Gorgon Gas Development and Jansz Feed Gas Pipeline

Post-Development Coastal and Marine State and Environmental Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing, Year 2: 2014

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Terms, Definitions, and Abbreviations

Terms, definitions, and abbreviations used in this document are listed below. These align with the terms, definitions and abbreviations defined in Schedule 2 of the Western Australian Gorgon Gas Development and Jansz Feed Gas Pipeline Ministerial Implementation Statements No. 800 and No. 769 respectively (Statement No. 800 and 769) and the Commonwealth Gorgon Gas Development and Jansz Feed Gas Pipeline Ministerial Approvals (EPBC Reference: 2003/1294, 2008/4178, and 2005/2184).

#	Number
|r|	Absolute value of the correlation coefficient
ABU	Australasia Business Unit
ANOVA	Analysis of Variance, which is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables. In its simplest form, ANOVA gives a statistical test of whether the means of several groups are all equal.
ARI	Assessment on Referral Information (for the proposed Jansz Feed Gas Pipeline dated September 2007) as amended or supplemented from time to time.
Assemblage	An organism group of interacting populations, e.g. fish assemblage.
At risk	Being at risk of Material Environmental Harm or Serious Environmental Harm and/or, for the purposes of the EPBC Act relevant listed threatened species, threatened ecological communities and listed migratory species at risk of Material Environmental Harm or Serious Environmental Harm.
BACI	Before-After-Control-Impact
Baseline	Baseline data presented in the Coastal and Marine Baseline State and Environmental Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing (CMBSEIR:OFGPS; Chevron Australia 2014a). All baseline data used for comparison between baseline and post-development conditions within this Report are the same as those used in the FGPDSY1 Report.
Benthic	Living upon or in the seabed
Benthic Cover	The composition of benthic categories (e.g. coral, seagrass, macroalgae, sediment, rock) expressed as a percentage of the total benthic categories
Benthic Habitats	Areas of the seabed that support living organisms. Examples include limestone pavement, reefs, sand, and soft sediments
Biomass	The total mass or amount of living organisms in a particular area or volume
Biota	All the plant and animal life of a particular region

Biotic	Of or relating to living organisms
BRUV	Baited Remote Underwater Video system
CAP	Canonical Analysis of Principal Coordinates
Carbon Dioxide (CO_2) Injection System	The mechanical components required to be constructed to enable the injection of reservoir carbon dioxide, including but not limited to compressors, pipelines, and wells
CMBSEIR	Coastal and Marine Baseline State and Environmental Impact Report
CMBSEIR:OFGPS	Coastal and Marine Baseline State and Environmental Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing (Chevron Australia 2014a)
CO_2	Carbon dioxide
Commonality	The degree to which a species is observed universally across all samples or areas. In the surveys presented in this Report, it is measured as the percentage of deployments where a species was observed. Distinct from relative abundance.
Construction	Construction includes any Proposal-related (or action-related) construction and commissioning activities within the Terrestrial and Marine Disturbance Footprints, excluding investigatory works such as, but not limited to, geotechnical, geophysical, biological and cultural heritage surveys, baseline monitoring surveys, and technology trials.
Coral	Marine organisms from the class Anthozoa that exist as small sea-anemone-like polyps, typically in colonies of many identical individuals. Includes 'hard corals' within the order Scleractinia which secrete calcium carbonate to form a hard skeleton and form reefs; and 'Soft corals' within the order Alcyonacea, which have no hard skeleton and are not considered reef-building organisms.
Coral assemblages	Benthic areas (minimum 10 m^2) or raised areas over which the average live coral cover is equal to or greater than 10%, as described in Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178.
CPCe	Coral Point Count with Excel extensions (software for the determination of coral cover from photographs)
DEC	Former Western Australian Department of Environment and Conservation (now Parks and Wildlife)
Demersal	Living on the seabed or just above the seabed
Detected change	The standard scientific practice of defining a detected change as one that is statistically significant (Legendre and Legendre 2012) is applied throughout this Report. As such, any change to ecological elements that is found to be statistically significant is reported as a detected change.
DEWHA	Former Commonwealth Department of the Environment, Water, Heritage and the Arts (now DotE)

df	Degrees of freedom
DISTLM	Distance-based linear modelling
Dominant	Most common in terms of percent cover or numbers of individuals, depending on the growth form of organisms (relating to the following ecological elements: macroalgae, seagrass, non-coral benthic macroinvertebrates, and demersal fish).
DotE	Commonwealth Department of the Environment (formerly DEWHA and SEWPaC)
Ecological Element	Element listed in listed in Condition 15.1 of Statement No. 769 and Condition 12.2 of Statement No. 769.
EIS/ERMP	Environmental Impact Statement/Environmental Review and Management Programme (for the Proposed Gorgon Gas Development dated September 2005) as amended or supplemented from time to time.
Environmental Harm	Has the meaning given by Section 3A of the *Environmental Protection Act 1986* (WA).
EP Act	Western Australian *Environmental Protection Act 1986*
EPA	Western Australian Environmental Protection Authority
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPBC Reference: 2003/1294	Commonwealth Ministerial Approval (for the Gorgon Gas Development) as amended or replaced from time to time.
EPBC Reference: 2005/2184	Commonwealth Ministerial Approval (for the Jansz Feed Gas Pipeline) as amended or replaced from time to time.
EPBC Reference: 2008/4178	Commonwealth Ministerial Approval (for the Revised Gorgon Gas Development) as amended or replaced from time to time.
EPCM	Engineering, Procurement and Construction Management
EventMeasure (Stereo)	A software package used for processing stereo-BRUV imagery, particularly counting the maximum number of fish (MaxN) and measuring the lengths of fish. EventMeasure (Stereo) incorporates the superseded PhotoMeasure and EventMeasure software versions as used in the CMBSEIR:OFGPS (Chevron Australia 2014a).
Feed Gas Pipeline	Pipeline from the wells to the Gas Treatment Plant on Barrow Island
FGPDSY1	Post-Development Coastal and Marine State and Environment Impact Report: Survey Year 1 for the Offshore Feed Gas Pipeline System and marine component of the shore crossing; consistent with the approved Scope of Works (RPS 2009, amended 2012) or as agreed upon by the Western Australian Department of Parks and Wildlife (Parks and Wildlife) on 14 October 2014.

FGPDSY2	Post-Development Coastal and Marine State and Environmental Impact Report: Survey Year 2 for the Offshore Feed Gas Pipeline System and marine component of the shore crossing; consistent with the approved Scope of Works (RPS 2009, amended 2014) or as agreed upon by the Western Australian Department of Parks and Wildlife (Parks and Wildlife) on 14 October 2014.
FL	Fork Length
Frac-out	Caused when drilling fluid pressure exceeds ground strength, typically resulting in drilling mud rupturing to the surface (ground or seabed) and collapse of the drill hole.
F-statistic	The (pseudo) F-statistic is the statistical basis used to determine the p-value which indicates the level of confidence in a PERMANOVA test result. The F-statistic is represented as ‘F(x,y)’ where x and y are component and total degrees of freedom (as per Anderson *et al*. 2008).
g	Gram
GDA	Geocentric Data of Australia
Gorgon Gas Development	The Gorgon Gas Development as approved under Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178 as amended or replaced from time to time.
GPS	Global Positioning System
GTP	Gas Treatment Plant
ha	Hectare
Habitat	The area or areas in which an organism and/or assemblage of organisms lives. It includes the abiotic factors (e.g. substrate and topography) and the biotic factors.
HDD	Horizontal Directional Drilling, a trenchless installation process by which a pipeline is installed beneath obstacles or sensitive areas.
HES	Health, Environment, and Safety
Hydrotest	Method whereby water is pressurised within pipes and vessels to detect leaks
Impact Site	Site that may potentially (but not necessarily) be impacted by the OFGPS
Interaction term	An effect of interaction occurs when a relation between at least two variables is modified by at least one other variable. In other words, the strength or the sign (direction) of a relation between at least two variables is different depending on the value (level) of some other variable(s) (StatSoft 2012).
ISO	International Organization for Standardization

IvR	A comparison of data collected from Impact (potential impact) and Reference Sites.
Jansz Feed Gas Pipeline	The Jansz Feed Gas Pipeline as approved in Statement No. 769 and EPBC Reference: 2005/2184 as amended or replaced from time to time.
JPEG	A commonly used method of lossy compression for digital images; developed by the Joint Photographic Experts Group
km	Kilometre
KS	Kolmogorov-Smirnov
LNG	Liquefied Natural Gas
m	Metre
m^2	Square metre
Macroalgae	Benthic marine plants that are non-flowering and lack roots, stems, and vascular tissue; can be seen without the aid of a magnification; includes large seaweeds.
Macroinvertebrates	An invertebrate animal (an animal without a backbone [vertebral column]) large enough to be seen without the aid of magnification; includes sponges, crinoids, hydroids, sea pens, sea whips, gorgonians, snails, clams, crayfish, and sea cucumbers
Marine Disturbance Footprint	The area of the seabed to be disturbed by construction or operations activities associated with the Marine Facilities listed in Condition 14.3 of Statement No. 800 and Condition 12.3 of Statement No. 769 and Condition 11.3 in EPBC Reference: 2003/1294 and 2008/4178 (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and dredge spoil disposal) and as set out in this Report.
Marine Facilities	In relation to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178, the Marine Facilities are the: • Materials Offloading Facility (MOF) • LNG Jetty • Dredge Spoil Disposal Ground • Offshore Feed Gas Pipeline System (in State Waters) and marine component of the shore crossing (OFGPS) • Domestic Gas Pipeline. Condition 14.3 of Statement No. 800 relates only to components of the Marine Facilities within State Waters (i.e. specifically the Offshore Feed Gas Pipeline System). For the purposes of Statement No. 800 Marine Facilities also include: • Marine upgrade of the existing WAPET Landing. In relation to Statement No. 769, Marine Facilities are the Offshore Feed Gas Pipeline System and marine component of the shore crossing.

Marine Facilities Footprint	The area of seabed associated with the physical footprint of the Marine Facilities, but excluding the area of the seabed disturbed by dredging an dredge spoil disposal, or for example, by anchoring
Material Environmental Harm	Has the meaning given by Section 3A of the *Environmental Protection Act 1986* (WA)
MaxN	Maximum number of fish belonging to each species, present in the field of view of the stereo-BRUVs at any single time
MBACI	Multiple Before–After, Control–Impact statistical design
MDF	*See* Marine Disturbance Footprint
MEG	Monoethylene glycol
MGA 50, GDA 94	Map Grid of Australia Zone 50 (WA); projection based on the Geocentric Datum of Australia 1994
mm	Millimetre
MOF	Materials Offloading Facility
Motile	Capable of movement
MS	Mean squares
MTPA	Million Tonnes Per Annum
Multivariate	Multiple variables; refers to a form of statistical analysis
n/a	Not applicable
Nearshore	Close to shore; or within 30 nautical miles of Barrow Island
nm	Nautical miles
NS	Not sampled/surveyed
OE	Operational Excellence
OEMS	Operational Excellence Management System

Offshore pipe laying	Offshore pipe laying is the installation of the Offshore Feed Gas Pipeline System, with the potential to affect the marine environment in State Waters, comprising: • installation of the Gorgon and Jansz Production pipelines, Monoethylene Glycol (MEG) pipelines, and Utility pipelines from the HDD shore crossing at North Whites Beach to the State Waters boundary (three nautical miles) • installation of Gorgon and Jansz umbilicals from the HDD shore crossing at North Whites Beach to the State Waters boundary (three nautical miles) • stabilisation of the offshore pipelines and umbilicals by rock dumping to the State Waters boundary (three nautical miles).
OFGPS	Offshore Feed Gas Pipeline System (in State Waters) and marine component of the shore crossing
Operations (Gorgon Gas Development)	In relation to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178, for the respective LNG trains, this is the period from the date on which the Gorgon Joint Venturers issue a notice of acceptance of work under the Engineering, Procurement and Construction Management (EPCM) contract, or equivalent contract entered into in respect of that LNG train of the Gas Treatment Plant; until the date on which the Gorgon Joint Venturers commence decommissioning of that LNG train.
Operations (Jansz Feed Gas Pipeline)	In relation to Statement No. 769, for the pipeline, this is the period from the date on which the Proponent issues a notice of acceptance of work under the Engineering, Procurement and Construction Management (EPCM) contract, or equivalent contract entered into in respect of that pipeline; until the date on which the Proponent commences decommissioning of that pipeline.
Orthogonal	In statistical analysis, the property that every level of one factor is present in the experiment in combination with every level of the other factor (or combinations of levels) (Underwood 1997).
P(MC)	p-value based on Monte Carlo bootstrapping
P(perm)	p-value generated via permutations
Parks and Wildlife	Western Australian Department of Parks and Wildlife (formerly DEC)
Pavement	Areas of flat hard substrate or large bare rocks on the seabed
PCO	Principal Coordinate Ordination
PER	Public Environmental Review for the Gorgon Gas Development Revised and Expanded Proposal dated September 2008, as amended or supplemented from time to time.
PERMANOVA	Permutational Multivariate Analysis of Variance
PERMDISP	Distance-based test for homogeneity of multivariate dispersions

Photoquadrat	A camera attached to a rectangle or square measuring frame to photograph a fixed area (quadrat) of seabed and associated living things in a given area
Photoquadrat image	An image captured using a camera attached to a rectangle or square measuring frame to photograph a fixed area (quadrat) of seabed and associated living things in a given area
Pooling	In ANOVA, pooling refers to the bundling of variance estimates from terms positioned lower in the model with terms positioned higher in the model. Pooling often improves the power of the test to detect a significant effect for the higher term. Test power is improved because pooling effectively increases replication (and thus degrees of freedom) in the higher term.
Practicable	Practicable means reasonably practicable having regard to, among other things, local conditions and circumstances (including costs) and to the current state of technical knowledge. For the purposes of the conditions of EPBC Reference: 2003/1294 and 2008/4178 that include the term 'practicable', when considering whether the draft plan meets the requirements of these conditions, the Commonwealth Minister will determine what is 'practicable' having regard to local conditions and circumstances including but not limited to personnel safety, weather or geographic conditions, costs, environmental benefit, and the current state of scientific and technical knowledge.
PRIMER	Plymouth Routines in Multivariate Ecological Research; a statistical analysis software package
Pseudo-F	F-statistic generated via permutations
p-value	In statistical hypothesis testing, the probability of obtaining a result at least as extreme as the one that was actually observed, assuming that the null hypothesis is true
QA/QC	Quality Assurance/Quality Control
Quadrat	A rectangle or square measuring area used to sample living things in a given site; can vary in size
R^2	Coefficient of determination
Reference Sites	Specific areas of the environment that are not at risk of being affected by the proposal or existing developments, that can be used to determine the natural state, including natural variability, of environmental attributes such as coral health or water quality
Relative Abundance	The abundance of a species within a given sample. In this Report, it is measured as MaxN. This measure is semi-quantitative and relative between samples as the unit of area measured is not strictly defined. Different to commonality.
Scleractinian	Corals that have a hard limestone skeleton and belong to the order Scleractinia

Scope of Works	The approved Scope of Works (RPS 2009, amended 2014) as required by Condition 12.1 of Statement No. 769
SE	Standard Error
Seagrass	Benthic marine plants that have roots, stems, leaves, and inconspicuous flowers with fruits and seeds much like terrestrial flowering plants. Unrelated to seaweed.
Serious Environmental Harm	Has the meaning given by Section 3A of the *Environmental Protection Act 1986* (WA)
Sessile	Permanently attached directly to the substrate by its base (i.e. immobile); without a stalk or stem
Significant (statistically)	The statistical significance of a result is an estimate of the degree to which it is true (in the sense of representative of the population) as indicated by the p-value.
sp. (plural: spp.)	Species
Spatial	Relating to space
Spoil Disposal Ground	The area where dredged and excavation material is to be disposed of at sea
SS	Sum of squares
State Waters	The marine environment within three nautical miles of the coast of Barrow Island or the mainland of Western Australia
Statement No. 748	Western Australian Ministerial Implementation Statement No. 748 (for the Gorgon Gas Development) as amended from time to time [superseded by Statement No. 800].
Statement No. 769	Western Australian Ministerial Implementation Statement No. 769 (for the Jansz Feed Gas Pipeline) as amended from time to time.
Statement No. 800	Western Australian Ministerial Implementation Statement No. 800 (for the Gorgon Gas Development) as amended from time to time.
Statement No. 865	Western Australian Ministerial Implementation Statement No. 865 (for the Gorgon Gas Development) as amended from time to time.
Statement No. 965	Western Australian Ministerial Implementation Statement No. 965, issued for the Additional Support Area, as amended from time to time. Statement No. 965 applies the conditions of Statement 800 to the Additional Support Area.
Statistical Power	The probability of detecting a meaningful difference, or effect, if one were to occur
Stereo-BRUVs	Baited Remote Underwater Stereo-Video systems

Subdominant	Other common taxa in terms of percent cover or numbers, depending on the growth form of organisms (relating to these ecological elements: macroalgae, seagrass, mangroves, benthic macroinvertebrates, and fish)
Substrate	The surface a plant or animal lives upon. The substrate can include biotic or abiotic materials. For example, encrusting algae that lives on a rock can be substrate for another animal that lives above the algae on the rock.
Surficial	Of or pertaining to the surface
TAPL	Texaco Australia Pty Ltd
Taxon (plural: taxa)	A taxon (plural taxa), or taxonomic unit, designates an organism or a group of organisms.
Temporal	Relating to, or limited by, time
Transect	The path along which a researcher moves, counts, and records observations
Transformation	ANOVA-style tests require that a number of assumptions are met prior to analysis: that samples are drawn from normally distributed data and the level of variance between samples is homogenous. Sample datasets are required to meet these assumptions so ANOVA techniques may be applied without risk of error. Transformation of data, via square-root or log functions (among several others), is undertaken in an effort to meet these assumptions (Fowler and Cohen 1990).
Treatments	Statistical treatment of data; refers to comparison between sites at risk of Material or Serious Environmental Harm and Reference Sites
t-test	A statistical test to determine whether the difference between two sample means is statistically significant
Turbidity	The cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.
Type I error	In statistical terms, a Type I error occurs when a statistical test concludes there is a significant difference between means, when there is in fact no difference (i.e. conclusion of change when actually 'no change' has occurred).
Type II error	In statistical terms, a Type II error occurs when a statistical test concludes there are no significant differences between means, when there is a difference (i.e. conclusion of 'no change' when change has actually occurred).
Type III sums of squares	The sums of squares obtained by fitting each effect after all the other terms in the model, i.e. the sums of squares for each effect corrected for the other terms in the model.
Umbilicals	Connections between topside equipment and subsea equipment

Univariate	Single variables; refers to a form of statistical analysis
Vessel	Craft of any type operating in the marine environment including hydrofoil boats, air-cushion vehicles, submersibles, floating craft, and fixed or floating platforms; also includes seaplanes when present on and in the water
WA	Western Australia
WAPET	West Australian Petroleum Pty Ltd.
WAPET Landing	Proper name referring to the site of the barge landing existing on the east coast of Barrow Island prior to the date of Statement No. 800.
Waters Surrounding Barrow Island	Refers to the waters of the Barrow Island Marine Park and Barrow Island Marine Management Area (approximately 4169 ha and 114 693 ha respectively) as well as the port of Barrow Island representing the Pilbara Offshore Marine Bioregion, which is dominated by tropical species that are biologically connected to more northern areas by the Leeuwin Current and the Indonesian Throughflow, resulting in a diverse marine biota is typical of the Indo–West Pacific flora and fauna.
West Coast Marine Facilities	In relation to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178, the West Coast Marine Facilities are the: • Offshore Feed Gas Pipeline System (in State Waters) and marine component of the shore crossing. Condition 14.3 of Statement No. 800 relates only to components of the Marine Facilities within State Waters (i.e. specifically the Offshore Feed Gas Pipeline System). In relation to Statement No. 769, Marine Facilities are the • Offshore Feed Gas Pipeline System and marine component of the shore crossing.
α	Alpha; the significance level of a statistical hypothesis test, expressed as a proportion. Also the probability of making a Type I error. Alpha is traditionally set at 0.05.

Executive Summary

This Post-Development Coastal and Marine State and Environment Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing, Year 2: 2014 (FGPDSY2 Report) has been prepared to meet the requirements of Condition 15.3 of Ministerial Implementation Statement No. 769 (Statement No. 769). The FGPDSY2 was undertaken to meet Condition 14.4(vi) of Statement No. 769 and Condition 23.5(iv) of Statement No. 800 and results from the FGPDSY2 will be reported in the annual report for the Offshore Feed Gas Pipeline Installation Management Plan.

The objectives of this Report are to determine any detected changes resulting from offshore pipe laying of the Offshore Feed Gas Pipeline System (in State Waters) and marine component of the shore crossing (hereafter referred to as OFGPS) on non-coral benthic macroinvertebrates, macroalgae, seagrass, and demersal fish, and report these results to the Minister.

The pre-development baseline marine environmental state of non-coral benthic macroinvertebrates, macroalgae, seagrass, and demersal fish is documented in the Coastal and Marine Baseline State and Environmental Impact Report: OFGPS (CMBSEIR:OFGPS; Chevron Australia 2014a), referred to in this Report as the Baseline.

The Baseline was designed to include sites on the west coast of Barrow Island that are potentially at risk of Material or Serious Environmental Harm due to the construction and operation of the OFGPS (i.e. those sites situated in the Marine Disturbance Footprint [MDF][1]), as well as Reference Sites that are not at risk of Material or Serious Environmental Harm due to the construction and operation of these Marine Facilities.

This is the second Post-Development Survey undertaken since completing offshore pipe laying for the OFGPS. The first survey—the Post-Development Coastal and Marine State and Environment Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing, Year 1: 2013 (FGPDSY1; Chevron Australia 2014b)—was undertaken in October/November 2013, between two and three months after completion of offshore pipe laying. In the assessment of detected change in ecological elements between the Baseline and Post-Development Surveys, the results from FGPDSY1 and FGPDSY2 are included in this Report.

