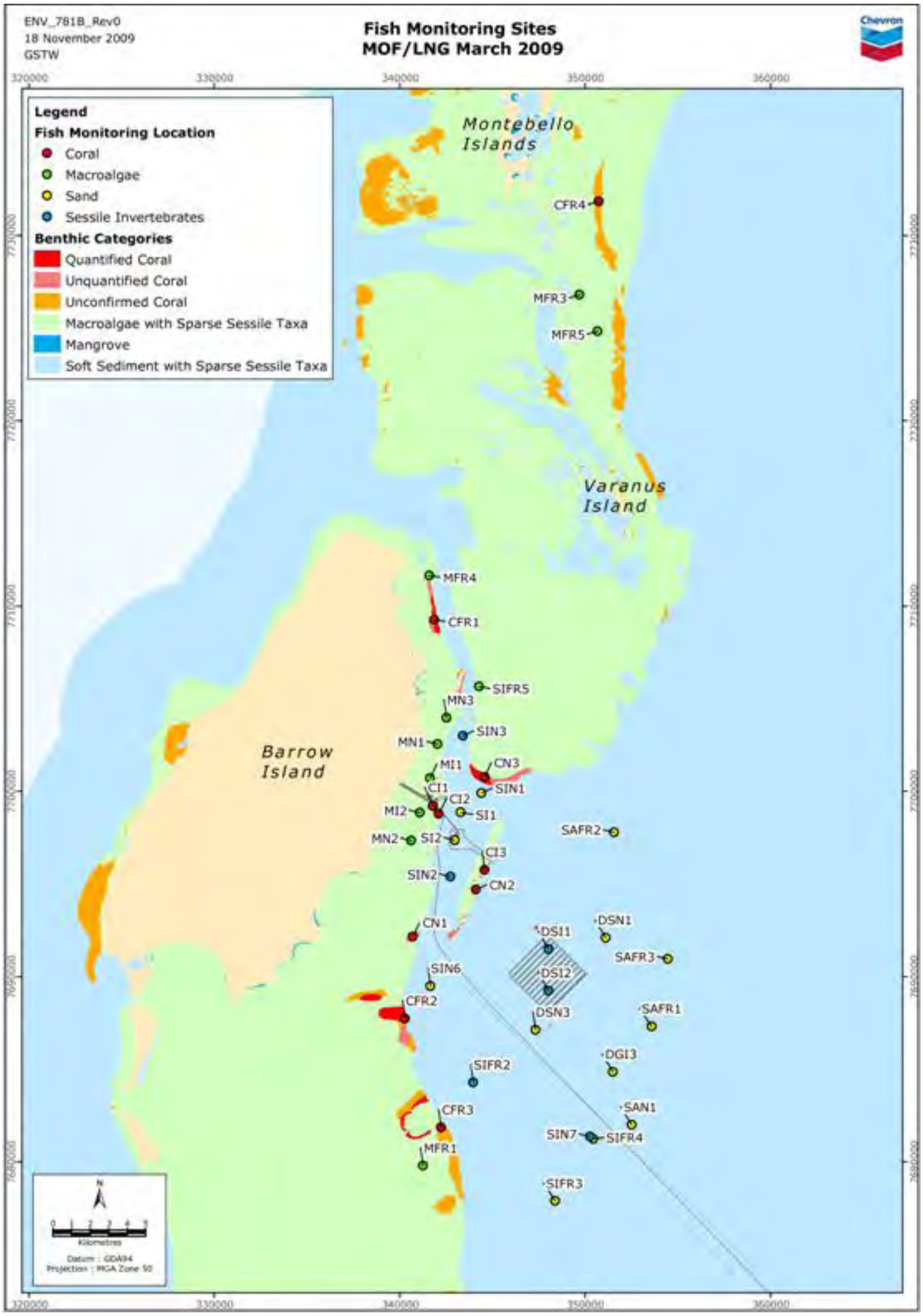
	Scarus psittacus	palenose parrotfish	Forsskål, 1775	13	5.7	75	1	0.46	247	X	X		
	Scarus rivulatus	surf parrotfish*	Valenciennes, 1840	20	7.5	59	54	12.39	37	X	X		
	Scarus rubroviolaceus	blackvein parrotfish	Bleeker, 1847	8	4.4	91				X			
	Scarus schlegeli	Schlegel's parrotfish	(Bleeker, 1861)	72	24.5	18	108	22.9	18	X	X		X
	Scarus sp1						19	1.38	157	X			
Scombridae	*Cybiosarda elegans*	leaping bonito*	(Whitley, 1935)				40	1.83	133			X	
	Grammatorcynus bicarinatus	shark mackerel*	(Quoy & Gaimard, 1825)				2	0.46	225			X	
	Scombridae sp	*		141	52.2	2	295	59.17	1	X	X	X	X
Serranidae	*Cephalopholis argus*	peacock rockcod*	Bloch & Schneider, 1801	1	0.6	243	1	0.46	209	X			
	Cephalopholis boenak	brownbarred rockcod*	(Bloch, 1790)	10	4.4	86	8	2.29	118	X			
	Cephalopholis miniata	coral rockcod*	(Forsskål, 1775)	14	6.3	69	13	4.13	88	X			X
	Cromileptes altivelis	barramundi cod*	(Valenciennes, 1828)	9	5	79	13	5	82	X			
	Epinephelus areolatus	yellowspotted rockcod*	(Forsskål, 1775)	1	0.6	244	1	0.46	220	X			
	Epinephelus bilobatus	frostback cod*	Randall & Allen, 1987	47	19.5	30	40	10.55	46	X	X		X
	Epinephelus coioides	goldspotted rockcod*	(Hamilton, 1822)	19	9.4	56	9	4.13	90	X	X		X
	Epinephelus fasciatus	blacktip rockcod*	(Forsskål, 1775)	23	11.3	51	22	8.72	53	X	X		X
	Epinephelus malabaricus	blackspotted rockcod*	(Bloch & Schneider, 1801)	3	1.9	144	1	0.46	221	X			
	Epinephelus merra	birdwire rockcod*	Bloch, 1793				1	0.46	222	X			
	Epinephelus multinotatus	rankin cod*	(Peters, 1877)	15	5.7	73	6	2.75	107	X	X		X
	Epinephelus polyphekadion	camouflage grouper*	(Bleeker, 1849)	9	5	80	25	9.63	48	X			
	Epinephelus quoyanus	longfin rockcod*	(Valenciennes, 1830)	4	1.3	150	1	0.46	223	X			
	Epinephelus rivulatus	chinaman rockcod*	(Valenciennes, 1830)	26	9.4	55	42	11.93	39	X	X		X
	Epinephelus tukula	potato rockcod	Morgans, 1959				1	0.46	224	X			
	Plectropomus maculatus	Bar-cheek coral trout*	(Bloch, 1790)	128	40.9	7	170	36.24	6	X	X		X
Siganidae	*Siganus argenteus*	forktail rabbitfish	(Quoy & Gaimard, 1825)	1	0.6	245					X		
	Siganus doliatus	bluelined rabbitfish	Cuvier, 1830	154	17	37	105	11.01	45	X			
	Siganus fuscescens	dusky rabbitfish	(Houttuyn, 1782)	221	24.5	17	605	17.89	29	X	X	X	X

	Siganus punctatissimus	finespotted rabbitfish	Fowler & Bean, 1929	6	1.9	133	10	2.29	127	X			
	Siganus punctatus	spotted rabbitfish	(Schneider, 1801)	18	6.3	68	17	5.05	79	X			
	Siganus trispilos	threespot rabbitfish	Woodland & Allen, 1977				2	0.46	249	X			
	Siganus virgatus	doublebar rabbitfish	(Valenciennes, 1835)	22	3.1	105	26	4.59	86	X			
Sillaginidae	*Sillago analis*	goldenline whiting*	Whitley, 1943	38	6.9	61	15	2.29	128			X	X
Sphyraenidae	*Sphyraena barracuda*	great barracuda*	(Walbaum, 1792)				1	0.46	250			X	
	Sphyraena flavicauda	yellowtail barracuda*	Rüppell, 1838				21	0.46	251			X	
	Sphyraena jello	pickhandle barracuda*	Cuvier, 1829	29	9.4	54	10	1.83	141	X	X	X	X
	Sphyraena obtusata	striped barracuda*	Cuvier, 1829	6	1.9	134	40	0.46	252		X	X	X
Sphyrnidae	*Sphyrna lewini*	scalloped hammerhead*	(Griffith & Smith, 1834)	1	0.6	246	1	0.46	253	X			
	Sphyrna mokarran	great hammerhead*	(Rüppell, 1837)	7	4.4	94	5	2.29	129	X	X		X
Stegostomatidae	*Stegostoma fasciatum*	zebra shark	(Hermann, 1783)	2	1.3	169	6	2.75	115			X	X
Syngnathidae	*Syngnathidae sp1*						1	0.46	255		X		
Synodontidae	*Saurida undosquamis*	largescale saury	(Richardson, 1848)				2	0.92	189			X	
	Synodontidae sp1						51	17.89	30			X	X
	Synodus variegatus	variegated lizardfish	(Lacépède, 1803)	3	1.3	156						X	X
	Trachinocephalus myops	painted grinner	(Forster, 1801)	1	0.6	247						X	
Terapontidae	*Terapon theraps*	largescale grunter	(Cuvier, 1829)				9	0.46	257			X	
Tetraodontidae	*Arothron stellatus*	starry puffer	(Bloch & Schneider, 1801)				1	0.46	198		X		
	Canthigaster coronata	crowned toby	(Vaillant & Sauvage, 1875)	1	0.6	248	1	0.46	202				X
	Feroxodon multistriatus	ferocious puffer	(Richardson, 1854)	1	0.6	249	7	3.21	102				X
	Lagocephalus lunaris	rough golden toadfish	(Bloch & Schneider, 1801)	7	4.4	95	4	1.83	136			X	X
	Lagocephalus sceleratus	silver toadfish	(Gmelin, 1789)				40	7.8	55			X	X
	Tetraodontidae sp1						11	1.38	160	X		X	
	Torquigener pallimaculatus	rusty-spotted toadfish	Hardy, 1983	167	6.3	66	161	18.35	28			X	X
Zanclidae	*Zanclus cornutus*	moorish idol	(Linnaeus, 1758)	9	4.4	88	7	3.21	105	X			

9. APPENDIX II

Additional maps separately illustrating the sites surveyed for each of the four habitat categories around Barrow Island in (1) October 2008 and (2) March 2009.




ENV_781B_Rev0
18 November 2009
GSTW
Fish Monitoring Sites
MOF/LNG March 2009
Legend
Fish Monitoring Location
Coral
Macroalgae
Sand
Sessile Invertebrates
Benthic Categories
Quantified Coral
Unquantified Coral
Unconfirmed Coral
Macroalgae with Sparse Sessile Taxa
Mangrove
Soft Sediment with Sparse Sessile Taxa
Montebello Islands
Varanus Island
Barrow Island
CFR4
MFR3
MFR5
MFR4
CFR1
SIFR5
MN3
SIN3
MN1
MI1
CN3
SIN1
CI1
CI2
MI2
SI1
SAFR2
MN2
SI2
CI3
SIN2
CN2
CN1
DSI1
DSN1
SAFR3
DSI2
SIN6
CFR2
DSN3
SAFR1
DGI3
SIFR2
SAN1
CFR3
SIN7
SIFR4
MFR1
SIFR3
Kilometres
320000
330000
340000
350000
360000

Appendix 7 Interactive Excel and ArcGIS Demersal Fish Mapping

Please refer to electronic database.

Appendix 8 Surficial Sediments Particle Size Distribution Results

					Particle Size Distribution (tabulated lab results)						Particle Size Distribution (µm) - Folk Triangle Categories			
					Mud		Sand			Gravel				
					Clay	Silt	Fine sand	Med sand	Coarse sand	Gravel	Mud	Sand	Gravel	
					0.02 - 4.0 um	4.0 - 62 um	62 - 250 um	250 - 500 um	500 - 2000 um	2000 - 10000 um	0.02 - 62.0	62 - 2000	2000 - 10000	Classification
Sample ID	Eastings	Northings	TIC %	TOC %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	
AHC	350243	7731659	9.9	0.3	0.49	0.65	1.64	20.92	71.8	4.5	1.14	94.36	4.50	S
ANT	342065	7708657	10.8	0.28	0.41	0.9	3.89	15.8	62.8	16.2	1.31	82.49	16.20	gS
BAT	340739	7681329	10.9	0.36	4.04	10.33	14.25	9.28	31.8	30.3	14.37	55.33	30.30	msG
BIG	328237	7702674	10.7	0.3	7.71	12.91	12.24	5.14	49.3	12.7	20.62	66.68	12.70	gmS
DUG	340196	7687442	11	0.27	0.22	0.48	0.63	4.87	40.6	53.2	0.70	46.10	53.20	sG
MOF1	342089	7698785	9.8	0.31	0.53	1.45	4.13	14.28	47.2	32.4	1.98	65.61	32.40	sG
MOF2	341709	7697690	10.2	0.37	0.58	0.87	2.07	18.67	53.1	24.7	1.45	73.84	24.70	gS
MOF3	341412	7696411	10.2	0.29	0.2	0.39	0.4	4.21	55.6	39.2	0.59	60.21	39.20	sG
LNG1	344584	7695833	10.9	0.34	2.68	6.55	14.23	17.65	37.5	21.4	9.23	69.38	21.40	gmS
LNG2	344396	7695372	10.7	0.34	2.39	7.35	5.23	5.73	45.00	34.30	9.74	55.96	34.30	msG
LNG3	343157	7692657	10.3	0.31	1.63	3.55	12.5	32.72	39.9	9.7	5.18	85.12	9.70	gS
LONE	347316	7692607	11.1	0.3	1.16	1.94	1.84	0.77	28.1	66.2	3.10	30.71	66.20	sG
LOW	344504	7700689	10.6	0.3	0	0	4.6	32.5	54	8.9	0.00	91.10	8.90	gS
SBS	345599	7666195	10.9	0.25	0.49	1.65	1.48	5.48	66.70	24.20	2.14	73.66	24.20	gS
SS1	334671	7711951	10	0.7	0	0	43.09	44.31	11.7	0.9	0.00	99.10	0.90	S
SS2	332083	7708795	10.2	0.4	0	0	40.81	55.69	3.5	0	0.00	100.00	0.00	S
SS3	329881	7706207	10.1	0.7	0.37	1.06	14.02	24.95	41.2	18.4	1.43	80.17	18.40	gS
SS4	343186	7701270	10.8	0.33	0.59	0.78	11.95	32.09	33.7	20.9	1.37	77.74	20.90	gS
SS5	341784	7701076	11.2	0.3	3.77	6.32	5.99	2.52	67.4	14	10.09	75.91	14.00	gmS
SS6	341481	7700354	11.2	0.3	7.45	12.5	11.86	4.98	60.3	2.9	19.95	77.14	2.90	mS
SS7	346353	7699598	10.2	0.4	2.12	7.44	62.61	18.22	8.1	1.5	9.56	88.93	1.50	S
SS8	343161	7699413	10.5	0.35	0	0.64	17.7	36.66	29.4	15.6	0.64	83.76	15.60	gS
SS9	344446	7699220	10.6	0.32	0.76	0.53	54.79	35.92	6.3	1.7	1.29	97.01	1.70	S
SS10	346059	7698237	10.1	0.4	1.05	3.31	61.81	19.92	10.3	3.6	4.36	92.03	3.60	S
SS11	343069	7697800	9.67	0.4	0.83	1.73	34.93	39.81	21.5	1.2	2.56	96.24	1.20	S
SS12	344220	7697775	10.5	0.6	0	0	18.79	45.01	30.7	5.5	0.00	94.50	5.50	gS
SS13	345740	7697011	0.7	0.7	1.53	4.53	17.61	17.92	43.7	14.7	6.06	79.23	14.70	gS
SS14	340582	7696918	10.2	0.35	1.00	1.70	0.56	8.14	84.90	3.70	2.70	93.60	3.70	S
SS15	343842	7696473	10.2	0.3	0.63	1.76	3	21.8	56.5	16.3	2.39	81.30	16.30	gS
SS16	343069	7696263	10.1	0.4	1.68	3.33	60.02	24.27	8.5	2.2	5.01	92.79	2.20	S
SS17	345463	7695893	9.34	0.8	1.03	3.4	16.67	24.3	39	15.6	4.43	79.97	15.60	gS
SS18	342834	7695331	9.7	0.5	1.42	2.41	62.48	19.18	10.4	4.1	3.83	92.06	4.10	S
SS19	339390	7695255	10.4	0.4	0.34	0.5	1.9	14.16	65.6	17.5	0.84	81.66	17.50	gS
SS20	346479	7694810	10.1	0.6	1.62	4.55	4.22	13.21	61.7	14.7	6.17	79.13	14.70	gS
SS21	347244	7693953	10.2	0.5	0.81	1.58	57.41	31.90	6.20	2.1	2.39	95.51	2.10	S
SS22	337550	7693751	10.3	0.2	0	0.78	8.29	26.64	58.7	5.6	0.78	93.63	5.60	gS
SS23	347891	7693231	10.4	0.4	0	1.42	55	40.09	2.9	0.6	1.42	97.99	0.60	S
SS24	342472	7693189	10.4	0.4	1.21	3.09	36.73	46.07	11	1.9	4.30	93.80	1.90	S
SS25	348647	7692643	10.6	0.5	0.4	1.58	44.06	44.76	7.8	1.4	1.98	96.62	1.40	S

					Particle Size Distribution (tabulated lab results)						Particle Size Distribution (µm) - Folk Triangle Categories			
					Mud		Sand			Gravel				
					Clay	Silt	Fine sand	Med sand	Coarse sand	Gravel	Mud	Sand	Gravel	
					0.02 - 4.0 um	4.0 - 62 um	62 - 250 um	250 - 500 um	500 - 2000 um	2000 - 10000 um	0.02 - 62.0	62 - 2000	2000 - 10000	Classification
Sample ID	Eastings	Northings	TIC %	TOC %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	
SS26	343959	7691828	10.2	0.4	1.76	6.2	14.75	34.09	34.6	8.6	7.96	83.44	8.60	gS
SS27	344841	7691021	9.7	0.7	2.16	8.19	27.59	25.47	29.2	7.4	10.35	82.26	7.40	gmS
SS28	345597	7690290	10	0.6	1.75	6.01	27.74	32.69	23.3	8.5	7.76	83.73	8.50	gS
SS29	346757	7688963	10.2	0.3	0	0.84	4.34	45.22	40.9	8.7	0.84	90.46	8.70	gS
SS30	345404	7688694	10.2	0.4	0.56	1.7	6.06	18.78	59.4	13.5	2.26	84.24	13.50	gS
SS31	346227	7688392	9.9	0.4	0.32	1.73	64.94	28.5	3.7	0.8	2.05	97.14	0.80	S
SS32	343615	7688392	10.3	0.5	0	1.14	13.91	54.74	29.4	0.8	1.14	98.05	0.80	S
SS33	341716	7688123	10.1	0.8	0.83	2.51	29.69	41.68	23.4	1.9	3.34	94.77	1.90	S
SS34	345800	7687820	10.1	0.4	0.85	2.39	54.31	31.35	9.2	1.9	3.24	94.86	1.90	S
SS35	344026	7686040	9.7	0.6	0.47	1.75	68.78	26	2.3	0.7	2.22	97.08	0.70	S
SS36	347693	7684827	9.85	0.5	0.09	1.52	59.04	35.76	3	0.6	1.61	97.80	0.60	S
SS37	341830	7684002	10.2	0.5	0.71	2.41	1.75	11.03	77.6	6.5	3.12	90.38	6.50	gS
SS38	347568	7681027	9.6	0.7	1.83	7.71	31.73	15.63	22.1	21	9.54	69.46	21.00	gmS
SS39	347931	7674624	9.6	0.5	1.43	4.3	51.97	20.3	12.1	9.9	5.73	84.37	9.90	gS
SS40	348022	7666246	9.7	0.5	1.98	6.83	8.2	11.2	38.7	33.1	8.81	58.10	33.10	msG
SS41	334659	7712959	10.2	0.4	0	0	28.65	62.35	8.9	0.1	0.00	99.90	0.10	S
SS42	334669	7713901	10.4	0.2	0	0	19.26	68.04	12.7	0	0.00	100.00	0.00	S
SS43	335490	7713236	10.1	0.5	0	0	16.58	54.92	27.6	0.9	0.00	99.10	0.90	S
SS44	336653	7714436	10.7	0.1	0	0	1.88	61.92	30.9	5.3	0.00	94.70	5.30	gS
SS45	337623	7714529	10.2	0.3	0	0	8.94	40.66	48.8	1.6	0.00	98.40	1.60	S
SS46	338472	7714252	10.4	0.2	0	0	6.75	49.35	43.6	0.3	0.00	99.70	0.30	S
SS47	333632	7710357	10.5	0.3	0	0.15	5.26	24.59	62.9	7.1	0.15	92.75	7.10	gS
SS48	334211	7711156	10.1	0.4	0	0	41.01	53.79	5	0.2	0.00	99.80	0.20	S
SS49	342105	7702593	10.6	0.4	4.46	7.47	7.09	2.98	76.7	1.3	11.93	86.77	1.30	mS
SS50	342285	7704096	9.6	0.5	4.04	6.76	6.41	2.69	70	10.1	10.80	79.10	10.10	gmS
SS51	343216	7702974	10.6	0.4	1.32	2.21	2.09	0.88	37.4	56.1	3.53	40.37	56.10	sG
SS52	340899	7698614	10.6	0.7	0.24	0.53	1.26	12.56	69.7	15.7	0.77	83.52	15.70	gS
SS53	341872	7698244	10.6	0.29	0.33	0.77	0.42	1.18	85.00	12.30	1.10	86.60	12.30	gS
SS54	340031	7696402	10.7	0.39	0.45	1.52	2.66	5.47	73.20	16.70	1.97	81.33	16.70	gS
SS55	341354	7695830	10.5	0.37	0.58	1.76	3.34	6.52	72.20	15.60	2.34	82.06	15.60	gS
SS56	338496	7694402	10.5	0.3	0	0	3.82	34.08	59.6	2.5	0.00	97.50	2.50	S
SS57	340994	7693216	11.1	0.47	0.22	0.72	0.32	0.55	74.10	24.10	0.94	74.97	24.10	gS
SS58	342645	7694222	9.88	0.5	1.16	3.32	41.83	41.79	10.7	1.2	4.48	94.32	1.20	S
SS59	342105	7694973	9.69	0.7	0.95	3.24	3.59	7.52	36	48.7	4.19	47.11	48.70	sG
SS60	341692	7692073	10.3	0.7	0.65	2.57	8.79	15.29	66.4	6.3	3.22	90.48	6.30	gS
SS61	341883	7693671	9.87	0.4	0.42	1.25	0.93	6.3	68.8	22.3	1.67	76.03	22.30	gS
SS62	344793	7688422	10.1	0.6	1.17	3.4	42.76	31.77	15.4	5.5	4.57	89.93	5.50	gS
SS63	350773	7685057	10.1	0.6	0.27	1.71	58.12	36.5	2.6	0.8	1.98	97.22	0.80	S
SS64	349223	7693202	10.4	0.4	0.1	1.67	48.23	45.9	3.2	0.9	1.77	97.33	0.90	S

					Particle Size Distribution (tabulated lab results)						Particle Size Distribution (µm) - Folk Triangle Categories			
					Mud		Sand			Gravel				
					Clay	Silt	Fine sand	Med sand	Coarse sand	Gravel	Mud	Sand	Gravel	
					0.02 - 4.0 um	4.0 - 62 um	62 - 250 um	250 - 500 um	500 - 2000 um	2000 - 10000 um	0.02 - 62.0	62 - 2000	2000 - 10000	Classification
Sample ID	Eastings	Northings	TIC %	TOC %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	
SS65	349740	7693761	10.4	0.3	0	1.28	33.74	53.79	10	1.2	1.28	97.53	1.20	S
SS66	350856	7695104	10.4	0.4	0	2.11	33.21	58.68	5.6	0.4	2.11	97.49	0.40	S
SS67	351931	7696406	10.2	0.3	0.47	1.51	8.11	38.11	46.7	5.1	1.98	92.92	5.10	gS
SS68	343248	7690179	10.1	0.4	0.58	1.73	2.14	16.15	63.1	16.3	2.31	81.39	16.30	gS
SS69	347651	7686803	9.8	0.5	0.84	2.53	60.01	27.62	6.3	2.7	3.37	93.93	2.70	S
NE BWI 1	343959	7716235	10.2	0.4	0.19	0.58	0.85	8.18	86.8	3.4	0.77	95.83	3.40	S
NE BWI 2	343137	7713600	10.8	1.1	0.23	1.02	2.74	6.41	18.3	71.3	1.25	27.45	71.30	sG
NW BWI 1	335123	7712472	10.2	0.5	0.2	1.35	7.15	10.9	17	63.4	1.55	35.05	63.40	sG
FLACOURT	329234	7705071	10.8	0.5	0	0	0.94	12.56	83.9	2.6	0.00	97.40	2.60	S
TP 1	342333	7701483	10.5	0.1	0.3	0.91	6.19	13.49	71	8.1	1.21	90.68	8.10	gS
TP 2	342235	7700923	10.3	0.3	0.6	2.56	17.53	47.91	25.1	6.3	3.16	90.54	6.30	gS
TP 4	342407	7698457	10.4	0.3	0	0.66	19.85	41.99	31.9	5.6	0.66	93.74	5.60	gS
TP 5	342085	7699098	10.6	0.1	0.25	0.62	1.55	4.89	65.7	27	0.87	72.14	27.00	gS
TP 6	342238	7699286	10.7	0.4	1.09	4.08	8.62	6.61	71.1	8.5	5.17	86.33	8.50	gS
TP 7	344321	7696403	10.7	0.3	1.14	4.13	5.34	16.4	59.2	13.8	5.27	80.94	13.80	gS
TP 8	344605	7696575	10.6	0.5	0.36	1.12	1.76	11.86	52.8	32.1	1.48	66.42	32.10	sG
TP 9	341069	7695738	10.8	0.4	0	1.25	3.69	29.76	59.6	5.7	1.25	93.05	5.70	gS
TP 10	337827	7694122	10.4	0.1	0.87	2.7	6.95	24.58	58.2	6.7	3.57	89.73	6.70	gS
HM-3	349709	7687693	10.8	0.1	0.1	2.3	43.45	49.16	3.9	1.1	2.40	96.51	1.10	S
HM-7	348224	7689316	11.2	0.1	0	1.11	14.52	55.17	28.3	0.9	1.11	97.99	0.90	S
HM-13	341766	7707027	5.41	0.1	0.56	0.73	12.2	37	41	8.5	1.29	90.20	8.50	gS
HM-15	341007	7712356	10.7	0.2	0.77	1.78	4.21	19.84	68.4	5	2.55	92.45	5.00	gS
DS1	348019	7691926	10.5	0.13	2	9.08	49.63	15.49	19	4.8	11.08	84.12	4.80	mS
DS2	347616	7689534	10.6	0.11	0.65	1.85	4.19	14.92	60.3	18.1	2.50	79.41	18.10	gS
DSS1	347316	7687119	10.8	0.09	1.11	4.21	35.49	19.89	26.1	13.2	5.32	81.48	13.20	gS
TPC1	342628	7694476	10.3	0.23	2.95	15.35	29.99	3.31	35.5	12.9	18.30	68.80	12.90	gmS
TPC2	342071	7694177	10.7	0.17	1.44	4.42	5.05	16.39	52.2	20.5	5.86	73.64	20.50	gS
TPC3	342102	7694973	10.4	0.15	3.92	17.51	20.94	6.53	35.7	15.4	21.43	63.17	15.40	gmS
LC1	344931	7700026	11.4	0.06	0.8	1.98	23.11	18.21	35.2	20.7	2.78	76.52	20.70	gS
LC2	344620	7700316	10.7	0.05	0.69	0.44	20.98	38.79	33.2	5.9	1.13	92.97	5.90	gS
LC3	344142	7699047	11.1	0.05	0.81	0.41	59	28.59	8.5	2.7	1.22	96.09	2.70	S
LC4	344832	7698996	11.1	0.08	1.66	4.68	19.43	25.43	39.3	9.5	6.34	84.16	9.50	gS
DSR1	347711	7684857	10.5	0.12	1.08	2.59	61.6	30.84	3.3	0.6	3.67	95.74	0.60	S
DSR2	352234	7689338	11.1	<0.05	0.32	1.04	2.41	2.53	70.6	23.1	1.36	75.54	23.10	gS
DSR3	353495	7695109	10.9	0.06	0.79	1.86	9.83	42.43	42.2	2.9	2.65	94.46	2.90	S
DSR5	346075	7694132	10.9	0.07	1	2.83	14.02	25.75	43.5	12.9	3.83	83.27	12.90	gS
DSR6	350775	7693683	11.2	<0.05	0.54	1.22	6.23	15.01	58.3	18.7	1.76	79.54	18.70	gS
TPCI1	342952	7697366	10.7	0.14	2.08	4.97	61.33	18.62	8.4	4.6	7.05	88.35	4.60	S