Non-coral Benthic Macroinvertebrates

Non-coral benthic macroinvertebrates were surveyed in November 2014 (one year after FGPDSY1) at four sites within the MDF and at four Reference Sites.

Twenty-two taxonomic groups were recorded across all sites during FGPDSY2 compared with 19 taxonomic groups in the Baseline. Fifteen taxonomic groups were common between the Baseline and FGPDSY2. The dominant taxonomic groups were similar between the Baseline and FGPDSY2 and comprised tunicates, cnidarians, echinoderms, and poriferans. Within the MDF, 60% of the dominant taxonomic groups in FGPDSY2 were shared with those in the Baseline, while at the Reference Sites, 70% of the dominant taxonomic groups in FGPDSY2 were shared with those in the Baseline.

No detected change was observed in the abundance or composition of non-coral benthic macroinvertebrates at MDF or Reference Sites from before to after offshore pipe laying.

[1] The Jansz Feed Gas Pipeline Marine Disturbance Footprint is as defined in Statement No. 769 and described in the CMBSEIR:OFGPS as the area of the seabed to be disturbed by construction or operations activities associated with the OFGPS. All MDF Sites presented in this Report are considered at risk of Material or Serious Environmental Harm.

Macroalgae

Macroalgae were surveyed in November 2014 (one year after FGPDSY1) at four sites within the MDF and at four Reference Sites.

The number of macroalgal taxa recorded was higher in FGPDSY2 (115 taxa) than in the Baseline (59 taxa). The diversity of all algal divisions was also higher in FGPDSY2, with Rhodophyta containing the highest number of taxa in both the Baseline and FGPDSY2. No sites had the same taxa (or suite of taxa) dominating the macroalgal flora during both the Baseline and FGPDSY2, although at some sites a subset of taxa was common between the two surveys. The green alga *Halimeda discoidea* was the only species found at all sites, but four brown algae of the division Heterokontophyta (*Hormophysa cuneiformis*, *Lobophora variegata*, *Sargassum* sp., *Sporochnus comosus*) were found at all sites except HDD4 in the MDF. A previously undescribed taxon was collected during FGPDSY2, which was provisionally assigned the name *Dudresnaya barrowense*.

No significant differences in macroalgal percent cover and macroalgal and seagrass combined biomass were recorded between the Baseline and FGPDSY2 at either the MDF Sites or Reference Sites. Although not statistically significant, macroalgal percent cover at MDF Sites was higher in FGPDSY2 (7.8%) compared with FGPDSY1 (2.4%), but still below the Baseline (11.9%). At the Reference Sites, macroalgal percent cover was higher in FGPDSY2 (42.7%) compared with the Baseline (18.2%) and FGPDSY1 (18.9%), although these changes were not statistically significant. The (non-significant) large increase in macroalgal percent cover at the Reference Sites during FGPDSY2 resulted in a statistically significant difference being detected between the MDF and Reference Sites in FGPDSY2.

Although there was some evidence to suggest that offshore pipe-laying activities may have resulted in a detected change in macroalgae at the MDF Sites between the Baseline and FGPDSY1, a significant increase in macroalgal percent cover was recorded between FGPDSY1 and FGPDSY2 within the MDF and no significant differences in macroalgal percent cover and macroalgal and seagrass combined biomass were recorded between the Baseline and FGPDSY2 within the MDF.

Seagrass

Seagrass was surveyed in November 2014 (one year after FGPDSY1) at four sites within the MDF and at four Reference Sites.

The number of seagrass taxa recorded across all survey sites was lower in FGPDSY2 (two taxa) than in the Baseline (four taxa), and the two taxa recorded during FGPDSY2 (*Halophila ovalis* and *Syringodium isoetifolium*) were also recorded during the Baseline. No significant differences in seagrass percent cover were detected at MDF or Reference Sites among survey years or between MDF and Reference Sites within survey years.

A significant difference was detected in macroalgal and seagrass combined biomass between the MDF and Reference Sites in FGPDSY2, but not between FGPDSY2 and the Baseline within the MDF, indicating a site-specific difference rather than an impact of the OFPGS. Additionally, seagrass is extremely sparse on both the west and east coasts of Barrow Island, and any changes in macroalgal and seagrass combined biomass is more indicative of changes in macroalgal biomass rather than seagrass.

Because no significant differences were detected in seagrass percent cover among MDF and Reference Sites, there is no evidence to suggest that offshore pipe-laying activities resulted in any detectable change in seagrass communities within the MDF Sites between the Baseline and FGPDSY2.

Demersal Fish

Demersal fish were surveyed in October/November 2014 (one year after FGPDSY1) at four sites within the MDF and at eight Reference Sites.

In FGPDSY2, a total of 2162 individuals from 120 species and 36 families were recorded from the 60 stereo-BRUVs deployments, with an average of 9.1 ± 1.1 species observed on each deployment.

No changes were detected in the total number of individuals, species richness, fish length, or abundance of dominant species within macroalgal habitat at MDF Sites between the Baseline and FGPDSY2.

However, there was a statistically significant change (decrease) in fish assemblages at Reference Sites from the Baseline to FGPDSY1 and FGPDSY2 that was not observed at MDF Sites. These changes were investigated further to determine whether they were indicative of a potential impact and/or natural temporal variability. None of the species that were investigated individually showed statistically significant changes between surveys at Reference Sites. Therefore, the detected change in the overall fish assemblage at Reference Sites was likely to have resulted from a combination of natural temporal variation, and the significant differences between Reference and MDF Sites that were detected for species richness and some species when tested individually. The species richness was found to be significantly greater at macroalgal MDF Sites than at Reference Sites during FGPDSY1, but during FGPDSY2, species richness at MDF and Reference Sites in macroalgal habitat was again similar. This change is consistent with a positive pulse response to pipeline construction followed by a return to Baseline levels. No changes were detected in the fish assemblage length distributions between the MDF and Reference Sites or among surveys.

Two species were significantly more abundant at sand/sessile invertebrates MDF Sites during FGPDSY1 and FGPDSY2 than during the Baseline. These were the sand/sessile invertebrate dominant species *Nemipterus* spp. (Threadfin Bream) and *Carangoides fulvoguttatus* (Gold-spotted Trevally). These species are mobile, and are associated with reef habitat, or with sand areas close to the reef. Their increase in abundance may reflect the creation of a new benthic habitat (rock armour) through installation of the OFGPS.

Conclusions and Recommendations

Summary of Findings for each Ecological Element for FGPDSY2

Ecological Element	Conclusions
Non-coral Benthic Macroinvertebrates	• No change was detected in the abundance or composition of non-coral benthic macroinvertebrates at MDF or Reference Sites between the Baseline and Post-Development Surveys.
Macroalgae	• The number of macroalgal taxa recorded, and the diversity of all algal divisions, was higher in FGPDSY2 than in the Baseline. The dominant and subdominant macroalgal taxa were variable at most sites between surveys. These changes are likely to reflect natural variation and were not likely to be associated with offshore pipe-laying activities. • No significant differences in macroalgal percent cover and macroalgal and seagrass combined biomass were detected between the Baseline and FGPDSY2 within the MDF and at the Reference Sites, but a large increase in macroalgal percent cover at the Reference Sites during FGPDSY2 resulted in significant differences being detected between the MDF and Reference Sites in FGPDSY2. Although there was some evidence to suggest that offshore pipe-laying activities may have resulted in a detected change in macroalgae at the MDF Sites between the Baseline and FGPDSY1, a significant increase in macroalgal percent cover was recorded between FGPDSY1 and FGPDSY2, resulting in no detectable difference in macroalgal percent cover and macroalgal and seagrass combined biomass at MDF Sites between the Baseline and FGPDSY2. Therefore, if the detected changes between the Baseline and FGPDSY1 were an impact of offshore pipe-laying activities, these changes were only temporary, with a return to a state with no detectable difference to Baseline levels by FGPDSY2.

Ecological Element	Conclusions
Seagrass	• Dominant seagrass taxa remained the same between the Baseline and FGPDSY2. • No change in seagrass percent cover was detected at MDF or Reference Sites among survey years or between MDF and Reference Sites within survey years. • A significant difference was detected in macroalgal and seagrass combined biomass between the MDF and Reference Sites in FGPDSY2, but not between FGPDSY2 and the Baseline within the MDF. There was little seagrass in the combined macroalgal and seagrass biomass samples, so this difference reflects changes in macroalgal biomass rather than seagrass biomass. • Because no significant difference was detected in seagrass percent cover among MDF and Reference Sites, there is no evidence to suggest that offshore pipe-laying activities resulted in any change in seagrass within the MDF between the Baseline and FGPDSY2.
Demersal Fish	• No changes in total number of individuals, species richness, fish length, or abundance of dominant species within macroalgal habitat were detected at MDF Sites between the Baseline and FGPDSY2. • Detected changes (decrease) in relative abundance of the overall fish assemblage were observed at Reference Sites from the Baseline to FGPDSY1 and FGPDSY2, but were not observed at MDF Sites. However, none of the species that were investigated individually showed statistically significant changes between surveys at Reference Sites. • Species richness was found to be significantly greater at macroalgal MDF Sites than at Reference Sites during FGPDSY1, but during FGPDSY2, species richness at MDF and Reference Sites in macroalgal habitat was again similar. This detected change may indicate a positive ‘pulse’ response to pipeline construction followed by a return to Baseline levels. • Sand/sessile invertebrate dominant species *Nemipterus* spp. (Threadfin Bream) and *Carangoides fulvoguttatus* (Gold-spotted Trevally) were significantly more abundant at sand/sessile invertebrate MDF Sites during FGPDSY1 and FGPDSY2 than during the Baseline; likely due to the creation of an additional benthic habitat (rock armour) through installation of the OFGPS.

Although some minor changes in ecological elements were detected between the Baseline and FGPDSY1 at MDF Sites, by FGPDSY2 ecological elements appear to have returned to a state where there is no detectable difference to Baseline levels. The only potential remaining effects of the OFGPS at sites within the MDF are i) an increased abundance of two demersal fish species potentially as a result of increased habitat complexity (rock armour), and ii) minor differences in macroalgal cover and biomass when compared to Reference Sites, which may have been caused by natural spatial or temporal variation and may not be project-attributable.

This is the second Post-Development Survey undertaken since completing offshore pipe-laying activities for the OFGPS. Condition 14.4(vi) of Statement No. 769 requires three Post-Development Surveys for the OFGPS, unless otherwise determined by the Minister. In light of the evidence presented in this Report, further surveys to monitor recovery will be of limited usefulness. Already, minor impacts that may have been associated with the OFGPS on ecological elements detected in FGPDSY1 were not detected in FGPDSY2, and any remaining effects (i.e. increased presence of two demersal fish species) are likely to persist over time due to the increased habitat complexity created by the rock armour.

1.0 Introduction

This Post-Development Coastal and Marine State and Environment Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing, Year 2: 2014 (FGPDSY2 Report) is specific to the requirements of Condition 15 of Statement No. 769, relating to the Jansz Feed Gas Pipeline. However, the Gorgon and Jansz Feed Gas Pipelines were installed simultaneously and as such, impacts from offshore pipe laying cannot be distinguished between the Gorgon and Jansz offshore pipe-laying activities.

1.1 Proponent

Chevron Australia Pty Ltd (Chevron Australia) is the proponent and the person taking the action for the Gorgon Gas Development on behalf of the following companies (collectively known as the Gorgon Joint Venturers):

- Chevron Australia Pty Ltd
- Chevron (TAPL) Pty Ltd
- Shell Development (Australia) Pty Ltd
- Mobil Australia Resources Company Pty Limited
- Osaka Gas Gorgon Pty Ltd
- Tokyo Gas Gorgon Pty Ltd
- Chubu Electric Power Gorgon Pty Ltd

pursuant to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178.

Chevron Australia is also the proponent and the person taking the action for the Jansz Feed Gas Pipeline on behalf of the Gorgon Joint Venturers, pursuant to Statement No. 769 and EPBC Reference: 2005/2184.

1.2 Project

Chevron Australia is developing the gas reserves of the Greater Gorgon Area (Figure 1-1).

Subsea gathering systems and subsea pipelines are being installed to deliver feed gas from the Gorgon and Jansz–Io gas reserves to the west coast of Barrow Island. The feed gas pipeline system is buried as it traverses from the west coast to the east coast of Barrow Island where the system ties in to the Gas Treatment Plant (GTP) located at Town Point. The GTP will comprise three Liquefied Natural Gas (LNG) trains capable of producing a nominal capacity of five Million Tonnes Per Annum (MTPA) per train. The GTP will also produce condensate and domestic gas. Carbon dioxide (CO_2), which occurs naturally in the feed gas, will be separated during the treatment process. As part of the Gorgon Gas Development, Chevron Australia will inject the separated CO_2 into deep formations below Barrow Island. The LNG and condensate will be loaded from a dedicated jetty offshore from Town Point and then transported by dedicated carriers to international markets. Gas for domestic use will be exported by a pipeline from Town Point to the domestic gas collection and distribution network on the mainland (Figure 1-2).

1.3 Location

The Gorgon gas field is located approximately 130 km and the Jansz–Io field approximately 200 km off the north-west coast of Western Australia . Barrow Island is located off the Pilbara coast 85 km north-north-east of Onslow and 140 km west of Karratha. Barrow Island is approximately 25 km long and 10 km wide and covers 23 567 ha. It is the largest of a group of islands, including the Montebello and Lowendal Islands.

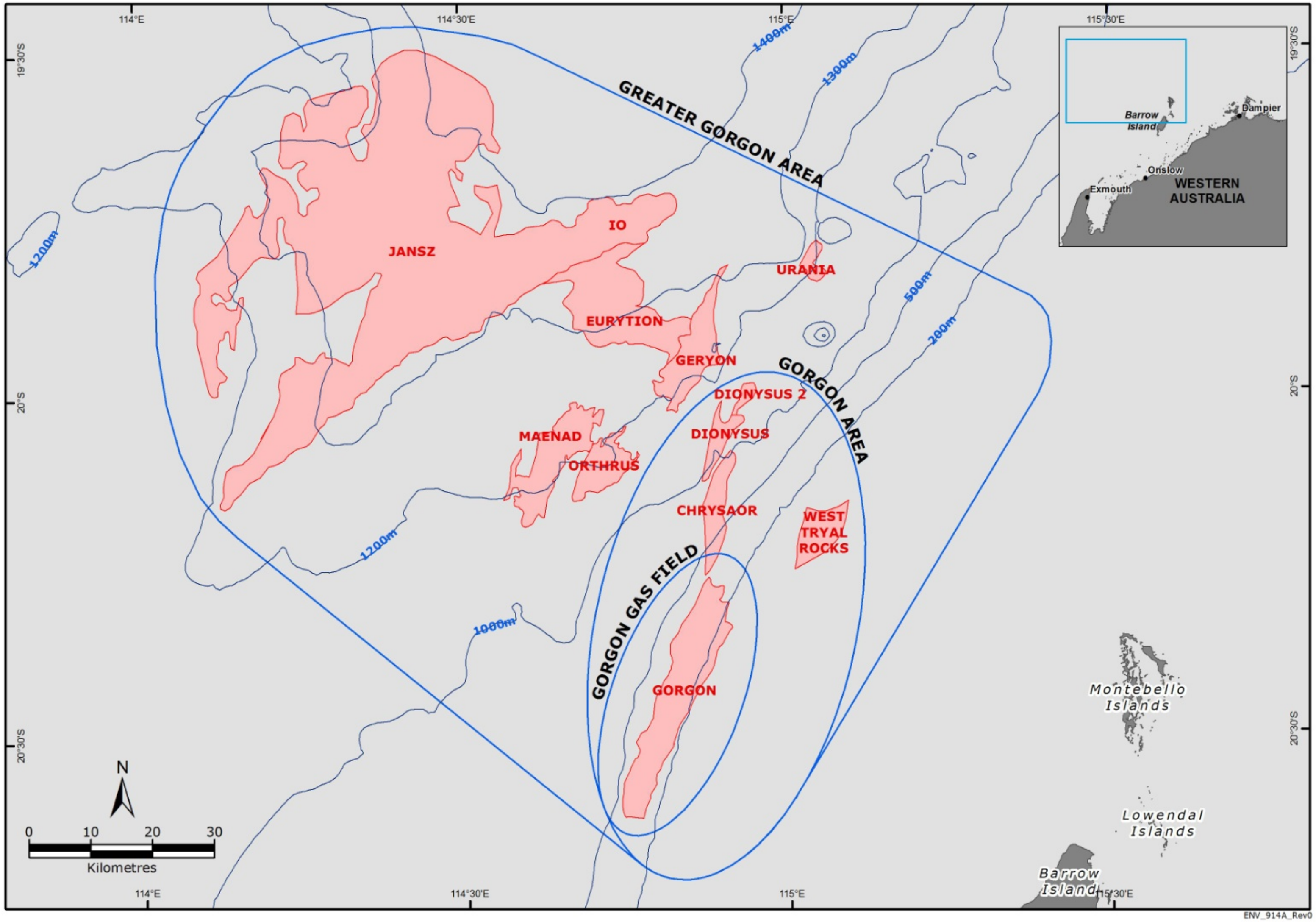


Figure 1-1 Location of the Greater Gorgon Area

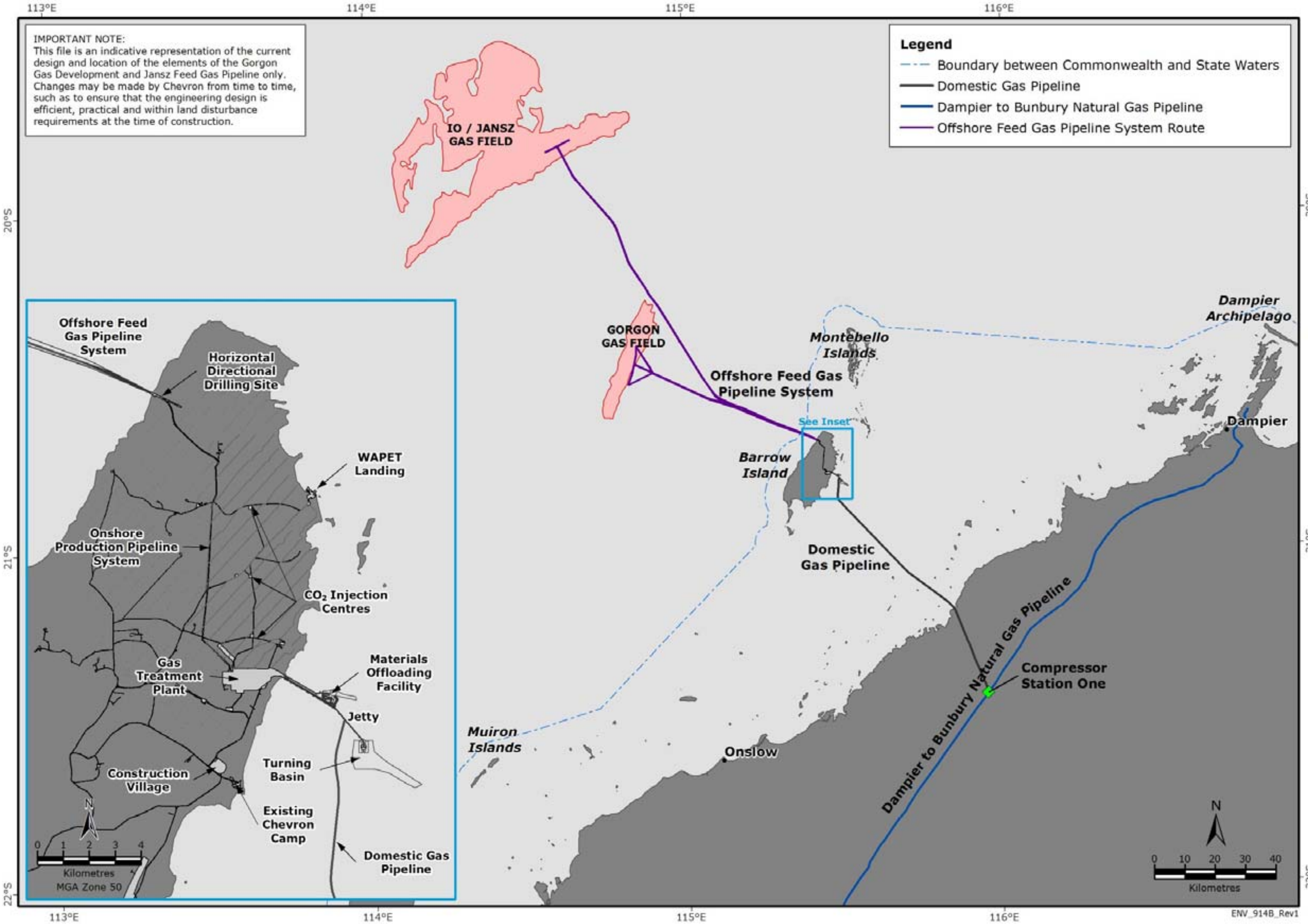


Figure 1-2 Location of the Gorgon Gas Development and Jansz Feed Gas Pipeline

1.4 Approvals

The initial Gorgon Gas Development was assessed through an Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) assessment process (Chevron Australia 2005, 2006).

The initial Gorgon Gas Development was approved by the Western Australian State Minister for the Environment on 6 September 2007 by way of Ministerial Implementation Statement No. 748 (Statement No. 748) and the Commonwealth Minister for the Environment and Water Resources on 3 October 2007 (EPBC Reference: 2003/1294).

In May 2008, under section 45C of the Western Australian *Environmental Protection Act 1986* (EP Act), the Environmental Protection Authority (EPA) approved some minor changes to the Gorgon Gas Development that it considered 'not to result in a significant, detrimental, environmental effect in addition to, or different from, the effect of the original proposal' (EPA 2008). The approved changes are:

- excavation of a berthing pocket at the Barge (WAPET) Landing facility
- installation of additional communications facilities (microwave communications towers)
- relocation of the seawater intake
- modification to the seismic monitoring program.