					Particle Size Distribution (tabulated lab results)						Particle Size Distribution (µm) - Folk Triangle Categories			
					Mud		Sand			Gravel				
					Clay	Silt	Fine sand	Med sand	Coarse sand	Gravel	Mud	Sand	Gravel	
					0.02 - 4.0 um	4.0 - 62 um	62 - 250 um	250 - 500 um	500 - 2000 um	2000 - 10000 um	0.02 - 62.0	62 - 2000	2000 - 10000	Classification
Sample ID	**Eastings**	**Northings**	**TIC %**	**TOC %**	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	Vol in %	
TPC2	342071	7694177	10.7	0.17	1.44	4.42	5.05	16.39	52.2	20.5	5.86	73.64	20.50	gS
TPC3	342102	7694973	10.4	0.15	3.92	17.51	20.94	6.53	35.7	15.4	21.43	63.17	15.40	gmS
LC1	344931	7700026	11.4	0.06	0.8	1.98	23.11	18.21	35.2	20.7	2.78	76.52	20.70	gS
LC2	344620	7700316	10.7	0.05	0.69	0.44	20.98	38.79	33.2	5.9	1.13	92.97	5.90	gS
LC3	344142	7699047	11.1	0.05	0.81	0.41	59	28.59	8.5	2.7	1.22	96.09	2.70	S
LC4	344832	7698996	11.1	0.08	1.66	4.68	19.43	25.43	39.3	9.5	6.34	84.16	9.50	gS
DSR1	347711	7684857	10.5	0.12	1.08	2.59	61.6	30.84	3.3	0.6	3.67	95.74	0.60	S
DSR2	352234	7689338	11.1	<0.05	0.32	1.04	2.41	2.53	70.6	23.1	1.36	75.54	23.10	gS
DSR3	353495	7695109	10.9	0.06	0.79	1.86	9.83	42.43	42.2	2.9	2.65	94.46	2.90	S
DSR5	346075	7694132	10.9	0.07	1	2.83	14.02	25.75	43.5	12.9	3.83	83.27	12.90	gS
DSR6	350775	7693683	11.2	<0.05	0.54	1.22	6.23	15.01	58.3	18.7	1.76	79.54	18.70	gS
TPCI1	342952	7697366	10.7	0.14	2.08	4.97	61.33	18.62	8.4	4.6	7.05	88.35	4.60	S
TPCI2	343537	7697097	11	0.12	2	4.42	66.21	20.57	6.3	0.5	6.42	93.08	0.50	S
LNGR1	344321	7694296	10.7	0.07	1.68	5.88	12.19	13.75	50.1	16.4	7.56	76.04	16.40	gS
LNGR2	345445	7697787	11.3	0.05	0.87	2.22	9.55	18.46	52.8	16.1	3.09	80.81	16.10	gS
LNGI1	344398	7696825	10.9	0.06	0.61	1.29	3.44	10.56	45	39.1	1.90	59.00	39.10	sG
LNGI2	344879	7696122	10.9	0.08	0.97	2.51	2.46	3.05	40.2	50.8	3.48	45.71	50.80	sG
DG1	342795	7690816	10.8	0.12	2.77	9.19	14.49	13.84	50.2	9.5	11.96	78.53	9.50	gmS
HDD	334656	7711447		0.24	0	0	58.43	40.54	1.03	0	0.00	100.00	0.00	S
HDD-S	334318	7710463		0.22	0	0	29.96	19.92	47.2	2.92	0.00	97.08	2.92	S
HDD-N	334745	7712431		0.23	0	0	70.77	26.69	2.49	0.05	0.00	99.95	0.05	S
HDD-S-REF	330087	7705312		0.33	0	0	23.71	42.84	32.97	0.48	0.00	99.52	0.48	S
HDD-N-REF	338255	7719053		0.23	0	0	26.8	45.99	26.41	0.8	0.00	99.20	0.80	S
Jetty	343147	7697811		0.43	3.29	5.91	65.21	13.9	7.78	3.91	9.20	86.89	3.91	S
Jetty-S	342532	7696982		0.38	2.65	4.7	49.63	23.45	18.34	1.23	7.35	91.42	1.23	S
Jetty-N	343677	7698785		0.34	1.97	8.29	50.04	26.77	11.03	1.9	10.26	87.84	1.90	mS
Jetty-S-Ref	342595	7686019		0.5	1.32	2.99	23.57	44.98	23.36	3.78	4.31	91.91	3.78	S
Jetty-N-Ref	354261	7702320		0.22	1	2.35	44.73	21.44	28.37	2.12	3.35	94.54	2.12	S
DS01	341442	7700596	10.9	0.21	1.9						1.9	95.1	3	S
DS02	341384	7700348	10.9	0.25	1.4						1.4	96.3	2.3	S
DS03	341315	7700151	11	0.18	2						2	91.2	6.8	gS
DS04	341296	7700031	11.1	0.29	0.9						0.9	87.5	11.6	gS
DS05	341251	7699840	10.8	0.2	5						5	89.3	5.7	gS
DS06	341150	7699555	10.8	0.37	12.9						12.9	77.1	10	gmS
DS10	341499	7699986	10.9	0.2	1.3						1.3	93.9	4.8	S
DS55	341781	7699928	11.2	0.18	2.8						2.8	89.1	8.1	gS
DS56	342194	7699790	11.2	0.11	2.6						2.6	87.9	9.5	gS
DS14	342737	7697643	10.4	0.22	6.9						6.9	91.3	1.8	S
DS27	343194	7696811	10.6	0.2	11.8						11.8	87.9	0.3	mS

					Particle Size Distribution (tabulated lab results)						Particle Size Distribution (µm) - Folk Triangle Categories			
					Mud		Sand			Gravel				
					Clay	Silt	Fine sand	Med sand	Coarse sand	Gravel	Mud	Sand	Gravel	
					0.02 - 4.0 um	4.0 - 62 um	62 - 250 um	250 - 500 um	500 - 2000 um	2000 - 10000 um	0.02 - 62.0	62 - 2000	2000 - 10000	Classification
Sample ID	**Eastings**	**Northings**	**TIC %**	**TOC %**	**Vol in %**	**Vol in %**	**Vol in %**	**Vol in %**	**Vol in %**	**Vol in %**	**Vol in %**	**Vol in %**	**Vol in %**	
DS28	343442	7697103	10.8	0.18	9.3						9.3	90.4	0.3	S
DS29	343797	7697402	10.9	0.19	14.8						14.8	84	1.2	mS
DS30	344338	7697512	11.2	0.13	4.9						4.9	88.2	6.9	gS
DS31	345092	7697539	11.1	0.13	5.4						5.4	88.4	6.2	gS
DS32	346005	7697446	10.2	0.26	20.3						20.3	77	2.7	mS
DS33	347037	7697195	10.3	0.21	11.2						11.2	88.1	0.7	mS
DS34	348240	7696837	10.5	0.15	6						6	93.7	0.3	S
DS35	349352	7696520	10.9	0.13	4.7						4.7	94.6	0.7	S
DS36	350251	7696242	11.1	0.09	8.2						8.2	90.9	0.9	S
DS37	346454	7695448	10.9	0.19	9.4						9.4	79.7	10.9	gmS
DS38	347010	7696017	10.6	0.14	14.7						14.7	83.1	2.2	mS
DS39	347010	7695012	10.8	0.17	8.5						8.5	68.6	22.9	gmS
DS40	348161	7695991	10.5	0.21	5.8						5.8	93.3	0.9	S
DS41	349100	7697592	11.2	0.08	2.5						2.5	97.4	0.1	S
DS43	349722	7697512	11.2	0.07	1.9						1.9	98	0.1	S
DS45	348198	7692119	10.6	0.13	11.1						11.1	87.7	1.2	mS
DS46	349828	7691949	11.1	0.09	2.3						2.3	97	0.7	S
DS47	348643	7689219	10.3	0.18	24.4						24.4	75.4	0.2	mS
DS48	349383	7685515	9.9	0.27	8						8	88.9	3.1	S
DS49	347627	7685599	11	0.1	4.5						4.5	94.6	0.9	S
DS50	355056	7692838	11.3	0.09	2.1						2.1	97.3	0.6	S
DS51	355014	7691018	11.4	0.09	2.6						2.6	95.6	1.8	S
DS52	357236	7691970	11.2	0.07	2.5						2.5	93.3	4.2	S
DS53	359438	7693050	11.1	0.11	3.1						3.1	94.4	2.5	S
DS54	359501	7690933	11.2	0.1	1.7						1.7	84.2	14.1	gS

Appendix 9 Pilot Study – Assessment of Light Attenuation in the Water Column around Barrow Island

(RPS, Perth, Western Australia)

1. Introduction

Measuring light attenuation in the sea ideally involves measuring light across the entire vertical profile of the water column to determine how quickly light decreases as a continuous function of depth. As an approximation of this, simultaneous measurement of light from just two in-water sensors at fixed positions is often used instead of many measurements across the entire water column. Light sensors are positioned at least 2 m apart (vertical distance) and the light attenuation coefficient (LAC) calculated as a function of the difference in light recorded over the known (constant) vertical separation distance (EPA 2005). A schematic representation of how paired-sensor monitoring methods might be applied to the sites around Barrow Island is presented in Figure 1.1.

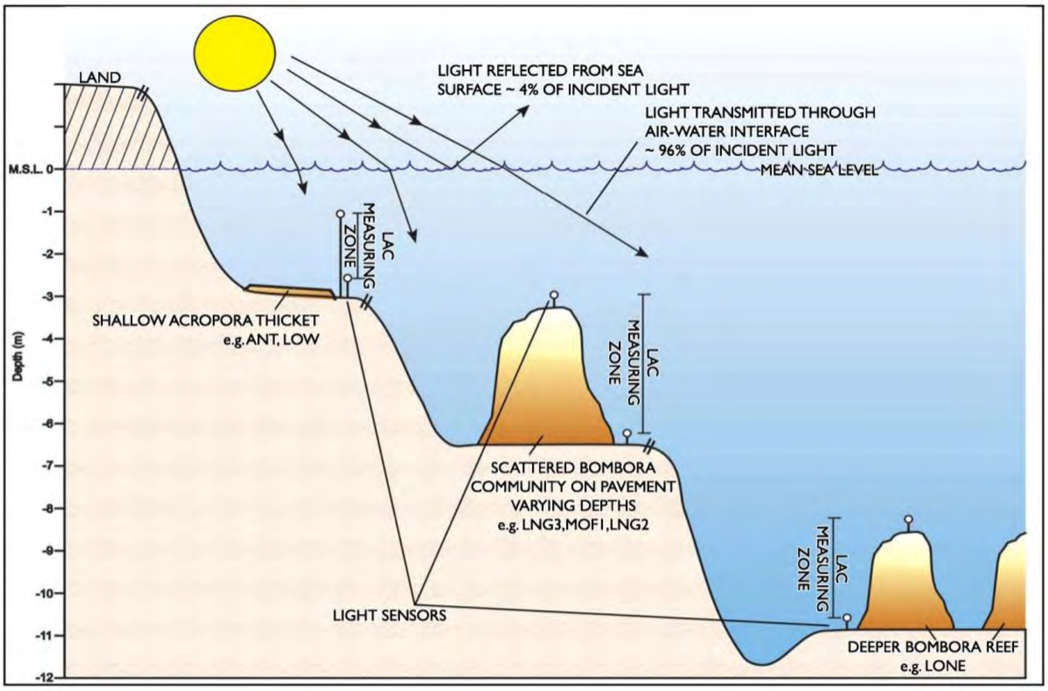


Figure 1.1: Diagrammatic representation of the measurement of light and light attenuation using paired-sensor methods at sites around Barrow Island

Note: Schematic representation only. Depths are indicative as are the relative heights of coral bombora and pickets holding the light sensors

Whilst widely used and an accepted practice in environmental monitoring, there are actually a number of issues associated with using paired-sensor methods to calculate LAC, particularly in shallow water sites like many of those chosen for water quality monitoring at Barrow Island. These are detailed below, but among the key issues is that a minimum separation distance between the sensors is required (usually 2 m) and both sensors need to remain submerged at all times; which restricts application to sites which are deeper than 2 m at extreme low tides. In reality, the practical range of this technique is actually depths much greater than 2 m, because near-surface equipment can present a navigation hazard to vessels. Furthermore, the potential variation in the light field and light attenuation is greatest near the water surface, so if the upper sensor is very near the surface this can interfere with the accuracy of light readings and hence the light attenuation calculations (see below).

To overcome these constraints, RPS proposed to measure light and light attenuation at water quality monitoring sites around Barrow Island using a combination of a terrestrial light sensor on the island and (near bottom) underwater light sensors at each site (Section 4.8.3.1 of RPS 2009). The terrestrial light sensor was used to approximate the light falling on the sea-surface at each site and a correction factor was applied to account for the reflection of light at the air-water interface. To demonstrate that this method would provide reliable LAC estimates, a pilot study was conducted to compare light attenuation data obtained using the more commonly applied paired-sensor method with the above-water and in-water sensor method proposed by RPS (2009).

This report presents: a) a summary of the potential issues associated with using paired- sensor methods at Barrow Island; b) the methodology of measuring light attenuation at monitoring sites around Barrow Island using above-water and in-water sensors; and c) the results of the pilot study comparing simultaneous measurements from the paired-sensor method with those from the above-water and in-water sensor method.

2. Paired-sensor LAC Monitoring Techniques – Constraints and Potential Inaccuracies at Barrow Island

As above, standard techniques for measuring light attenuation often involve measuring down-welling irradiance at two fixed points in the water column. LAC is then calculated as a function of the difference in light between the points which are a known distance apart (EPA 2005). As the measuring points are fixed, the vertical separation distance only needs to be measured once and the LAC between these points is generally assumed to be not affected by variation in water height above the sensors (e.g. due to tides). However, the effect of fluctuating water levels (i.e. from tide and to a lesser extent atmospheric conditions) can nonetheless actually introduce substantial variability into the measurement of light and light attenuation, especially at shallow locations. In particular, variability due to near-surface effects from surface waves and the variable attenuation of light with depth can both affect measurements, especially where the upper sensor is near the surface. In addition, depth constraints at shallow sites may also affect the accuracy of measurements. These factors are described in detail below.

2.1 Near-surface Effects and Depth Constraints

The use of near-surface light sensors to measure downwelling irradiance has been extensively used for calibration of satellite ocean colour sensors (Mueller 2003). However, experience has demonstrated that, due to downwelling irradiance fluctuations associated with the focussing and defocusing of light by surface waves (lens effects), these measurements are far noisier than irradiance measurements taken from above the surface (Zaneveld *et al.* 2001). Reliable readings are difficult to make shallower than 2 m and data associated with this zone generally requires some form of smoothing or averaging prior to use (Mueller 2003). The magnitude of this effect also depends on the measurement period of the light sensor e.g. a longer measurement period has the effect of smoothing the data. Shadow effects are also difficult to avoid when using near-surface sensors deployed from buoys or other solid structures. Thus, the upper sensor in a two sensor system should not be placed too near the water surface.

It is generally accepted that measurements of light attenuation using paired-sensor methods should incorporate a minimum vertical separation of 2 m between the sensors (EPA 2005), although some suggest that a separation of at least 4 m is needed (Smith and Baker 1984, 1986, in Mueller 2003). The minimum water depth (to the seabed at spring low tide) at the marine monitoring sites around Barrow Island (not including site BIG) range from less than 1 m (LOW) to approximately 8 m (LONE), with the majority of sites having a minimum depth of less than 5 m. Thus, due to the shallow nature of many of the monitoring sites, it would be difficult to achieve sufficient separation distance (2 m) between subsurface light sensors to allow accurate measurement of light attenuation. Even where this was possible, at some sites the near-surface sensor would be periodically (if not always) in the zone where strong light fluctuations are experienced from surface waves (as above). At some sites both the separation between the two sensors would have to be less than 2 m and the upper sensor would still be close enough to the surface to be influenced periodically by near-surface effects. Further, the use of near-surface sensors is logistically difficult in sensitive environments as solid or floating structures are required where the relief of the seabed and natural structures do not provide sufficient vertical separation distance between monitoring points.

2.2 Variable Attenuation of Light with Depth

Different wavelength bands of light behave and interact differently in pure seawater. For example, infra-red light is strongly absorbed by water molecules in the surface 1 m of water such that all of the energy entering the sea from infra-red is absorbed in the very thin surface layer (Wozniak 2007). The inherent optical properties of seawater are also dependent on the relative composition of dissolved and suspended constituents, plus factors like gas bubbles and turbulence. Typically, bluish-green light penetrates furthest in optically clear oceanic waters as red light is absorbed strongly in the first few metres of the water column, but greenish-yellow light is the most penetrating in seawater containing large amounts of organic substances (Wozniak 2007; Kirk 1994).

The complex and variable interaction of water and its constituents with light results in inconsistencies in the attenuation of light through the water column, with the greatest variability occurring within the first few metres (Dierssen and Smith 1996; Kirk 1994). Due to the differing depths of the monitoring sites, the relative influence of the higher light attenuation in surface waters on the overall light attenuation value will be different at each monitoring site. These effects will also vary through time as a result of the moderately-large tidal variations experienced at Barrow Island (>3 m) and the shallow depths of many of the monitoring sites, meaning that ‘fixed’ sensor points are essentially changing their relative location within the water column due to tide. Because of this, the inherent variability within the light attenuation measurement zone will change with the tide height and throughout the tidal cycle, with the extent of change dependent on water depth (Figure 2.1). Other than their periodicity, such changes will be indistinguishable from other potential changes to light or light attenuation that might have occurred above the uppermost sensor, such as surface slicks/plumes, shallow clines and atmospheric effects (e.g. cloud).

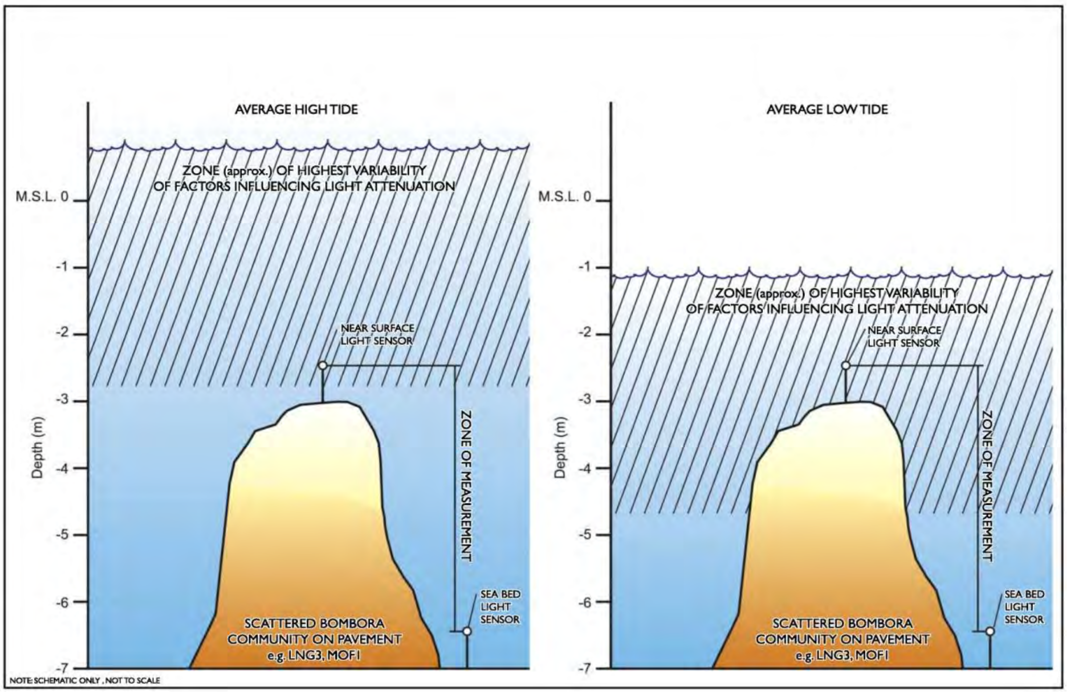


Figure 2.1: Diagrammatic representation of how the relative zone of measurement can fluctuate throughout the tidal cycle using traditional light attenuation monitoring techniques

Note: Schematic representation only. Depths are indicative as are the relative heights of coral bombora and pickets holding the light sensors

3. Proposed Methodology

RPS (2009) proposed measuring light and light attenuation at marine monitoring sites around Barrow Island using a combination of an above-water light sensor (the terrestrial light logger) located on the island and in-water light sensors at each site. The terrestrial light logger is used to approximate the amount of light falling on the sea-surface at each monitoring site and a correction factor applied to account for the proportion of light that would be reflected at the air-water interface. This corrected value is therefore an approximation of the irradiance at the upper boundary of the water column i.e. immediately below the air-water interface. Light at the seabed is measured using an underwater light sensor (see Cooper *et al.* 2008). The water depth at the seabed sensor is measured continuously and therefore the effective vertical separation distance between the two measurement points is known. The LAC can then be calculated according to standard methods.

One potential concern about these methods is that the terrestrial light logger cannot measure the light directly above the monitoring sites coincidently with the subsurface loggers; thus a cloud positioned over a monitoring site might not be accounted for in the light measurement at the terrestrial site, which may be cloudless at the same time. While this is true for individual measurements, the calculations of LAC will use the average of multiple light measurements taken between 10:00 and 14:00 WST each day. Thus any localised effects such as passing clouds over specific sites would be expected to be averaged out and be equal among sites over that four hour period.

A second potential concern might be that the correction factor to account for reflectance at the air-water interface does not replicate reality, so the estimate of the amount of light entering the water column is not well estimated by the terrestrial measurements. When atmospheric light reaches the air-water interface it is either reflected back to the atmosphere or it passes through the interface, undergoing refraction in the process. The amount of light that is transmitted across the interface, however, is primarily determined by the angle of incidence of the sun.

Atmospheric conditions, such as the relative contribution of skylight and sunlight (e.g. cloudiness, haze), and roughening of the sea-surface created by wind play only a minor role (Kirk 1994; Mueller 2003). Similarly, whitecaps from waves have only a small effect on the proportion of light reflected to the atmosphere (Kirk 1994).

The proportion of incident light which is reflected by a flat water surface increases from 2% for vertically incident light towards 100% for grazing light i.e. light that is horizontally incident. Reflectance remains low, however, increasing only slowly up to zenith angles (angle of incidence from the vertical) of 50°, but rises rapidly thereafter (Kirk 1994). For this reason LAC is generally calculated from measurements gathered in the middle of the day, when the zenith angle is low, and not during the hours close to sunrise and sunset (see EPA 2005); this restriction is similarly applied in the proposed above-water and in-water sensor method.

While roughening of the wind surface by waves can increase the transmission of light through the interface at low solar elevations (low angle of incidence), this effect is minimal during the middle of the day when the solar elevation is high (Kirk 1994; Dierssen and Smith 1996). The influence of wind roughening on transmittance also varies depending on atmospheric conditions, particularly the ratio of sunlight to skylight, such that relatively more light is transmitted under overcast conditions. However, under normal daily fluctuations in atmospheric conditions this further influence generally amounts to less than 1% at solar elevations <70° (Baker and Smith 1990). Similarly, white caps on the surface can increase the reflectance of the water by up to 0.25% at a wind speed of 36 km/h (~19.5 kn) and up to 3% at wind speeds of 90 km/h (>50 kn) (Kirk 1994).

Thus, aside from solar angle effects, the cumulative potential effect on the transmission of light through the air-water interface through other factors is minimal and typically amounts to less than a few percent variation. Typical mean reflectance at the sea surface described in the literature ranges from 3% to 6% (Morel and Mueller 2003; Mueller and Morel 2003; Smith and Baker 1986; Baker and Smith 1990), with 4% to 5% used in previous studies to calculate irradiance below the interface (Dierssen and Smith 1996; Cooper *et al.* 2008). For this reason, above-water measurements have been used previously to estimate the irradiance immediately below the air-water interface (e.g. Dierssen and Smith 1996).

Similar to previous studies (Dierssen and Smith 1996), a constant transmittance of 96% will be used here. A schematic of the above-water and in-water sensor method monitoring approach proposed by RPS (2009) is depicted in Figure 3.1.

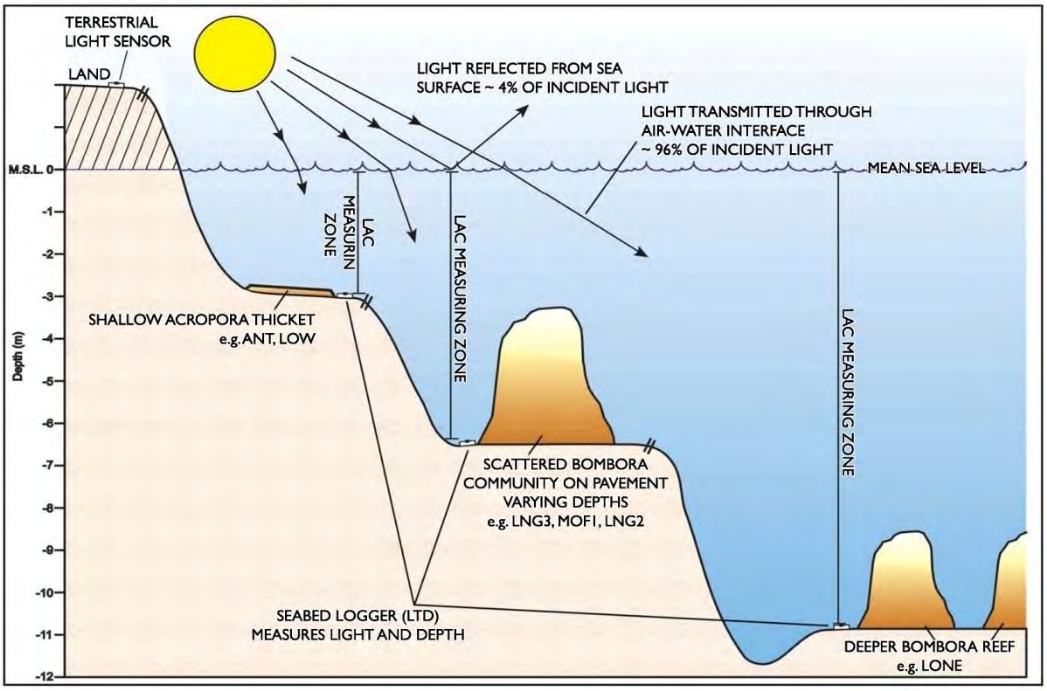


Figure 3.1: Diagrammatic representation of the measurement of light and light attenuation

Note: Schematic representation only. Depths are indicative as are the relative heights of coral bombora.

4. Methods – Pilot Study

4.1 Incident Irradiance at the Sea Surface

Irradiance is generally described as the radiant flux per unit area through that point from all directions in the hemisphere above the surface i.e. all light received at a point from any direction above that point.

A terrestrial light logger, consisting of a Licor LI-192 2π PAR sensor attached to a Licor LI-1400 data logger, was installed at the Chevron Camp on the east coast of Barrow Island to measure the irradiance incident at the sea-surface in the Barrow Island area (Figure 4.1, Plate 4.1). By design, a 2π sensor only records downward irradiance and therefore light reflected upwards from surfaces (such as the ground) below the sensor is not captured.

The sensor measured the incident irradiance in a burst of samples once every minute and averaged the readings over a 15 minute logging interval. The data was used to represent the average incident light falling on the sea-surface at MOF1, approximately 4.5 km away, during that time period. Measurements recorded on a total of 43 days over two periods – 9 September to 7 October 2008, and 6 to 19 December 2008 – were used for the pilot study.

Plate 4.1: Terrestrial light logger

4.2 Measurement of In-water Light

In-water measurements were recorded at two depths at the MOF1 site (light sensors MOF1 and MOF1-S; Figure 4.1). The light sensor at the seabed at MOF1 was approximately 6.4 m below mean sea level, whilst the light sensor at MOF1-S was positioned on top of a large bombora 70 m from the MOF1 light sensor, at a depth of approximately 3.10 m below mean sea level (Plate 4.2).

Light was measured using light sensors incorporated into a light, turbidity, deposition (LTD) and pressure logger manufactured by PortMap (School of Maths, Physics and Information Technology) at James Cook University, Townsville (Mk5 series, JCU). The JCU loggers measure light by a vertically oriented 2π quantum sensor. The measurements recorded by the sensor are averaged over a burst of samples taken over a 1s second period every 10 minutes and the data logged internally. The sensor is automatically wiped at 2-hour intervals to keep it free of biofouling and routine maintenance of the logger unit and download of the data occurred twice during the monitoring periods. The sensors are calibrated against a portable Licor LI-192 underwater light sensor prior to distribution from JCU.

Data recovered from periods coincident with the terrestrial light logger were used for the pilot study.