In September 2008, Chevron Australia sought both State and Commonwealth approval through a Public Environment Review (PER) assessment process (Chevron Australia 2008) for the Revised and Expanded Gorgon Gas Development to make some changes to 'Key Proposal Characteristics' of the initial Gorgon Gas Development, as outlined below:

- addition of a five MTPA LNG train, increasing the number of LNG trains from two to three
- expansion of the CO_2 Injection System, increasing the number of injection wells and surface drill locations
- extension of the causeway and the Materials Offloading Facility (MOF) into deeper water.

The Revised and Expanded Gorgon Gas Development was approved by the Western Australian State Minister for the Environment on 10 August 2009 by way of Ministerial Implementation Statement No. 800 (Statement No. 800). Statement No. 800 also superseded Statement No. 748 as the approval for the initial Gorgon Gas Development. Statement No. 800 therefore provides approval for both the initial Gorgon Gas Development and the Revised and Expanded Gorgon Gas Development, which together are known as the Gorgon Gas Development. Amendments to Statement No. 800 Conditions 18, 20, and 21 under section 46 of the EP Act were approved by the Western Australian State Minister for the Environment on 7 June 2011 by way of Ministerial Implementation Statement No. 865 (Statement No. 865). Implementation of the Gorgon Gas Development will continue to be in accordance with Statement No. 800, as amended by Statement No. 865.

On 26 August 2009, the then Commonwealth Minister for the Environment, Heritage and the Arts issued approval for the Revised and Expanded Gorgon Gas Development (EPBC Reference: 2008/4178) and varied the conditions for the initial Gorgon Gas Development (EPBC Reference: 2003/1294).

On 2 April 2014, the Western Australian Minister for Environment; Heritage issued approval for an Additional Construction Laydown and Operations Support Area on Barrow Island by way of Statement No. 965, which includes additional conditions for the Gorgon Gas Development. The Proposal is for the use of a further 32 ha of uncleared land required to support the construction and operation of the Gorgon Gas Development Proposal referred to in Statement No. 800. On 15 April 2014, the Commonwealth Assistant Secretary, Compliance Enforcement Branch Department of the Environment (DotE) issued a Variation to EPBC 2003/1294 and EPBC

2008/4178 to update two definitions and insert a definition for the use of a further 32 ha of Additional Support Area.

The Jansz Feed Gas Pipeline was assessed via Environmental Impact Statement/Assessment on Referral Information (ARI) and EPBC Referral assessment processes (Mobil Australia 2005, 2006).

The Jansz Feed Gas Pipeline was approved by the Western Australian State Minister for the Environment on 28 May 2008 by way of Ministerial Implementation Statement No. 769 (Statement No. 769) and the Commonwealth Minister for the Environment and Water Resources on 22 March 2006 (EPBC Reference: 2005/2184).

The proponent for the Jansz Feed Gas Pipeline under Statement No. 769 was transferred from Mobil Australia Resources Company Pty Ltd to Chevron Australia Pty Ltd on 28 August 2009. Amendments to Statement No. 769 Conditions 4, 5, and 21 under section 46C of the EP Act were approved by the Western Australian Minister for the Environment on 4 May 2012. The nominated person taking the action for the development of the Jansz–Io deepwater gas field under EPBC 2005/2184 was transferred from Mobil Exploration and Producing Australia Pty Ltd to Chevron Australia Pty Ltd on 8 September 2009. A variation to EPBC 2005/2184 Condition 5 was approved by the Commonwealth Minister for the Environment on 16 January 2012.

1.5 Purpose of this Report

1.5.1 Legislative Requirements

This Report is required under Condition 15.3 of Statement No. 769, which is quoted below:

> *The Proponent shall repeat the survey annually for at least three years following completion of pipe laying, unless otherwise determined by the Minister and within 3 months of completion of each survey report the results to the Minister including detected changes to marine ecological elements.*

1.5.2 Objectives

The objective of this Report, as stated in Condition 15.3 of Statement No. 769 is to report the results of FGPDSY2, including detected changes to marine ecological elements.

FGPDSY2 is the second Post-Development Survey undertaken since completion of offshore pipe laying of the OFGPS. FGPDSY1 was undertaken to meet Condition 15.1 of Statement No. 769; the subsequent FGPDSY1 Report (Post-Development Coastal and Marine State and Environment Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing, Year 1: 2013; Chevron Australia 2014b) was submitted 18 February 2014 and subsequently acknowledged by the Western Australian Department of Parks and Wildlife (Parks and Wildlife) on 4 July 2014 as having satisfied Condition 15.2 of Statement No. 769.

Note: The Post-Development Coastal and Marine State and Environmental Impact Surveys required under Conditions 15.1 and 15.3 of Statement No. 769 refer specifically to the Marine Facility listed in Condition 12.3 of Statement No. 769, and as repeated below:

> *Offshore Feed Gas Pipeline System* [in State Waters] *and marine component of the shore crossing* (hereafter referred to as the OFGPS).

The FGPDSY2 was also undertaken to meet Condition 14.4(vi) of Statement No. 769 and Condition 23.5(iv) of Statement No. 800. Results relating to Condition 14.4(vi) of Statement No. 769 and Condition 23.5(iv) of Statement No. 800 will be reported in the annual report for the Offshore Feed Gas Pipeline Installation Management Plan.

1.5.3 Requirements

Table 1-1 lists the requirements of this Report in relation to the OFGPS, as stated in Condition 15 of Statement No. 769. Table 1-1 also references the specific sections of this Report where each requirement is addressed.

Table 1-1 Requirements of this Report

Ministerial Document	Condition No.	Requirement	Section Reference in this Report
Statement No. 769	15.1	Within three months following the completion of offshore pipe laying, the Proponent shall repeat the surveys of marine habitats consistent with Condition 12.2 to determine the initial impacts on marine ecological elements consistent with the scope of works required by Condition 12.1.	Data collection methods consistent with the Scope of Works (RPS 2009, amended 2014) are presented in Sections 4.3.3, 5.3.3, 6.3.3, and 7.3.3
Statement No. 769	15.3	The proponent shall repeat the survey annually for at least three years following completion of pipe laying, unless otherwise determined by the Minister and within 3 months of completion of each survey report the results to the Minister including detected changes to marine ecological systems.	See FGPDSY2 sampling completion date in Section 3.4. Comparison between Baseline and FGPDSY2 is presented in Sections 4.5, 5.5, 6.5, and 7.5, and detected changes are summarised in Section 8.0.

Note:

1. *See Section 3.2 for information regarding ecological elements listed in Condition 12.2 of Statement No. 769 that were not necessary to survey in the OFGPS Post-Development Surveys, as agreed by Parks and Wildlife on 14 October 2013.*

For reporting detected changes to ecological elements as per Condition 15.3 of Statement No. 769, the standard scientific practice of defining a detected change as one that is statistically significant (Legendre and Legendre 2012) is applied throughout this Report. As such, any change to ecological elements that is found to be statistically significant is reported as a detected change.

1.5.4 Hierarchy of Documentation

This Report will be implemented for the Gorgon Gas Development and the Jansz Feed Gas Pipeline via the Chevron Australasia Business Unit (ABU) Operational Excellence Management System (OEMS). The OEMS is the standardised approach that applies across the ABU to continuously improve the management of safety, health, environment, reliability, and efficiency to achieve world-class performance. Implementation of the OEMS enables the Chevron ABU to integrate its Operational Excellence (OE) objectives, processes, procedures, values and behaviours into the daily operations of Chevron Australia personnel and contractors working under Chevron Australia's supervision. The OEMS is designed to be consistent with and, in some respects, go beyond ISO 14001:2004 (Environmental Management Systems – Requirements with Guidance for Use) (Standards Australia/Standards New Zealand 2004).

Figure 1-3 shows the overall hierarchy of environmental management documentation within which this Report exists.

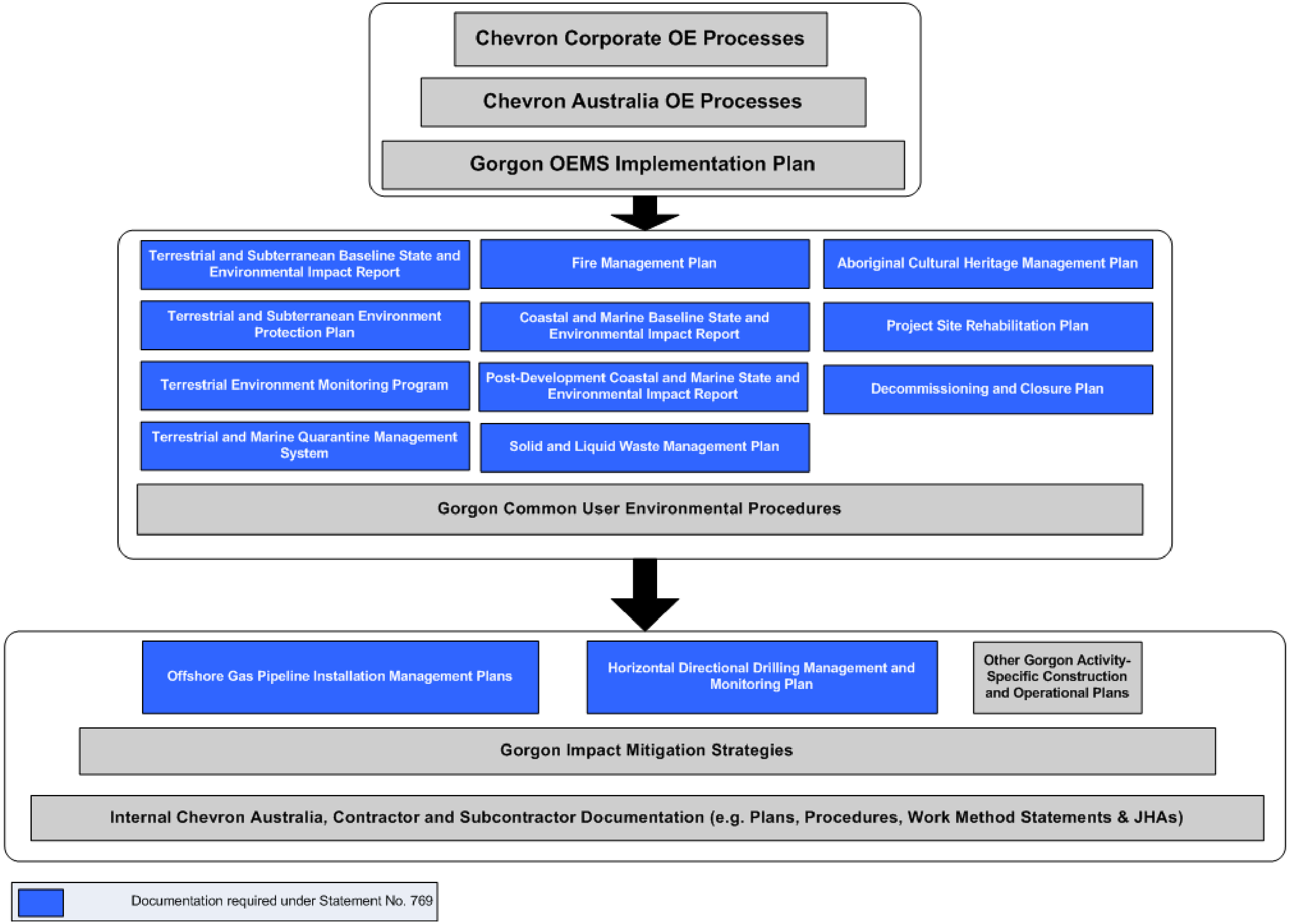


Figure 1-3 Hierarchy of Jansz Feed Gas Pipeline Environmental Documentation

Note: Figure 1-3 refers to all Plans etc. required for Statement No. 769. They are only relevant to EPBC Reference: 2005/2184 if required for the conditions of that approval.

1.5.5 Scientific Expertise

The field component of FGPDSY2 was primarily managed and undertaken by MScience Pty Ltd and supported by Empress Marine Pty Ltd, Cal Dive International (Australia) Pty Ltd, and Jetwave Marine Services Pty Ltd. Field sampling for the demersal fish scope was supported by the Fish Ecology Laboratory (Curtin University).

The data analysis and reporting component of FGPDSY2 was undertaken by BMT Oceanica for these ecological elements: non-coral benthic macroinvertebrates, macroalgae, and seagrass. Doctor John Huisman (Murdoch University, Western Australia) performed formal identification of macroalgae and seagrass specimens. Professor Sean Connell (University of Adelaide) provided advice on statistical design.

The data analysis and reporting for the subtidal demersal fish scope was undertaken by the Fish Ecology Laboratory (Curtin University). BMT Oceanica provided advice on statistical design for the subtidal demersal fish analyses.

1.5.6 Stakeholder Consultation

Regular consultation with stakeholders has been undertaken by Chevron Australia throughout the development of the environmental impact assessment management documentation for the Gorgon Gas Development and Jansz Feed Gas Pipeline. This stakeholder consultation has included engagement with the community, government departments, industry operators, and contractors to Chevron Australia via planning workshops, risk assessments, meetings, teleconferences, and the PER and EIS/ERMP formal approval processes.

1.5.7 Public Availability

This Report will be made public as and when determined by the Minister, under Condition 20 of Statement No. 769.

2.0 Relevant Facilities and Areas

2.1 Marine Facilities and Activities

2.1.1 Overview

This Report addresses issues associated with the Marine Facilities of the Gorgon Gas Development, which are shown in Figure 1-2. The Marine Facilities relevant to this Report are defined in Condition 12.3 of Statement No. 769 as the OFGPS.

The sections that follow summarise the main activities associated with construction of the OFGPS. Information regarding construction activities occurring in Commonwealth Waters is included for information purposes only. Additional details on these Marine Facilities can be found in the EIS/ERMP (Chevron Australia 2005, 2006), the PER (Chevron Australia 2008), the Horizontal Directional Drilling Management and Monitoring Plan (Chevron Australia 2010a), the Offshore Feed Gas Pipeline Installation Management Plan (Chevron Australia 2013a), and the Jansz Feed Gas Pipeline Preparatory Works (Northern Scarp) Environment Plan (Chevron Australia 2010b). Offshore pipe laying was completed on 21 August 2013. An overview of the offshore pipeline installation activities in State and Commonwealth Waters is provided in Section 2.1.2.

2.1.2 Offshore Feed Gas Pipeline System (OFGPS)

The offshore installation activities included:

- installing 55 km of 34” feed gas pipeline, 8” monoethylene glycol (MEG) line, and 6” utility line from the Gorgon field to the shore crossing at North Whites Beach on Barrow Island
- installing 135 km of 30”/34” feed gas pipeline, 8” MEG line, and 6” utility line from the Jansz field to the shore crossing at North Whites Beach
- installing infield 6”, 8”, 24”, and 26” pipelines
- installing pipeline end terminations and associated supports and skids
- trenching sections of the pipeline
- installing crossing and support mattresses
- installing the umbilical systems to the Gorgon and Jansz fields
- installing subsea structures (i.e. production manifolds and pipeline termination structures), foundations, and spool pieces
- placing rocks over the pipeline and umbilicals system for stabilisation.

Pipeline installation commenced from the tail of the HDD section. All offshore pipelines were installed in separate lay corridors, with the MEG and utility pipelines installed close to each other (approximately 2 m separation). The pipeline corridor for the Gorgon and Jansz offshore pipelines varies in width along its length so that subsea features—such as reefs and existing infrastructure (e.g. the East Spar pipeline)—could be taken into account during construction of the pipeline.

Note: This Report considers only offshore pipe laying—the only component of the installation of the OFGPS with the potential to affect the marine environment in State Waters. Offshore pipe-laying activities comprise:

- installation of the Gorgon and Jansz Production pipelines, MEG pipelines, and utility pipelines from the HDD shore crossing at North Whites Beach to the State Waters’ boundary (3 nm)
- installation of the Gorgon and Jansz umbilicals from the HDD shore crossing at North Whites Beach to the State Waters’ boundary (3 nm)

- stabilisation of the offshore pipelines and umbilicals by rock dumping to the State Waters' boundary (3 nm).

2.1.3 Marine Component of the Shore Crossing (Horizontal Directional Drilling)

Using HDD, the pipeline system made landfall at the shore crossing at North Whites Beach on the north-west coast of Barrow Island. The shore crossing corridor is centred on the coordinates of 335061 E, 7711245 N (GDA 94, MGA Zone 50). The HDD drilling site was located approximately 100 m from the shoreline. The HDD break-out point was in water approximately 12.5 m deep and 400 m from the shore. A tail string approximately 400 m long extends out from the break-out point and lays on the seabed for the offshore pipeline tie-in at a water depth of between 16 and 17 m.

HDD marine activities included:

- running a small water intake line (nominally 150 mm) down the beach to gain water for drilling the water-winning hole. The water-winning intake line was secured by rock bolting and clump weights
- horizontal drilling of the water-winning hole to beyond the surf zone (to provide seawater supply for the HDD operations)
- horizontal drilling of eight parallel holes to install the offshore feed gas pipelines, associated utility lines, and casing for the installation of umbilicals that will service the Gorgon and Jansz gas fields
- installing the pipelines through the HDD exit alignment using a combination of thrusting from onshore and pulling from offshore. Divers connected a winch wire to the pipeline pulling head after it emerged from the HDD exit alignment and a marine vessel towed out the pipeline. The vessel was anchored on a four- or six-point mooring approximately 200 m offshore from the laydown location
- temporarily stabilising the pipelines (e.g. by clump weights) where required
- using span correction (comprising concrete mattresses and/or grout bags to fill in depressions on the seabed) and some levelling of raised features
- cleaning, gauging, and pressure testing the pipe strings. The hydrotest water was dewatered into onshore storage tanks for re-use in subsequent tests. However, it was expected that a small percentage of this hydrotest water would be discharged at the HDD subsea end.

Water-based drilling fluids were used during HDD to lubricate the drill bit, suspend and transport the cuttings away from the drill face, and provide hole stability. The fluid was used in a closed-loop circuit where the returns were separated from the suspended cuttings and pumped back down the drill string and recirculated through the hole where fracture gradient and porosity allowed. A small amount of drilling fluid and cuttings was expected to be discharged when the drill broke through to the seabed at the exit points, approximately 490 m from the drill entry points.

2.2 Marine Areas

2.2.1 Marine Disturbance Footprint (MDF)

The Jansz Feed Gas Pipeline MDF is defined in Statement No. 769 as:

> *The area of the seabed to be disturbed by construction or operations activities associated with the Marine Facilities listed in Condition 12.3.*

Therefore, the MDF includes the Marine Facilities Footprint (the areas of the seabed associated with the physical footprint of the Marine Facilities [the OFGPS]) and the extent of the surrounding seabed in which the construction and operation activities could be expected to disturb the seabed. The boundary of the MDF for the west coast Marine Facilities is shown in Figure 2-1; it encompasses an area extending 100 m either side of the outermost pipeline route.

As described in the CMBSEIR:OFGPS (Chevron Australia 2014a), direct physical disturbance to the seabed within the MDF is expected to include pipe laying and stabilising directly on the seabed; vessel anchoring and propeller wash; operating drilling equipment, including drilling through subsea geological formations and break-out at the HDD exit alignment; installing guide-wires and water-winning spread, including placing pumps on the seabed and discharging from self-cleaning filters; placing clump weights; span correction; and possible frac-outs. The MDF for the OFGPS also includes areas that would not be disturbed (e.g. areas between anchor positions, and between anchor positions and the vessel where no anchors or chains contact the seabed). Thus, the levels of potential disturbance within the MDF of the OFGPS may vary from negligible to Material Environmental Harm to Serious Environmental Harm (see Section 2.2.2 for further details).

The MDF of the marine component of the shore crossing includes those areas of the seabed and the associated benthic ecological elements (non-coral benthic macroinvertebrates, macroalgae, and seagrass characteristics) that may be directly affected by the construction and operation activities. The MDF associated with the OFGPS includes those areas of the seabed and associated benthic ecological elements that may be directly affected by the pipe-laying activities.

2.2.1.1 Indicative Anchoring Areas Adjacent to the MDF

The MDF includes the indicative location of anchoring areas around the HDD exit alignment (the hatched areas in Figure 2-1). Anchoring activities were restricted to within this area and within the MDF, as far as practicable. It was not proposed that the entire area identified as anchoring areas would be disturbed. Each anchor would create minor, localised, and temporary disturbance at the points of contact with the seabed only and there would be areas between anchor positions and between the anchor positions and the vessel where no anchors or chains contact the seabed. Refer to the Horizontal Directional Drilling Management and Monitoring Plan (Chevron Australia 2010a) for details on the management of anchoring.