Plate 4.2: LTD logger deployed on a large bombora at MOF1-S, approximately 70 m from the LTD logger at the seabed at MOF1

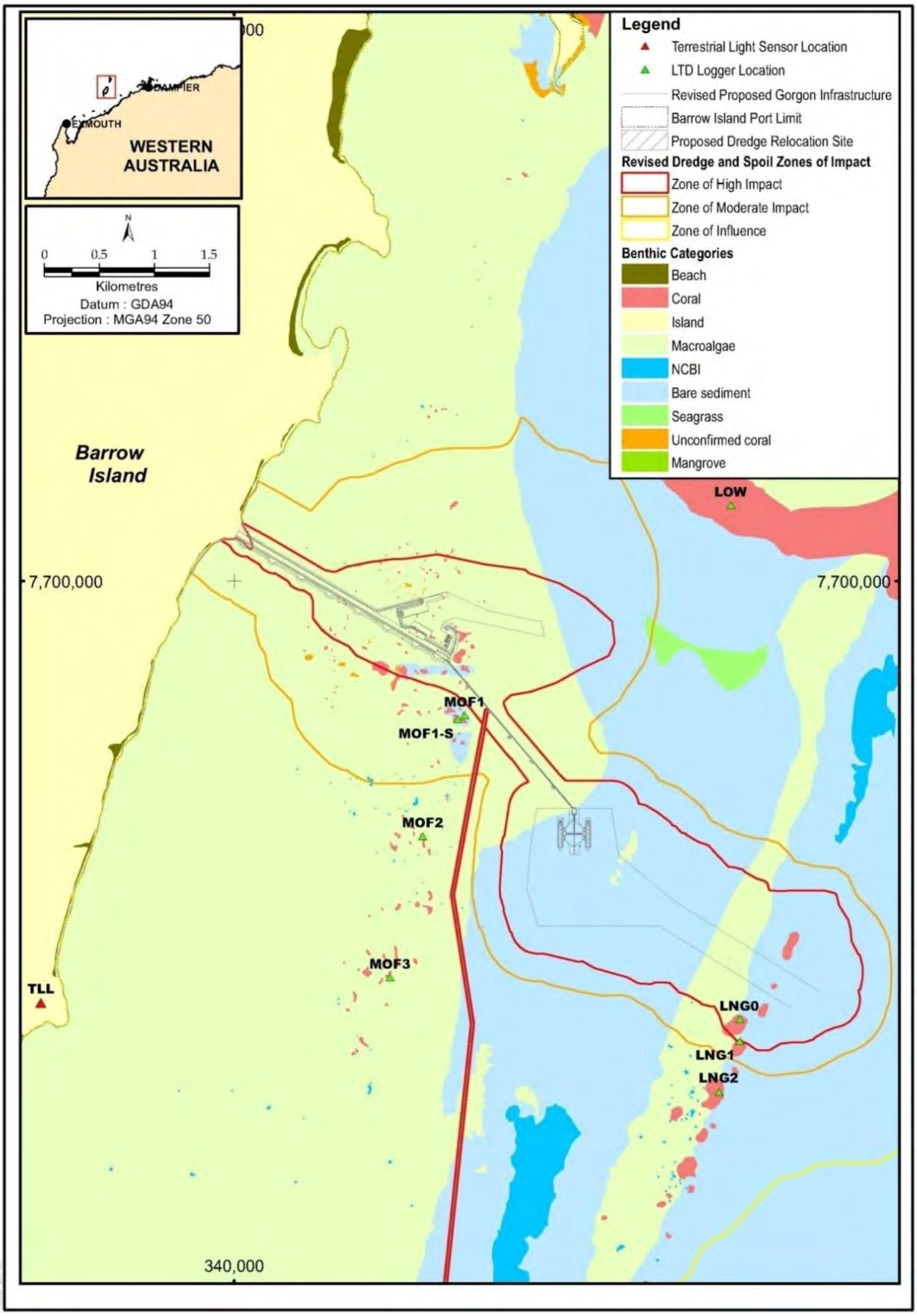


Figure 4.1: Location of above-water (TLL) and in-water (MOF1, MOF1-S) light sensors

4.3 Calculation of Light Attenuation Coefficient

The LAC was calculated separately for data recorded by the JCU loggers at MOF1 and MOF1-S (in-water to in-water), and for the terrestrial light logger and the JCU logger at MOF1 (above-water to in-water). Only data collected in the period 10:00–14:00 WST (the 'midday period') was used in the calculation of LAC.

4.4 Above-water to In-water Logger

The daily mean midday surface irradiance value was obtained by averaging all measurements from the terrestrial PAR sensor for the midday period. This daily mean was then multiplied by a factor of 0.96 to estimate the irradiance immediately below the air-water interface (surface) at MOF1. Similarly, the daily mean irradiance recorded by at the seabed at MOF1 was calculated by averaging all measurements recorded by the JCU logger for the midday period.

To account for the fluctuating water height, and therefore effective vertical separation distance between the two measurement points, a daily average depth for the midday period was calculated from the pressure data obtained by the JCU logger.

The daily LAC for each monitoring site was then calculated according to the following equation:

> LAC = *[(*Log_e *average light at seabed – *Log_e *average light at surface) ÷ average water depth]*

To confirm that the temporal resolution (4hr average) provided sufficient precision, the LAC was also calculated at a 0.5 hr time resolution on a subset of data. The same methods were used to calculate LAC for each half hour period in the midday period and these values were averaged to provide the daily LAC. The daily values of LAC varied at the third decimal place between the two time resolutions, indicating that averaging the light and water depth across the four hour midday period provided sufficient precision for LAC calculations.

Correlations between the daily average datasets were examined using SYSTAT v12. Pearson correlation coefficients were calculated, with p-values based on Bartlett chi-square statistic (1 d.f.). Each test period was considered as a separate experiment for these analyses.

5. Results and Discussion

There were significant, strong positive correlations between the datasets captured by the different methods, with the first test period producing a correlation of $r = 0.90$ ($p < 0.001$) and the second period $r = 0.94$ ($p < 0.001$). The LAC calculated from the above-water and in-water measurements (MOF1 TERR-LTD) were generally higher than the LAC calculated from measurements by the two in-water loggers (MOF1 LTD-LTD) during both periods (Figures 5.1, 5.2). This probably reflects the fact that the above-water to in-water measurement method captures the light attenuation over the entire water column, including the near-surface zone where higher attenuation of light can occur. More importantly, both methods show the same temporal trends (which are presumably responses to changes in water clarity), demonstrating that the variation in light attenuation is adequately captured by the above-water to in-water method and that the results are comparable to traditional methods.

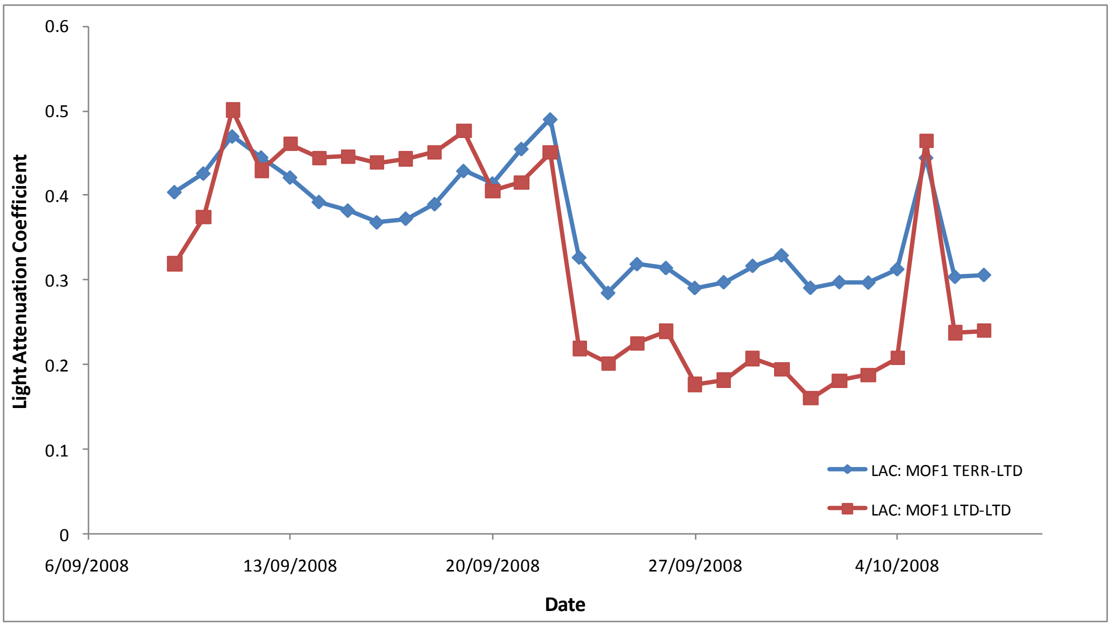
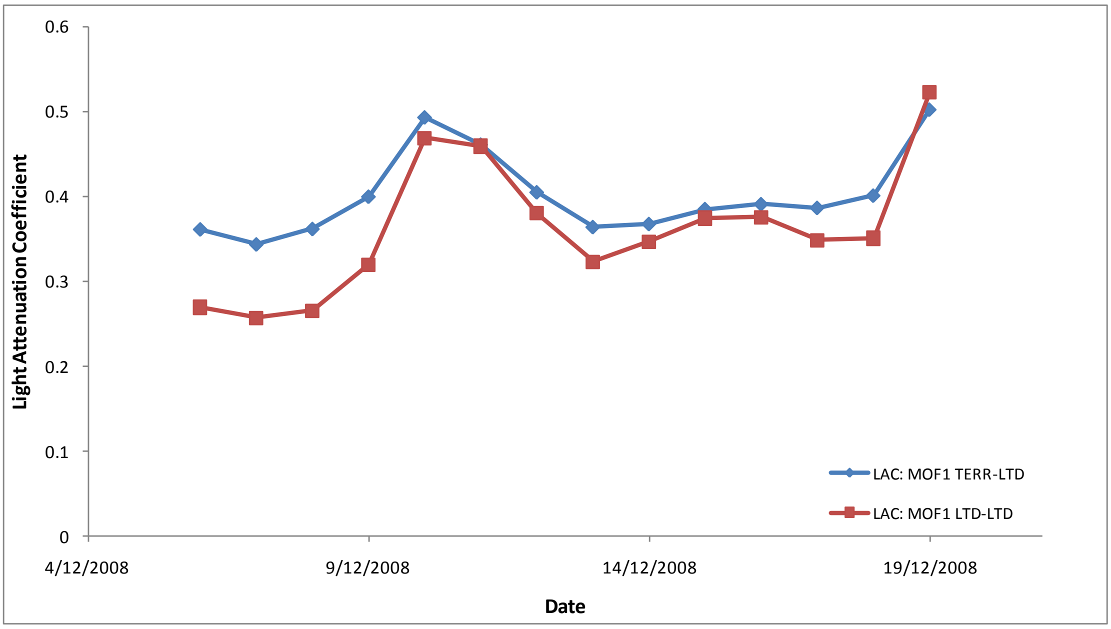


Figure 5.1: Time series plot of daily light attenuation at site MOF1, calculated from two in-water light sensors (red line) and an in-water and above-water light sensor (blue line), 9 September to 7 October 2008



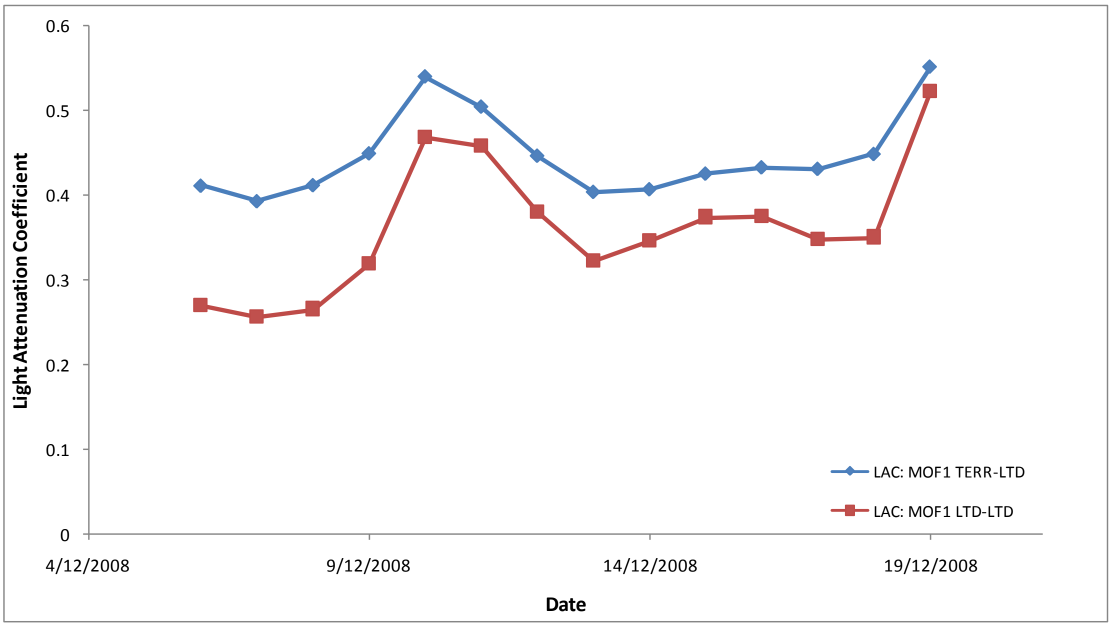


Figure 5.2: Time series plot of daily light attenuation at site MOF1, calculated from two in-water light sensors (red line) and an in-water and above-water light sensor (blue line), 6–19 December 2008

6. Conclusion

In the past, measuring light attenuation continuously has generally involved the use of two in-water sensors, separated by a fixed vertical distance. Whilst this method is relatively easy to employ and involves few assumptions, its application and accuracy can be problematic in shallow water environments with high tidal amplitudes.

Measuring LAC over the entire water column by the in-water and above-water light sensor method increases the accuracy of shallow water measurements by reducing the near-surface effects on light from waves. Light attenuation can also be measured over the maximum possible distance (entire water column), not just a lower (site-dependent) subsection, which means that the (near-surface) zone of high variability is always measured. During dredging, this zone may include plumes of surface confined, higher turbidity water that would influence the penetration of light, but the effects of which may not be measured using fixed paired-sensor methods.

Calculating light attenuation using an above-water sensor and in-water sensor, whilst making different assumptions about the spatial consistency of terrestrial irradiance and the transmittance of light, will also allow the accurate monitoring of light attenuation at all of the monitoring sites around Barrow Island, regardless of tidal stage. The amount of in-water monitoring equipment is reduced, which can increase the data recovery rate. Also, the potential for damage to sensitive near-surface equipment and interference with vessels is removed.

The results of this pilot study produced a significant, strong correlation between data collected using the two different methods, showing that the methods proposed in RPS (2009) are suitable for implementation at the water quality monitoring sites.

7. References

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Appendix 10 Procedures for Calibration of LTD Loggers and Outcomes of Calibrations for the Gorgon Marine Baseline Program

(based on information provided by Dr James Whitney, James Cook University, Queensland)

1. Pre-deployment Calibration

Prior to deployment in the field, each LTD logger was calibrated against a set of plastic target optical standards that were developed in the James Cook University (JCU) laboratory. These standards are specific to the JCU instruments and allow precise comparison of the output of different instruments. In addition, the turbidity sensors were calibrated to determine the zero reading. Seawater can be far cleaner than tap water and therefore a zero reading was taken in seawater as well as in a salt-water swimming pool.

2. Quality Control and Conversion of Data into Engineering Units

Upon return from each field trip the LTD logger data were sent to JCU for conversion, analysis and preliminary interpretation. The instrument output readings were visually verified for accuracy, and erroneous data, including that caused by fouling, were removed. The data were then converted to engineering units via site-specific algorithms to give values of SSC in mg/L, Accumulated Sediment Surface Density (ASSD) in mg/cm^2, and light ($\mu E/m^2/s^1$).

2.1 Converting NTU to SSC

The output of turbidity sensors is highly sensitive to variations in grain-size and therefore conversion of turbidity readings into SSC is suspension- and site-specific. Turbidity readings were converted to estimates of SSC through calibration of the instrument response to water samples with measured concentrations of SSC.

The calibration procedure was repeated for each site and involved placing an instrument in a large container (50 L or greater) with black sides and recording the output on a computer attached to the logger. Seawater was used to fill the container and sediment from the study site was added to the container and stirred with a paddle connected to a slowly rotating electric drill. Water samples were taken and analysed for total suspended solids (dry mass) using standard laboratory techniques. Approximately six different concentrations of sediment are normally needed to give a good calibration with an r^2 correlation of greater than 0.95.

The primary error normally associated with this calibration is that the sediment taken from the bottom sample in the field may not be representative of the sediment in suspension. This may cause a factor of two error in the calibration.

The results of the calibration for each site are tabulated below.

Table 2.1: Calibration Equations to NTU values to SSC

Site Name	Calibration Equation
AHC	SSC = 3.26 x NTU
ANT	SSC = 1.5 x NTU
BAT	SSC = 1.79 x NTU

Site Name	Calibration Equation
BIG	SSC = 1.9 x NTU
DUG	SSC = 2.08 x NTU
LONE	SSC = 2.31 x NTU
LOW	SSC = 1.58 x NTU
LNG0	SCC = 0.928 x NTU
LNG1	SSC = 2.72 x NTU
LNG2	SSC = 1.86 x NTU
LNG3	SSC = 2.3 x NTU
MOF1	SSC = 1.22 x NTU
MOF1-S	SSC = 1.22 x NTU
MOF2	SSC = 0.8 x NTU
MOF3	SSC = 1.94 x NTU
SBS	SSC = 1.62 x NTU

Typically NTU values need to be multiplied by a factor of between 1 and 4 to produce reasonable SSC results. Results collected to date indicate that the relationships at most sites are relatively similar and it is therefore proposed to use an average value for the conversion of NTU to SSC that can be applied across all sites. During dredging and spoil disposal activities, if the instruments are measuring the effect of dredged material on NTU, it is anticipated the relationship between NTU and SSC produced by the dredged material at all sites should be similar, as the bulk of the material in the water column is likely to be dredged material.

2.2 Calculating Accumulated Sediment Surface Density

The deposition sensors were calibrated to the sediment found at each site to give measurements in units of mg/cm^2 using the methodology outlined in Ridd *et al.* (2001) and Thomas *et al.* (2003) and summarised below.

A deposition sensor was placed in a fall tower which consisted of a large acrylic cylinder filled with water. An electronic mass balance was situated at the top of the tower and connected to a weighing pan near the bottom of the cylinder. The scale recordings were recorded on a computer to allow continuous readings to be taken. The OBS sensor was placed in the bottom of the tower such that the sensor's optical aperture was just below a specially cut hole in the pan, wide enough to allow the wiper to activate without touching the pan.

Sediment (from a monitoring site) was introduced to the fall tower by mixing it with water and pouring it gently into the top of the fall tower. Measurements from the OBS sensor and the mass balance were simultaneously recorded. Typically, a calibration run takes a few hours to complete, depending upon the grain size of the sediment. Although each individual instrument has a different calibration curve, the basic form of the curves are similar for all instruments, and the curves are repeatable (SD <5%) with the same sediment type.

Using the calibration curves obtained by the laboratory experiments, the amount accumulated over a given area is expressed in accumulated surface density (in mg/cm^2).

2.3 Converting pressure data to depth and RMS water depth

All pressure sensors were calibrated by JCU against a pressure gauge and the pressure readings were converted into water depth using a calibration curve. Average water depth and Root Mean Square (RMS) water depth were calculated to provide a measure of tidal fluctuation and an indication wave height. During each sampling event (every 10 minutes), the logger measured a burst of samples (5000) over a 100-second period. From these samples average water depth and Root Mean Square (RMS) water depth were calculated. Change in the average water depth over consecutive times was used to measure the tidal fluctuation. The RMS water depth shows the variation in water depth within a time and is therefore an indication of wave height.

RMS water depth, D_{rms} was calculated as follows:

$$D_{rms} = \sqrt{\sum_{n=1}^{10} (D_n - \overline{D})^2 / n}$$

where D_n is the n^{th} of the 10 readings and $\overline{D}$ is the mean water depth of the *n* readings.

3. References

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Appendix 11 Water Quality Sampling Matrix

Note: Entries where ‘no data’ appears indicates that the water quality sampling equipment was not yet deployed and thus no data were available.

SITE	DATA POINT	Dec-07																														
		Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND

- FULL DATA SET
- PARTIAL DATA SET
- NO DATA
- TRAP SAMPLED

SITE	DATA POINT	Jan-08																														
		T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th
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MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND

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NO DATA
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SITE	DATA POINT	Feb-08																												
		F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
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BWI Onshore	Terrestrial Light Logger																													

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SITE	DATA POINT	Mar-08																														
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SITE	DATA POINT	Apr-08																													
		T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
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SITE	DATA POINT	May-08																														
		Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa
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BWI Onshore	Terrestrial Light Logger																															

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SITE	DATA POINT	Jun-08																													
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BWI Onshore	Terrestrial Light Logger																														

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SITE	DATA POINT	Jul-08																														
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LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Aug-08																														
		F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF2	LTD Logger																															
MOF3	LTD Logger																															
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Sep-08																													
		M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AHC	LTD Logger																														
ANT	LTD Logger																														
BAT	LTD Logger																														
BIG	LTD Logger																														
DUG	LTD Logger																														
LNG0	LTD Logger																														
LNG1	LTD Logger																														
LNG2	LTD Logger																														
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MOF3	LTD Logger																														
SBS	LTD Logger																														
DUG	Sediment Trap Array																														
LNG3	Sediment Trap Array																														
LONE	Sediment Trap Array																														
MOF3	Sediment Trap Array																														
SBS	Sediment Trap Array																														
BWI Onshore	Terrestrial Light Logger																														

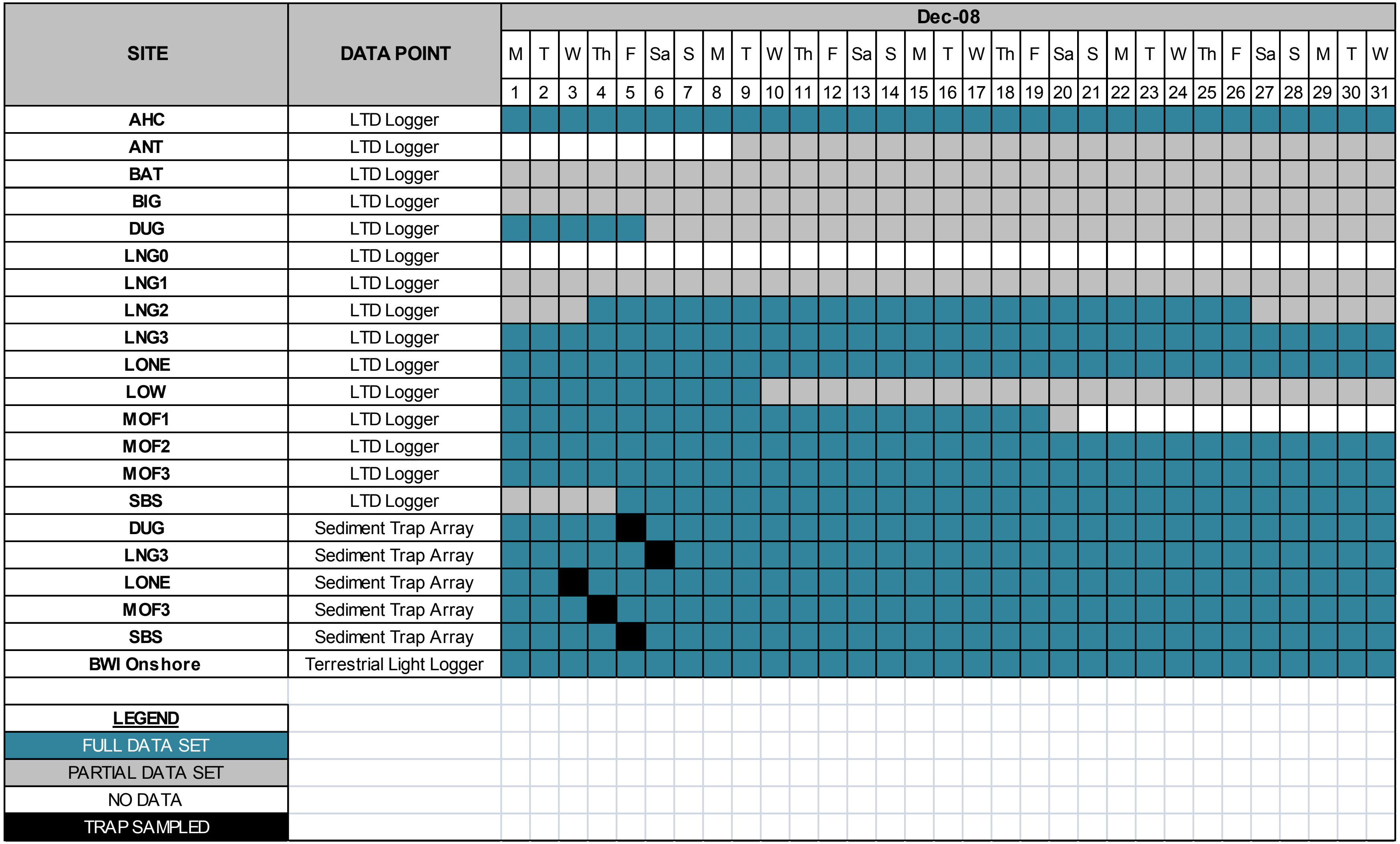
LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Oct-08																														
		W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF2	LTD Logger																															
MOF3	LTD Logger																															
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Nov-08																													
		Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AHC	LTD Logger																														
ANT	LTD Logger																														
BAT	LTD Logger																														
BIG	LTD Logger																														
DUG	LTD Logger																														
LNG0	LTD Logger																														
LNG1	LTD Logger																														
LNG2	LTD Logger																														
LNG3	LTD Logger																														
LONE	LTD Logger																														
LOW	LTD Logger																														
MOF1	LTD Logger																														
MOF2	LTD Logger																														
MOF3	LTD Logger																														
SBS	LTD Logger																														
DUG	Sediment Trap Array																														
LNG3	Sediment Trap Array																														
LONE	Sediment Trap Array																														
MOF3	Sediment Trap Array																														
SBS	Sediment Trap Array																														
BWI Onshore	Terrestrial Light Logger																														

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED


SITE
DATA POINT
Dec-08
M T W Th F Sa S M T W Th F Sa S M T W Th F Sa S M T W Th F Sa S M T W
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
AHC LTD Logger
ANT LTD Logger
BAT LTD Logger
BIG LTD Logger
DUG LTD Logger
LNG0 LTD Logger
LNG1 LTD Logger
LNG2 LTD Logger
LNG3 LTD Logger
LONE LTD Logger
LOW LTD Logger
MOF1 LTD Logger
MOF2 LTD Logger
MOF3 LTD Logger
SBS LTD Logger
DUG Sediment Trap Array
LNG3 Sediment Trap Array
LONE Sediment Trap Array
MOF3 Sediment Trap Array
SBS Sediment Trap Array
BWI Onshore Terrestrial Light Logger
LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Jan-09																														
		Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF2	LTD Logger																															
MOF3	LTD Logger																															
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Feb-09																											
		S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
AHC	LTD Logger																												
ANT	LTD Logger																												
BAT	LTD Logger																												
BIG	LTD Logger																												
DUG	LTD Logger																												
LNG0	LTD Logger																												
LNG1	LTD Logger																												
LNG2	LTD Logger																												
LNG3	LTD Logger																												
LONE	LTD Logger																												
LOW	LTD Logger																												
MOF1	LTD Logger																												
MOF2	LTD Logger																												
MOF3	LTD Logger																												
SBS	LTD Logger																												
DUG	Sediment Trap Array																												
LNG3	Sediment Trap Array																												
LONE	Sediment Trap Array																												
MOF3	Sediment Trap Array																												
SBS	Sediment Trap Array																												
BWI Onshore	Terrestrial Light Logger																												

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Mar-09																														
		S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF2	LTD Logger																															
MOF3	LTD Logger																															
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND	Note: Terrestrial light logger moved to location near Terminal Tanks on 8 March 2009
FULL DATA SET	
PARTIAL DATA SET	
NO DATA	
TRAP SAMPLED	

SITE	DATA POINT	Apr-09																													
		W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AHC	LTD Logger																														
ANT	LTD Logger																														
BAT	LTD Logger																														
BIG	LTD Logger																														
DUG	LTD Logger																														
HDD	LTD Logger																														
LNG0	LTD Logger																														
LNG1	LTD Logger																														
LNG2	LTD Logger																														
LNG3	LTD Logger																														
LONE	LTD Logger																														
LOW	LTD Logger																														
MOF1	LTD Logger																														
MOF1-S	LTD Logger																														
MOF2	LTD Logger																														
MOF3	LTD Logger																														
MOF3-S	LTD Logger																														
SBS	LTD Logger																														
DUG	Sediment Trap Array																														
LNG3	Sediment Trap Array																														
LONE	Sediment Trap Array																														
MOF3	Sediment Trap Array																														
SBS	Sediment Trap Array																														
BWI Onshore	Terrestrial Light Logger																														

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	May-09																														
		F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
HDD	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF1-S	LTD Logger																															
MOF2	LTD Logger																															
MOF3	LTD Logger																															
MOF3-S	LTD Logger																															
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Jun-09																													
		M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AHC	LTD Logger																														
ANT	LTD Logger																														
BAT	LTD Logger																														
BIG	LTD Logger																														
DUG	LTD Logger																														
HDD	LTD Logger																														
LNG0	LTD Logger																														
LNG1	LTD Logger																														
LNG2	LTD Logger																														
LNG3	LTD Logger																														
LONE	LTD Logger																														
LOW	LTD Logger																														
MOF1	LTD Logger																														
MOF1-S	LTD Logger																														
MOF2	LTD Logger																														
MOF3	LTD Logger																														
MOF3-S	LTD Logger																														
SBS	LTD Logger																														
DUG	Sediment Trap Array																														
LNG3	Sediment Trap Array																														
LONE	Sediment Trap Array																														
MOF3	Sediment Trap Array																														
SBS	Sediment Trap Array																														
BWI Onshore	Terrestrial Light Logger																														

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Jul-09																														
		W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
ANT	LTD Logger	Full	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
BAT	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
BIG	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
DUG	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
HDD	LTD Logger	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
LNG0	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
LNG1	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
LNG2	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
LNG3	LTD Logger	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
LONE	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
LOW	LTD Logger	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
MOF1	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Partial	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
MOF1-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF2	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
MOF3	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
MOF3-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SBS	LTD Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
DUG	Sediment Trap Array	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Sampled	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
LNG3	Sediment Trap Array	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Sampled	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
LONE	Sediment Trap Array	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Sampled	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
MOF3	Sediment Trap Array	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Sampled	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full
SBS	Sediment Trap Array	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Sampled	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial	Partial
BWI Onshore	Terrestrial Light Logger	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Sampled	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full

LEGEND

- FULL DATA SET
- PARTIAL DATA SET
- NO DATA
- TRAP SAMPLED

SITE	DATA POINT	Aug-09																														
		Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
HDD	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF1-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF2	LTD Logger																															
MOF3	LTD Logger																															
MOF3-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Sep-09																													
		T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
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HDD	LTD Logger																														
LNG0	LTD Logger																														
LNG1	LTD Logger																														
LNG2	LTD Logger																														
LNG3	LTD Logger																														
LONE	LTD Logger																														
LOW	LTD Logger																														
MOF1	LTD Logger																														
MOF1-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF2	LTD Logger																														
MOF3	LTD Logger																														
MOF3-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SBS	LTD Logger																														
DUG	Sediment Trap Array																														
LNG3	Sediment Trap Array																														
LONE	Sediment Trap Array																														
MOF3	Sediment Trap Array																														
SBS	Sediment Trap Array																														
BWI Onshore	Terrestrial Light Logger																														