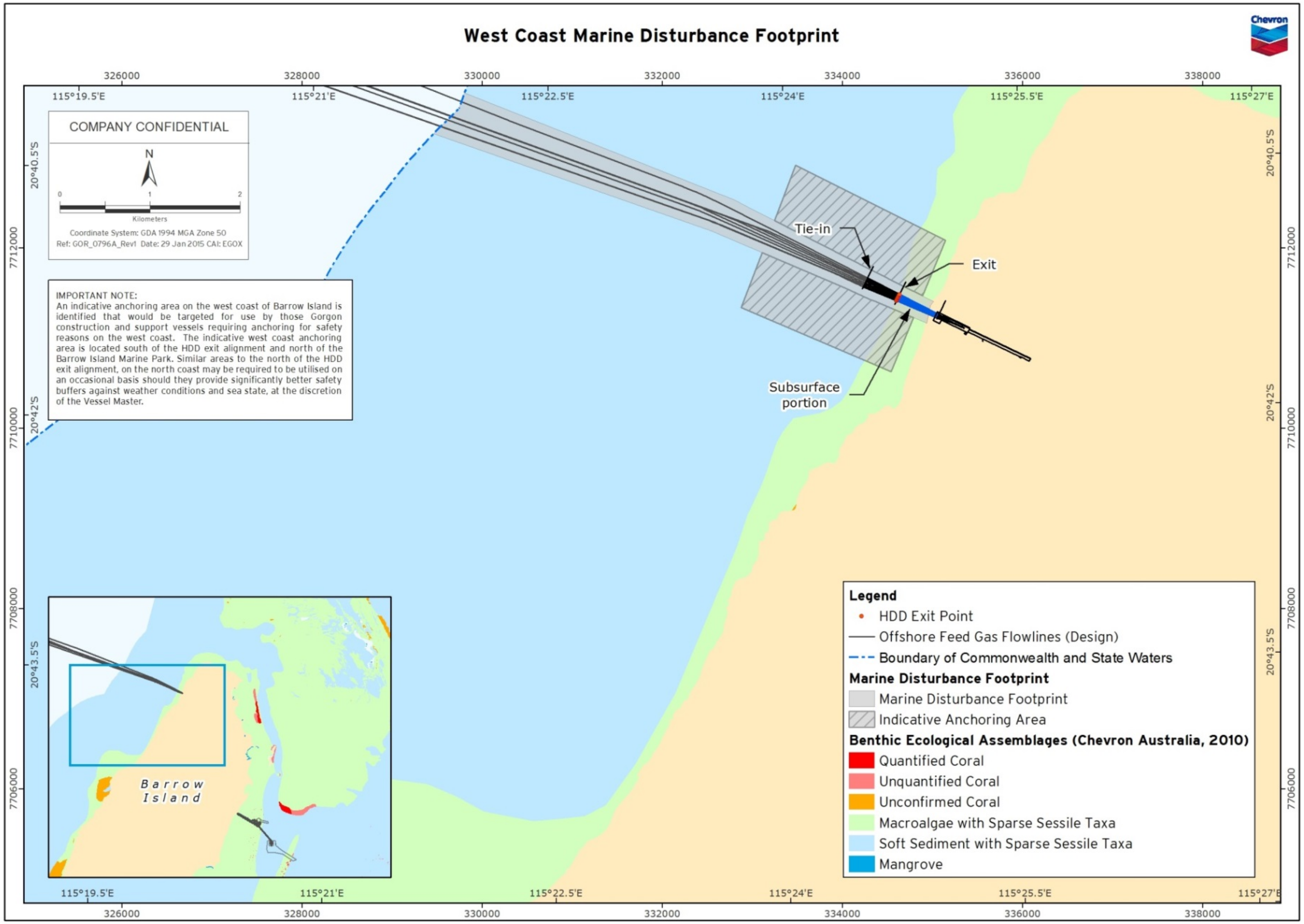


Figure 2-1 MDF for the OFGPS

2.2.2 Areas at Risk of Material or Serious Environmental Harm

Material Environmental Harm and Serious Environmental Harm are both defined in Section 3A of the EP Act.

Material or Serious Environmental Harm due to the construction or operation of the west coast Marine Facilities may occur within the MDF for the OFGPS (described in Section 2.2.1). The level of environmental harm predicted at a particular location within the MDF depends on the types of stressors, the sensitivity of the ecological elements at any location, the likelihood of complete or partial recovery from the disturbance, and the management or mitigation measures taken to reduce impacts.

Serious Environmental Harm, caused by directly placing the Marine Facilities on the seabed and physically removing the substrate, was predicted to affect all benthic ecological elements within the Marine Facilities Footprint of the OFGPS. Recovery to the original state will not be possible, although there will be some colonisation of the new hard substrates created by the Marine Facilities. Examples of seabed disturbances that were predicted to cause Serious Environmental Harm to benthic ecological elements include permanent or irreversible loss or removal of existing substrates and associated ecological elements (e.g. through the direct placement of the OFGPS on the seabed and break-out at the HDD exit alignment) and, in shallower waters, potential shading by infrastructure.

Within the surrounding areas in the MDF, beyond the Marine Facilities Footprint, there are likely to be temporary or sublethal impacts that may remove or reduce the existing ecological elements. This is considered to represent Material Environmental Harm. However, the substrate is likely to retain its ecological function as benthic habitat and the benthic ecological elements are predicted to recover in the short term (within one to five years) following cessation of the disturbance. Macroalgae and seagrass are well adapted to cycles of disturbance and recovery, thus macroalgal-dominated limestone reefs, subtidal limestone reef platforms with macroalgae, and reef platform/sand with scattered seagrass are predicted to be affected only temporarily (Chevron Australia 2006). Examples of seabed disturbances that are predicted to cause Material Environmental Harm to benthic ecological elements include: localised or short-term (less than five years) impacts such as anchor scouring in a macroalgal bed, seagrass bed, or benthic macroinvertebrate assemblage; disturbance or resuspension of unconsolidated sediments by vessel propeller wash; discharge of drilling cuttings and fluids from HDD activities.

Outside the MDF, the ecological elements are not considered to be at risk of Material or Serious Environmental Harm due to the construction or operation of the OFGPS. Therefore, sites located in these areas are considered to be Reference Sites suitable for comparison with impacted areas.

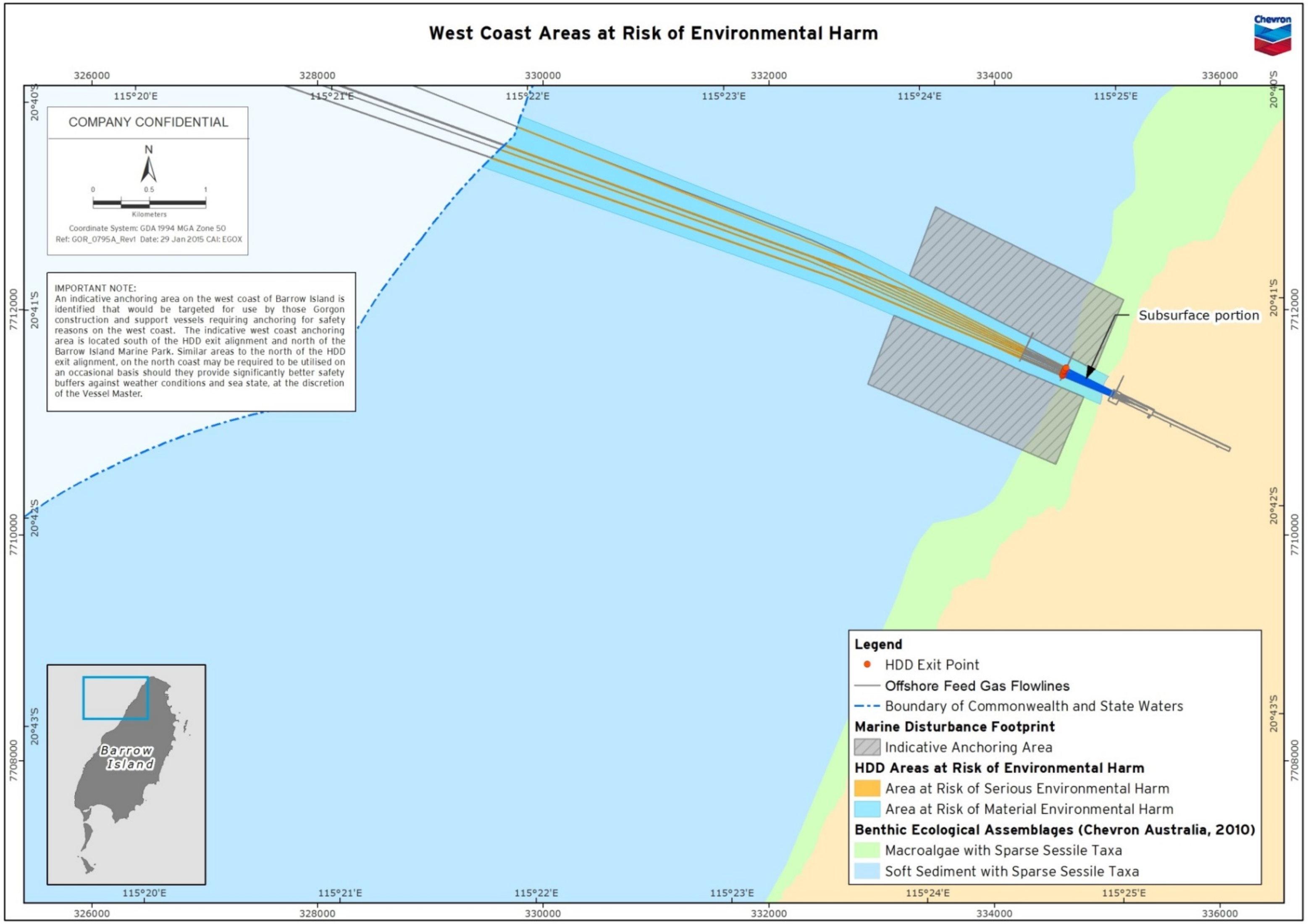


Figure 2-2 Areas at Risk of Material or Serious Environmental Harm for Benthic Ecological Elements within the West Coast Marine Facilities MDF

3.0 General Approach to Methods

3.1 Introduction

The Coastal and Marine Baseline State and Environmental Impact Report (CMBSEIR) required under Condition 12 of Statement No. 769, Condition 14 of Statement No. 800, and Condition 11 of EPBC Reference: 2003/1294 and 2008/4178, was initiated in November 2007. Baseline surveys, consistent with the approved Scope of Works (RPS 2009, amended 2014), were undertaken between November 2008 and October 2010. Results from these surveys are presented in the CMBSEIR:OFGPS (Chevron Australia 2014a).

All baseline data used for comparison between baseline and post-development conditions within this Report are the same as those used in the FGPDSY1 Report. The seasonal abundance of the ecological elements seagrass and macroalgae (and to a lesser extent, benthic macroinvertebrates) varies considerably. For comparative analysis to be relevant, surveys should be repeated at the same time of year, where possible. The August to October 2010 baseline surveys (Chevron Australia 2014a) were completed during the same season as FGPDSY1 and FGPDSY2, and thus provide a more relevant dataset than the initial baseline data collected between November 2008 and March 2010; this allows a meaningful statistical comparison between baseline and post-development conditions. Additionally, the August to October 2010 surveys provide a more complete dataset by which to assess change, as they comprise data from multiple Reference Sites, all sampled during the same season as FGPDSY1 and FGPDSY2. As such, the August to October 2010 baseline surveys, as presented in the CMBSEIR:OFGPS (Chevron Australia 2014a), constitute Baseline conditions for the ecological elements of non-coral benthic macroinvertebrates, macroalgae, and seagrass within this Report. All baseline demersal fish data, collected between March 2009 and March 2010 as presented in the CMBSEIR:OFGPS (Chevron Australia 2014a), constitute Baseline conditions for the ecological element of demersal fish within this Report.

Chevron Australia submitted the latest revision of the CMBSEIR:OFGPS (Chevron Australia 2014a) on 19 August 2014 as per Condition 12.2 of Statement No. 769. The revised Report was accepted by the Western Australian Office of the Environmental Protection Authority as the current version on 22 October 2014, and was endorsed by DotE on 28 January 2015.

3.2 Sampling Methodology

As required under Condition 15.1 of Statement No. 769, the FGPDSY2 repeats the methodology of FGPDSY1, and is consistent with the approved Scope of Works (RPS 2009, amended 2014) or as agreed by Parks and Wildlife on 14 October 2013.

Based on the results of the CMBSEIR:OFGPS (Chevron Australia 2014a), and on the justification presented to Parks and Wildlife on 28 August 2013, Chevron Australia recommended the removal of Surficial Sediments from OFGPS Post-Development Surveys. This recommendation was agreed by Parks and Wildlife on 14 October 2013, and the FGPDSY1 Report was subsequently acknowledged by Parks and Wildlife on 4 July 2014 as having satisfied Condition 15.2 of Statement No. 769.

The ecological elements surveyed during the Baseline (Chevron Australia 2014a), FGPDSY1 (Chevron Australian 2014b), and FGPDSY2 for the OFGPS are listed in Table 3-1.

Table 3-1 Ecological Elements Surveyed During the Coastal and Marine Baseline State and Environmental Impact Survey (Baseline) and the Post-Development Coastal Marine State and Environmental Impact Surveys (FGPDSY1 and FGPDSY2) for the OFGPS

Ecological Element	Baseline	FGPDSY1	FGPDSY2
Hard and Soft Coral[1]			
Macroalgae			
Dominant and Subdominant Species	●	●	●
Percent Cover	●	●	●
Biomass Estimates	●	●	●
Non-coral Benthic Macroinvertebrates			
Dominant and Subdominant Species	●	●	●
Mean Abundance	●	●	●
Seagrass			
Dominant and Subdominant Species	●	●	●
Percent Cover	●	●	●
Biomass Estimates	●	●	●
Surficial Sediment Characteristics[2]			
Particle Size Distribution	●		
Total Organic and Total Inorganic Carbon	●		
Demersal Fish			
Species Composition	●	●	●
Species Abundance	●	●	●
Size Structure	●	●	●
Water Quality[3]			
Light, Turbidity, Deposition	●		
Water Column Profiles	●		
Total Suspended Solids	●		
Light Attenuation	●		
Gross Sedimentation (Sediment Traps)	●		

Notes:

1 *No assemblages of this ecological element were recorded within 200 m of the OFGPS, and hence no baseline survey was undertaken.*

2 *Results from monitoring, undertaken after construction of the marine component of the shore crossing, concluded that there were no detected changes to surficial sediments from construction activities (Chevron Australia 2013b). In addition, environmental impacts on sediment from the installation and stabilisation of pipeline, including from thruster wash, are considered to be minor given the high-energy environment of the waters around the west coast of Barrow Island.*

3 *The survey timing and frequency, as listed in the Scope of Works (RPS 2009, amended 2014), does not require post-development surveys for water quality. This approach is consistent with the approach used for the (dredging) Post-Development Coastal and Marine State and Environmental Impact Survey Reports (Chevron Australia 2012a, 2013c, 2014c).*

3.3 Sampling Sites

The Baseline surveys were designed to include sites on the west coast of Barrow Island that are potentially at risk of Material or Serious Environmental Harm (Section 2.2.2) due to the construction and operation of the OFGPS, as well as Reference Sites that are not at risk of Material or Serious Environmental Harm due to the construction and operation of these Marine Facilities (Section 2.2.2). All MDF Sites presented in this Report are considered at risk of Material or Serious Environmental Harm, and were in benthic habitats within 200 m of the pipeline facilities as per Condition 7ii of Statement No. 769.

Sampling sites for FGPDSY2 are listed in the individual sections for each ecological element (Sections 4.0 to 7.0). The FGPDSY2 sites included all sites from the Baseline for the respective ecological elements.

3.4 Sampling Frequency and Temporal Scope

Consistent with the Scope of Works (RPS 2009, amended 2014), the sampling frequency and temporal scope for each ecological element surveyed during the Baseline, FGPDSY1, and FGPDSY2 for the OFGPS are summarised in Table 3-2.

Condition 15.1 of Statement No. 769 requires the initial survey of marine habitats to be undertaken within three months of the completion of offshore pipe laying. Offshore pipe-laying activities concluded on 21 August 2013, and FGPDSY1 sampling was undertaken between 23 October 2013 and 19 November 2013. Condition 15.3 of Statement No. 769 requires the surveys to be repeated annually, and thus FGPDSY2 sampling was undertaken between 29 October and 27 November 2014.

Table 3-2 Summary of the Baseline, FGPDSY1, and FGPDSY2 Program for the OFGPS

Ecological Element	Sites		Baseline		FGPDSY1		FGPDSY2	
			Sampling Frequency	Sampling Period	Sampling Frequency	Sampling Period	Sampling Frequency	Sampling Period
Non-coral benthic macroinvertebrates (Section 4.0)	MDF	HDD1	Once	Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDD2	Once	Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDD3	Once	Aug 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDD4	Once	Aug/Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014
	Reference	HDDRN	NS[1]	NS[1]	Once	Oct/Nov 2013	Once	Nov 2014
		BR	Once	Oct 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDDRS2	Once	Oct 2010	Once	Oct/Nov 2013	Once	Nov 2014
		NEBWI2	Once	Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014

Ecological Element	Sites		Baseline		FGPDSY1		FGPDSY2	
			Sampling Frequency	Sampling Period	Sampling Frequency	Sampling Period	Sampling Frequency	Sampling Period
Macroalgae (Section 5.0) and Seagrass (Section 6.0)	MDF	HDD1	Once	Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDD2	Once	Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDD3	Once	Aug 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDD4	Once	Aug/Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014
	Reference	HDDRN	NS[1]	NS[1]	Once	Oct/Nov 2013	Once	Nov 2014
		BR	Once	Aug 2010	Once	Oct/Nov 2013	Once	Nov 2014
		HDDRS2	Once	Oct 2010	Once	Oct/Nov 2013	Once	Nov 2014
		NEBWI1	Once	Sep 2010	Once	Oct/Nov 2013	Once	Nov 2014
Demersal fish (Section 7.0)	MDF	FGI1	Twice	Mar 2009 Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		FGI2	Twice	Mar 2009 Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		FGI4	Once	Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		HDD1	Once	Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
	Reference	FGFR1	Twice	Mar 2009 Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		FGFR2	Twice	Mar 2009 Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		FGFR3	Twice	Mar 2009 Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		FGFR4	Once	Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		FGN1	Once	Mar 2009	Once	Oct 2013	Once	Oct/Nov 2014
		HDDN1	Once	Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		HDDN2	Once	Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014
		HDDN3	Once	Feb/Mar 2010	Once	Oct 2013	Once	Oct/Nov 2014

Notes:

1 Site not surveyed due to poor weather conditions.

3.5 Basis of Program Design

The Baseline surveys were designed (see RPS 2009, amended 2014) to provide a direct comparison with the post-development surveys. The basis of the design was to provide pre- and post-development data to be analysed using the Multiple Before-After, Control-Impact (MBACI) approach (Keough and Mapstone 1995). This approach involves statistical analyses that test for an interaction between predicted impact and (multiple) reference areas across periods of time before and after predicted impacts occur. By determining whether changes in ecological elements from the Baseline (before) to the FGPDSY2 (after) differed between the MDF and Reference Sites, potential environmental changes associated with offshore pipe laying could be assessed.

MBACI designs are widely considered the most appropriate (and powerful) design for separating natural variation in the marine environment from changes caused by anthropogenic disturbances, and traditionally refer to sampling within multiple control areas and, if possible, greater than one impact area. The location of the Reference Sites is such that they should always remain independent of any potential impacts associated with offshore pipe laying.

This design allows for the detection of potential impacts by assessing whether the temporal trajectories of 'potentially impacted sites' (MDF Sites) change more or less than that of the average of Reference Sites (i.e. sites within the potential impact area must change more/less from the Baseline to FGPDSY2, than sites within the reference area). From this basis, some of the most powerful and robust tests available are those that analyse variance (Underwood 1997). The approach adopted for post-development survey reporting was Analysis of Variance (ANOVA)-based statistical analyses via Permutational Multivariate Analysis of Variance (PERMANOVA) test statistics (univariate and multivariate), which specifically assess change in variance as well as in means (Anderson *et al.* 2008).

A stepwise approach was adopted for assessing potential environmental impacts to ecological elements. The purpose of this approach was to address the most common form of statistical error in environmental impact assessment studies: Type II error (statistical conclusion of no change when change has actually occurred [Schmitt and Osenberg 1996]). Each step of the approach was designed to address potential issues in the datasets (i.e. statistical power and high variance), thus reducing the chance of a Type II error. Steps to improve power were achieved by partitioning of variance in the analysis, and pooling terms in the analysis. Flow charts were developed for each scope (see Sections 4.0 to 7.0), outlining the analyses, pooling, and partitioning steps particular to each dataset.

Statistical analyses were consistent with the Scope of Works (RPS 2009, amended 2014). In addition, further statistical analyses were undertaken to enhance the ability to detect change (BMT Oceanica 2013). All statistical analyses, including post-hoc tests on the significant interaction term, were undertaken using PERMANOVA (non-parametric analysis of variance, Version 1.0.1, Primer-E Ltd) (Anderson 2001a, 2001b; Anderson *et al*. 2008). This method enabled analysis of univariate and multivariate datasets, while not explicitly requiring normalised data or homogeneous variances. All analyses were run using permutations of residuals under a reduced model (n=9999 permutations) and Type III sums of squares, a conservative method well-suited to unbalanced designs (Anderson *et al.* 2008).

If any of the PERMANOVA analyses (univariate or multivariate) yielded a significant result ($p<0.05$) for the term of interest (Survey × IvR interaction term) for any step of the stepwise approaches, a post-hoc, pairwise comparison of the sample means was performed. Post-hoc tests focused on evaluating changes among survey periods at sites within the MDF and at Reference Sites to detect for statistically significant differences between the Baseline and Post-Development Surveys.

Caution should be used in interpreting the results of all ecological elements due to caveats associated with the statistical designs. Although the statistical design was established to reduce the likelihood of failing to detect statistically significant change (Type II error), Step 2 of the stepwise approach subsequently increases the chance of detecting significant changes where no actual change occurred (Type I error).

Note: During the Baseline and FGPDSY2, Reference Sites were situated at different locations in the waters surrounding Barrow Island, with sites NEBWI1 and NEBWI2 located on the north-east side, site BR located on the south-west side, while site HDDRN was located on the north-west side of Barrow Island. The locations of these Reference Sites were not partitioned into an additional level of spatial hierarchy (e.g. Reference North and Reference South) as the low replication at each level would result in poor test power and an increased chance of Type II error (failing to detect an impact). The disadvantage of combining all Reference Sites into one treatment was that it increased the sample variance at Reference Sites compared to the smaller sample variances observed at MDF Sites ('Impact' sites within the MBACI approach), which has the potential to increase the chance of either a Type I error (i.e. detecting a change when there was not one) or Type II error (i.e. detecting no change when there was one).

Therefore, when assessing whether impacts to ecological parameters occurred as a result of offshore pipe laying, changes in ecological parameters were carefully interpreted from before (Baseline) to after (FGPDSY2) at MDF and Reference Sites.

4.0 Non-Coral Benthic Macroinvertebrates

4.1 Introduction

Non-coral benthic macroinvertebrates (hereafter referred to as 'benthic macroinvertebrates') are a broad category of fauna that include sessile, filter-feeding taxa such as sponges, gorgonians, and ascidians, as well as motile taxa such as asteroids (starfish), echinoids (sea urchins), and holothurians (sea cucumbers). The soft corals (order Alcyonacea) are commonly observed in benthic macroinvertebrate-dominated assemblages in Barrow Island waters (outside coral reef habitats) and represent an important part of the sessile benthic macroinvertebrate assemblages; they are also included in this Section. The hard coral *Turbinaria* spp. is also common in these assemblages and has been included as a benthic macroinvertebrate as, from a habitat perspective, it is more like other benthic macroinvertebrates (i.e. solitary with a low profile and low benthic cover) than other hard corals.

Although the knowledge of the benthic macroinvertebrate assemblages in the Montebello Islands/Barrow Island region is generally limited to species lists and distributions of taxa, the available information suggests that the assemblages are species-rich (Marsh 1993; Wells *et al.* 1993; Chevron Australia 2005, 2010a; Department of Environment and Conservation [DEC] 2007; RPS Bowman Bishaw Gorham 2007). Invertebrate species richness is considered high in the Montebello Islands region in particular, with 633 species of molluscs and 170 species of echinoderms recorded (Wells *et al.* 1993; Marsh *et al*. 1993b cited in DEC 2007).

The habitats on the east and west coasts of Barrow Island support different benthic macroinvertebrate assemblages (Chevron Australia 2005). Of the 316 species of molluscs recorded from Barrow Island, less than one-third occur on both coasts. The muddier habitats on the east coast support a greater proportion of bivalve species, while the west coast supports a greater proportion of coral reef gastropod species (Chevron Australia 2005). The gastropod *Amoria macandrewi* is endemic to sandbars within the Montebello Islands/Barrow Island region (Chevron Australia 2005). The macroinvertebrate fauna of the rocky shores and intertidal mudflats on the leeward sides of the offshore islands in the Montebello Islands/Barrow Island region also have strong affinities with the fauna of the nearshore intertidal areas on the mainland (Chevron Australia 2005).

Benthic macroinvertebrate assemblages characteristic of the western shores of Barrow Island are typical of the Pilbara Offshore Bioregion and have affinities with assemblages of the west coast of the Montebello Islands (Chevron Australia 2005). Previous surveys have recorded 32 species of echinoderm and 75 species of mollusc on the intertidal reef at Biggada Reef on the west coast of Barrow Island (Bowman Bishaw Gorham 1996; Chevron Australia 2005).

The infauna community in the shallow subtidal areas off North Whites Beach on the west coast of Barrow Island was surveyed between 2002 and 2004 and again in 2006 (Chevron Australia 2005; RPS Bowman Bishaw Gorham 2007). The benthic habitats along the Offshore Feed Gas Pipeline route comprise soft sediments of varying grain-size, with isolated rocky reefs and patches of exposed pavement reef supporting sparse filter-feeding assemblages dominated by sea whips, gorgonians, and sponges (Chevron Australia 2005). A total of 406 individuals from 15 sample sites were recorded during the 2006 survey (RPS Bowman Bishaw Gorham 2007). Along the Offshore Feed Gas Pipeline route, in water depths of approximately 11 m (near the HDD exit alignment), benthic fauna were sparse and included branching and tubular sponges, tube worms, and soft corals such as sea whips and *Sarcophyton* spp. (Chevron Australia 2005; RPS Bowman Bishaw Gorham 2007). These habitats are widespread in the Pilbara Region (Chevron Australia 2005).

Further offshore, outside State Waters in water depths of approximately 40 to 45 m, rocky reefs provide structural diversity to an otherwise planar seabed (Chevron Australia 2005). Areas of platform reef are known to support benthic invertebrates including scattered black corals (*Cirrhipathes* spp., *Antipathes* spp.), sponges, sea whips (*Junceella*), and branching gorgonians (Chevron Australia 2005).

4.2 Scope

This section is in two parts. The first part describes the benthic macroinvertebrate assemblages recorded during FGPDSY2:

- at sites within the MDF (area at risk of Material or Serious Environmental Harm due to the OFGPS)
- at References Sites not at risk of Material or Serious Environmental Harm due to the OFGPS.

The second part compares the Post-Development Surveys with the Baseline to identify any detected changes to marine ecological elements as per Condition 15.3 of Statement No. 769.

4.3 Methods

4.3.1 Site Locations

Baseline surveys were conducted at four sites within the MDF (HDD1, HDD2, HDD3, and HDD4), and at three Reference Sites (NEBWI2, BR, and HDDRS2) (Table 4-1; Figure 4-1). FGPDSY2 sampling was undertaken at the same sites as the Baseline surveys and FGPDSY1 (Table 4-1; Figure 4-1). Reference Site HDDRN could not be accessed during Baseline surveys due to poor weather, but was surveyed in FGPDSY1 and FGPDSY2 (Table 4-1; Figure 4-1).

Table 4-1 Baseline and Post-Development Survey Sites for Non-Coral Benthic Macroinvertebrates

Area	Site	Baseline[1]		FGPDSY1[1]		FGPDSY2[1]	
		Easting[2]	Northing[2]	Easting[2]	Northing[2]	Easting[2]	Northing[2]
MDF	HDD1	334655	7711392	334656	7711361	334666	7711398
	HDD2	334678	7711541	334677	7711541	334677	7711541
	HDD3	334549	7711352	334546	7711353	334548	7711351
	HDD4	334739	7711539	334753	7711551	334738	7711539
Reference	HDDRN	NS[3]	NS[3]	334972	7712174	334965	7712144
	BR	329877	7704929	329874	7704922	329877	7704929
	HDDRS2	329675	7705354	329675	7705357	329675	7705354
	NEBWI2	343137	7713599	343157	7713588	343137	7713599

Notes:

1 *Eastings and northings are the start of transects*

2 *Datum used: GDA94 Projection MGA Zone 50*

3 *Site not sampled due to poor weather conditions*

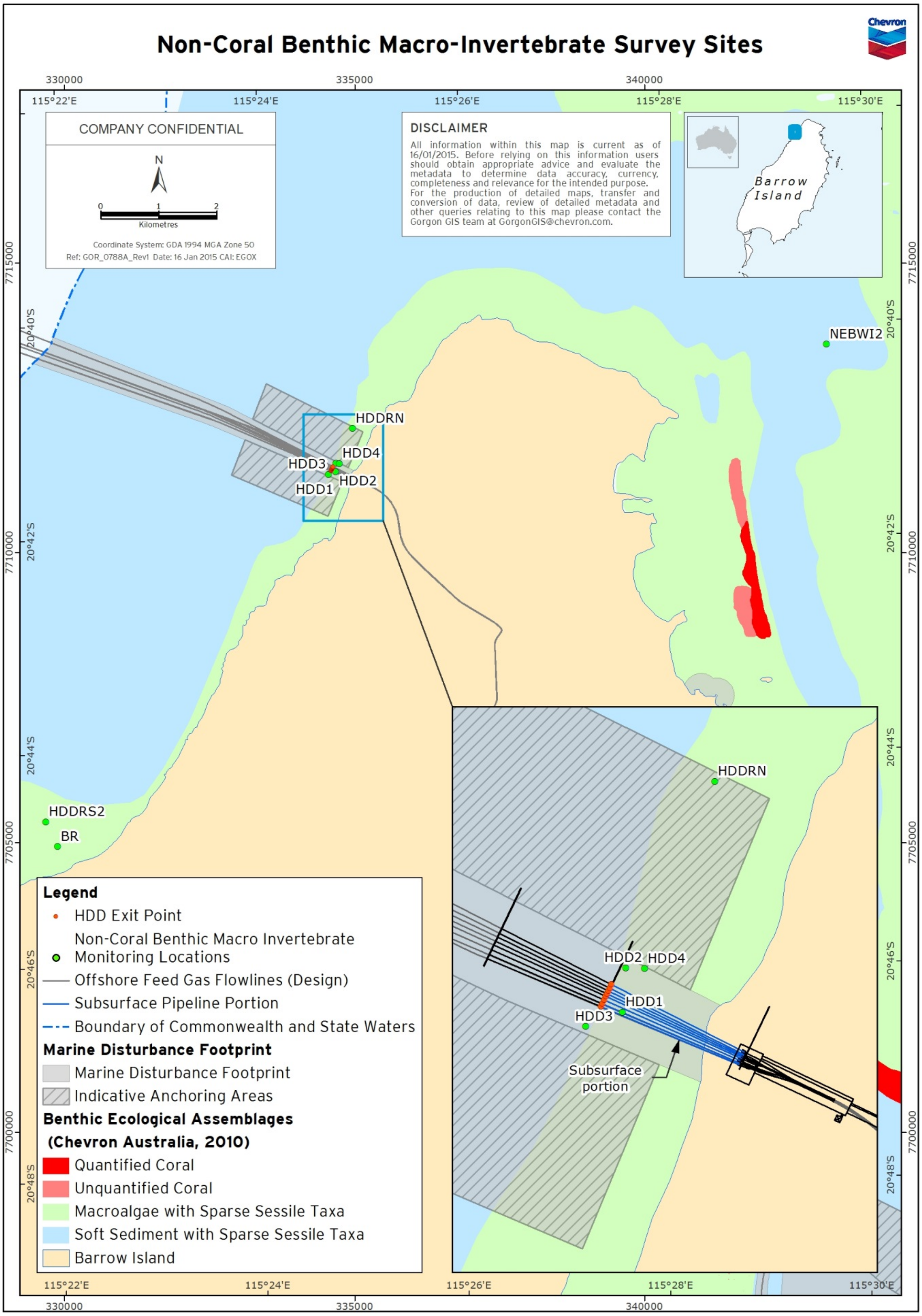


Figure 4-1 FGPDSY2 Sites for Non-Coral Benthic Macroinvertebrates

4.3.2 Timing of Sampling

The FGPDSY2 was undertaken in November 2014.

4.3.3 Methods

Benthic macroinvertebrate data collection methods are consistent with the Scope of Works (RPS 2009, amended 2014).

At each site, three 30 m long transects were laid out from a randomly placed central clump weight. The first transect was oriented parallel to the anchor line and the two others were laid at approximately 90° to the first. Coordinates of the start point of each transect were recorded using GPS and the transect bearing was noted. The 0.5 m wide belt transects were along the same three 30 m long transects (15 m^2) used for the macroalgal and seagrass surveys (see Sections 5.3.3 and 6.3.3). High-definition video footage was used to record the substratum along each 30 m long transect. The video system had two laser pointers that defined a path width of 0.5 m for analysis. The most common benthic macroinvertebrates along each transect were also photographed with a digital still camera and voucher specimens were collected.

4.3.4 Treatment of Survey Data

Video footage was analysed by marine scientists using TransectMeasure software (SeaGIS 2013). To reduce observer bias and for consistency between categories, all video footage analyses from Baseline and FGPDSY2, and quality assurance/quality control (QA/QC) of those analyses, were undertaken by BMT Oceanica scientists. To further mitigate observer bias, video analysts did not classify more than two of the three transects from each site. Video analysts were also required to classify benthic macroinvertebrate taxa to within 10% accuracy of the calibration classifications done by the BMT Oceanica invertebrate taxonomic expert.

The number and type of benthic macroinvertebrates present was determined by counting the number of individuals in each of the taxonomic groups along the length of each video transect. Counts were limited to benthic macroinvertebrate specimens visually estimated to be greater than 4 cm in diameter; specimens smaller than this were difficult to classify accurately. Counts were averaged to determine the mean abundance of taxonomic groups per transect.

Dominant and subdominant taxonomic groups of benthic macroinvertebrates were determined based on average abundance across sites. Taxonomic groups were defined as dominant or subdominant according to the criteria outlined in RPS (2009, amended 2014):

- Dominant: most common in terms of species percent cover or numbers of individuals depending on the growth form of organisms
- Subdominant: other common taxa in terms of percent cover or numbers, depending on the growth form of organisms.

Dominance was determined as the top ten most abundant taxa based on mean abundance values pooled across all MDF and Reference Sites. However, greater than ten dominant taxa can result from two or more taxa having the same mean abundance, and less than ten dominant taxa can result when fewer than ten taxa are recorded in a survey.

The same benthic macroinvertebrate categories were used in the Baseline, FGPDSY1, and FGPDSY2 (Table 4-2), except for the addition of the taxonomic group bryozoan and zoanthid in FGPDSY1, and bivalve, gastropod, and sea pen in FGPDSY2. Representative benthic macroinvertebrate voucher specimens were collected at each site (along video transects) for identification purposes if the video footage analysis required assistance with broad taxonomic classification.

Table 4-2 Naming Categories Applied to Non-Coral Benthic Macroinvertebrates Identified in the Baseline, FGPDSY1, and FGPDSY2

Benthic Macroinvertebrate Category
Anemone
Ascidian (colonial)
Ascidian (solitary)
Bivalve
Bryozoan
Crinoid
Gastropod
Gorgonian
Hydroid
Nudibranch
‘other’ hard coral
‘other’ soft coral (e.g. Alcyoniidae)
Sea cucumber
Sea pen
Sea star
Sea urchin
Sea whip
Sponge (barrel)
Sponge (branching)
Sponge (cup)
Sponge (digitate)
Sponge (fan)
Sponge (globular)
Sponge (tubular)
Sponge (variable)
Turbinaria spp.
Zoanthid
Unidentified

Note:

‘other’ hard coral includes all hard corals except those individually listed (e.g. Turbinaria *spp.).*

‘other’ soft coral include all soft corals except those individually listed (e.g. gorgonian, sea whip, sea pen).

Bryozoan and zoanthid added in FGPDSY1, and bivalve, gastropod, and sea pen added in FGPDSY2. None of these taxa were present in the Baseline.

Each transect per site was assigned a substrate category (soft sediment or limestone) based on the dominant substrate observed in the video footage. Classification was based on the percent cover of observed substrate, with transects defined by the substrate representing greater than 50% of the total cover. For example, transects classified as 10% coral, 10% limestone, and 80% soft sediment were classified into the soft sediment category. Sites were assigned a substrate category based on the classification of most transects (Table 4-3).

Table 4-3 Substrate Categories for Non-Coral Benthic Macroinvertebrate Survey Sites

Area	Site	Baseline	FGPDSY1	FGPDSY2
MDF	HDD1	Soft sediment	Soft sediment	Soft sediment
	HDD2	Soft sediment	Soft sediment	Soft sediment
	HDD3	Soft sediment	Soft sediment	Soft sediment
	HDD4	Soft sediment	Soft sediment	Soft sediment
Reference	HDDRN	NS[1]	Limestone	Limestone
	NEBWI2	Soft sediment	Soft sediment	Soft sediment
	BR	Soft sediment	Soft sediment	Soft sediment
	HDDRS2	Soft sediment	Soft sediment	Soft sediment

Notes:

1 Site not sampled due to poor weather conditions.

4.3.5 Statistical Approach for Comparison against Baseline

A summary of the statistical treatment and analyses used to assess any detected changes on benthic macroinvertebrates, consistent with the Scope of Works (RPS 2009, amended 2014) as per Condition 15.1 of Statement No. 769, is presented in Table 4-4 and further explained in Sections 4.3.5.1 and 4.3.5.2.

Table 4-4 Statistical Treatment and Analyses used for Non-Coral Benthic Macroinvertebrates

Random Transects	
Pre-treatment of data	• Site comparison test done as an uneven number of sites were sampled between the Baseline and Post-Development Surveys, to determine whether the additional site should be retained or removed. • Benthic macroinvertebrate categories that had zero values across all transects in the Baseline and Post-Development Surveys were excluded from analyses.
Sites used in statistical analyses	Baseline: • MDF (MDF): HDD1, HDD2, HDD3, HDD4 • Reference: BR, HDDRS2, NEBWI2 FGPDSY1 and FGPDSY2: • MDF: HDD1, HDD2, HDD3, HDD4 • Reference: HDDRN, BR, HDDRS2, NEBWI2
Stepwise approach	Stepwise approach adopted (see flow chart: Figure 4-2)
Main statistical design	Three-factor statistical design: • Survey (fixed, orthogonal) • Impact vs Reference [IvR] (fixed, orthogonal) • Site (random, nested within IvR)
Terms of interest	Survey × IvR
Statistical program	PERMANOVA[1]
Statistical test (PERMANOVA[1])	Benthic macroinvertebrate assemblages (Multivariate)
Transformation	Fourth-root transformed

Random Transects	
Distance measure	Bray-Curtis dissimilarity measure

Notes:

1 PERMANOVA = Non-parametric analysis of variance (Version 1.0.1, Primer-E Ltd) (Anderson 2001a, 2001b).

4.3.5.1 Pre-treatment of Data

For MDF and Reference Sites, if a site was sampled during only one or two surveys (and not all three) steps were taken to minimise the effect of this uneven replication of sites on statistical analyses. The solution to this problem was to only include extra sites that fell within the range of variation of sites sampled during both surveys (hereafter termed comparative sites). This was determined by independent statistical tests that compared extra sites against each of the comparative sites, within their respective survey period, for each of the ecological elements. The extra sites were excluded from subsequent analyses if the ecological element differed significantly from all comparison sites. This reduced the likelihood that differences in the number of sites from the Baseline to Post-Development Surveys could drive any significant results of statistical analyses.

Benthic macroinvertebrate categories that had zero values across all transects in the Baseline and Post-Development Surveys were excluded from analyses.

Benthic macroinvertebrate sites were grouped into substrate categories as described in Section 4.3.4 and Table 4-3. As part of the stepwise approach to assess potential detected changes in benthic macroinvertebrate community structure, separate analyses were conducted on the full dataset (combined soft sediment and limestone) and soft sediment dataset only. The limestone dataset was not analysed separately as only one site was classified as limestone substrate.

Following pre-treatment, the final list of sites used for assessing the potential impact of offshore pipe laying on benthic macroinvertebrates was determined, and is provided in Table 4-5.

Table 4-5 Sites Included in Statistical Analyses of Non-Coral Benthic Macroinvertebrates

Area	Baseline	FGPDSY1	FGPDSY2
MDF	HDD1	HDD1	HDD1
	HDD2	HDD2	HDD2
	HDD3	HDD3	HDD3
	HDD4	HDD4	HDD4
Reference	–	HDDRN	HDDRN
	BR	BR	BR
	HDDRS2	HDDRS2	HDDRS2
	NEBWI2	NEBWI2	NEBWI2

Note: Site HDDRN not sampled during the Baseline due to poor weather conditions.

For all multivariate analyses of benthic macroinvertebrates abundances, data were fourth-root transformed prior to analysis. This transformation allowed intermediate or rarer groups to play a part in the analyses (Clarke 1993). The Bray-Curtis dissimilarity measure was used on the multivariate dataset prior to analysis with PERMANOVA.

Where necessary, data on the composition of benthic macroinvertebrates may be zero-adjusted prior to analyses (i.e. dummy variable of 1 inserted prior to producing the resemblance matrix) (Clarke *et al*. 2006). Dummy variables are required where datasets are constrained by a high proportion of blank samples and/or samples with only one species recorded. Without the use of a dummy variable, a Bray-Curtis matrix produces undefined similarities where (i) no species were recorded in two compared samples, and (ii) only one species was recorded in the two samples. The insertion of the dummy variable moderates these effects.

4.3.5.2 Statistical Design and Analysis

Following pre-treatment of data, a Before-After-Control-Impact (BACI) approach was used to assess changes between the Baseline and Post-Development Surveys. This approach is required as per the Scope of Works (RPS 2009, amended 2014) and is one of the most powerful statistical designs for detecting changes caused by anthropogenic disturbances (Keough and Mapstone 1995) and thus for assessing detected changes in benthic macroinvertebrates associated with offshore pipe laying.

A stepwise approach was adopted for assessing potential environmental impacts to benthic macroinvertebrates. The purpose of this approach was to address the most common form of statistical error in environmental impact assessment studies: Type II error (statistical conclusion of no change when change has actually occurred [Schmitt and Osenberg 1996]). Each step of the approach was designed to address potential issues in the datasets (i.e. statistical power and high variance), thus reducing the chance of a Type II error. Steps to improve power were achieved by:

- partitioning of variance in the analysis
- pooling terms in the analysis.

For statistical analyses of changes in benthic macroinvertebrate community structure, it was important to differentiate among substrate types as benthic macroinvertebrates are known to be associated with different substrates (Pante *et al*. 2006; Slacum *et al*. 2010). Sites were grouped according to the dominant substrate (see Section 4.3.4; Table 4-3). It was not practicable to run all data in a single analysis with a ‘Substrate’ factor partitioning the variation as there was uneven replication of data among substrates (e.g. only one Reference Site [HDDRN] had limestone substrate). Therefore, a two-step approach was used:

1. Analyse the full dataset (combined soft sediment and limestone) without incorporating any statistical factors to differentiate among substrate types. This analysis tested whether the invertebrate assemblages—regardless of substrate type—were significantly impacted by offshore pipe laying.
2. If results were non-significant with the full dataset, this may have been due to invertebrate assemblages associating differently with various substrate types. Therefore, including different substrates in the analysis may have increased the estimates of variation and could have led to the conclusion of no change when change had actually occurred (i.e. Type II error). The next step was to partition variation caused by limestone substrate by excluding Reference Site HDDRN and running separate analyses on data associated with soft sediment only.

Pooling was done by removing factors in the test that had no interpretive value towards identifying whether impacts had occurred. This approach incorporated the replication from those pooled factors into the remaining terms to potentially improve the power of tests. Where pooling of factors was required, this sometimes occurred regardless of the p-value of any terms that included the factor in question. Pooling of factors when the p-value is <0.25 can increase the chance of Type I error (conclusion of change when actually no change occurred; Winer *et al.* 1991). If the pooled analysis fails to detect change despite the increased risk of Type I error, then the interpretation of no change is strengthened. If the pooled analysis detects change, Type I error cannot be ruled out, but, as a minimum, the taxa and places of potential concern are identified.

A flow chart (Figure 4-2) outlines the stepwise approach adopted for assessment of changes in benthic macroinvertebrate community structure before and after offshore pipe laying. Separate analyses were conducted on the full dataset (combined soft sediment and limestone) and soft sediment dataset only. The full dataset was firstly analysed according to the process shown in Figure 4-2. If no interaction terms of interest were significant at the end of this process, then the data were partitioned into soft sediment dataset only and re-analysed.