LEGEND

- FULL DATA SET
- PARTIAL DATA SET
- NO DATA
- TRAP SAMPLED

SITE	DATA POINT	Oct-09																														
		Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa
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AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
HDD	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF1-S	LTD Logger																															
MOF2	LTD Logger																															
MOF3	LTD Logger																															
MOF3-S	LTD Logger																															
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Nov-09																													
		S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AHC	LTD Logger																														
ANT	LTD Logger																														
BAT	LTD Logger																														
BIG	LTD Logger																														
DUG	LTD Logger																														
HDD	LTD Logger																														
LNG0	LTD Logger																														
LNG1	LTD Logger																														
LNG2	LTD Logger																														
LNG3	LTD Logger																														
LONE	LTD Logger																														
LOW	LTD Logger																														
MOF1	LTD Logger																														
MOF1-S	LTD Logger																														
MOF2	LTD Logger																														
MOF3	LTD Logger																														
MOF3-S	LTD Logger																														
SBS	LTD Logger																														
DUG	Sediment Trap Array																														
LNG3	Sediment Trap Array																														
LONE	Sediment Trap Array																														
MOF3	Sediment Trap Array																														
SBS	Sediment Trap Array																														
BWI Onshore	Terrestrial Light Logger																														

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Dec-09																														
		T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger																															
DUG	LTD Logger																															
HDD	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF1-S	LTD Logger																															
MOF2	LTD Logger																															
MOF3	LTD Logger																															
MOF3-S	LTD Logger																															
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Jan-10																														
		F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DUG	LTD Logger																															
HDD	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF1-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF2	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF3	LTD Logger																															
MOF3-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Feb-10																											
		M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
AHC	LTD Logger																												
ANT	LTD Logger																												
BAT	LTD Logger																												
BIG	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DUG	LTD Logger																												
HDD	LTD Logger																												
LNG0	LTD Logger																												
LNG1	LTD Logger																												
LNG2	LTD Logger																												
LNG3	LTD Logger																												
LONE	LTD Logger																												
LOW	LTD Logger																												
MOF1	LTD Logger																												
MOF1-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF2	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF3	LTD Logger																												
MOF3-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SBS	LTD Logger																												
DUG	Sediment Trap Array																												
LNG3	Sediment Trap Array																												
LONE	Sediment Trap Array																												
MOF3	Sediment Trap Array																												
SBS	Sediment Trap Array																												
BWI Onshore	Terrestrial Light Logger																												

LEGEND
FULL DATA SET
PARTIAL DATA SET
NO DATA
TRAP SAMPLED

SITE	DATA POINT	Mar-10																														
		M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W	Th	F	Sa	S	M	T	W
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
AHC	LTD Logger																															
ANT	LTD Logger																															
BAT	LTD Logger																															
BIG	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DUG	LTD Logger																															
HDD	LTD Logger																															
LNG0	LTD Logger																															
LNG1	LTD Logger																															
LNG2	LTD Logger																															
LNG3	LTD Logger																															
LONE	LTD Logger																															
LOW	LTD Logger																															
MOF1	LTD Logger																															
MOF1-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF2	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MOF3	LTD Logger																															
MOF3-S	LTD Logger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SBS	LTD Logger																															
DUG	Sediment Trap Array																															
LNG3	Sediment Trap Array																															
LONE	Sediment Trap Array																															
MOF3	Sediment Trap Array																															
SBS	Sediment Trap Array																															
BWI Onshore	Terrestrial Light Logger																															

LEGEND

- FULL DATA SET
- PARTIAL DATA SET
- NO DATA
- TRAP SAMPLED

SITE	Number of Water Column Profiles Undertaken per Month													
	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Total
AHC	0	1	0	1	0	1	0	0	0	2	0	1	0	6
ANT	0	0	0	1	0	0	0	0	0	2	1	1	0	5
BAT	0	1	0	1	0	1	1	0	0	2	1	0	0	7
BIG	0	1	0	1	0	0	1	0	0	1	1	0	0	5
DUG	0	1	0	1	0	1	0	0	0	1	0	2	0	6
HDD	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNG0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNG1	0	0	0	0	0	0	0	1	0	2	1	0	0	4
LNG2	0	1	0	1	0	1	0	1	0	1	0	0	0	5
LNG3	0	1	0	1	0	1	1	1	0	2	0	1	0	8
LONE	0	1	0	1	0	1	0	1	0	0	1	0	0	5
LOW	0	1	0	0	0	0	0	1	0	2	1	2	0	7
MOF1	0	1	0	1	0	0	0	1	0	1	3	0	0	7
MOF2	0	0	0	0	0	0	0	0	0	1	0	0	0	1
MOF3	0	1	0	1	0	0	0	0	0	1	2	0	0	5
SBS	0	1	0	1	0	0	0	1	0	1	1	0	0	5

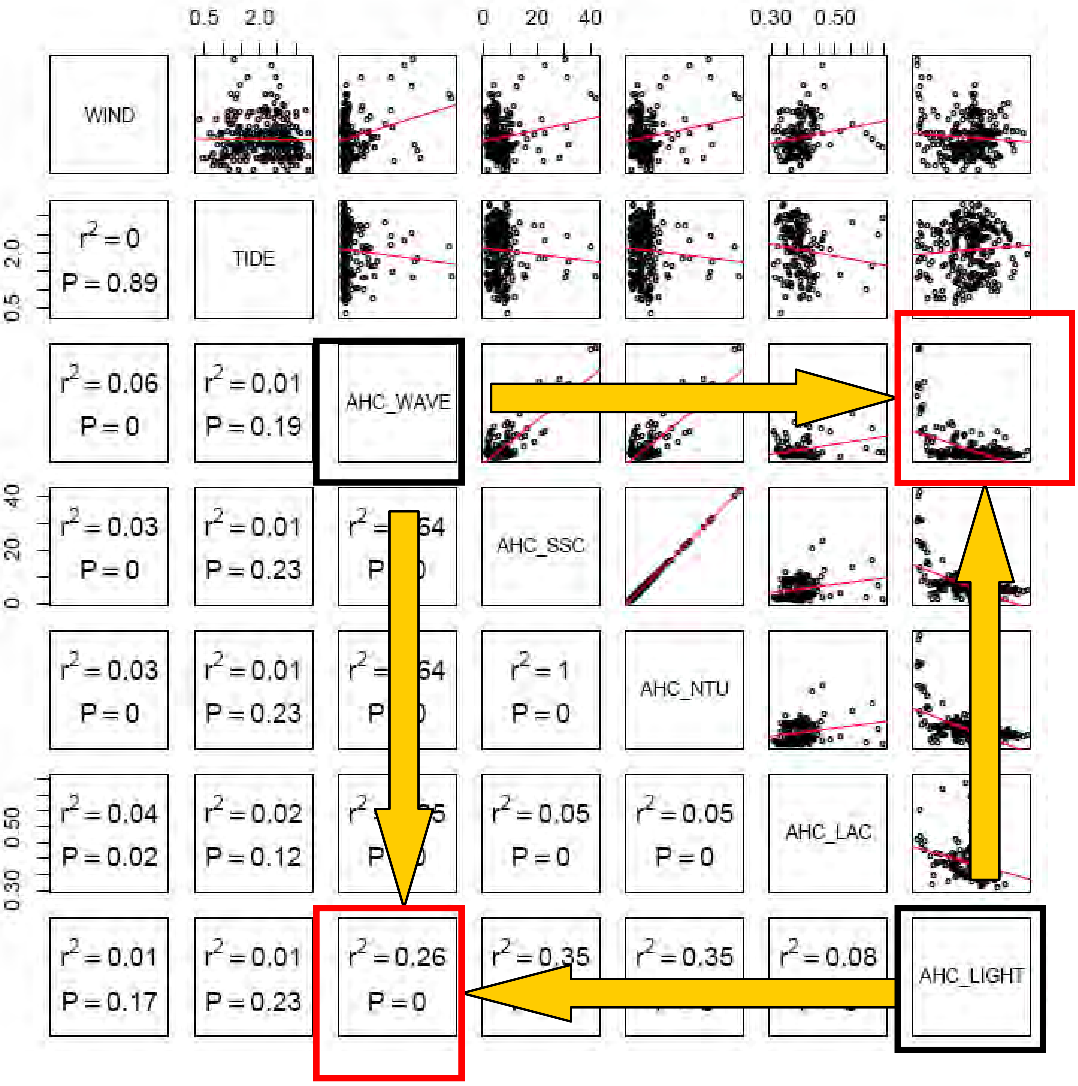
SITE	Number of Water Column Profiles Undertaken per Month												
	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Total
AHC	0	0	0	0	0	1	0	0	0	1	0	0	2
ANT	0	0	0	0	0	1	0	0	0	1	0	0	2
BAT	0	0	0	0	0	1	1	1	1	2	1	0	7
BIG	0	0	0	0	0	0	0	1	0	0	0	0	1
DUG	0	0	0	0	0	0	1	0	1	0	0	0	2
HDD	0	0	0	0	16	0	0	1	0	1	1	0	19
LNG0	0	0	0	0	0	0	1	0	1	1	1	1	5
LNG1	0	0	0	0	0	0	1	0	0	0	0	0	1
LNG2	0	0	0	0	0	1	1	0	0	0	0	0	2
LNG3	0	0	0	0	0	1	0	1	1	0	0	0	3
LONE	0	0	0	0	0	1	1	1	1	0	0	0	4
LOW	0	0	0	0	0	0	0	1	1	0	1	0	3
MOF1	0	0	0	0	0	0	1	0	0	1	3	0	5
MOF2	0	0	0	0	0	0	0	0	1	0	0	0	1
MOF3	0	0	0	0	0	1	1	0	1	0	2	0	5
SBS	0	0	0	0	0	1	1	0	0	2	1	0	5

Appendix 12 Water Quality Scatter Plots

Note: These figures show a matrix of correlations for seven different variables. The corresponding correlations and scatter plots of any pair of variables can be found at the intersection of the rows and columns that stem from those variables. For example, in the example figure below, the scatter plot and associated statistic between the variables wave height and light at site AHC (black boxes) can be viewed by looking at the intersection (follow orange arrows) of the rows and columns (red boxes).

Environmental variables: Tide – Greatest daily tidal movement; Wind – Median of the 30-minute maximum wind speed; WAVE – Daily median of 10-minute wave height.

Water quality variables (measured or estimated with LTD loggers): SSC – Daily median Suspended Sediment Concentration; NTU – Daily median turbidity (Nephelometric Turbidity Units); LAC – Daily Light Attenuation Coefficient; Light – median of daily midday light.



Site LNG0

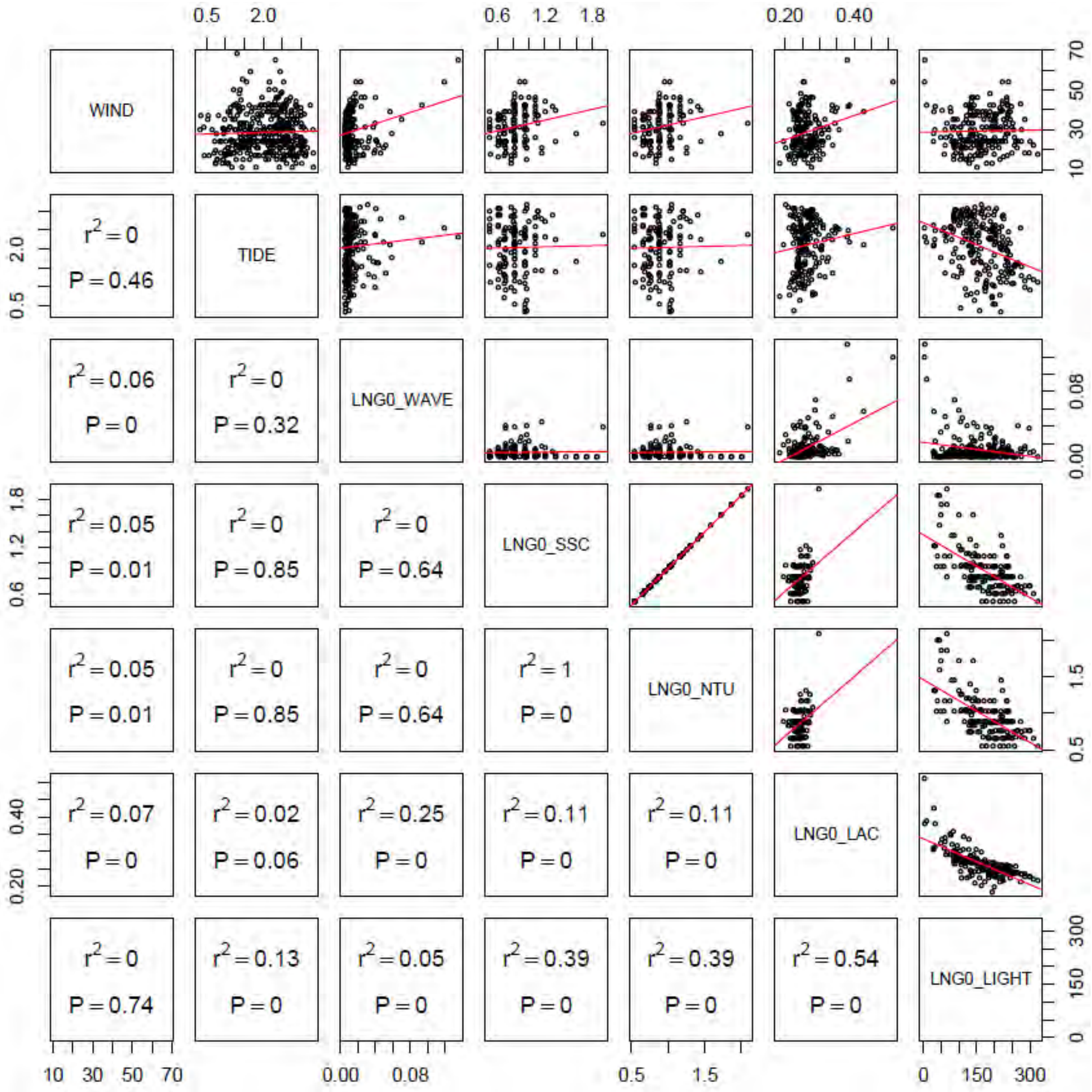


Figure 1: Relationship During the Summer Period Between Environmental and Water Quality Variables at LNG0 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 19 January 2009 – 30 April 2009 and 1 November 2009 – 24 March 2010.

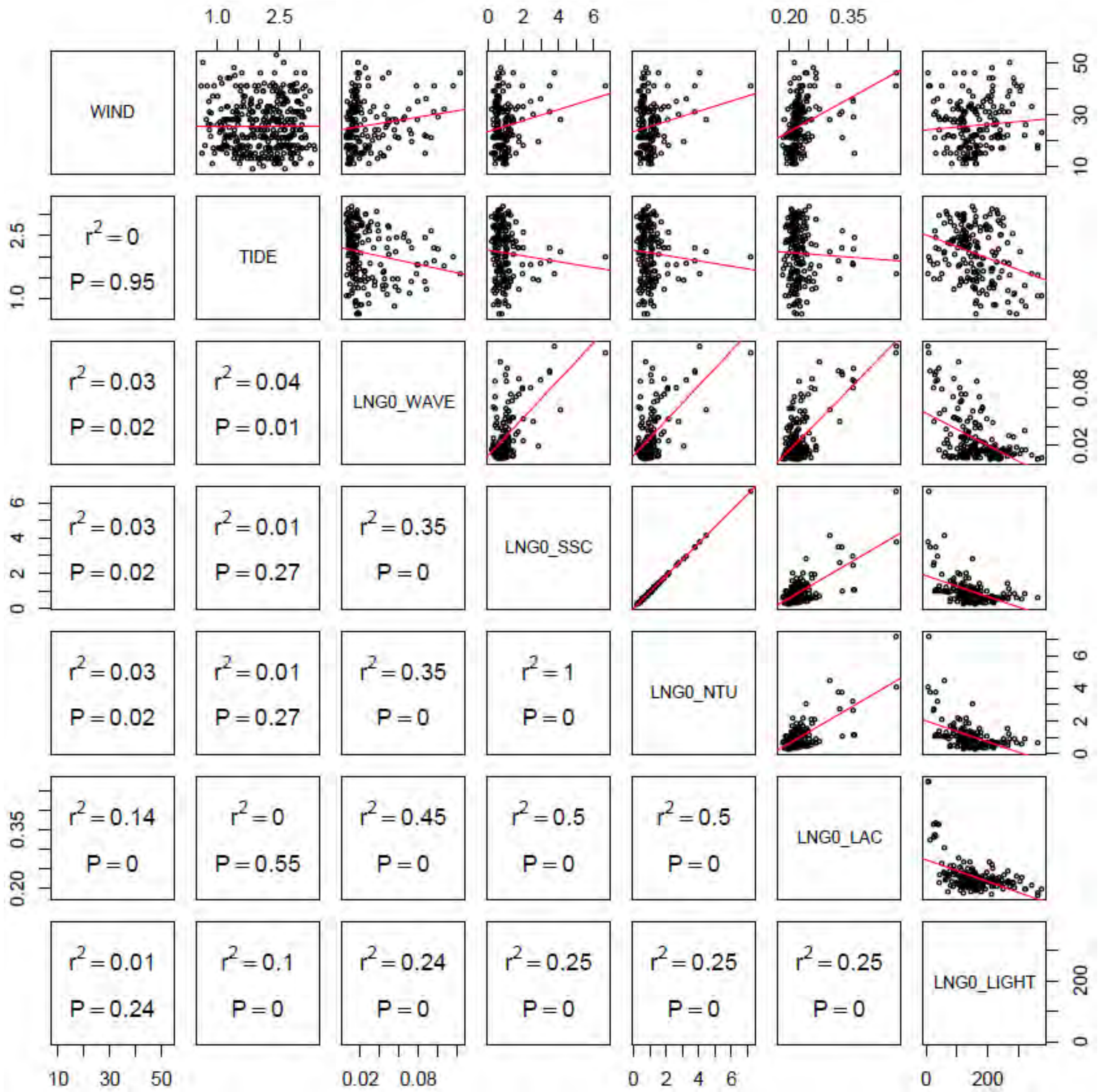


Figure 2: Relationship During the Winter Period Between Environmental and Water Quality Variables at LNG0 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 1 May 2009 – 31 October 2009.

Site MOF1

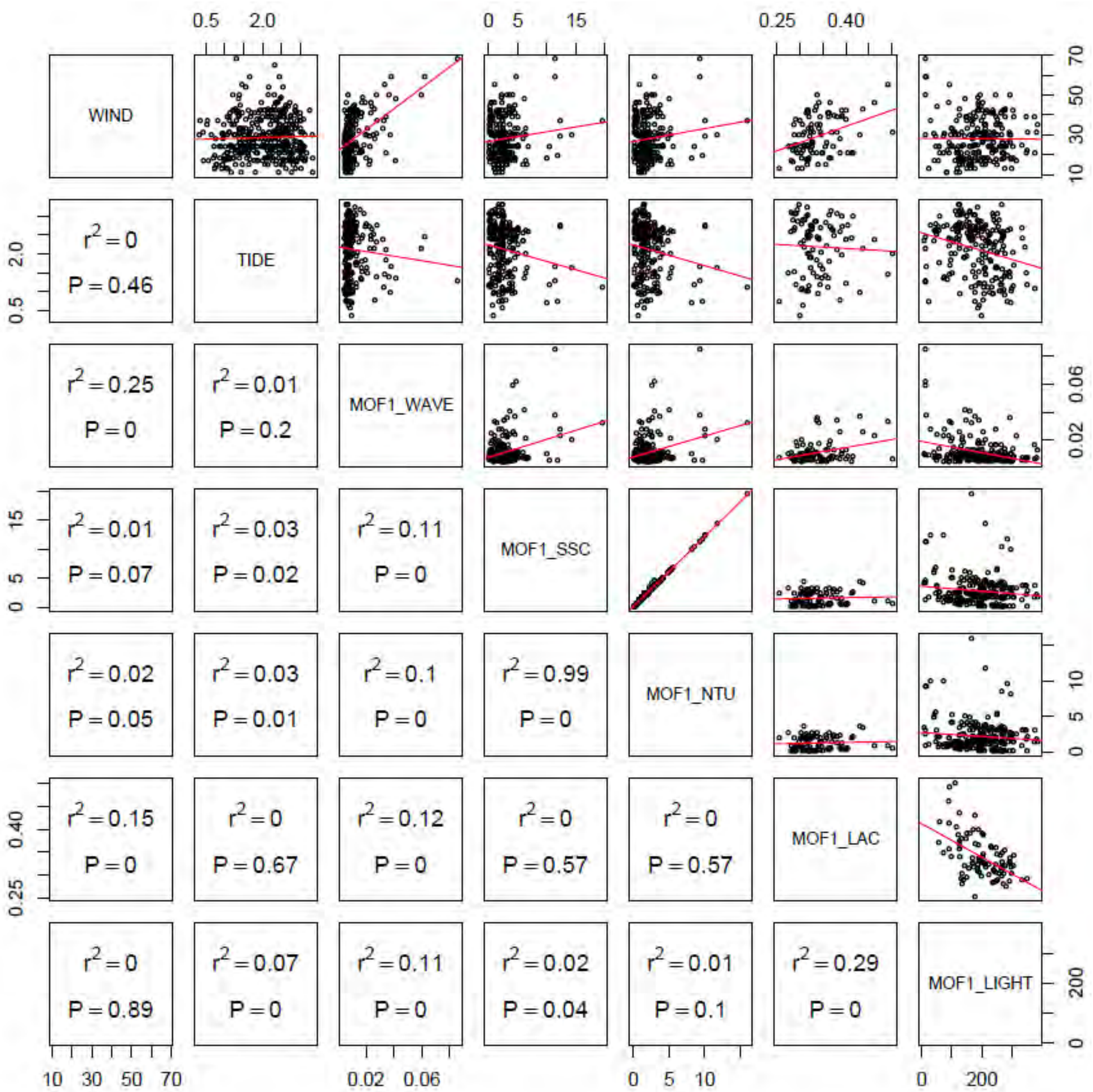


Figure 3: Relationship During the Summer Period Between Environmental and Water Quality Variables at MOF1 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 6 December 2007 – 25 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 21 November 2009.

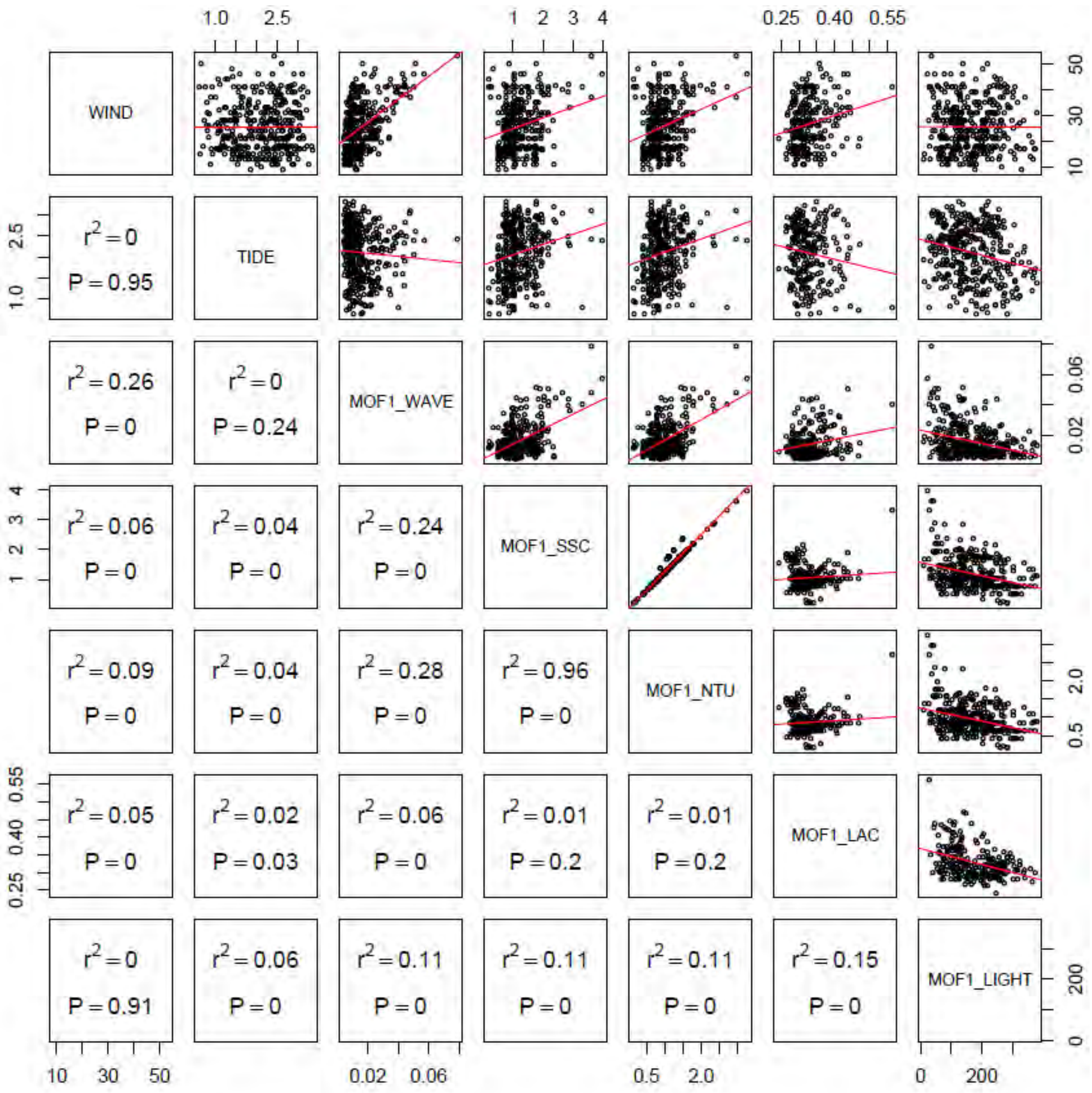


Figure 4: Relationship During the Winter Period Between Environmental and Water Quality Variables at MOF1 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 5 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site Lone Reef (LONE)

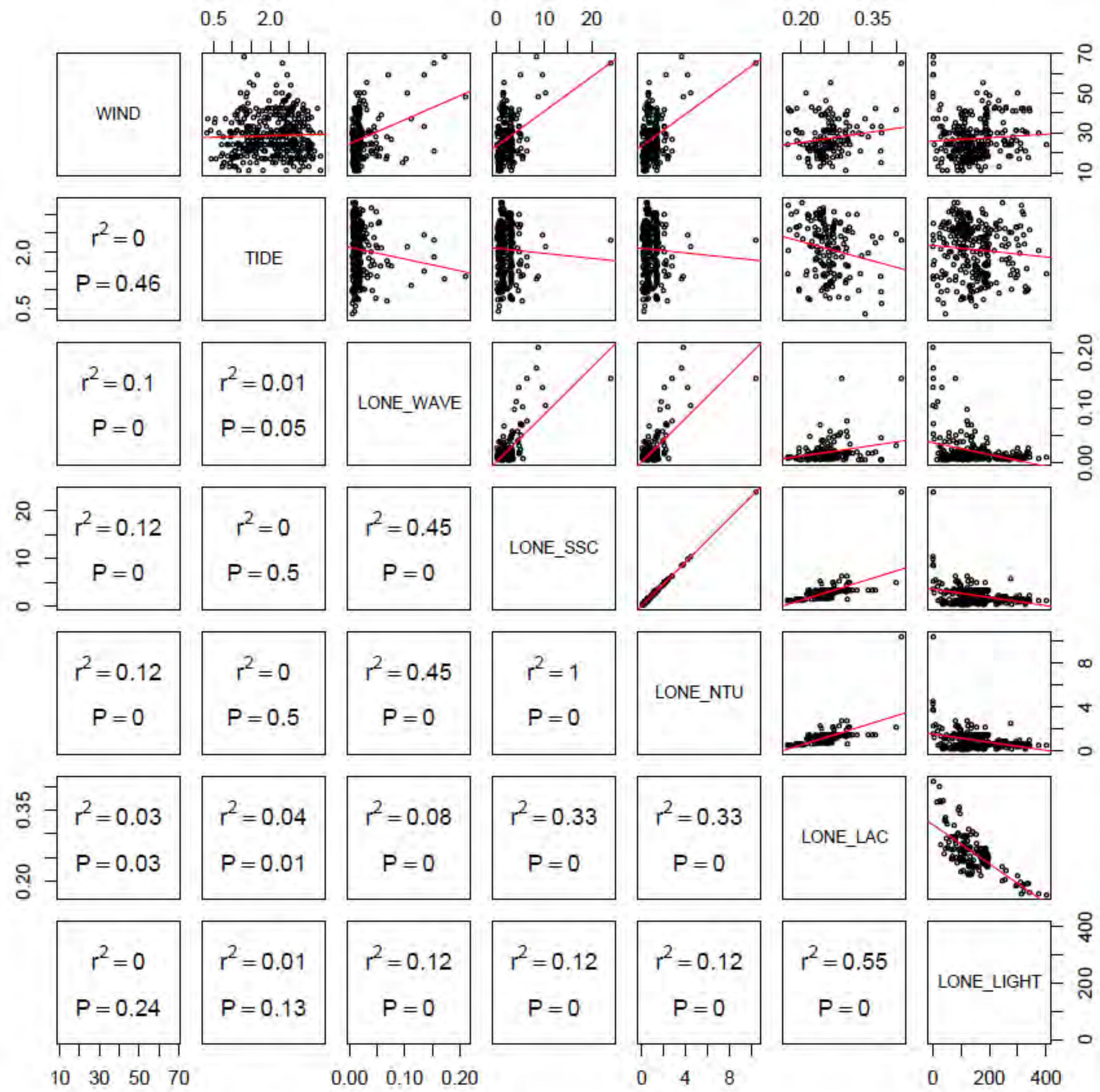


Figure 5: Relationship During the Summer Period Between Environmental and Water Quality Variables at Lone Reef (LONE) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 10 December 2007 – 30 April 2008 and 1 November 2008 – 30 April 2009.