A three-factor design was used to test whether offshore pipe laying had an effect on benthic macroinvertebrates (Figure 4-2). The interpretation of results for statistical designs in this flow chart (Figure 4-2) focused on the 'Survey × IvR' interaction term that was potentially indicative of a change. If the interaction term of interest was significant at any stage in the flow chart (Figure 4-2), it was interpreted using post-hoc, pairwise comparisons combined with graphing to determine the direction of any changes. A significant 'Survey × IvR' interaction term indicated that ecological elements had changed between surveys at sites within the MDF, compared with Reference Sites.

If the interaction term of interest was non-significant, the next step in the flow chart was followed; either variation was partitioned by analysing the soft sediment dataset, or factors were pooled. After the conclusion of Step 2, if the 'Survey × IvR' interaction term remained non-significant, it could be concluded that no change associated with offshore pipe laying had occurred.

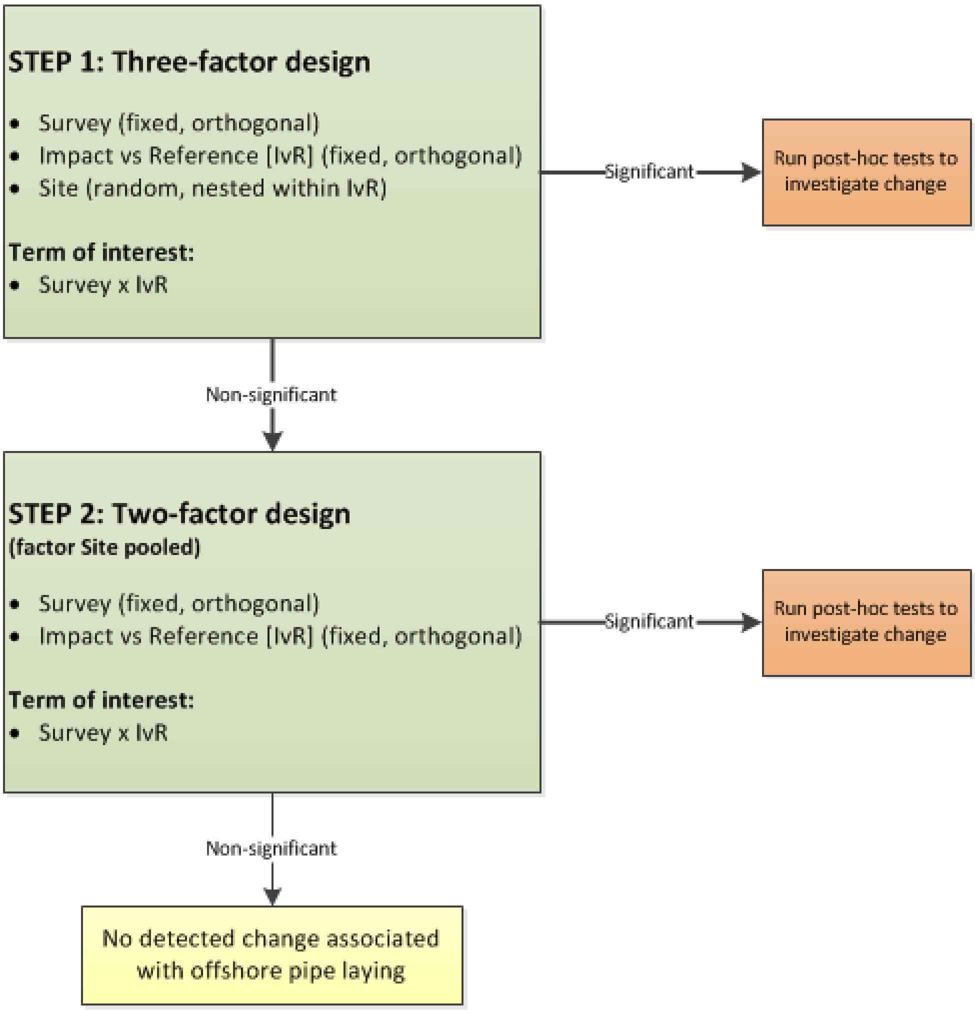


Figure 4-2 Statistical Design and Stepwise Approach for Assessment of Change in Non-Coral Benthic Macroinvertebrates Before and After Offshore Pipe Laying

4.4 Results of Post-Development Survey

4.4.1 Benthic Macroinvertebrates in West Coast Barrow Island Waters

Twenty-two taxonomic groups (including unidentified) were recorded across all sites during FGPDSY2; 15 groups were recorded among the four MDF Sites, and 18 groups were recorded among the four Reference Sites (Table 4-6). The highest number of taxonomic groups was recorded at the limestone site HDDRN, with the soft sediment sites ranging from one (HDD1, HDD4) to 12 (HDD2) taxonomic groups (Table 4-6).

Table 4-6 Mean Number of Individuals per Site (± SE) of Non-Coral Benthic Macroinvertebrates Observed During FGPDSY2

Taxonomic Group	MDF Sites				Reference Sites			
	HDD1	HDD2	HDD3	HDD4	HDDRN	BR	HDDRS2	NEBWI2
Anemone	–	–	–	–	–	–	–	–
Ascidian (colonial)	**–**	**0.33 (0.33)**	**–**	**–**	**3.00 (1.00)**	**–**	**–**	**17.67 (6.89)**
Ascidian (solitary)	–	–	–	–	–	–	–	0.33 (0.33)
Bivalve	–	–	0.33 (0.33)	–	–	–	–	–
Bryozoan	**–**	**0.67 (0.67)**	**–**	**–**	**2.33 (0.88)**	**–**	**–**	**–**
Crinoid	–	–	–	–	1.00 (0.58)	–	–	–
Gastropod	–	–	0.33 (0.33)	–	–	–	–	–
Gorgonian	–	–	–	–	–	–	–	–
Hydroid	–	0.33 (0.33)	–	–	0.33 (0.33)	–	–	–
Nudibranch	–	–	–	–	–	–	–	–
‘other’ hard coral	–	**0.33 (0.33)**	–	–	**6.67 (0.88)**	**2.33 (1.20)**	**0.67 (0.67)**	–
‘other’ soft coral	–	**3.00 (2.52)**	**0.67 (0.67)**	–	**11.33 (2.19)**	–	**0.33 (0.33)**	**0.33 (0.33)**
Sea cucumber	–	–	–	–	0.33 (0.33)	–	–	–
Sea pen	0.33 (0.33)	–	–	–	–	–	–	–
Sea star	–	**0.33 (0.33)**	**0.33 (0.33)**	–	**0.67 (0.67)**	–	–	–
Sea urchin	–	–	–	–	–	–	–	0.00 (0.00)
Sea whip	–	**4.67 (2.40)**	**2.67 (2.67)**	–	**164.00 (18.08)**	**1.00 (0.58)**	**1.00 (0.00)**	**2.33 (1.33)**
Sponge (barrel)	–	0.33 (0.33)	–	–	–	–	–	–

Taxonomic Group	MDF Sites				Reference Sites			
	HDD1	HDD2	HDD3	HDD4	HDDRN	BR	HDDRS2	NEBWI2
Sponge (branching)	–	–	–	–	–	–	–	–
Sponge (cup)	–	–	–	–	–	–	–	–
Sponge (digitate)	–	–	–	–	–	–	–	0.33 (0.33)
Sponge (fan)	–	**2.00 (1.00)**	–	–	**2.00 (0.58)**	–	–	**1.33 (0.67)**
Sponge (globular)	–	–	–	–	0.33 (0.33)	–	–	–
Sponge (tubular)	–	0.33 (0.33)	–	–	0.67 (0.67)	–	–	–
Sponge (variable)	–	**12.00 (6.24)**	**3.00 (2.52)**	**0.33 (0.33)**	**26.33 (3.28)**	**1.67 (0.67)**	**2.33 (2.33)**	**3.00 (2.00)**
***Turbinaria* spp.**	–	**3.33 (2.40)**	–	–	**8.67 (2.96)**	**1.33 (0.88)**	–	**0.67 (0.67)**
Zoanthid	–	–	–	–	**2.00 (0.58)**	–	–	–
Unidentified	–	–	–	–	**1.00 (0.58)**	–	–	**0.33 (0.33)**
Total number of taxa	**1**	**12**	**6**	**1**	**16**	**4**	**4**	**9**

Notes:

Standard Errors (SE) are shown in parentheses

Bold font (except 'Total number of taxa') = dominant (top ten most abundant taxonomic groups pooled across all FGPDSY2 sites)

– = zero value recorded

Eleven dominant taxonomic groups are identified, as Sea Star and Unidentified shared equal mean abundance values pooled across all sites

Site HDDRN substrate = limestone (Table 4-3)

4.4.2 Dominant Benthic Macroinvertebrates in West Coast Barrow Island Waters

The dominant taxonomic groups were similar between the MDF and Reference Sites during FGPDSY2 (Table 4-6). Nine of the 11 dominant taxonomic groups (ascidian (colonial), bryozoan, 'other' hard coral, 'other' soft coral, sea star, sea whip, sponge (fan), sponge (variable), *Turbinaria* spp.) were shared across the MDF and Reference Sites. The only differences were that zoanthids and unidentified taxa were dominant at Reference Sites only (Table 4-6). Subdominant benthic macroinvertebrate taxa at Reference Sites included ascidian (solitary), crinoid, hydroid, sea cucumber, sponges (digitate), sponge (globular), and sponge (tubular) (Table 4-6). Subdominant benthic macroinvertebrate taxa at sites within the MDF included bivalve, gastropod, hydroids, sea pen, sponges (barrel), and sponges (tubular) (Table 4-6).

4.4.3 Description of Benthic Macroinvertebrate Assemblages in the MDF (Area at Risk of Material or Serious Environmental Harm due to the OFGPS)

Fifteen taxonomic groups were recorded across the four MDF Sites (Table 4-6). The number of taxonomic groups varied among sites, ranging from one taxonomic group at sites HDD1 and HDD4, to 12 taxonomic groups at site HDD2 (Table 4-6).

The most abundant taxonomic group across the MDF Sites was sponge (variable), ranging from a mean abundance of 0.3 individuals at site HDD4 to 12 individuals at site HDD2. Sea whips were the next most abundant, ranging from a mean abundance of 2.7 individuals at site HDD3 to 4.7 individuals at site HDD2 (Table 4-6). The mean abundance of the remaining dominant taxonomic groups were low: *Turbinaria* spp. (3.3 individuals), 'other' soft corals (≤3 individuals), sponge (fan) (2 individuals), bryozoan (0.7 individuals), ascidians (colonial) (0.3 individuals), 'other' hard coral (0.3 individuals), and sea star (≤0.3 individuals) (Table 4-6).

Four taxonomic groups ('other' soft coral, sea star, sea whip, sponge (variable)) were common at more than one MDF Site (Table 4-6).

4.4.4 Description of Benthic Macroinvertebrate Assemblages at Reference Sites not at Risk of Material or Serious Environmental Harm due to the OFGPS

Eighteen taxonomic groups were recorded across the four Reference Sites during FGPDSY2 (Table 4-6). The number of taxonomic groups varied among sites, ranging from four taxonomic groups at sites HDDRS2 and BR, to 16 at site HDDRN (Table 4-6).

The dominant taxonomic groups were similar to sites within the MDF, with nine of the 11 dominant taxonomic groups recorded within the MDF shared with Reference Sites. The most abundant taxonomic group at the Reference Sites was sea whip, ranging from a mean abundance of one individual at sites BR and HDDRS2 to 164 individuals at site HDDRN (Table 4-6). Sponge (variable) was the next most abundant, ranging from a mean abundance of 1.7 individuals at site BR to 26.3 individuals at site HDDRN (Table 4-6). The remaining dominant taxonomic groups had lower mean abundances: ascidian (colonial) (≤17.7 individuals), 'other' soft coral (≤11.3 individuals), *Turbinaria* spp. (≤8.7 individuals), 'other' hard coral (≤6.7 individuals), bryozoan (2.3 individuals), zoanthid (2 individuals), sponge (fan) (≤2 individuals), sea star (0.7 individuals), and unidentified (≤1 individual) (Table 4-6).

Eight taxonomic groups (ascidian (colonial), 'other' hard coral, 'other' soft coral, sea whip, sponges (fan), sponges (variable), *Turbinaria* spp., unidentified) were common at more than one Reference Site (Table 4-6).

4.5 Comparison between the Post-Development Survey and the Marine Baseline Environmental State

4.5.1 Descriptive Comparison

Twenty-two taxonomic groups were recorded across all sites during FGPDSY2, compared with 19 taxonomic groups during Baseline; 15 taxonomic groups were common between the two survey periods. The dominant taxonomic groups were similar between the Baseline and FGPDSY2 and comprised tunicates, cnidarians, echinoderms, and poriferans (Table 4-7).

Within the MDF, there was little variation in the dominant taxonomic groups between the Baseline and FGPDSY2; 60% of the dominant taxonomic groups in FGPDSY2 were also present in the Baseline (Table 4-7). At the Reference Sites, 70% of the dominant taxonomic groups in FGPDSY2 were also present in the Baseline (Table 4-7).

Table 4-7 Dominant Non-Coral Benthic Macroinvertebrate Taxonomic Groups during the Baseline and Post-Development Surveys

Area	Baseline	FGPDSY1	FGPDSY2
MDF	Sea whip	**Sea whip**	**Sponge (variable)**
	Hydroid Sponge (variable)	**Sponge (variable)**	Sea whip
	'other' soft coral	***Turbinaria* spp.**	**'other' soft coral**
	Ascidian (colonial)	**'other' soft coral**	***Turbinaria* spp.**
	'other' hard coral Sponge (fan)	**Hydroid**	**Sponge (fan)**
	Turbinaria spp. Unidentified	**Ascidian (colonial)** **'other' hard coral**	Bryozoan Sea star
	Anemone Ascidian (solitary) Sponge (barrel)	**Anemone** **Ascidian (solitary)** Sea star **Sponge (fan)** **Unidentified**	**Ascidian (colonial)** Bivalve Gastropod **Hydroid** **'other' hard coral** Sea pen **Sponge (barrel)** Sponge (tubular)
Reference	Hydroid	**Sea whips**	**Ascidian (colonial)**
	Ascidian (colonial)	**Sponges (variable)**	**Sponge (variable)**
	Turbinaria spp.	**Ascidians (colonial)**	**Sea whip**
	Sea whip	**'other' soft corals**	**'other' hard coral**
	'other' hard coral	***Turbinaria* spp.**	***Turbinaria* spp.**
	Sponge (variable)	**'other' hard corals**	**Sponge (fan)**
	'other' soft coral	Sea stars Unidentified	**'other' soft coral**
	Sponge (fan)		Ascidian (solitary) Sponge (digitate) Unidentified
	Gorgonian		
	Sponge (cup) Sponge (branching)		

Notes:

Taxonomic group listed in order of abundance from highest to lowest.

Site HDDRN was excluded from the analysis. Further details and rationale behind this approach are given in Section 4.3.5.1.

Bold font = dominant taxonomic groups that are shared with the Baseline.

Multiple categories within a cell = categories with the same relative abundance.

Only eight taxonomic categories were present at Reference Sites in FGPDSY1.

4.5.2 Statistical Comparison

The 'Survey × IvR' interaction term was non-significant at Step 2 of the stepwise approach (two-factor design: Figure 4-2) when the full dataset (soft sediment and limestone combined) was used. When the data were partitioned by removing the limestone site HDDRN, the soft sediment dataset remained non-significant for the 'Survey × IvR' interaction term (Table 4-8) at

Step 2 of the stepwise approach. This result suggests that there has been no impact on benthic macroinvertebrate assemblages at MDF soft sediment sites due to offshore pipe laying.

Table 4-8 Results of Two-factor Statistical Analyses of Non-Coral Benthic Macroinvertebrate Assemblages during the Baseline Survey and Post-Development Surveys for Soft Sediment Only

Source	df	SS	MS	Pseudo-F	p-value
Survey	2	3930.8	1965.4	1.2315	0.2663
IvR	1	6379.2	6379.2	3.997	0.0137
Survey × IvR	2	4963.5	2481.8	1.555	0.1541
Residual	57	90971	1596		
Total	62	1.0568E5			

Note: No statistically significant term of interest was detected

4.6 Discussion and Conclusions

Twenty-two taxonomic groups were recorded across all sites during FGPDSY2, compared with 19 and 17 taxonomic groups in the Baseline and FGPDSY1, respectively. Fifteen taxonomic groups were common between the Baseline and FGPDSY2. The diversity and abundance of benthic macroinvertebrates was similar between the MDF and Reference Sites in FGPDSY2, with nine of the dominant taxonomic groups (ascidian (colonial), bryozoan, 'other' hard coral, 'other' soft coral, sea star, sea whip, sponge (fan), sponge (variable), *Turbinaria* spp.) shared across the MDF and Reference Sites. However, the diversity and abundance of benthic macroinvertebrates was higher on limestone substrate (represented by a single site) compared to soft sediment substrate, which is likely due to different benthic macroinvertebrates associating with different substrate types (Pante *et al.* 2006; Slacum *et al.* 2010).

Within the MDF, there was little variation in the dominant taxonomic groups between the Baseline and FGPDSY2, with nine of the dominant taxonomic groups in FGPDSY2 shared with those in the Baseline. At the Reference Sites, seven of the dominant taxonomic groups in FGPDSY2 were shared with those in the Baseline.

No significant differences in the benthic macroinvertebrate communities were detected for the interaction term 'Survey × IvR', indicating that no detected change was evident at MDF or Reference Sites from before to after offshore pipe laying. However, a significant 'IvR' main effect was detected, indicating that the benthic macroinvertebrate communities differed significantly between the MDF and Reference Sites. However, these spatial differences were present during both the Baseline and FGPDSY2, and therefore, there is no evidence to suggest that the offshore pipe-laying activities resulted in any change in the benthic macroinvertebrate communities.

5.0 Macroalgae

5.1 Introduction

The macroalgal flora of tropical northern Australia are relatively poorly known compared to temperate regions and there have been few systematic collections undertaken to date (Huisman and Borowitzka 2003). A marine flora checklist for the Dampier Archipelago lists some 210 species, including 114 species of red algae (Rhodophyta), 50 species of green algae (Chlorophyta), 32 species of brown algae (Heterokontophyta; referred to as Phaeophyta in the FGPDSY1 Report [Chevron Australia 2014b]), and five species of blue-green algae (Cyanophyta) (Huisman and Borowitzka 2003). Fifty-seven species were new records for Western Australia (WA) and five were new records for Australia. Ninety-one species of macroalgae have been identified in Barrow Island waters, including 35 species of red algae, 27 species of brown algae, 28 species of green algae, and one blue-green species (Cyanophyta) (Chevron Australia 2012b).

The macroalgal assemblages are typically dominated by species of brown algae, particularly of the genera *Sargassum*, *Turbinaria*, and *Padina* (Chevron Australia 2005; DEC 2007). Other common taxa include *Halimeda*, *Dictyopteris*, *Dictyota*, *Cystoseira*, *Codium*, and *Laurencia*. Macroalgal-dominated limestone reef and subtidal reef platform/sand mosaic are the most extensive habitat types in the Montebello Islands/Barrow Island region (DEC 2007), including in the waters around Barrow Island (Chevron Australia 2012b). During the Baseline, macroalgal assemblages were commonly recorded on limestone pavement in depths of 5 to 10 m, and were also common across the shallow limestone pavement of the Southern Lowendal Shelf that extends north towards the Montebello Islands. Macroalgae often co-occurred in lower abundance with seagrass and non-coral benthic macroinvertebrates.

At North Whites Beach on the west coast of Barrow Island, macroalgae species grow on the shallow subtidal pavement reef at varying densities (Chevron Australia 2005). Macroalgae species are particularly dense in reef fissures and holes. Macroalgal beds are also found on the high profile reefs that stand up to three metres above the seabed in nearshore waters of approximately 5 to 10 m water depth (Chevron Australia 2005). The macroalgal assemblages found on the limestone reef off North Whites Beach include *Sargassum* spp., *Dictyopteris* spp., and *Halimeda* spp. (Chevron Australia 2005).

5.2 Scope

This section is in two parts. The first part describes the macroalgae recorded during the FGPDSY2:

- at sites within the MDF (area at risk of Material or Serious Environmental Harm due to the OFGPS)
- at References Sites not at risk of Material or Serious Environmental Harm due to the OFGPS.

The second part compares the Post-Development Surveys with the Baseline to identify any detected changes to marine ecological elements as per Condition 15.3 of Statement No. 769.

5.3 Methods

5.3.1 Site Locations

Baseline surveys were conducted at four sites within the MDF (HDD1, HDD2, HDD3, and HDD4), and at three Reference Sites (NEBWI2, BR, and HDDRS2) (Table 5-1; Figure 5-1). FGPDSY2 sampling was undertaken at the same sites as the Baseline surveys and FGPDSY1

(Table 5-1; Figure 5-1). Reference Site HDDRN could not be accessed during Baseline surveys due to poor weather, but was surveyed in FGPDSY1 and FGPDSY2 (Table 5-1; Figure 5-1).