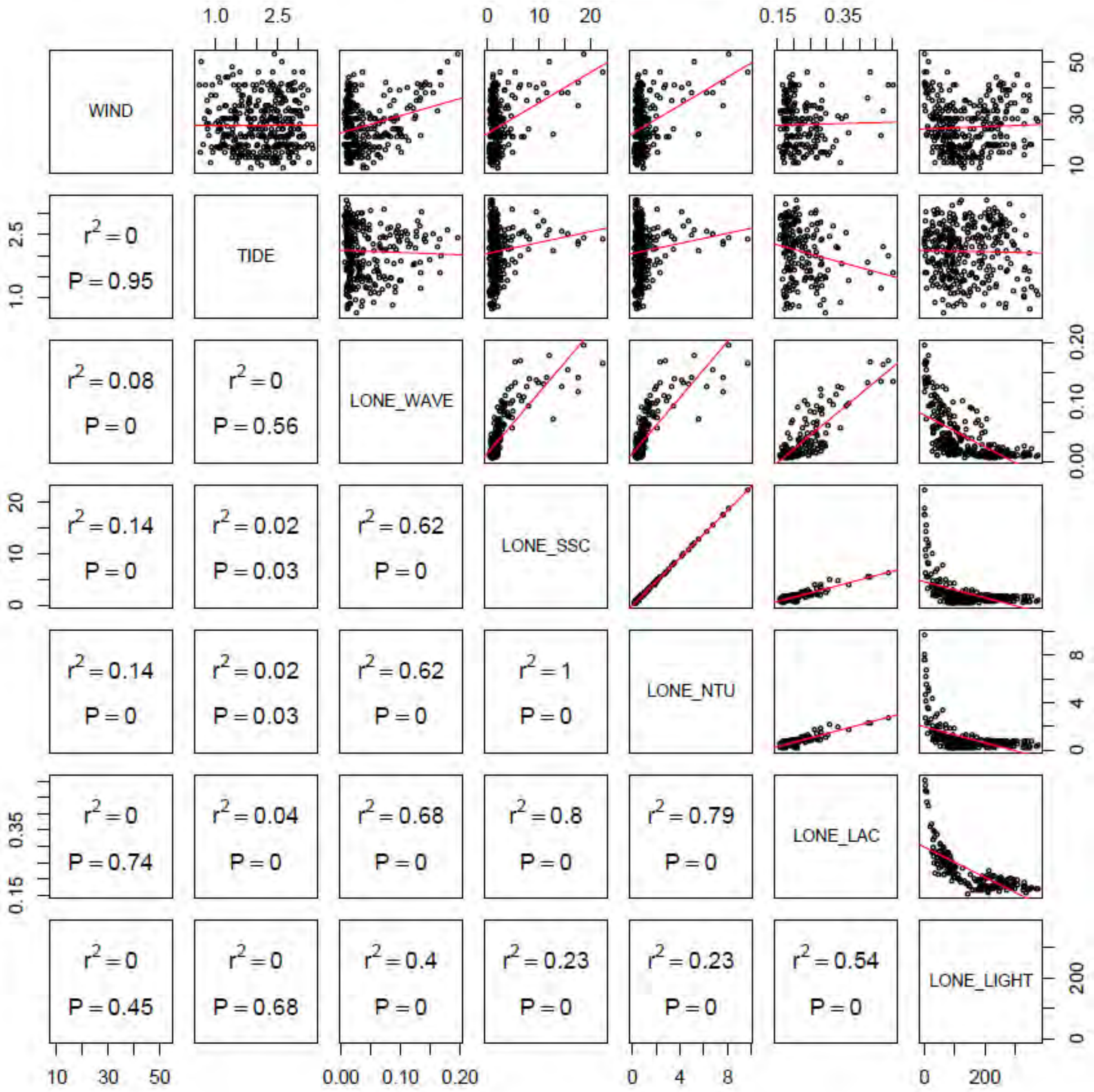


Figure 6: Relationship During the Winter Period Between Environmental and Water Quality Variables at Lone Reef (LONE) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 1 May 2009 – 15 September 2009.

Site LNG1

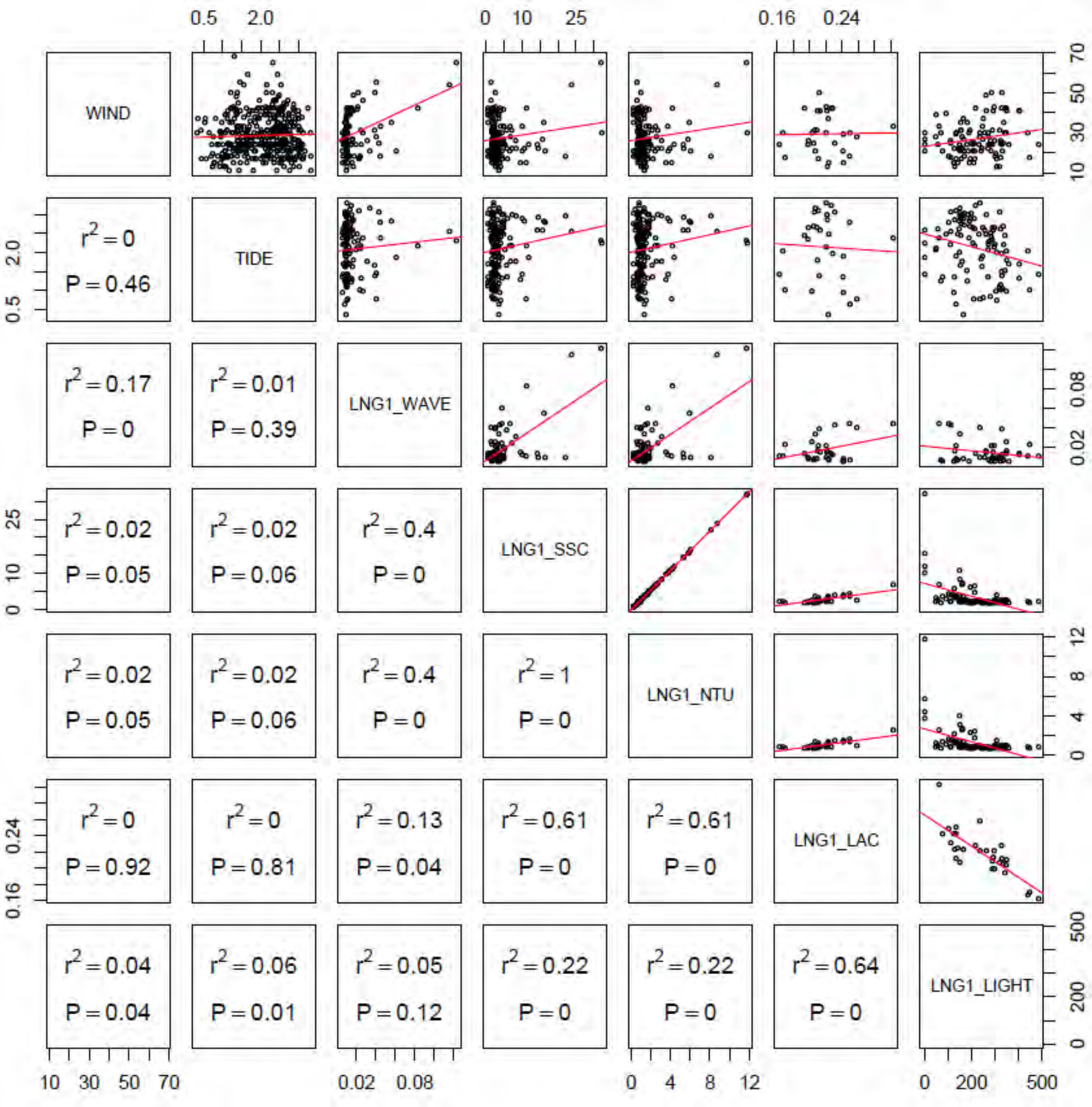


Figure 7: Relationship During the Summer Period Between Environmental and Water Quality Variables at LNG1 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 1 November 2008 – 30 April 2009.

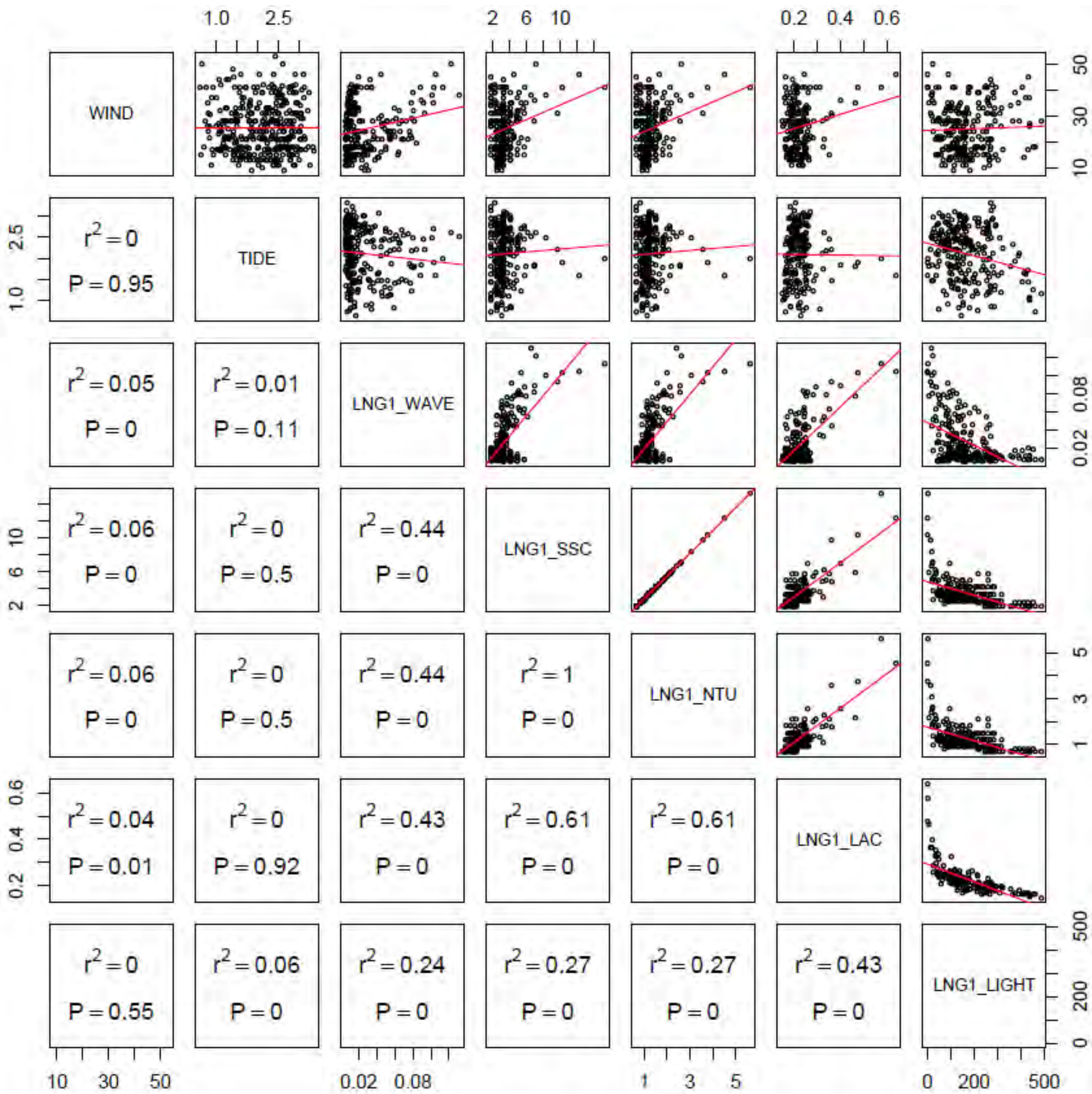


Figure 8: Relationship During the Winter Period Between Environmental and Water Quality Variables at LNG1 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 15 July 2008 – 31 October 2008 and 1 May 2009 – 14 September 2009.

Site Ant Point Reef (ANT)

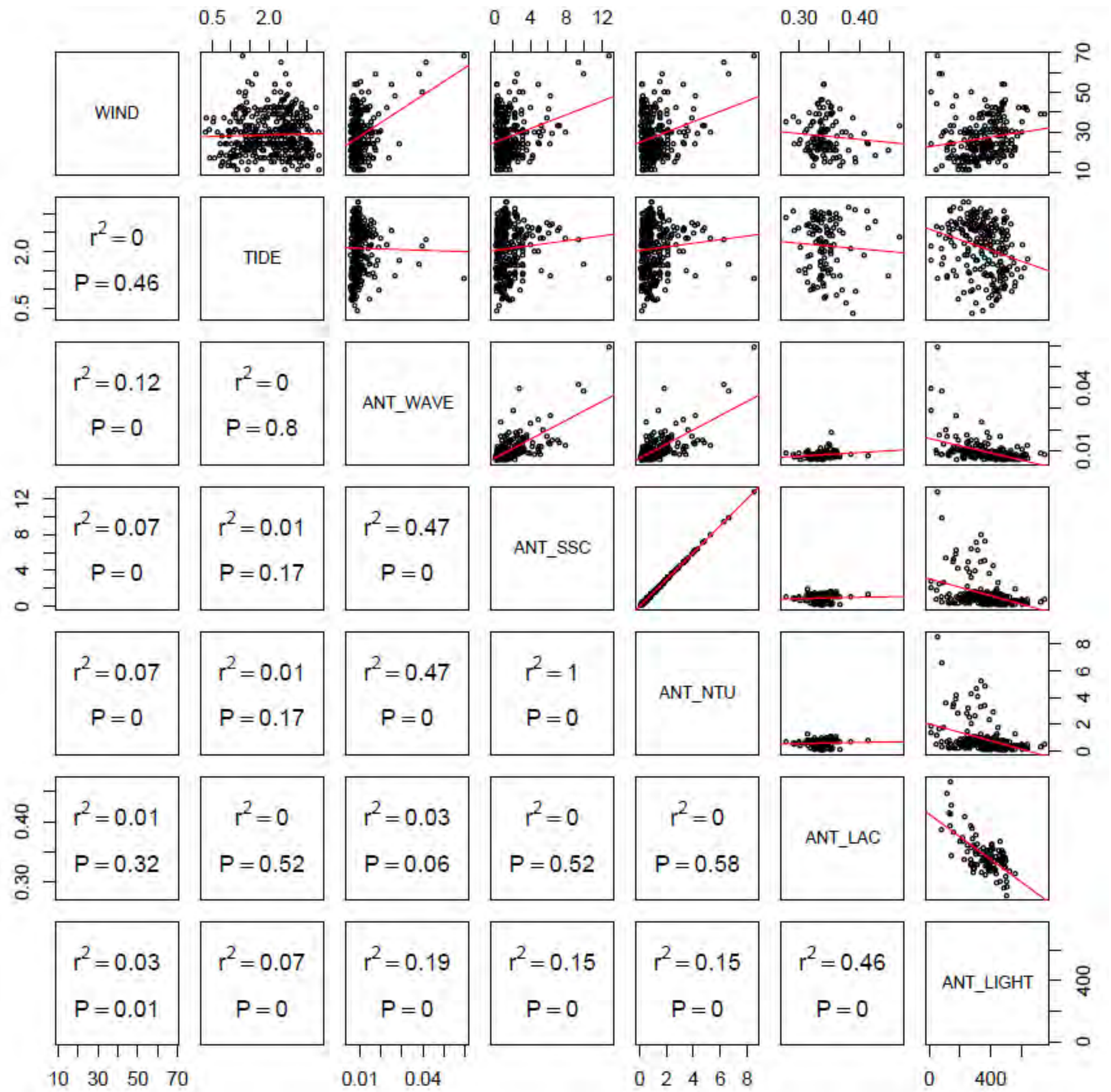


Figure 9: Relationship During the Summer Period Between Environmental and Water Quality Variables at Ant Point Reef (ANT) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 3 December 2007 – 30 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 12 January 2010.

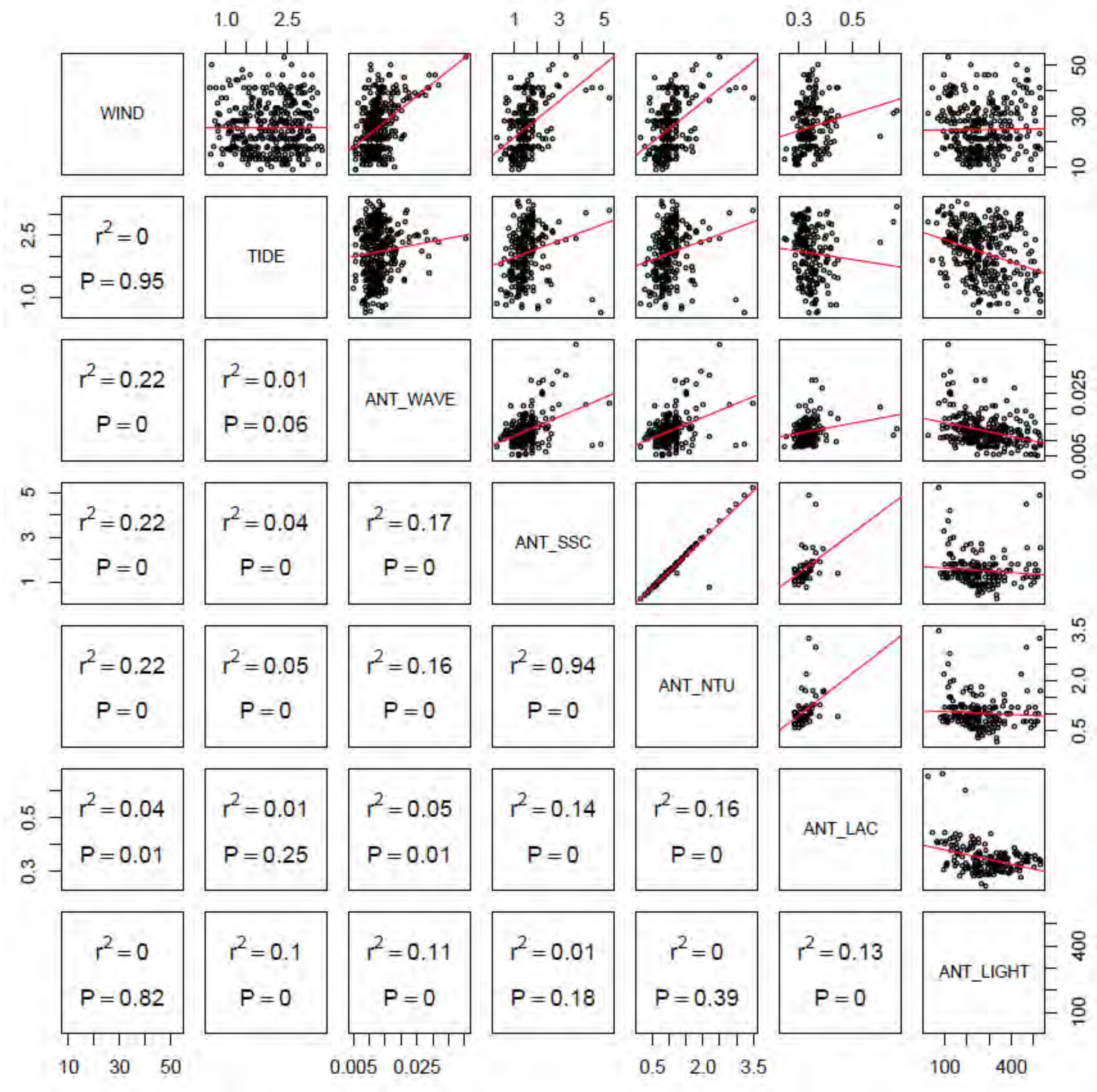


Figure 10: Relationship During the Winter Period Between Environmental and Water Quality Variables at Ant Point Reef (ANT) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site Southern Lowendal Shelf (LOW)

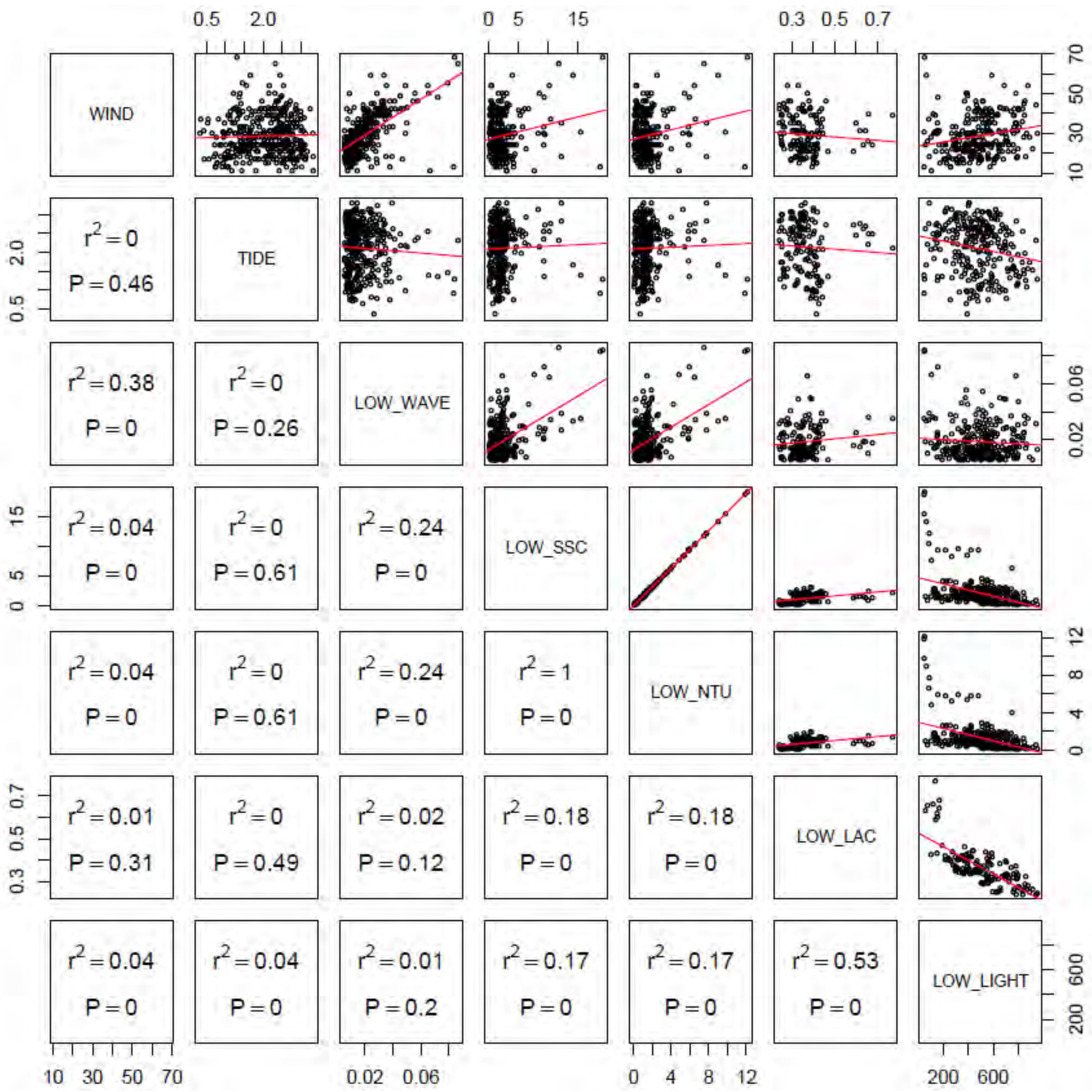


Figure 11: Relationship During the Summer Period Between Environmental and Water Quality Variables at Southern Lowendal Shelf (LOW) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 3 December 2007 – 14 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 14 January 2010.

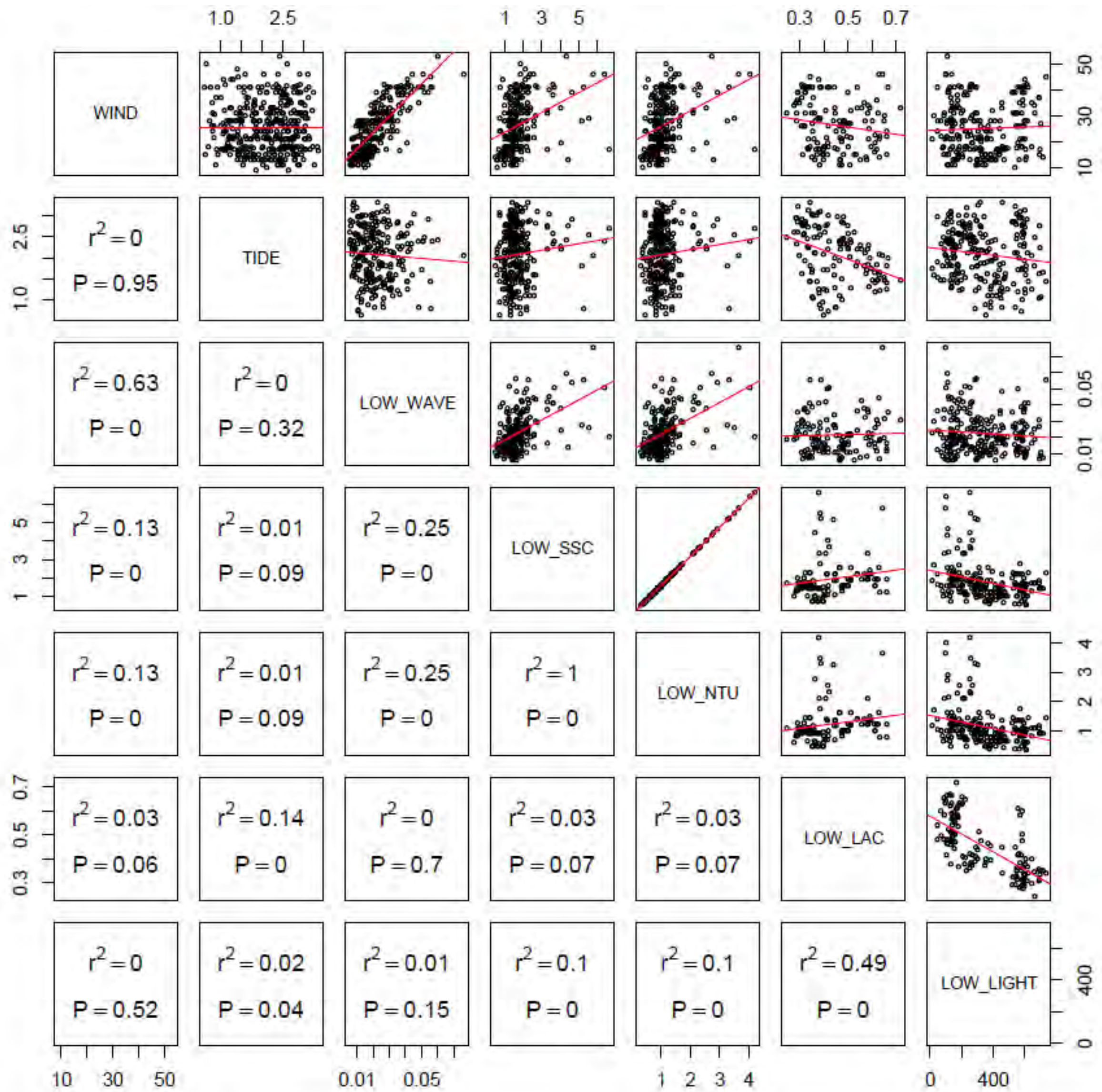


Figure 12: Relationship During the Winter Period Between Environmental and Water Quality Variables at Southern Lowendal Shelf (LOW) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 2 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site MOF2

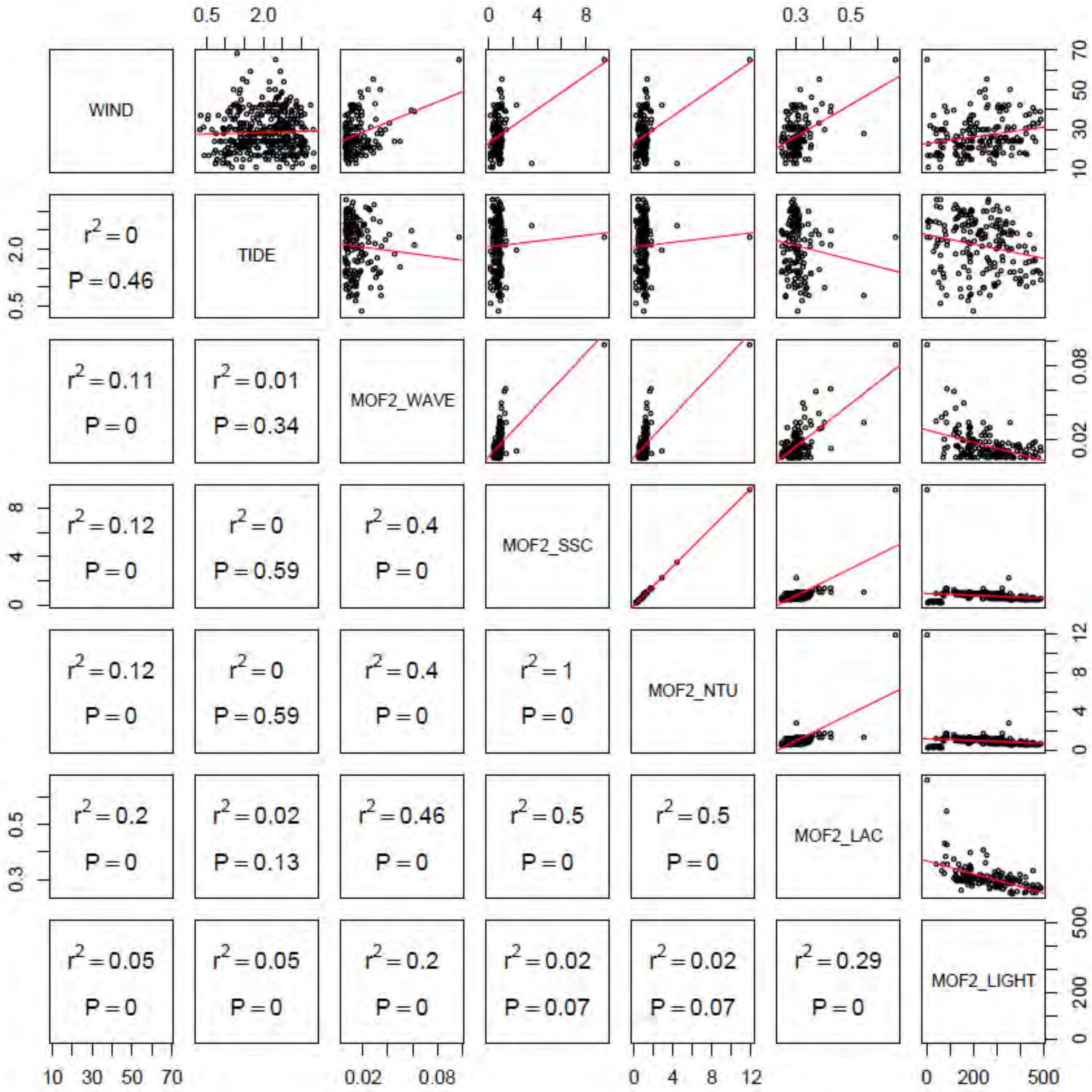


Figure 13: Relationship During the Summer Period Between Environmental and Water Quality Variables at MOF2 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 2 April – 24 April 2008 and 1 November 2008 – 30 April 2009.