Table 5-1 Baseline and Post-Development Survey Sites for Macroalgae

Area	Site	Baseline[1]		FGPDSY1[1]		FGPDSY2[1]	
		Easting[2]	Northing[2]	Easting[2]	Northing[2]	Easting[2]	Northing[2]
MDF	HDD1	334655	7711392	334656	7711361	334666	7711398
	HDD2	334678	7711541	334677	7711541	334677	7711541
	HDD3	334549	7711352	334546	7711353	334548	7711351
	HDD4	334739	7711539	334753	7711551	334738	7711539
Reference	HDDRN	NS[3]	NS[3]	334972	7712174	334965	7712144
	BR	329877	7704929	329874	7704922	329877	7704929
	HDDRS2	329675	7705354	329675	7705357	329675	7705354
	NEBWI2	343137	7713599	343157	7713588	343137	7713599

Notes:

1 *Eastings and northings are the start of transects.*

2 *Datum used: GDA94 Projection MGA Zone 50.*

3 *Site not sampled due to poor weather conditions.*

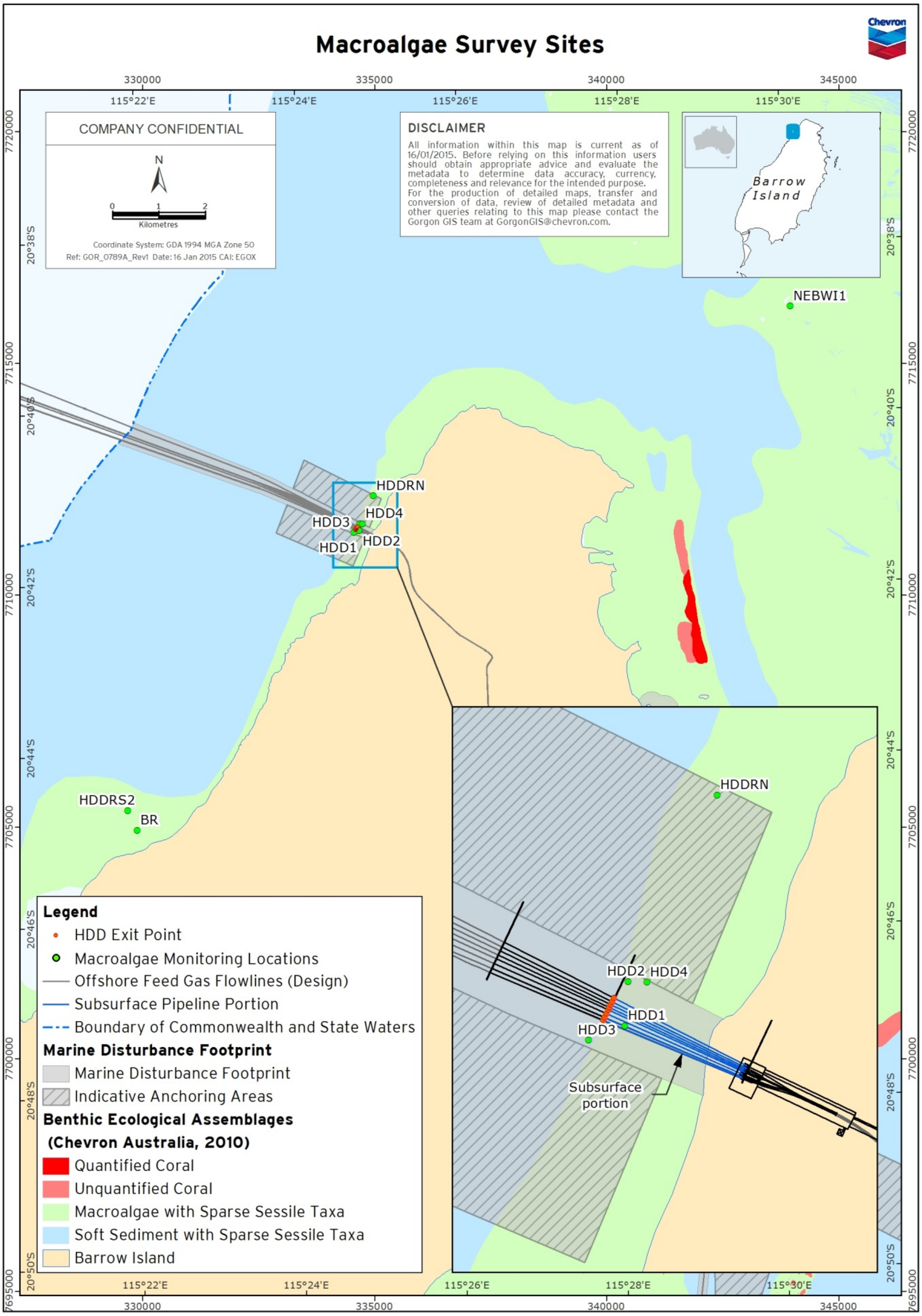


Figure 5-1 FGPDSY2 Sites for Macroalgae

5.3.2 Timing of Sampling

The FGPDSY2 was undertaken in November 2014.

5.3.3 Methods

Macroalgae data collection methods were consistent with the Scope of Works (RPS 2009, amended 2014). Minor differences exist in the methods used during the Baseline and Post-Development Surveys; any such differences are explained in this Section and in Section 5.3.4.

At each site, three 30 m long transects were laid out from a randomly placed central clump weight. The first transect was oriented parallel to the anchor line and the two others were laid at approximately 90° to the first. Coordinates of the start point of each transect were recorded using GPS and the transect bearing was noted. These survey transects were also used for non-coral benthic macroinvertebrate surveys (see Section 4.3.3) and seagrass surveys (see Section 6.3.3).

Benthic cover was surveyed by positioning seven 1 m^2 quadrats at 5 m intervals along the right side of each transect. Each 1 m^2 quadrat was divided into four subquadrats of 0.25 m^2 (0.5 × 0.5 m) and individually photographed for percent cover analyses. Macroalgal voucher specimens were collected from within the quadrats positioned at 0 m, 10 m, 20 m, and 30 m along each transect.

Macroalgal biomass samples were collected within 0.25 m^2 (0.5 × 0.5 m) quadrats positioned at 10 m, 10.5 m, 20 m, and 20.5 m along the left side of each transect (the opposite side of the transect line used for sampling benthic cover). All above- and below-ground biomass of macroalgae were harvested. Two photographs of each quadrat were taken prior to and after harvesting. Biomass samples were blot dried and wet weighed then combined with seagrass biomass to record the total wet weight to the nearest gram.

Minor differences exist in the methods used to measure biomass during the Baseline and Post-Development Surveys. During the Baseline, samples with zero biomass were excluded from analyses, causing insufficient replication for statistical analyses at some sites. As such, during FGPDSY1 and FGPDSY2, a minimum of three non-zero replicate quadrats were required per site to enable sufficient replication for statistical analysis of biomass. If fewer than three samples were collected over the three transects (i.e. the quadrats had no macroalgae or seagrass), additional sampling was undertaken at 1 m intervals from the start of the transect until three replicate biomass samples were obtained at the site. If no biomass samples were collected over the three transects, a new biomass transect was established where patches of seagrass or macroalgae were present. If no seagrass or macroalgal patches were observed after five minutes of searching, the site was deemed to support no seagrass or macroalgae, and thereafter was excluded from sampling and statistical analyses. During FGPDSY2, combined biomass samples at all sites were collected from established transects to achieve sufficient replication for statistical analyses. Any quadrats with zero values were excluded from statistical comparison as outlined in the statistical approach (Section 5.3.5).

Macroalgae were identified to the lowest taxonomic level possible (generally, to genus and species) for assessment of macroalgal diversity and dominant taxa at all sites. Taxa identification of macroalgae present during FGPDSY2 was undertaken on voucher specimens that were forwarded to Dr John Huisman (Murdoch University) for formal identification. The dominant and subdominant macroalgal taxa at each site were determined by qualitative assessment of macroalgal percent cover as observed in the photoquadrat images, in conjunction with the list of verified taxa identified by Dr Huisman.

5.3.4 Treatment of Survey Data

5.3.4.1 Benthic Cover

The percent cover of major benthic categories (macroalgae, seagrass, turf algae, coral, benthic macroinvertebrates, sand, rubble, pavement) was estimated by analysing photoquadrat images using the computer software program Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006).

All CPCe classifications, video analyses, and QA/QC were undertaken by BMT Oceanica scientists. To reduce inter-observer variability that is generally present in monitoring programs when two or more scientists make quantitative observations, analysts did not classify more than two of the three transects from each site. A taxonomic expert from BMT Oceanica was appointed to perform calibration classifications, against which the analysts were required to be within 10% accuracy.

Eight points per subquadrat image (32 points per 1 m^2 quadrat) were randomly generated and each point was visually classified by trained observers into one of eight major benthic cover categories (macroalgae, seagrass, turf algae, coral, benthic macroinvertebrates, sand, rubble, pavement, or where accurate identification was not possible, as unidentifiable). Note: The sparse distribution of some benthic cover categories meant they were not always scored in an image even when present in that image.

Estimates of the percent cover of benthic categories were then calculated as the number of points classified into each individual category divided by the total number of points classified. Points falling into the unidentifiable category were removed from the total prior to calculation of percent cover. This resulted in a slight overestimate of the percent cover of the remaining categories, but as only a few points were unidentifiable, the overestimation was expected to be negligible.

5.3.4.2 Biomass

For FGPDSY1 and FGPDSY2, the sampling method allowed the recording of macroalgae wet weight (when observed) at each site separately from seagrass wet weight, and thus provided a dataset by which to estimate macroalgae biomass (as per RPS 2009, amended 2014). However, during Baseline surveys, seagrass and macroalgal biomass from two sites within the MDF (HDD1 and HDD2), one replicate transect at site HDD4 within the MDF, and one of the Reference Sites (NEBWI1) were not easily separated and so a combined weight was measured (Chevron Australia 2014a). For all these sites, seagrass comprised a small proportion of the total biomass along transects, and wet weights were dominated by macroalgae. To allow for statistical comparison between the Baseline and Post-Development Surveys, analysis was performed on the combined macroalgal and seagrass biomass.

The 0.25 m^2 quadrats were used as replicates for statistical analyses of the combined macroalgal and seagrass biomass. Quadrats with a zero value for macroalgal and seagrass biomass were excluded in the descriptive results of the FGPDSY2 data (Sections 5.4 and 6.4), for consistency with the Baseline (Chevron Australia 2014a). For statistical comparisons of Baseline and Post-Development Survey data, quadrats and sites with zero values for the combined macroalgal and seagrass biomass were excluded from the analysis to stratify the analysis to areas of seabed supporting seagrass and/or macroalgae (Section 5.3.3). Mean macroalgal biomass per square metre (excluding zero values) at each site (g/m^2) was calculated for graphical presentation (Section 5.4).

5.3.5 Statistical Approach for Comparison against Baseline

A summary of the statistical treatment and analyses used to assess any detected changes on macroalgae, consistent with the Scope of Works (RPS 2009, amended 2014) as per Condition 15.1 of Statement No. 769, is presented in Table 5-2 and further explained in Sections 5.3.5.1 and 5.3.5.2.

Table 5-2 Statistical Treatment and Analyses used for Macroalgal Cover and Macroalgal and Seagrass Combined Biomass

Random Transects	
Pre-treatment of data	Site comparison test done because an uneven number of sites were sampled between the Baseline and FGPDSY1 and FGPDSY2, to determine whether the additional site should be retained or removed
Sites used in statistical analyses	Macroalgal cover, and macroalgae and seagrass combined biomass: Baseline: • MDF1: HDD1, HDD2, HDD3, HDD4 • Reference: BR, HDDRS2, NEBWI1 FGPDSY1 and FGPDSY2: • MDF1: HDD1, HDD2, HDD3, HDD4 • Reference: HDDRN, BR, HDDRS2, NEBWI1
Ste-wise approach	Ste-wise approach adopted (see flow chart: Figure 5-2)
Main statistical design	Three-factor statistical design: • Survey: Baseline, FGPDSY1, FGPDSY2 (fixed, orthogonal) • Impact vs Reference [IvR] (fixed, orthogonal) • Site (random, nested within IvR)
Terms of interest	Survey × IvR
Statistical program	PERMANOVA[1]
Statistical tests (PERMANOVA[1])	• Percent cover of macroalgae (Univariate) • Macroalgae and seagrass combined biomass (Univariate)
Transformation	Macroalgal cover: • square-root arcsine transformed Macroalgae and seagrass combined biomass: • No transformation
Distance measure	Macroalgal cover: • Euclidean dissimilarity Macroalgae and seagrass combined biomass: • No distance measure

Notes:

1 PERMANOVA = Non-parametric analysis of variance (Version 1.0.1, Primer-E Ltd) (Anderson 2001a, 2001b)

5.3.5.1 Pre-treatment of Data for Statistical Analysis

For MDF and Reference Sites, if a site was sampled during only one or two surveys (and not all three), steps were taken to minimise the effect of this uneven replication of sites on statistical analyses. The solution to this problem was to only include extra sites that fell within the range of variation of sites sampled during both surveys (hereafter termed comparative sites). This was determined by independent statistical tests that compared extra sites against each of the comparative sites, within their respective survey period. The extra sites were excluded from subsequent analyses if the ecological element differed significantly from all the comparison sites. This reduced the likelihood that differences in the number of sites from Baseline to the Post-Development Surveys could drive any significant results of statistical analyses.

Quadrats and/or transect replicates that had zero values for combined macroalgal and seagrass biomass for Baseline and/or Post-Development Surveys were excluded from analyses (see Section 5.3.3 for details on stratification of samples).

Following pre-treatment, the final list of sites used for assessing the potential impact of offshore pipe laying on macroalgae was determined, and is provided in Table 5-3.

Table 5-3 Sites Included in Statistical Analyses of Macroalgal Cover and Combined Macroalgae and Seagrass Biomass

Area	Baseline	FGPDSY1	FGPDSY2
MDF	HDD1	HDD1	HDD1
	HDD2	HDD2	HDD2
	HDD3	HDD3	HDD3
	HDD4	HDD4	HDD4
Reference	–	HDDRN	HDDRN
	BR	BR	BR
	HDDRS2	HDDRS2	HDDRS2
	NEBWI1	NEBWI1	NEBWI1

Note: Site HDDRN not sampled during the Baseline due to poor weather conditions.

For univariate analysis of the percent cover of macroalgae, data were square-root arcsine transformed prior to analysis as this is a standard transformation for proportional datasets that are often binomially distributed (Underwood 1997). For univariate analysis of combined macroalgal and seagrass biomass, data were not transformed prior to analysis. Euclidean distance was used as a dissimilarity measure for univariate analyses. By using the Euclidean measure, PERMANOVA returns an equivalent test statistic to a standard ANOVA (Anderson *et al.* 2008).

5.3.5.2 Statistical Design and Analysis

Following pre-treatment of data, a BACI approach was used to assess changes between the Baseline and Post-Development Surveys. This approach is required as per the Scope of Works (RPS 2009, amended 2014) and is one of the most powerful statistical designs for detecting changes caused by anthropogenic disturbances (Keough and Mapstone 1995) and thus for assessing detected changes in macroalgae associated with offshore pipe laying.

A stepwise approach was adopted for assessing potential environmental impacts to macroalgae. The purpose of this approach was to address the most common form of statistical error in environmental impact assessment studies: Type II error (statistical conclusion of no change when change has actually occurred [Schmitt and Osenberg 1996]). Each step of the approach was designed to address potential issues in the datasets (i.e. statistical power and high variance), thus reducing the chance of a Type II error. Steps to improve power were achieved by pooling terms in the analysis.

Pooling was done by removing factors in the test that had no interpretive value towards identifying whether impacts had occurred. This approach incorporated the replication from those pooled factors into the remaining terms to potentially improve the power of tests. Where pooling of factors was required, this sometimes occurred regardless of the p-value of any terms that included the factor in question. Pooling of factors when the p-value is <0.25 can increase the chance of Type I error (conclusion of change when actually no change occurred; Winer *et al*. 1991). If the pooled analysis fails to detect change despite the increased risk of Type I error, then the interpretation of no change is strengthened. If the pooled analysis detects change, Type I error cannot be ruled out, but, as a minimum, the taxa and places of potential concern are identified.

A flow chart (Figure 5-2) outlines the stepwise approach and three-factor design adopted for assessment of change in macroalgae before and after offshore pipe laying. The interpretation of results for statistical designs in this flow chart (Figure 5-2) focused on the ‘Survey × IvR’ interaction term that was potentially indicative of a change. If the interaction term of interest was significant at any stage in the flow chart (Figure 5-2), it was interpreted using post-hoc, pairwise comparisons combined with graphing to determine the direction of any changes. A significant ‘Survey × IvR’ interaction term indicated that ecological elements had changed differently between surveys at sites within the MDF, compared with Reference Sites.

If the interaction term of interest was non-significant, the next step in the flow chart was followed and factors were pooled. After the conclusion of Step 2, if the ‘Survey × IvR’ interaction term remained non-significant, it could be concluded that no change associated with offshore pipe laying had occurred.

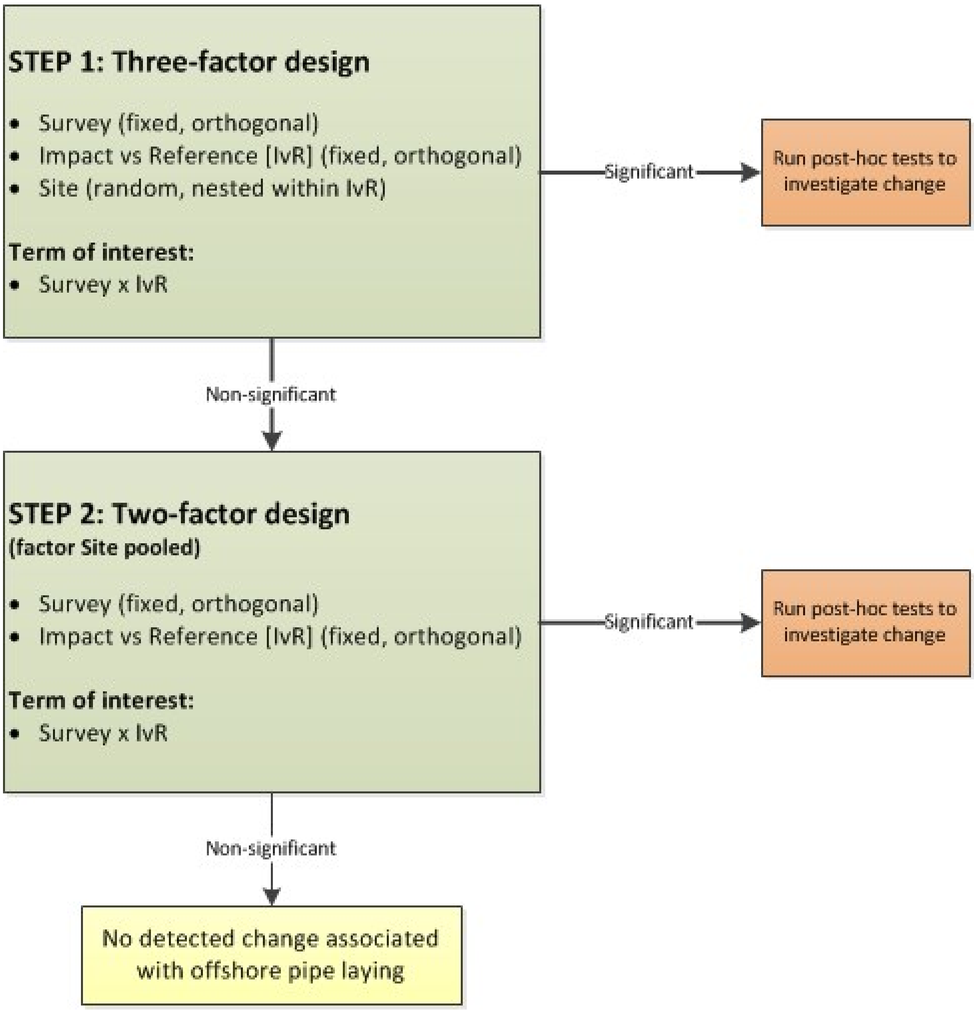


Figure 5-2 Statistical Design and Stepwise Approach for Assessment of Change in Macroalgae Before and After Offshore Pipe Laying

5.4 Results of Post-Development Survey

5.4.1 Macroalgae in West Coast Barrow Island Waters

During FGPDSY2, 115 macroalgal taxa were identified in the waters around Barrow Island. The diversity of red, brown, and green algae was 66, 26, and 23 taxa, respectively. The distribution of taxa among sites was relatively heterogeneous, with ~47%, ~31%, and ~65% of the identified taxa found only at individual sites for the red, brown, and green algae, respectively. *Dudresnaya barrowense* was a new taxon collected during FGPDSY2 (Table 5-4).