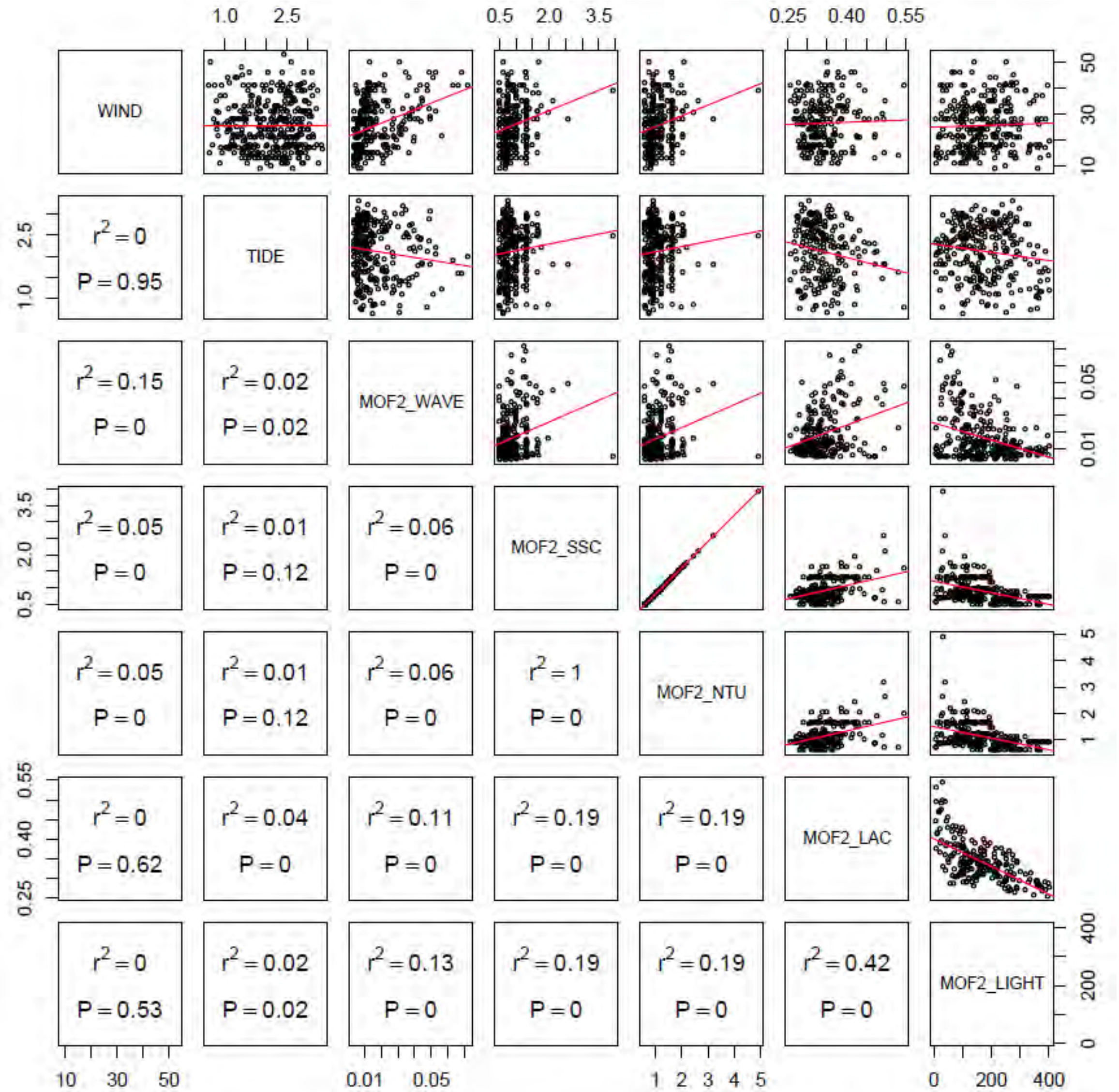


Figure 14: Relationship During the Winter Period Between Environmental and Water Quality Variables at MOF2 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 15 July 2008 – 31 October 2008 and 1 May 2009 – 11 October 2009.

Site MOF3

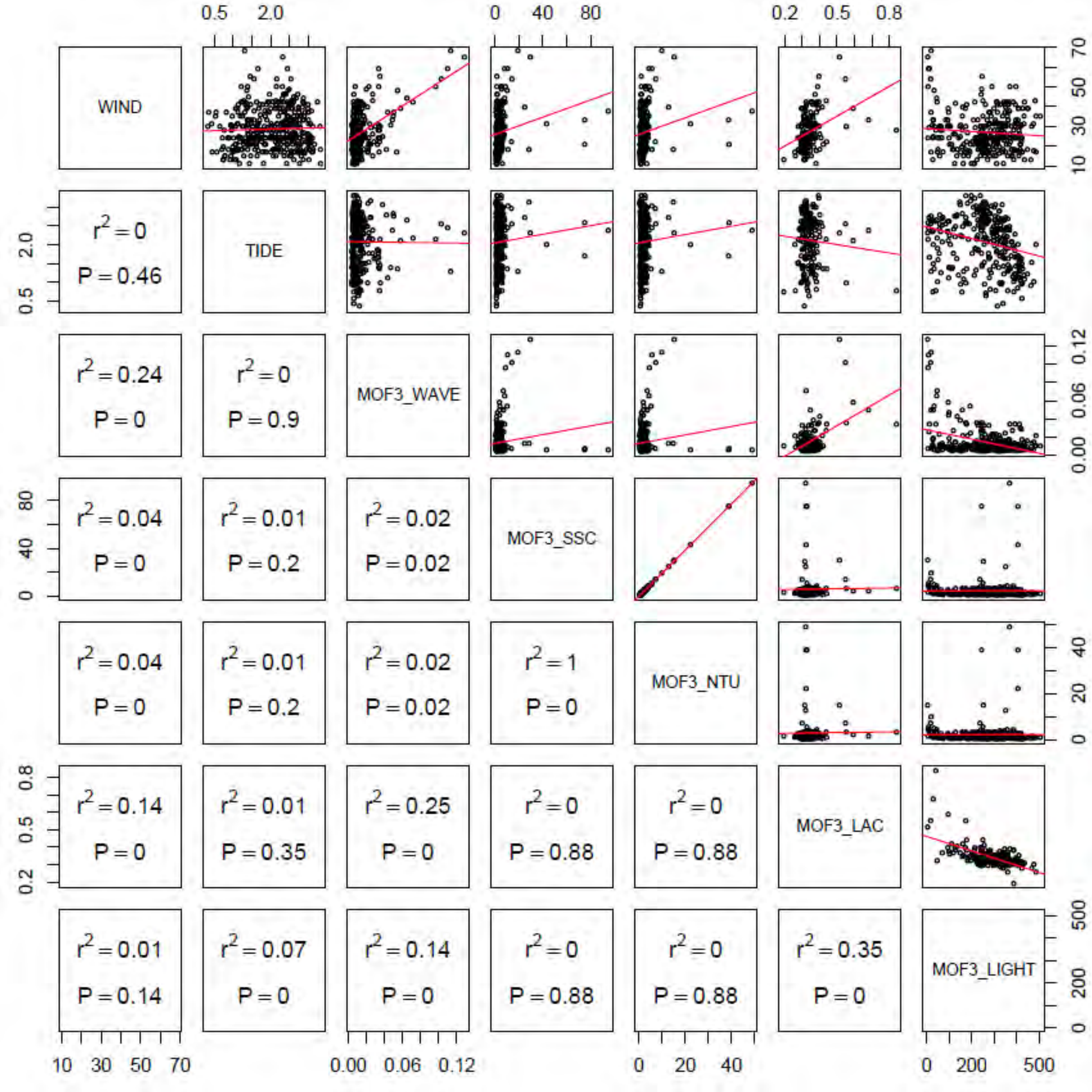


Figure 15: Relationship During the Summer Period Between Environmental and Water Quality Variables at MOF3 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 6 December 2007 – 30 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 5 November 2009.

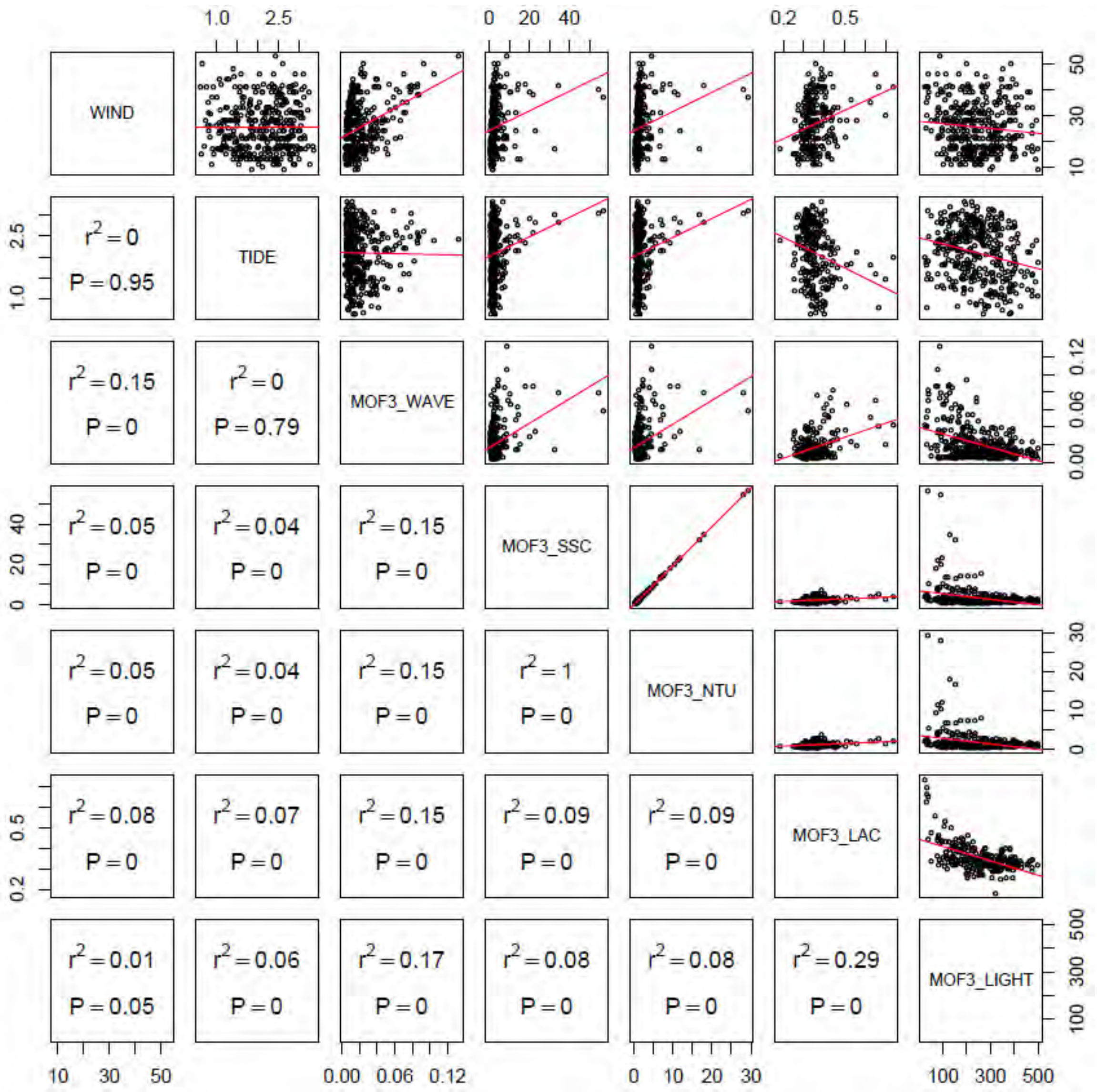


Figure 16: Relationship During the Winter Period Between Environmental and Water Quality Variables at MOF3 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site LNG2

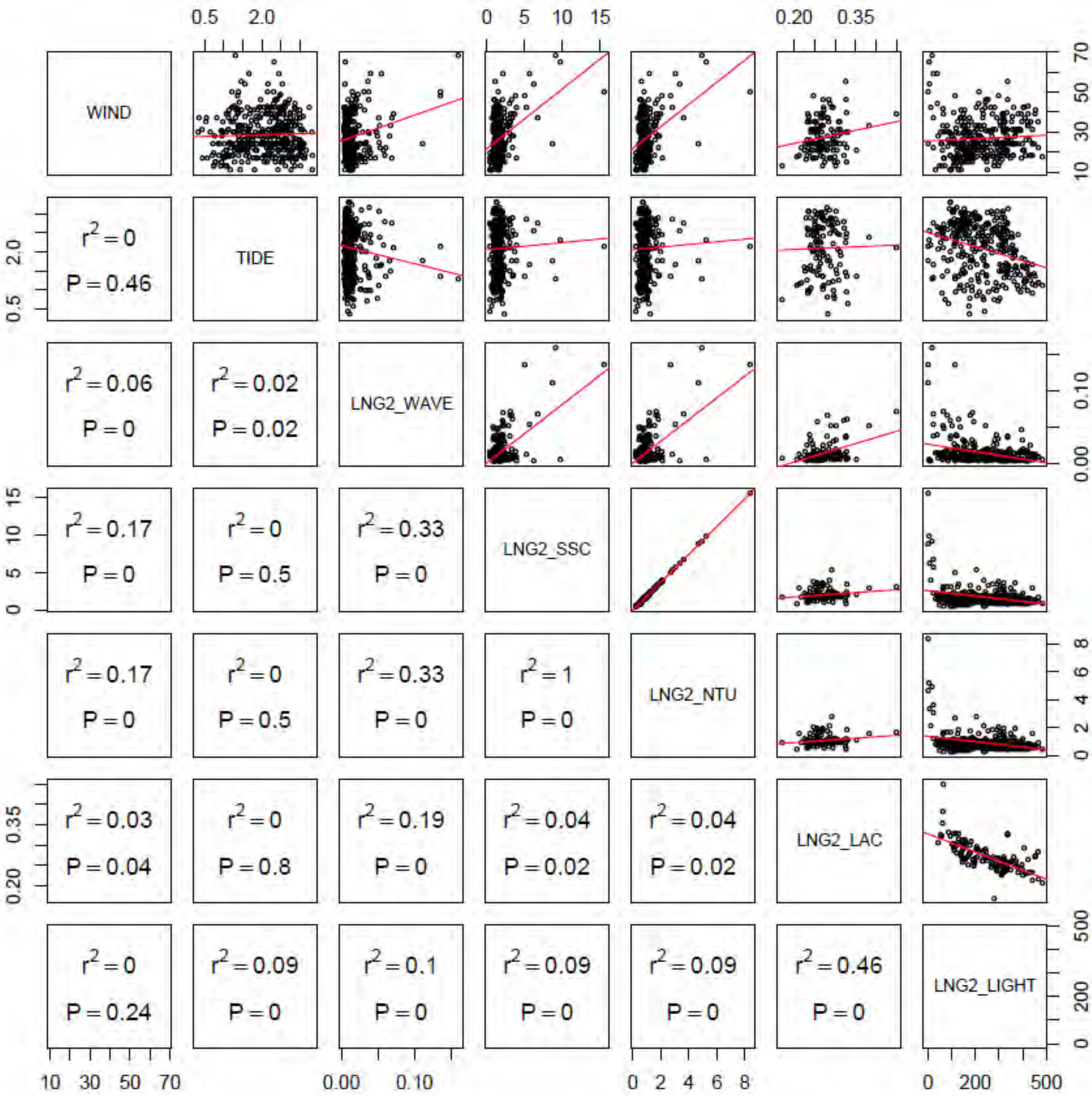


Figure 17: Relationship During the Summer Period Between Environmental and Water Quality Variables at LNG2 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 6 December 2007 – 30 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 18 December 2009.

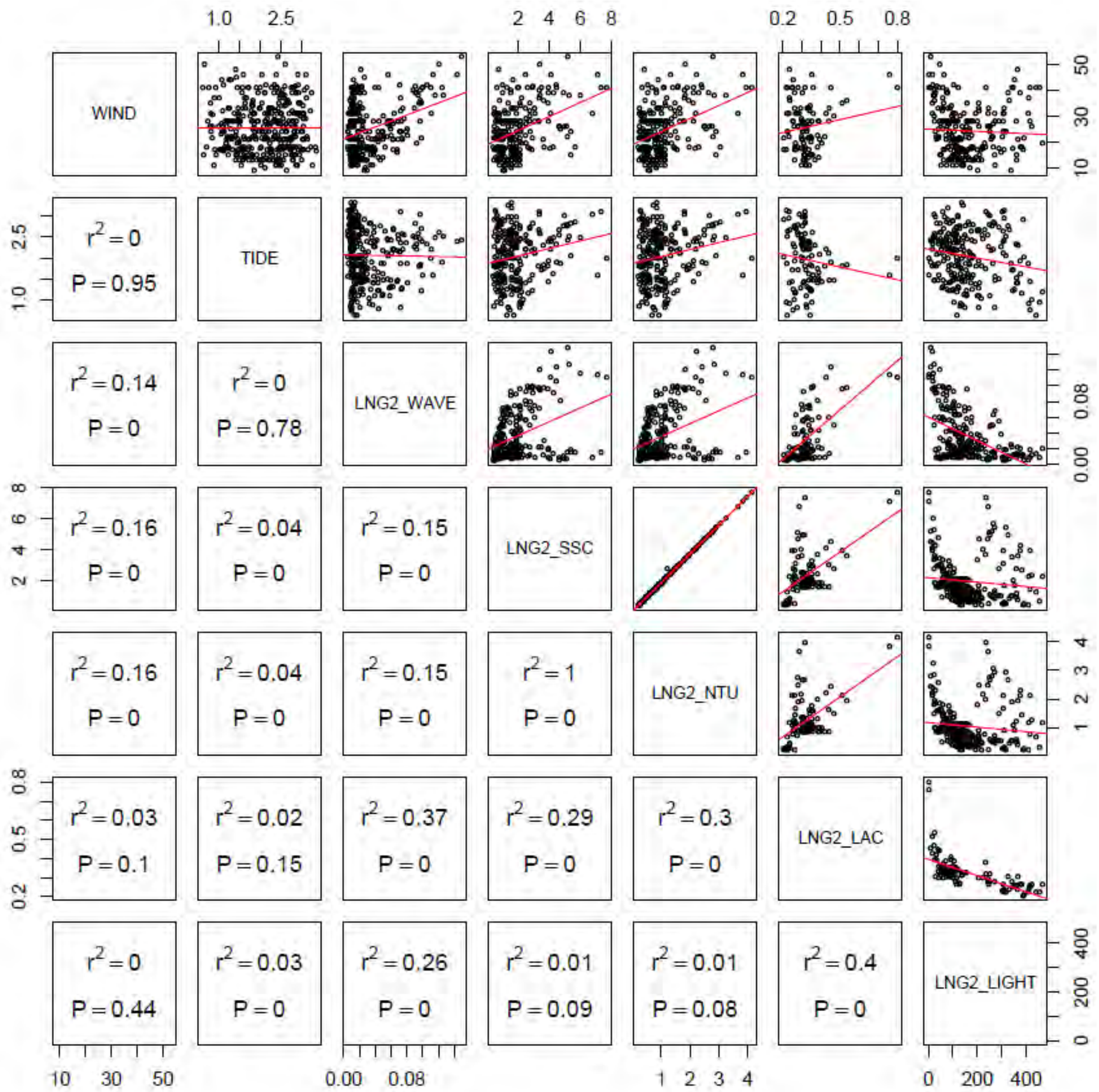


Figure 18: Relationship During the Winter Period Between Environmental and Water Quality Variables at LNG2 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site Ah Chong (AHC)

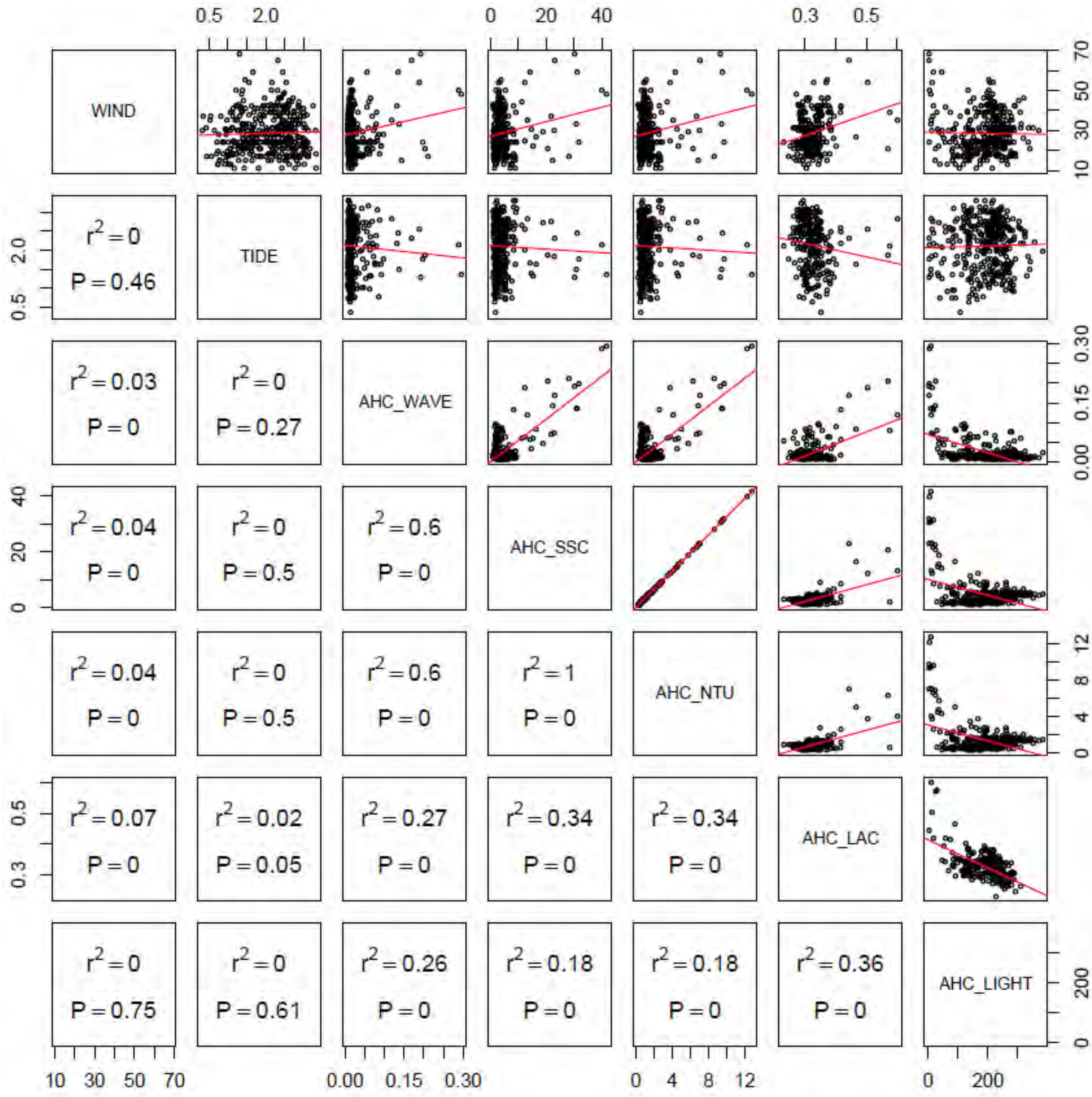


Figure 19: Relationship During the Summer Period Between Environmental and Water Quality Variables at Ah Chong (AHC) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 9 December 2007 – 10 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 25 January 2010.

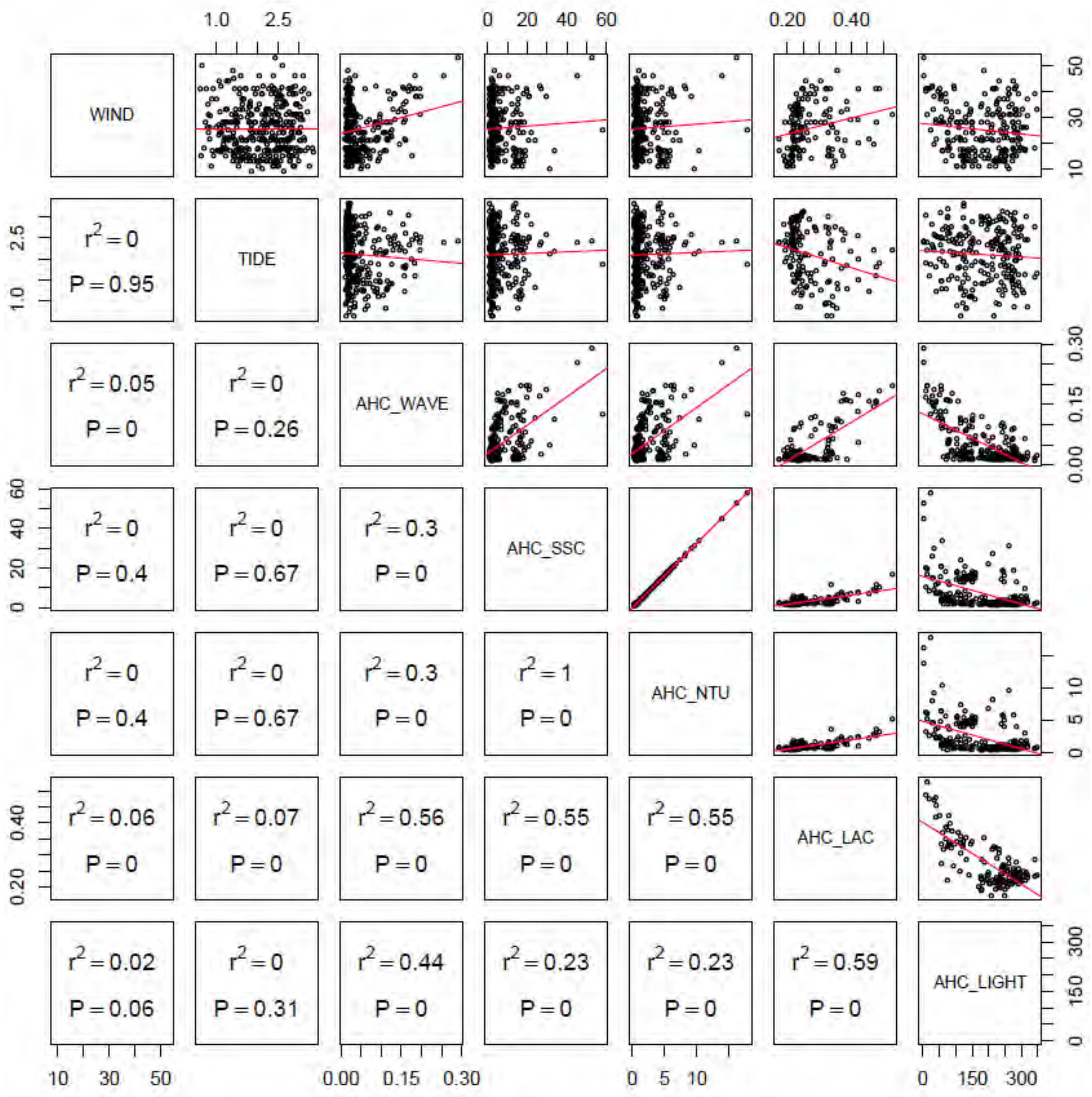


Figure 20: Relationship During the Winter Period Between Environmental and Water Quality Variables at Ah Chong (AHC) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 3 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site Biggada Reef (BIG)

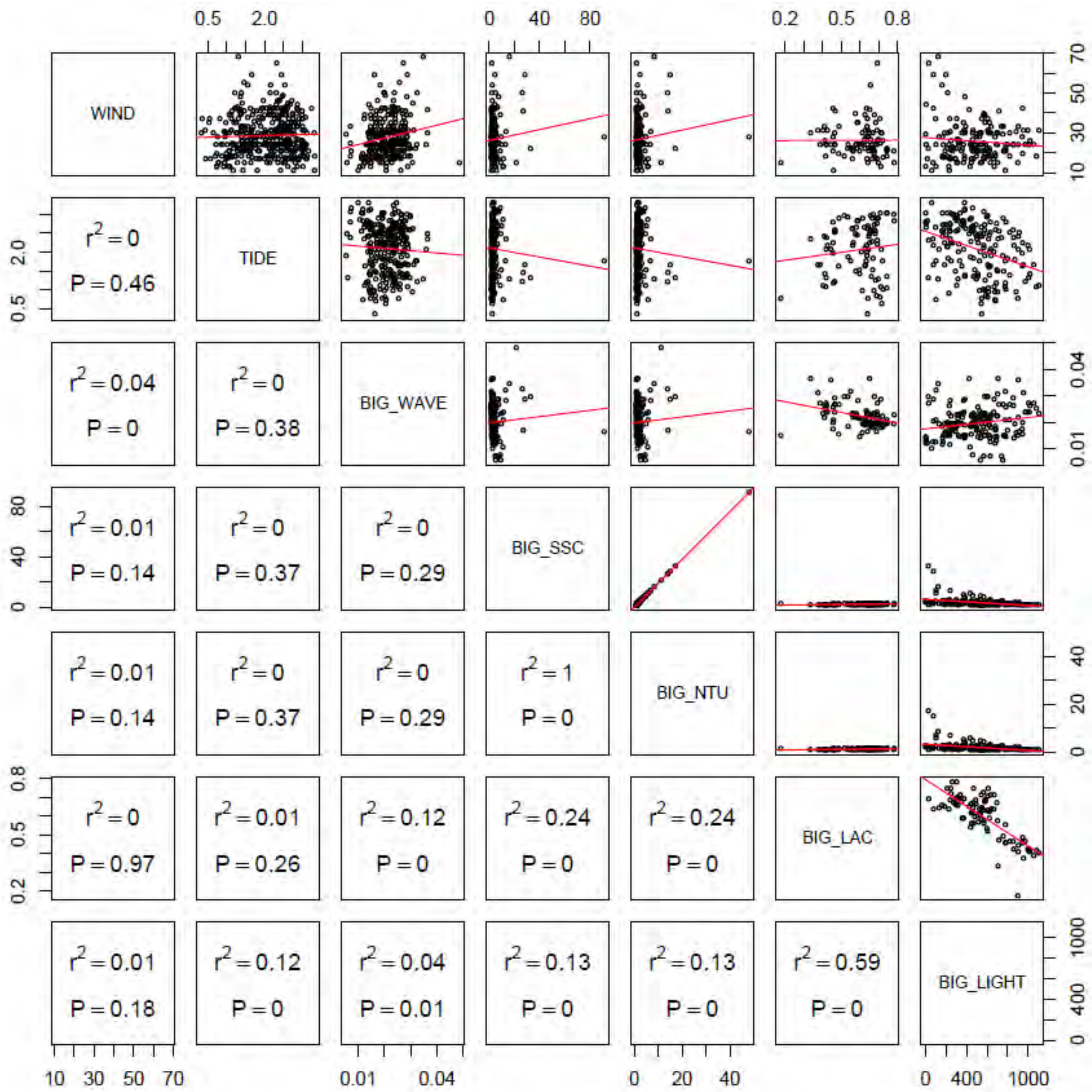


Figure 21: Relationship During the Summer Period Between Environmental and Water Quality Variables at Biggada Reef (BIG) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 8 December 2007 – 9 April 2008 and 1 November 2008 – 30 April 2009.

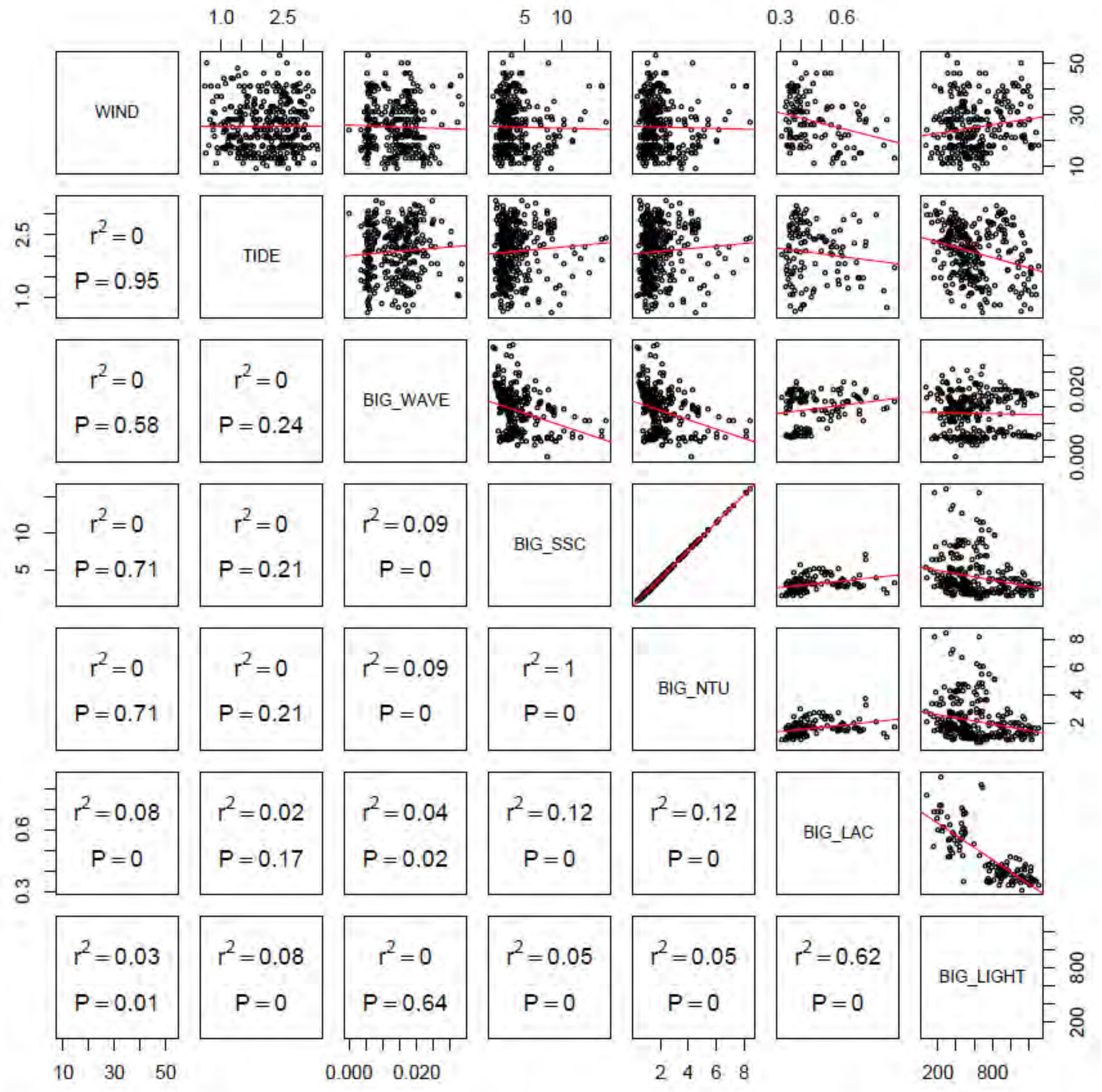


Figure 22: Relationship During the Winter Period Between Environmental and Water Quality Variables at Biggada Reef (BIG) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 2 May 2008 – 31 October 2008 and 1 May 2009 – 16 October 2009.

Site LNG3

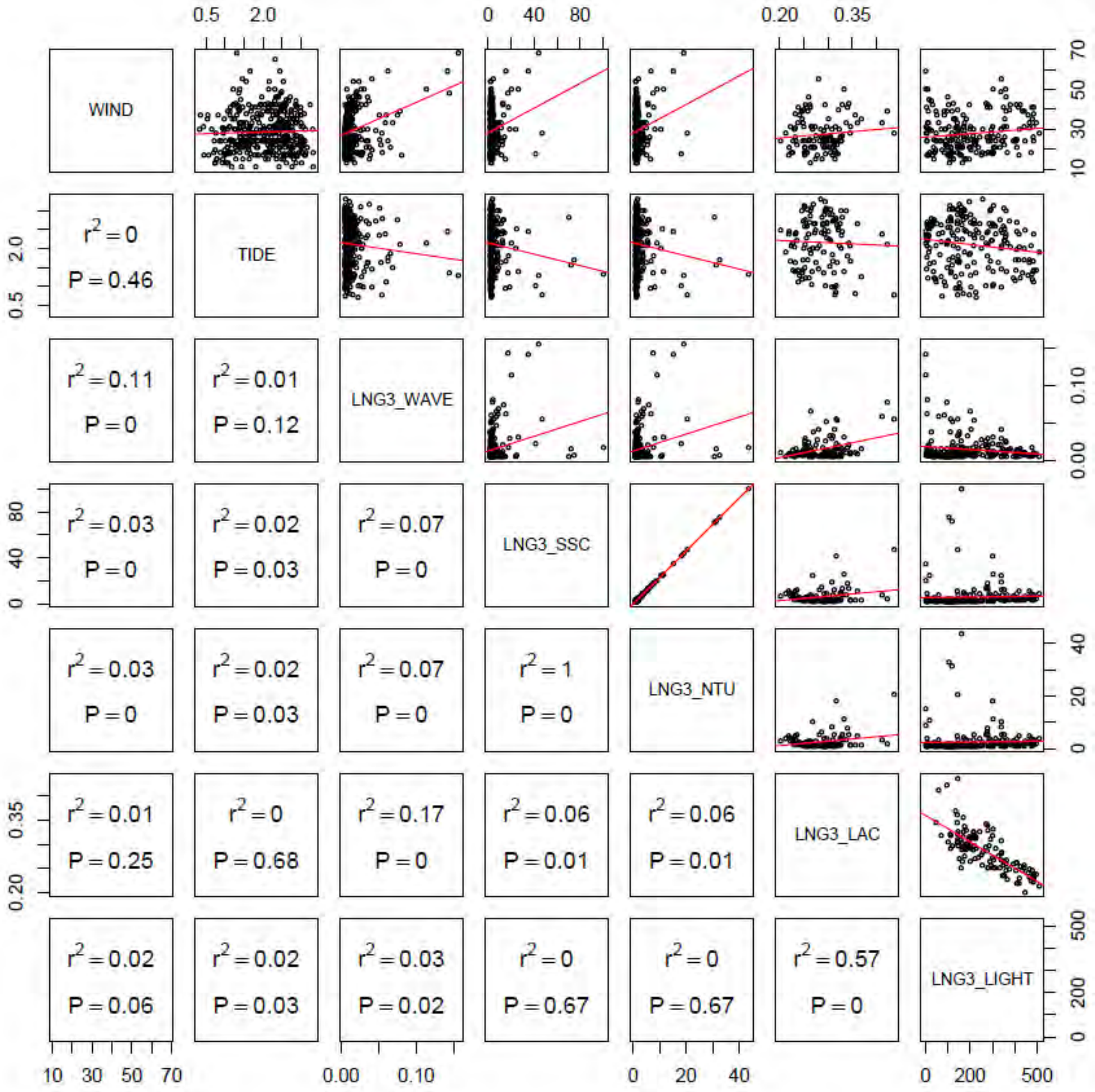


Figure 23: Relationship During the Summer Period Between Environmental and Water Quality Variables at LNG3 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 5 December 2007 – 29 March 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 28 January 2010.

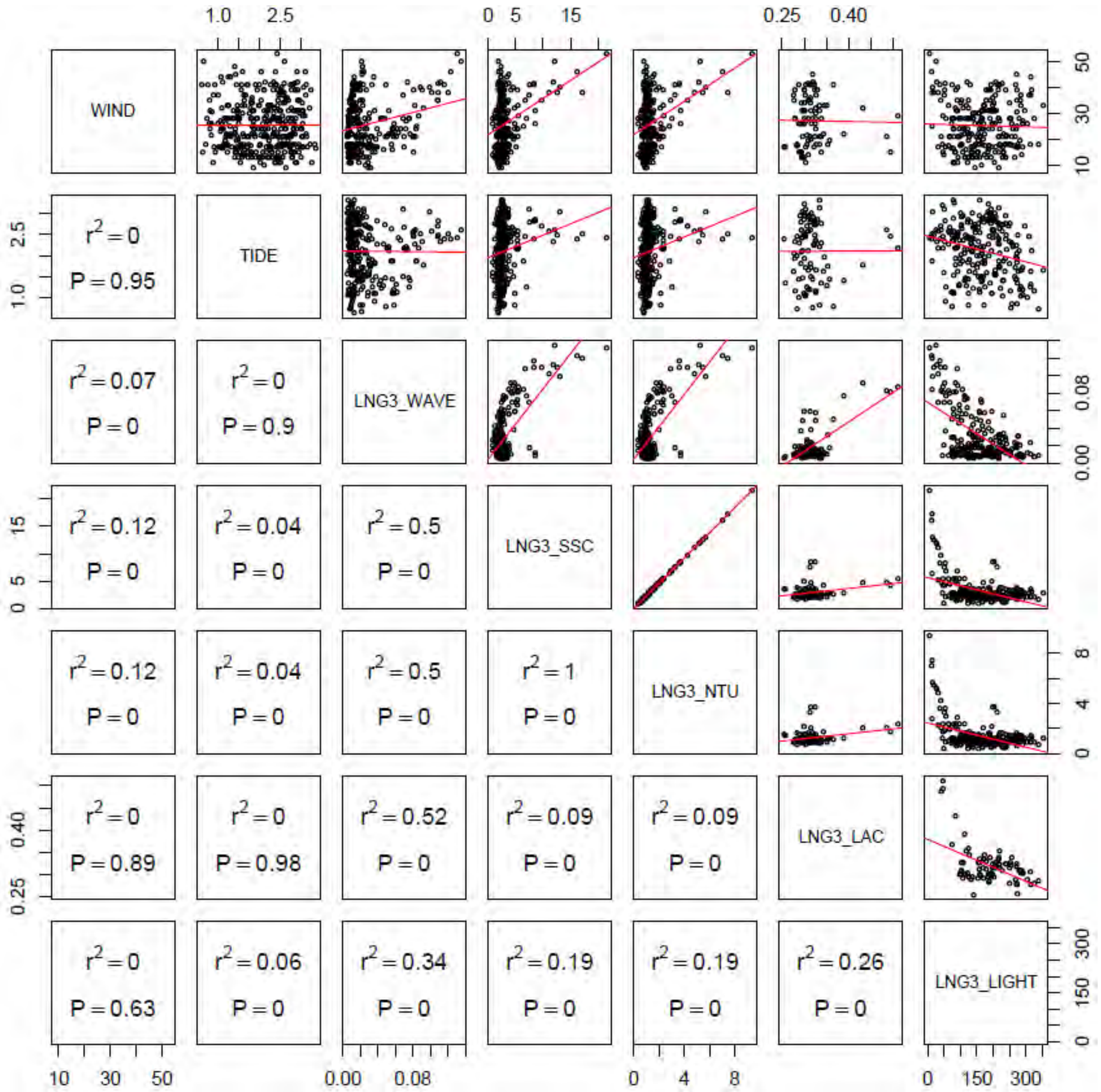


Figure 24: Relationship During the Winter Period Between Environmental and Water Quality Variables at LNG3 (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 4 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site Dugong Reef (DUG)

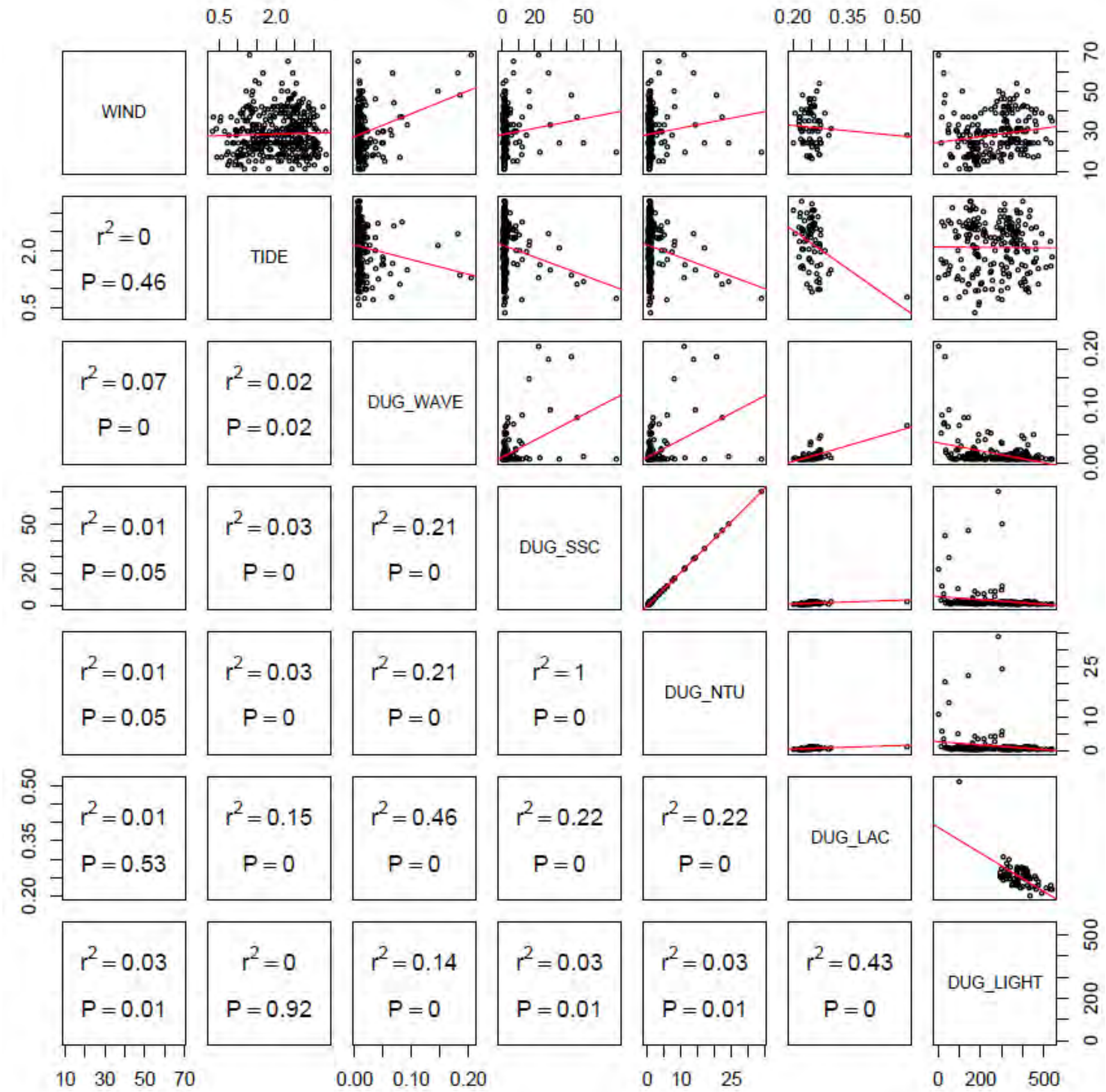


Figure 25: Relationship During the Summer Period Between Environmental and Water Quality Variables at Dugong Reef (DUG) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 4 December 2007 – 25 April 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 23 December 2009.

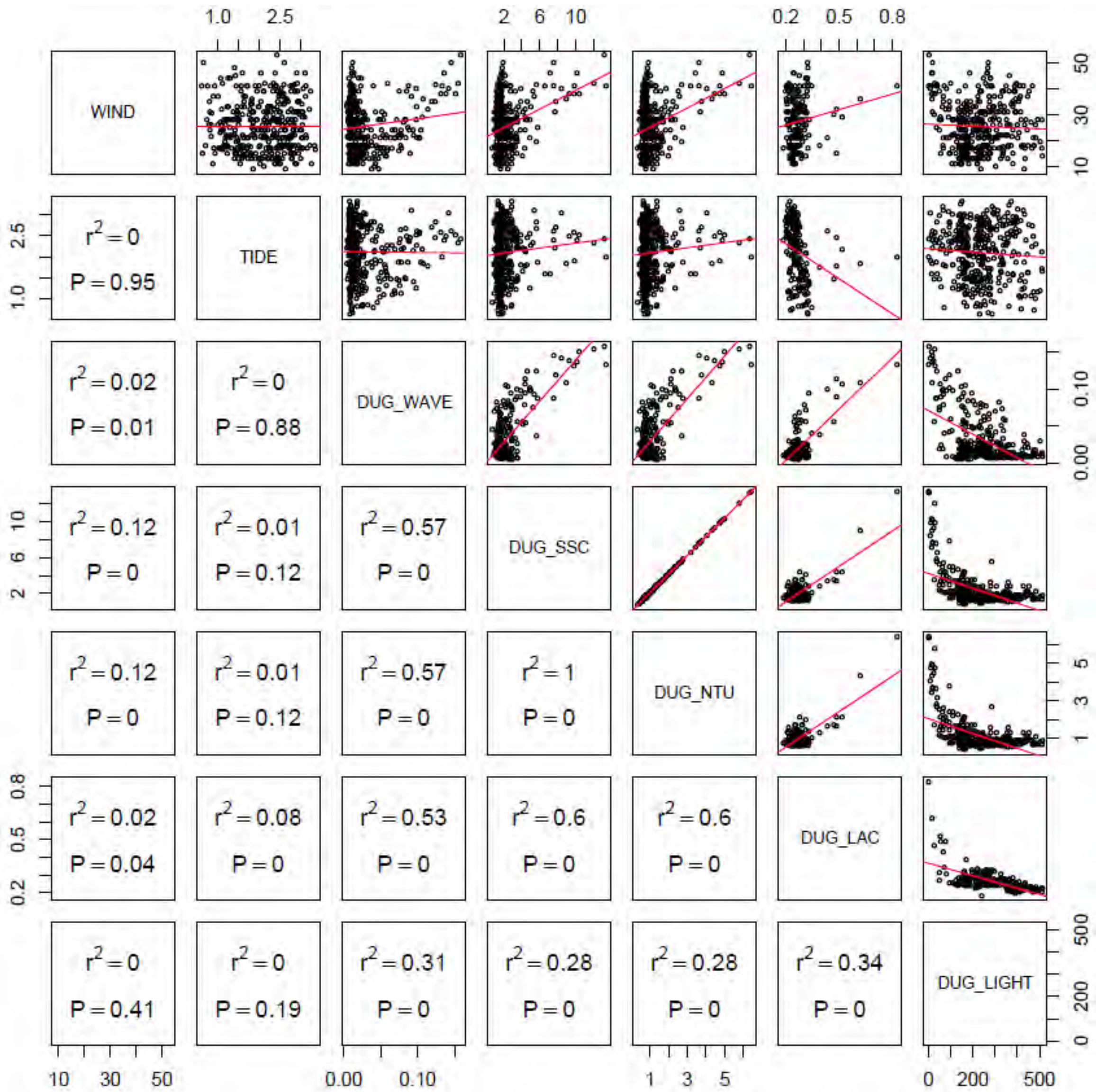


Figure 26: Relationship During the Winter Period Between Environmental and Water Quality Variables at Dugong Reef (DUG) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Site Batman Reef (BAT)

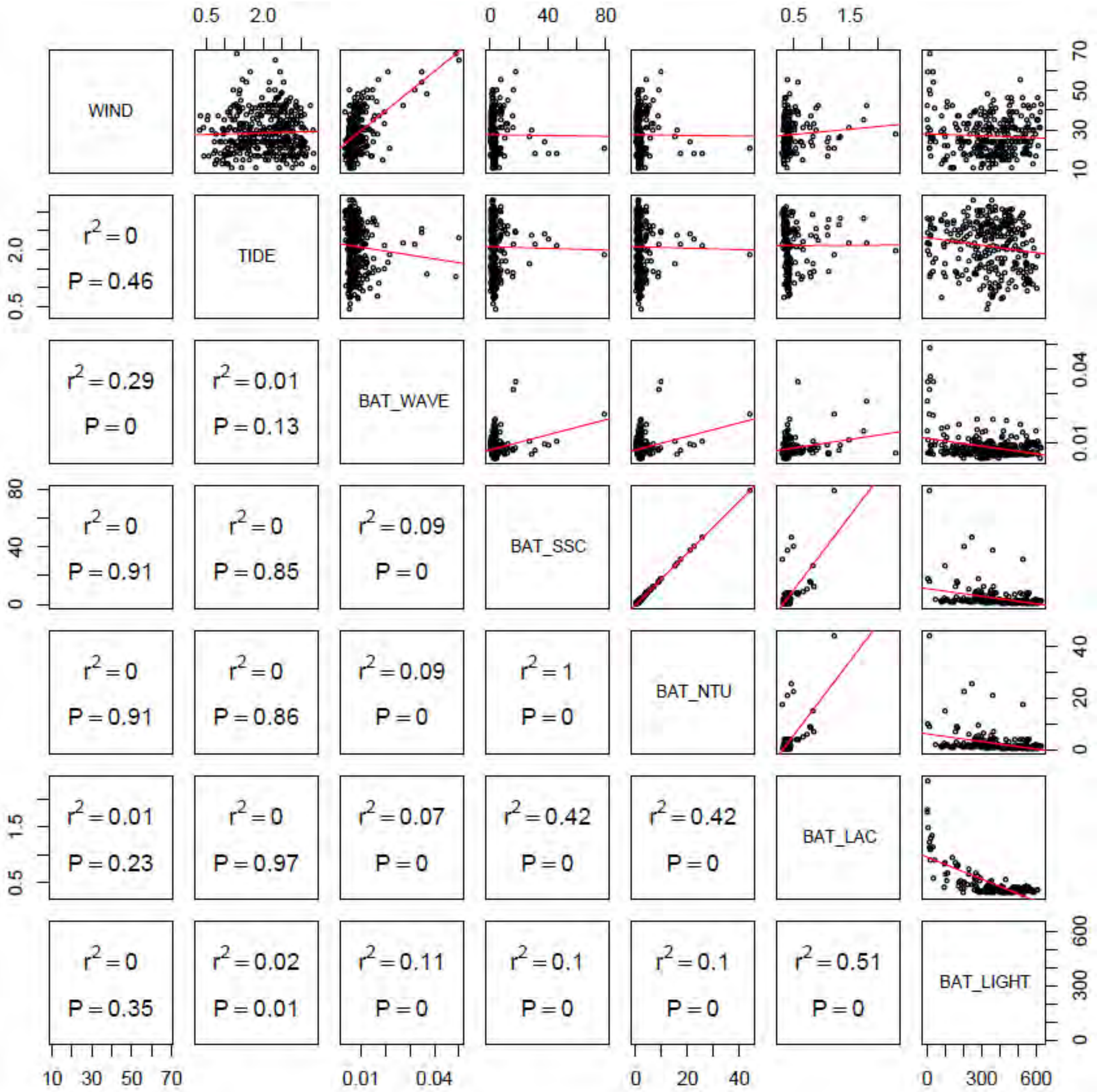


Figure 27: Relationship During the Summer Period Between Environmental and Water Quality Variables at Batman Reef (BAT) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 4 December 2007 – 30 April 2008, 1 November 2008 – 9 April 2009 and 1 November 2009 – 17 December 2009.

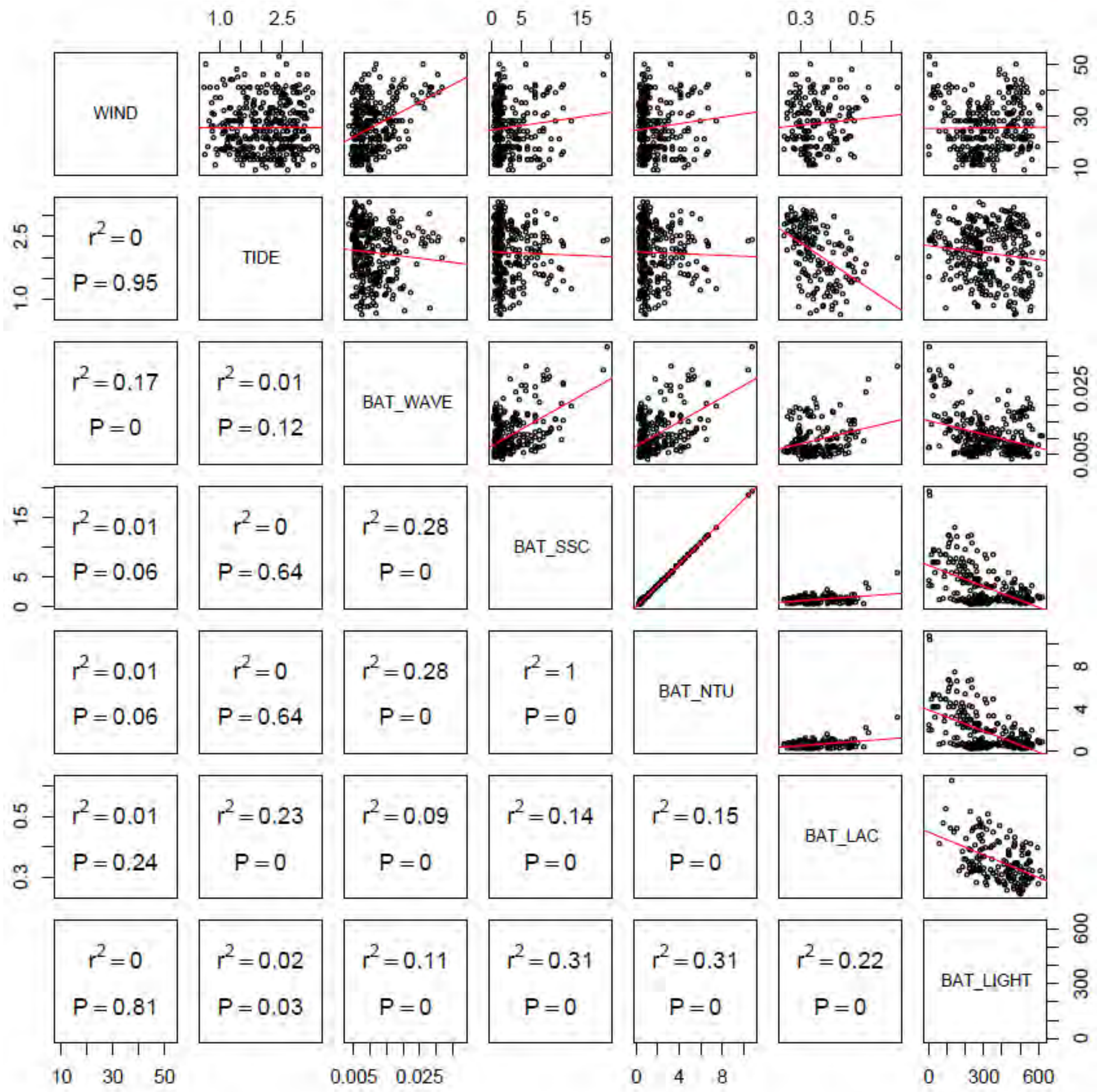


Figure 28: Relationship During the Winter Period Between Environmental and Water Quality Variables at Batman Reef (BAT) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 1 May 2008 – 31 October 2008 and 20 June 2009 – 31 October 2009.

Site Southern Barrow Shoals (SBS)

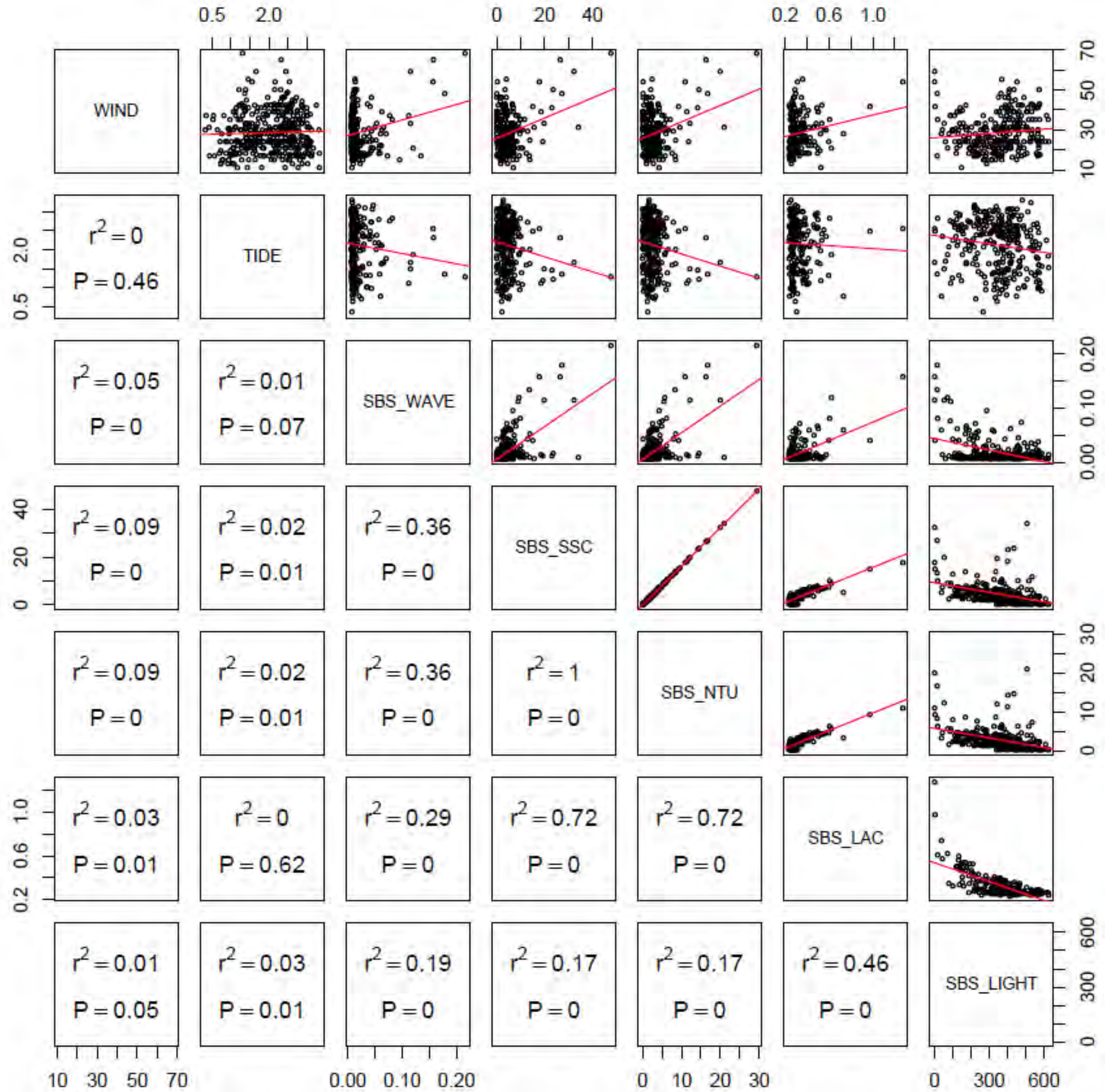


Figure 29: Relationship During the Summer Period Between Environmental and Water Quality Variables at Southern Barrow Shoals (SBS) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the summer period is represented from 7 December 2007 – 18 March 2008, 1 November 2008 – 30 April 2009 and 1 November 2009 – 22 December 2009.

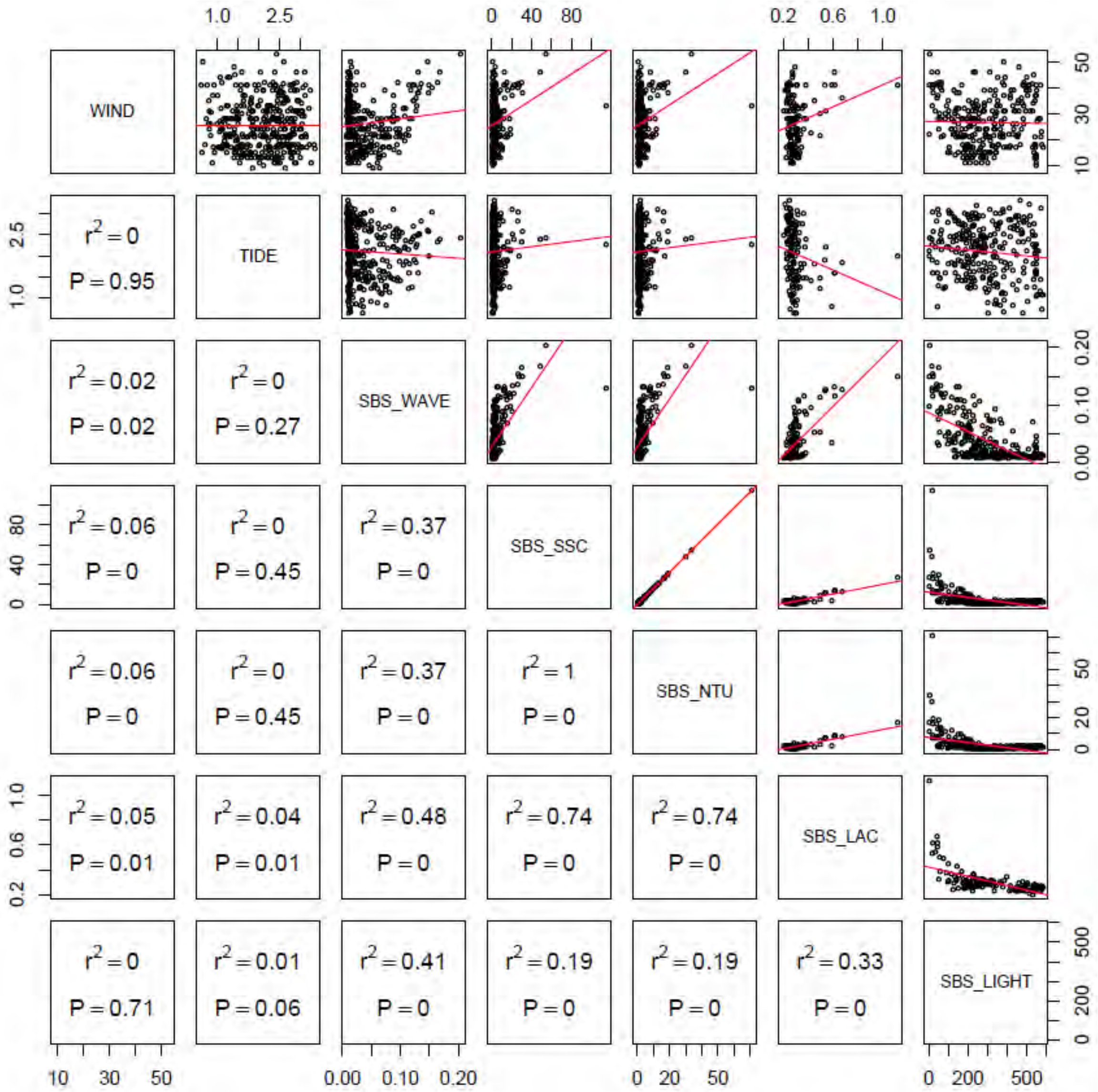


Figure 30: Relationship During the Winter Period Between Environmental and Water Quality Variables at Southern Barrow Shoals (SBS) (Scatter Plot with Trend Line, Pearson's R-squared and Level of Significance; P = 0 is Equivalent to P<0.005)

Note: Data for the winter period is represented from 4 June 2008 – 31 October 2008 and 1 May 2009 – 31 October 2009.

Appendix 13 Water Quality Summary Data

Table 1: Summary Data for Each Water Quality Monitoring Variable, Summer Period

		Zone of High Impact	Zone of Moderate Impact			Zone of Influence					Reference Sites			Regionally Significant Areas		
Summer period		**LNG0**	**MOF1**	**LONE**	**LNG1**	**ANT**	**LOW**	**MOF2**	**MOF3**	**LNG2**	**AHC**	**BIG**	**LNG3**	**DUG**	**BAT**	**SBS**
Median daily light ($\mu E.m^{-2}.s^{-1}$)	median	151.1	191.4	139.8	213.3	332.5	483.3	231.5	273.6	228.1	207.6	495.4	164.1	285.2	363.5	368.9
	5%ile	39.6	49.0	18.0	48.3	110.9	104.8	45.7	51.4	33.6	36.4	133.7	14.4	50.1	41.2	59.4
	10%ile	63.1	70.8	41.4	84.7	141.9	135.3	76.9	94.8	60.7	72.7	230.2	40.4	95.4	116.7	121.0
	20%ile	99.7	103.3	81.9	124.0	199.2	203.7	147.4	153.3	98.4	120.9	318.9	85.0	148.8	211.5	188.1
Daily LAC	median	0.26	0.33	0.26	0.22	0.34	0.35	0.30	0.33	0.27	0.32	0.63	0.30	0.25	0.37	0.29
	80%ile	0.27	0.36	0.27	0.24	0.37	0.48	0.32	0.38	0.33	0.34	0.68	0.33	0.28	0.44	0.36
	90%ile	0.30	0.40	0.30	0.26	0.40	0.59	0.35	0.41	0.35	0.37	0.71	0.34	0.31	0.53	0.44
	95%ile	0.33	0.42	0.33	0.26	0.42	0.63	0.36	0.44	0.40	0.40	0.74	0.36	0.33	0.82	0.53
Median daily turbidity (NTU)	median	0.9	1.8	0.7	1.0	0.7	1.0	1.0	1.1	0.8	0.9	1.6	1.2	0.8	1.0	2.2
	80%ile	1.2	1.9	1.4	1.4	1.3	1.6	1.1	2.6	1.1	1.8	2.3	1.6	1.2	2.4	3.9
	90%ile	1.5	3.0	1.7	2.2	1.8	2.2	1.3	3.2	1.7	4.1	3.4	3.1	1.8	4.1	5.7
	95%ile	1.9	3.7	2.6	3.7	2.5	3.3	1.5	4.4	2.3	5.3	4.6	5.0	3.7	5.6	9.3
Median daily SSC (mg/L)	median	0.8	2.4	1.6	2.7	1.1	1.6	0.8	2.1	1.5	3.0	3.0	2.7	1.7	1.9	3.6
	80%ile	1.1	2.4	3.2	3.7	1.9	2.5	0.9	5.0	2.1	5.9	4.4	3.7	2.5	4.3	6.3
	90%ile	1.4	3.6	4.0	5.9	2.7	3.5	1.0	6.2	3.1	13.3	6.4	7.1	3.8	7.3	9.2
	95%ile	1.7	4.5	6.1	10.1	3.7	5.2	1.2	8.5	4.3	17.4	8.7	11.5	7.6	10.0	15.1
Median daily wave height index (m)	median	0.009	0.008	0.013	0.010	0.008	0.015	0.012	0.009	0.010	0.014	0.021	0.012	0.008	0.007	0.011
	80%ile	0.025	0.020	0.035	0.026	0.014	0.029	0.017	0.024	0.033	0.049	0.024	0.028	0.028	0.012	0.045
	90%ile	0.045	0.027	0.067	0.054	0.017	0.037	0.024	0.038	0.059	0.092	0.027	0.055	0.061	0.016	0.080
	95%ile	0.068	0.037	0.102	0.071	0.019	0.045	0.032	0.054	0.078	0.137	0.029	0.077	0.089	0.020	0.112

Table 2: Summary Data for Each Water Quality Monitoring Variable, Winter Period

		Zone of High Impact	Zone of Moderate Impact			Zone of Influence					Reference Sites			Regionally Significant Areas		
Winter period		**LNG0**	**MOF1**	**LONE**	**LNG1**	**ANT**	**LOW**	**MOF2**	**MOF3**	**LNG2**	**AHC**	**BIG**	**LNG3**	**DUG**	**BAT**	**SBS**
Median daily light ($\mu E.m^{-2}.s^{-1}$)	median	135.2	167.7	127.6	163.8	270.6	334.3	190.5	258.0	157.3	186.9	543.3	191.6	230.9	317.3	309.8
	5%ile	32.1	53.6	23.2	30.7	113.0	100.0	40.1	81.3	29.7	38.7	226.5	51.0	53.2	31.1	53.2
	10%ile	61.6	71.1	39.5	55.2	136.8	126.3	71.3	115.4	56.8	68.5	290.0	78.2	96.6	107.8	114.8
	20%ile	88.6	102.5	63.7	93.1	187.1	159.9	107.7	165.2	86.8	112.0	350.9	112.8	149.7	192.2	172.2
Daily LAC	median	0.23	0.32	0.24	0.21	0.34	0.40	0.31	0.34	0.30	0.31	0.52	0.30	0.25	0.37	0.29
	80%ile	0.28	0.37	0.27	0.25	0.37	0.51	0.36	0.38	0.34	0.35	0.67	0.33	0.29	0.45	0.37
	90%ile	0.31	0.40	0.30	0.26	0.41	0.61	0.39	0.41	0.38	0.38	0.70	0.34	0.32	0.57	0.47
	95%ile	0.34	0.42	0.34	0.32	0.42	0.64	0.43	0.44	0.43	0.42	0.72	0.36	0.33	0.86	0.53
Median daily turbidity (NTU)	median	0.9	0.9	0.7	1.1	1.0	1.0	1.0	1.2	0.9	0.8	1.3	1.2	0.8	1.1	1.7
	80%ile	1.3	1.4	1.4	1.5	1.5	1.4	1.3	2.6	1.2	1.8	2.4	1.8	1.3	3.0	3.7
	90%ile	1.7	1.9	1.7	2.1	1.8	1.9	1.6	3.3	1.8	4.3	3.5	3.3	1.7	4.5	5.0
	95%ile	2.2	2.2	2.3	3.1	2.1	2.8	1.8	4.7	2.4	5.3	4.5	4.9	3.2	6.0	8.3
Median daily SSC (mg/L)	median	0.8	1.1	1.7	3.1	1.5	1.6	0.8	2.4	1.7	2.7	2.6	2.8	1.7	2.0	2.7
	80%ile	1.2	1.8	3.2	4.1	2.1	2.2	1.0	5.1	2.2	6.0	4.5	4.2	2.7	5.3	5.9
	90%ile	1.6	2.3	3.9	5.6	2.6	3.0	1.3	6.3	3.4	14.1	6.7	7.5	3.5	8.0	8.1
	95%ile	2.0	2.6	5.4	8.4	3.1	4.4	1.4	9.1	4.5	17.4	8.6	11.4	6.6	10.7	13.4
Median daily wave height index (m)	median	0.014	0.012	0.018	0.013	0.012	0.018	0.011	0.013	0.013	0.020	0.018	0.014	0.013	0.008	0.014
	80%ile	0.037	0.022	0.048	0.036	0.015	0.029	0.023	0.026	0.039	0.062	0.024	0.033	0.038	0.013	0.053
	90%ile	0.057	0.028	0.084	0.059	0.017	0.038	0.035	0.039	0.067	0.108	0.027	0.060	0.074	0.017	0.088
	95%ile	0.080	0.037	0.120	0.079	0.020	0.045	0.043	0.058	0.091	0.154	0.028	0.081	0.098	0.021	0.115

Appendix 14 Water Column Profile Data

Table 1: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at LNG0 and MOF1 from January 2008 to November 2009

Month	LNG0						MOF1					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)		Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	-	-	-	-	-	-	35.6	35.6	28.9	28.9	9.8	10.3
Mar-08	-	-	-	-	-	-	35.4	35.4	29.9	29.8	-	-
Jul-08	-	-	-	-	-	-	35.4	35.4	22.2	22.2	8.8	8.8
Sep-08	-	-	-	-	-	-	35.2	35.3	23.6	23.6	10.3	10.7
Oct-08	-	-	-	-	-	-	35.4	35.3	24.1	24	10.3	10.7
Jul-09	35.3	35.3	21.6	21.6	11.7	9.8	35.3	35.3	21.4	21.4	10.0	10.3
Sep-09	35.4	35.4	22.7	22.4	9.8	10.3	-	-	-	-	-	-
Oct-09	35.2	35.4	24.9	24.4	10.3	10.3	35.3	35.2	25.6	25.3	10.7	10.3
Nov-09	35.3	35.3	26.6	26.3	11.7	12.2	35.6	35.6	27.6	27.1	11.2	11.7
Dec-09	35.2	35.2	27.7	27.0	9.3	9.8	-	-	-	-	-	-

Table 2: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at Lone Reef (LONE) and LNG1 from January 2008 to November 2009

Month	Lone Reef (LONE)						LNG1					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)		Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	35.1	35.1	28.1	28.0	9.3	9.8	-	-	-	-	-	-
Mar-08	35.2	35.3	30.1	29.8	-	-	-	-	-	-	-	-
May-08	35.0	35.0	28.8	28.6	9.8	9.8	-	-	-	-	-	-
Jul-08	35.5	35.5	22	21.8	8.3	9.8	35.5	35.4	22.0	22.0	8.8	9.8
Sep-08	-	-	-	-	-	-	35.1	35.1	24.4	23.6	9.8	10.3
Oct-08	35.0	35.1	24.2	24.0	10.3	10.3	35.1	35.1	24.3	24.2	11.7	10.3
Jun-09	35.5	35.5	24.4	24.3	10.7	10.7	-	-	-	-	-	-
Jul-09	35.3	35.3	21.7	21.6	10.3	10.3	35.2	35.2	21.9	21.9	10.7	10.3
Aug-09	35.5	35.5	22.0	21.6	9.3	9.8	-	-	-	-	-	-
Sep-09	35.3	35.3	22.4	22.4	9.8	9.8	-	-	-	-	-	-

Table 3: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at Ant Point Reef (ANT) and Southern Lowendal Shelf (LOW) from January 2008 to November 2009

Month	Ant Point Reef (ANT)						Southern Lowendal Shelf (LOW)					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)		Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	-	-	-	-	-	-	35.1	35.1	28.2	28.1	9.3	9.8
Mar-08	35.2	35.2	30.1	30.1	-	-	-	-	-	-	-	-
Jul-08	-	-	-	-	-	-	35.5	35.5	21.6	21.6	9.8	9.3
Sep-08	35.2	35.2	23.9	23.9	10.4	10.3	35.1	35.1	24.3	24.3	9.8	9.8
Oct-08	35.4	35.4	23.7	23.7	10.7	10.7	35.2	35.2	25.1	25	11.2	10.7
Nov-08	35.8	35.8	23.1	23.1	11.2	11.7	35.5	35.6	24.8	23.7	13.2	12.7
Jun-09	35.5	35.5	24.3	24.3	10.2	10.2	-	-	-	-	-	-
Aug-09	-	-	-	-	-	-	35.4	35.5	22.2	21.7	9.3	9.3
Sep-09	-	-	-	-	-	-	35.2	35.2	23.0	23.0	11.7	10.3
Oct-09	35.3	35.3	24.6	24.6	12.7	10.3	-	-	-	-	-	-
Nov-09	-	-	-	-	-	-	35.5	35.5	26.7	26.6	10.7	9.8

Table 4: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at MOF2 and MOF3 from January 2008 to November 2009

Month	MOF2						MOF3					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)		Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	-	-	-	-	-	-	35.4	35.5	29.0	28.8	9.8	10.3
Mar-08	-	-	-	-	-	-	35.4	35.4	29.8	29.8	-	-
Sep-08	35.4	35.4	23.6	23.3	10.3	10.3	35.4	35.4	22.8	22.8	10.3	10.3
Oct-08	-	-	-	-	-	-	35.2	35.2	23.9	23.9	10.7	10.7
Jun-09	-	-	-	-	-	-	35.5	35.5	24.1	24.1	9.8	10.7
Jul-09	-	-	-	-	-	-	35.3	35.3	21.4	21.4	9.8	10.3
Sep-09	35.4	35.4	22.3	22.3	9.8	9.3	35.4	35.5	22.4	22.2	9.3	9.8
Nov-09	-	-	-	-	-	-	35.5	35.5	26.2	26.2	10.7	10.3

Table 5: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at LNG2 and Ah Chong (AHC) from January 2008 to November 2009

Month	LNG2						Ah Chong (AHC)					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)		Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	35.3	35.3	28.4	28.3	9.3	9.8	35.1	35.1	28.5	28.4	9.3	9.8
Mar-08	35.4	35.4	29.5	29.5	-	-	35.2	35.3	29.9	29.5	-	-
May-08	35.1	35.1	29.0	28.4	9.3	10.3	35.0	35.1	29.2	29.0	9.8	9.8
Jul-08	35.5	35.5	22.0	22.0	9.1	9.8	-	-	-	-	-	-
Sep-08	35.1	35.2	23.8	23.5	10.3	10.3	35.1	35.1	23.6	23.5	9.3	10.3
Nov-08	-	-	-	-	-	-	35.2	35.2	24.6	24.2	11.7	11.7
Jun-09	35.5	35.5	24.2	24.2	9.8	10.3	35.3	35.3	23.0	23.1	9.8	9.8
Jul-09	35.2	35.2	22.3	21.9	10.3	10.3	-	-	-	-	-	-
Oct-09	-	-	-	-	-	-	35.1	35.1	24.3	24.5	9.8	10.3

Table 6: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at Biggada Reef (BIG) and LNG3 from January 2008 to November 2009

Month	Biggada Reef (BIG)						LNG3					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)		Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	35.1	35.0	29.7	28.5	9.8	9.8	35.4	35.4	28.9	28.8	9.3	9.8
Mar-08	35.1	35.1	29.8	29.4	-	-	35.1	35.2	30.3	29.9	-	-
May-08	-	-	-	-	-	-	35.1	35.2	28.7	28.5	9.8	10.3
Jun-08	34.9	34.9	26.6	26.6	10.3	9.8	35.3	35.3	23.0	22.7	9.8	9.8
Jul-08							35.4	35.4	22.2	22.2	8.8	8.8
Sep-08	35.1	35.1	23.4	23.4	10.7	11.2	35.3	35.3	23.6	23.2	10.7	10.3
Oct-08	35.1	35.1	24.5	24.3	11.2	11.7	-	-	-	-	-	-
Nov-08	-	-	-	-	-	-	35.5	35.5	24.6	24.3	11.2	11.7
Jun-09	-	-	-	-	-	-	35.5	35.6	24.1	24.0	9.8	10.3
Aug-09	35.1	35.1	22.4	22.5	10.9	10.7	35.5	35.6	21.6	21.3	8.8	9.8
Sep-09	-	-	-	-	-	-	35.4	35.4	22.4	22.3	9.8	9.8

Table 7: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at Dugong Reef (DUG) and Batman Reef (BAT) from January 2008 to November 2009

Month	Dugong Reef (DUG)						Batman Reef (BAT)					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)		Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	35.4	35.4	30.7	29.0	10.3	9.8	35.5	35.5	30.1	30.0	9.3	10.7
Mar-08	35.3	35.3	29.8	29.6	-	-	35.2	35.2	30.6	30.5	-	-
May-08	35.3	35.2	25.4	25.4	9.8	9.8	35.2	35.2	28.1	28.1	9.8	10.7
Jun-08	-	-	-	-	-	-	35.3	35.3	25.5	25.5	9.8	9.8
Sep-08	35.3	35.3	23.5	23.4	10.3	9.8	35.4	35.4	24.0	24.0	10.3	10.3
Oct-08	-	-	-	-	-	-	35.2	35.2	25.2	25.1	10.3	10.3
Nov-08	35.6	35.6	24.1	23.8	11.7	11.7	-	-	-	-	-	-
Jun-09	-	-	-	-	-	-	35.6	35.5	22.0	22.0	9.8	10.3
Jul-09	35.3	35.3	22.2	22.2	10.7	10.3	35.4	35.4	21.9	21.9	9.8	10.3
Aug-09	-	-	-	-	-	-	35.6	35.6	21.5	21.5	9.8	9.8
Sep-09	35.5	35.5	22.0	21.9	9.8	9.8	35.6	35.6	22.0	22.0	10.3	9.8
Oct-09	-	-	-	-	-	-	35.7	35.7	23.4	23.3	10.3	10.3
Nov-09	-	-	-	-	-	-	35.6	35.6	26.8	26.8	11.2	11.7

Table 8: Surface (~1 m below) and Near-seabed (~0.5 m above) Physicochemical Water Quality Data from Vertical Profiles Undertaken at Southern Barrow Shoals (SBS) from January 2008 to November 2009

Month	Southern Barrow Shoals					
	Salinity (PSU)		Temperature (degrees C)		Turbidity (NTU)	
	Near-surface	Near-seabed	Near-surface	Near-seabed	Near-surface	Near-seabed
Jan-08	35.9	35.9	29.7	29.6	10.7	10.3
Mar-08	35.3	35.3	30.0	29.9	-	-
Jul-08	35.7	35.7	21.2	21.2	9.3	8.8
Sep-08	35.5	35.5	23.5	23.5	10.7	10.7
Oct-08	35.5	35.5	23.6	23.6	10.3	10.3
Jun-09	35.7	35.7	23.9	23.9	10.7	10.7
Jul-09	35.5	35.5	21.1	21.1	10.3	10.3
Oct-09	36.5	36.5	23.5	23.5	10.3	10.3
Nov-09	35.7	35.7	25.5	25.5	9.8	10.3

Appendix 15 Compliance reporting

Table 1: Commitments from the Marine Baseline Report Revision 3

Section No.	Action identified in previous Revisions of the Marine Baseline Report	Timing	Current Status
2.3.2	The Marine Disturbance Footprint relevant to the west coast Marine Facilities will be determined in subsequent revisions of the Marine Baseline Report and other relevant plans.	Prior to construction of west coast Marine Facilities	**Completed.** Refer to the Gorgon Gas Development and Jansz Feed Gas Pipeline Coastal and Marine Baseline State and Environmental Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing (Chevron Australia 2011; G1-NT-PLNX0002749)
6.3.2.1.2	Quantitative assessment of live coral cover will involve the analysis of photo-quadrats along transects using the software program Coral Point Count with Excel extensions (CPCe) to assess percentage composition of assemblages. The results from these surveys will be presented in a Supplementary Report to the Marine Baseline Report.	Prior to commencement of dredging and spoil disposal activities	**Completed.** Refer to the Gorgon Gas Development and Jansz Feed Gas Pipeline Coastal and Marine Baseline State and Environmental Impact Report Supplement: Area of Coral Assemblages (Chevron Australia 2010; G1-NT-PLNX0002539)
13.3.1.1	One LTD logger was deployed at the HDD site on the west coast of Barrow Island in May 2009. The water quality results from this site will be reported in the next revision of the Marine Baseline Report.	Prior to construction of west coast Marine Facilities	**Completed.** Refer to the Gorgon Gas Development and Jansz Feed Gas Pipeline Coastal and Marine Baseline State and Environmental Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing (Chevron Australia 2011; G1-NT-PLNX0002749)
13.3.3.1	Twelve LTD loggers were deployed in December 2007 (Table 13.3). The LTD logger at MOF2 was deployed in April 2008, the logger at LNG1 in July 2008, and the logger at LNG0 in January 2009. The logger at the HDD site was deployed in May 2009. More than one complete annual cycle of water quality data has been collected at 15 of the monitoring sites. Note that data collection is ongoing and additional baseline results will be presented in the next revision of the Marine Baseline Report.	Mid-2010	**Completed.** Refer to the Gorgon Gas Development and Jansz Feed Gas Pipeline Coastal and Marine Baseline State and Environmental Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing (Chevron Australia 2011; G1-NT-PLNX0002749)

Section No.	Action identified in previous Revisions of the Marine Baseline Report	Timing	Current Status
13.3.3.5	Sediment traps remain in situ for ongoing data collection and additional baseline results will be presented in the next revision of the Marine Baseline Report.	Mid-2010	**Completed.** Refer to the Gorgon Gas Development and Jansz Feed Gas Pipeline Coastal and Marine Baseline State and Environmental Impact Report (Chevron Australia 2011; G1-NT-PLNX0001838)