Table 5-4 Macroalgal Species Recorded during FGPDSY2

Species (or taxon)	No. of sites where species recorded	MDF Sites				Reference Sites			
		HDD1	HDD2	HDD3	HDD4	HDDRN	BR	HDDRS2	NEBWI1
Rhodophyta (red algae)									
Aglaothamnion cordatum	1						X		
Amansia rhodantha	1								X
Amphiplexia hymenocladioides	1						X		
Aneurianna lorentzii	1	X							
Anotrichium tenue	1		X						
Asparagopsis taxiformis	1		X						
Betaphycus speciosum	1						X		
Centroceras clavulatum	1							X	
Ceramium sp.	2				X	X			
Ceratodictyon scoparium	1			X					
Ceratodictyon spongiosum	1						X		
Chamaebotrys boergesenii	1					X			
Champia sp.	1						X		
Champia stipitata	2					X			X
Chondria sp. 1 'coarse'	2			X			X		
Chondria sp. 2 'narrow'	4	X	X	X					X
Chondria sp. 3 'cladurus'	2			X				X	
Chondria sp. 4 'dimples'	1					X			
Chondrophycus sp.	*3*	*X*	*X*				*X*		
Coelarthrum opuntia	5	X	X	X		X	X		
Corynomorpha prismatica	1		X						
Crouania sp.	1						X		
Crustose coralline	1						X		
Dasya anastomosans	4	X	X	X		X			
Dasya sp. 1	6	X	X	X	X	X	X		
Dasya sp. 2	3		X	X		X			
Desikacharyella sp.	1								X
Dichotomaria marginata	3	X	X	X					
Dichotomaria obtusata	4		X			X	X		X
Ditria sp.	1								X
Dudresnaya barrowense[1]	1		X						
Erythroclonium elongatum	2		X	X					
Erythroclonium sonderi	3		X			X	X		

Species (or taxon)	No. of sites where species recorded	MDF Sites				Reference Sites			
		HDD1	HDD2	HDD3	HDD4	HDDRN	BR	HDDRS2	NEBWI1
Eucheuma denticulatum	1						X		
Galaxaura rugosa	4		X	X			X		X
Gayliella sp.	2	X				X			
Gracilaria blodgettii	2			X	X				
Gracilaria sp.	1			X					
Gracilaria textorii	1	X							
Halymenia sp. 1	1			X					
Halymenia sp. 2	1					X			
Herposiphonia sp.	2			X				X	
Heterosiphonia crassipes	3		X			X	X		
Hypnea spinella	3	X				X	X		
Jania adhaerens	3						X	X	X
Jania rosea	3		X				X	X	
Laurencia brongniartii	2					X			X
Laurencia sp. 1 'prostrate'	3			X			X		X
Laurencia sp. 2 'implicata'	2						X		X
Leveillea jungermannioides	4		X	X				X	X
Lophocladia sp.	4	X		X		X		X	
Neosiphonia sertularioides	2				X			X	
Neosiphonia sp.	1		X						
Periphykon beckerae	1								X
Polysiphonia infestans	3	X				X		X	
Polysiphonia sp.	2			X				X	
Rhodymenia sp.	1			X					
Sarconema scinaioides	2	X		X					
Scinaia tsinglanensis	2		X			X			
Solieria robusta	4	X		X		X	X		
Spyridia dasyoides	1					X			
Spyridia filamentosa	1						X		
Tolypiocladia calodictyon	1						X		
Tolypiocladia glomerulata	3	X		X			X		
Tricleocarpa cylindrica	1			X					
Vidalia melvillei	3		X					X	X
Subtotal		**15**	**21**	**24**	**4**	**20**	**25**	**11**	**14**
Heterokontophya[2] (brown algae)									
Canistrocarpus cervicornis	2						X		X
Canistrocarpus crispata	1								X
Dictyopteris australis	2						X		X
Dictyopteris serrata	3		X			X			X

Species (or taxon)	No. of sites where species recorded	MDF Sites				Reference Sites			
		HDD1	HDD2	HDD3	HDD4	HDDRN	BR	HDDRS2	NEBWI1
Dictyopteris woodwardia	3					X	X		X
Dictyota ciliolata	2					X	X		
Dictyota sp.	2						X		X
Feldmannia mitchelliae	1						X		
Hormophysa cuneiformis	7	X	X	X		X	X	X	X
Hydroclathrus clathratus	1								X
Lobophora variegata	7	X	X	X		X	X	X	X
Nereia intricata	1								X
Padina australis	1						X		
Padina elegans	1						X		
Padina sanctae-crucis	2						X	X	
Padina sp.	4			X			X	X	X
Sargassopsis decurrens	5		X	X		X	X	X	
Sargassum aquifolium	2						X		X
Sargassum cf. *ilicifolium*	3						X	X	X
Sargassum cf. *linearifolium*	1						X		
Sargassum linearifolium	1								X
Sargassum polycystum	2							X	X
Sargassum sp.	7	X[3]	X	X		X	X	X	X
Sirophysalis trinodis	3						X	X	X
Sphacelaria rigidula	4			X			X	X	X
Sporochnus comosus	7	X	X	X		X	X	X	X
Subtotal		**4**	**6**	**7**	**0**	**8**	**20**	**11**	**19**
Chlorophyta (green algae)									
Anadyomene plicata	1								X
Avrainvillea nigricans	1			X					
Avrainvillea obscura	1		X						
Caulerpa brachypus	1						X		
Caulerpa corynephora	4					X	X	X	X
Caulerpa cupressoides	3	X	X	X					
Caulerpa delicatula	1						X		
Caulerpa fergusonii	1								X
Caulerpa lentillifera	2						X		X
Caulerpa sertularioides	3	X					X	X	
Caulerpa taxifolia	5		X	X		X	X	X	
Caulerpa verticillata	1						X		
Cladophora vagabunda	1			X					
Codium dwarkense	1								X
Dictyosphaeria cavernosa	1								X

Species (or taxon)	No. of sites where species recorded	MDF Sites				Reference Sites			
		HDD1	HDD2	HDD3	HDD4	HDDRN	BR	HDDRS2	NEBWI1
Halimeda discoidea	8	X	X	X	X	X	X	X	X
Halimeda velasquezii	1								X
Penicillus nodulosus	1						X		
Siphonocladus tropicus	4	X	X	X			X		
Udotea argentea	2					X	X		
Udotea flabellum	1						X		
Ulva lactuca	1			X					
Valonia ventricosa	1						X		
Subtotal		**4**	**5**	**7**	**1**	**4**	**13**	**4**	**8**
Total (all macroalgae)		**23**	**32**	**38**	**5**	**32**	**58**	**26**	**41**

Notes:

1 *The rhodophyte* Dudresnaya barrowense *is a new species that is yet to be formally described at the time of this Report (Dr John Huisman, pers. comm.).*

2 *Heterokontophyta was referred to as Phaeophyta in the FGPDSY1 Report (Chevron Australia 2014b).*

3 *Visual identification by BMT Oceanica's taxonomic expert.*

5.4.2 Dominant Macroalgae in West Coast Barrow Island Waters

Sixty-six red algal taxa were recorded but did not, singularly or collectively, dominate the benthic cover at any site, as many species identified were turfing or epiphytic algae. Close to half (47%) of the 66 taxa were recorded only at individual sites (Table 5-4). *Sargassum* spp. were the dominant macroalgal taxa observed within the MDF. Subdominant taxa at sites within the MDF included *Halimeda discoidea*, *Lobophora variegata*, and *Sporochnus comosus* (Table 5-5). Reference Sites were dominated by *Halimeda discoidea* and *Sargassum* spp. Subdominant taxa at Reference Sites included *Halimeda discoidea*, *Sargassopsis decurrens*, *Sargassum* spp., *Sirophysalis trinodis*, *Sporochnus comosus*, and various red algae (Table 5-5).

Table 5-5 Dominant and Subdominant Macroalgae Recorded during FGPDSY2

Area	Site	Dominant Taxa	Subdominant Taxa
MDF	HDD1	*Sargassum* spp.[1]	*Sporochnus comosus* *Lobophora variegata*
	HDD2	*Sargassum* spp.[1]	*Halimeda discoidea* *Sporochnus comosus*[1]
	HDD3	*Sargassum* spp.[1]	*Sporochnus comosus* *Lobophora variegata*
	HDD4	–[2]	–[2]

Area	Site	Dominant Taxa	Subdominant Taxa
Reference	HDDRN	*Halimeda discoidea*	*Sporochnus comosus* Various red algae *Sargassum* sp.
	BR	*Sargassum* spp.	*Sirophysalis trinodis* *Sporochnus comosus* *Halimeda discoidea*
	HDDRS2	*Sargassum* spp.	*Sargassopsis decurrens* *Sporochnus comosus* *Halimeda discoidea* *Sirophysalis trinodis*
	NEBWI1	*Sargassum* spp.	*Halimeda discoidea* *Sargassum* spp.

Notes:

1 *Species/taxa were visually identified from photoquadrats by BMT Oceanica's nominated taxonomic expert; these species were not collected and therefore identities have not been confirmed by Dr John Huisman.*

2 *No dominant/subdominant macroalgal taxa recorded.*

5.4.3 Description of Macroalgal Assemblages in the MDF (Area at Risk of Material or Serious Environmental Harm due to the OFGPS)

Macroalgal cover within the MDF ranged from 0.0% (HDD4) to 19.2% (HDD3) (Table 5-6; Figure 5-3). Sand was the dominant major benthic cover category within the MDF followed by turf algae (Table 5-6; Figure 5-3). Macroalgal biomass within the MDF ranged from 18.0 g/m^2 (HDD4) to 434.9 g/m^2 (HDD3) (Figure 5-4).

Sixty macroalgal taxa were identified within the MDF during FGPDSY2: 43 Rhodophyta (red algae), eight Heterokontophyta (brown algae), and nine Chlorophyta (green algae) (Table 5-4). Sites HDD2 and HDD3 were the most diverse sites, with 21 and 24 red algal taxa, six and seven brown algal taxa, and five and seven green algal taxa, respectively (Table 5-4). Macroalgae unidentified was the most abundant macroalgal subcategory, ranging from 0% (HDD4) to 11.9% (HDD3) (Table 5-7). The next most abundant macroalgal taxa were *Sargassum* and *Halimeda*, which ranged from 0.0% (HDD1, HDD4) to 5.8% (HDD3), and 0.0% (HDD1, HDD4) to 2.1% (HDD2), respectively (Table 5-7). The genera *Caulerpa*, *Dictyopteris*, and *Padina* were also present within the MDF, but with low overall percent cover (Table 5-7).

Table 5-6 Percent Cover (mean ± SE) of Major Benthic Cover Categories at MDF Sites during FGPDSY2

Site	Major Benthic Cover Categories							
	Seagrass	Macroalgae	Turf algae	Coral	Benthic macro-invertebrates	Sand	Rubble	Pavement
HDD1	0.30 (0.30)	1.19 (0.85)	2.53 (1.17)	–	0.15 (0.15)	95.68 (1.80)	0.15 (0.15)	–
HDD2	0.30 (0.21)	10.71 (2.96)	11.16 (2.72)	–	1.04 (0.62)	73.07 (5.28)	2.53 (1.17)	1.19 (0.73)

Site	Major Benthic Cover Categories							
	Seagrass	Macroalgae	Turf algae	Coral	Benthic macro-invertebrates	Sand	Rubble	Pavement
HDD3	0.15 (0.15)	19.20 (4.48)	9.23 (1.80)	0.30 (0.30)	1.34 (0.85)	69.79 (4.96)	–	–
HDD4	–	–	0.15 (0.15)	–	–	98.07 (1.63)	1.64 (1.64)	0.15 (0.15)

Notes:

SE are shown in parentheses.

– = zero value recorded.

Macroalgal percent cover values are rounded to one decimal place in the text.

Table 5-7 Percent Cover (mean ± SE) of Macroalgal Subcategories at MDF Sites during FGPDSY2

Site	Macroalgal Subcategories						
	Macroalgae unidentified	*Caulerpa*	*Dictyopteris*	*Halimeda*	*Padina*	*Sargassum*	*Udotea*
HDD1	1.19 (0.85)	–	–	–	–	–	–
HDD2	5.51 (1.94)	–	–	2.08 (0.92)	–	3.13 (1.41)	–
HDD3	11.90 (3.82)	0.15 (0.15)	0.15 (0.15)	1.19 (0.63)	–	5.80 (1.50)	–
HDD4	–	–	–	–	–	–	–

Notes:

SE are shown in parentheses.

– = zero value recorded.

Macroalgal percent cover values are rounded to one decimal place in the text.

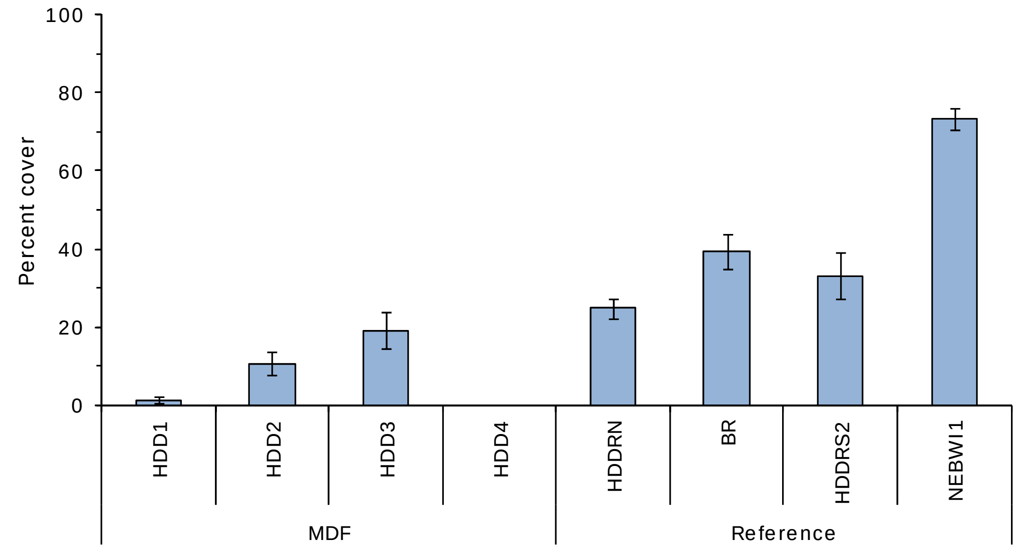


Figure 5-3 Mean (± SE) of Macroalgal Percent Cover during FGPDSY2 at MDF and Reference Sites

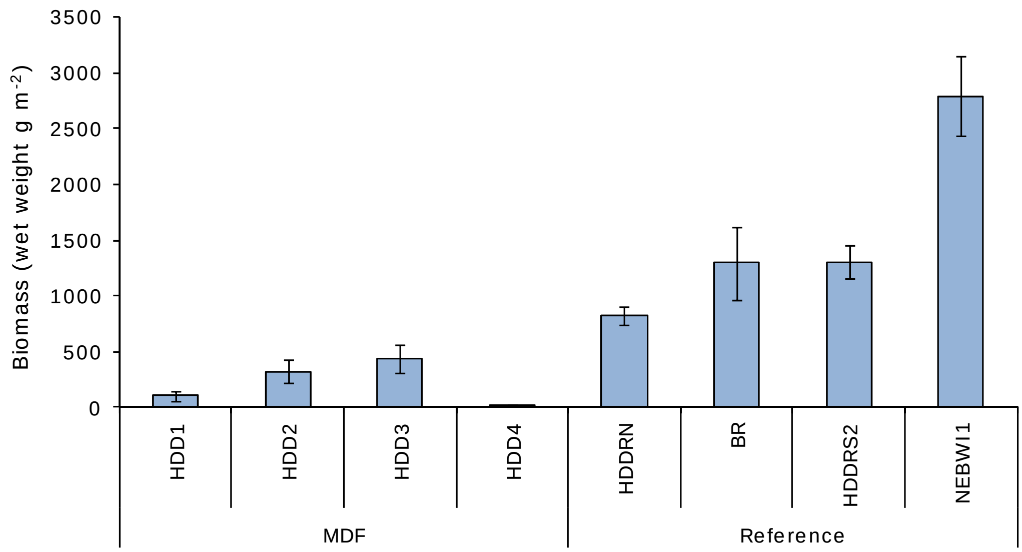


Figure 5-4 Mean (± SE) of Macroalgal Biomass during FGPDSY2 at MDF and Reference Sites

Notes:

Quadrats that had zero values for biomass were excluded in calculation of mean and SE (see Section 5.3.4.2).

Biomass values scaled to 1 m^2.

5.4.4 Description of Macroalgal Assemblages at Reference Sites not at Risk of Material or Serious Environmental Harm due to the OFGPS

Macroalgal cover at the Reference Sites ranged from 24.9% (HDDRN) to 73.3% (NEBWI1) and was the dominant major benthic category at the Reference Sites, followed by sand (Table 5-8; Figure 5-3). Macroalgal biomass at the Reference Sites ranged from 824.7 g/m^2 (HDDRN) to 2791.3 g/m^2 (NEBWI1) (Figure 5-4).

Ninety-four macroalgal taxa were identified at the Reference Sites during FGPDSY2: 50 red algae, 26 brown algae, and 18 green algae (Table 5-4). Site BR was the most diverse site, with

25 red algal taxa, 20 brown algal taxa, and 58 green algal taxa (Table 5-4). *Sargassum* spp. was the most abundant macroalgal taxa, ranging from 1.6% (HDDRN) to 64.4% (NEBWI1) (Table 5-9). The next most abundant macroalgal taxa were Macroalgae unidentified and *Halimeda*, which ranged from 2.5% (NEBWI1) to 18.1% (BR), and 2.1% (HDDRS2) to 11.3% (HDDRN), respectively (Table 5-9).

Table 5-8 Percent Cover (mean ± SE) of Major Benthic Cover Categories at Reference Sites during FGPDSY2

Site	Major Benthic Cover Categories							
	Seagrass	Macroalgae	Turf algae	Coral	Benthic macro-invertebrates	Sand	Rubble	Pavement
HDDRN	–	24.87 (2.57)	42.84 (3.20)	1.49 (0.60)	4.32 (1.04)	25.89 (2.40)	0.30 (0.21)	0.30 (0.30)
BR	0.15 (0.15)	39.52 (4.41)	33.44 (3.18)	–	0.45 (0.24)	24.51 (5.59)	1.64 (0.96)	0.30 (0.21)
HDDRS2	2.72 (0.95)	33.18 (5.96)	15.35 (3.57)	0.15 (0.15)	0.74 (0.43)	47.70 (6.10)	0.15 (0.15)	–
NEBWI1	–	73.32 (2.61)	21.02 (2.42)	–	0.89 (0.44)	4.17 (0.95)	0.30 (0.21)	0.30 (0.30)

Notes:

SE are shown in parentheses.

– = zero value recorded.

Macroalgal percent cover values are rounded to one decimal place in the text.

Table 5-9 Percent Cover (mean ± SE) of Macroalgal Subcategories at Reference Sites during FGPDSY2

Site	Macroalgal Subcategories						
	Macroalgae unidentified	*Caulerpa*	*Dictyopteris*	*Halimeda*	*Padina*	*Sargassum*	*Udotea*
HDDRN	10.57 (2.04)	0.60 (0.27)	0.60 (0.35)	11.33 (1.90)	0.15 (0.15)	1.64 (0.74)	–
BR	18.05 (3.17)	–	0.15 (0.15)	3.27 (0.66)	1.79 (0.63)	16.26 (3.16)	–
HDDRS2	4.38 (1.28)	–	0.15 (0.15)	2.08 (0.58)	0.30 (0.30)	26.28 (5.14)	–
NEBWI1	2.53 (0.93)	0.15 (0.15)	0.74 (0.37)	5.51 (1.16)	–	64.39 (3.60)	–

Notes:

SE are shown in parentheses.

– = zero value recorded.

Macroalgal percent cover values are rounded to one decimal place in the text.

5.5 Comparison between the Post-Development Survey and the Marine Baseline Environmental State

5.5.1 Descriptive Comparison

Based on identification of collected specimens and algae visible in the photoquadrat images, the number of macroalgal taxa recorded were higher in FGPDSY2 (115 taxa) than in FGPDSY1 (97 taxa) or in the Baseline (59 taxa) (Table 5-10). The diversity of taxa within each algal division was higher in FGPDSY2 than in the Baseline, with the Rhodophyta containing the highest number of taxa in all three surveys (Table 5-10).

Comparison of macroalgal diversity at the site level indicated that the number of taxa increased at six sites and decreased at one site between the Baseline and FGPDSY2 (Table 5-11). The greatest increase was at the Reference Site BR, whereas increases at the other Reference Sites (HDDRS2, NEBWI1) and at MDF Sites (HDD1, HDD2, HDD2) were of a similar magnitude (Table 5-11). A decrease in diversity was recorded at the MDF site HDD4 (Table 5-11).

In general, changes in the dominant macroalgal taxa were recorded between the Baseline, FGPDSY1, and FGPDSY2. No sites had the same taxa (or suite of taxa) dominating the macroalgal flora during the Baseline, FGPDSY1, and FGPDSY2, although at some sites a subset of taxa was common among the three surveys (Table 5-12). *Sargassum* spp., *Halimeda discoidea*, *Lobophora variegata*, *Sirophysalis trinodis*, and *Sporochnus comosus* featured across all surveys and most sites (Table 5-12).

Table 5-10 Number of Macroalgal Taxa Recorded in the Baseline and Post-Development Surveys

Taxonomic Group	Baseline	FGPDSY1	FGPDSY2
Macroalgae			
Rhodophyta	31	52	66
Heterokontophyta[1]	15	27	26
Chlorophyta	13	18	23
Total	**59**	**97**	**115**

Note:

1 *Heterokontophyta was referred to as Phaeophyta in the FGPDSY1 Report (Chevron Australia 2014b)*

Table 5-11 Macroalgal Diversity (as Species Richness) Observed in the Baseline and Post-Development Surveys

Area	Site	Baseline	FGPDSY1	FGPDSY2	Difference between the Baseline and FGPDSY2
MDF	HDD1	12	6	23	+11
	HDD2	19	15	32	+13
	HDD3	21	15	38	+17
	HDD4	11	9	5	-6

Area	Site	Baseline	FGPDSY1	FGPDSY2	Difference between the Baseline and FGPDSY2
Reference	HDDRN	NS[1]	35	32	n/a
	BR	15	54	58	+43
	HDDRS2	8	30	26	+18
	NEBWI1	27	50	41	+14

Notes:

1 Site not surveyed due to poor weather conditions

Table 5-12 Dominant and Subdominant Macroalgae Observed in the Baseline and Post-Development Surveys

Area	Site	Species	Baseline	FGPDSY1	FGPDSY2
MDF	HDD1	Dominant	*Lobophora variegata*	*Sargassum* sp.[1]	*Sargassum* spp.[1]
		Subdominant	*Sargassum* spp. *Dictyopteris* spp.[1]	*Dictyopteris* sp.[1] *Caulerpa cupressoides*	*Sporochnus comosus* *Lobophora variegata*
	HDD2	Dominant	*Lobophora variegata*[1]	*Sargassum* spp.	*Sargassum* spp.[1]
		Subdominant	*Dictyopteris serrata* *Halimeda discoidea* *Haliptilon roseum*	*Lobophora variegata* *Dictyopteris* spp. *Halimeda discoidea.*	*Halimeda discoidea* *Sporochnus comosus*[1]
	HDD3	Dominant	*Sargassum spinuligerum*	*Sargassum* spp.	*Sargassum* spp.[1]
		Subdominant	*Lobophora variegata* *Dictyopteris serrata*	*Sporochnus comosus*[1] *Halimeda discoidea*	*Sporochnus comosus* *Lobophora variegata*
	HDD4	Dominant	*Dictyopteris serrata*	*Halimeda discoidea*	–[5]
		Subdominant	*Lobophora variegata* *Sargassum* spp. *Dichotomaria* sp.	*Dictyopteris* spp. *Sargassum* spp.	–[5]
Reference	HDDRN	Dominant	NS[4]	*Dictyopteris* spp.	*Halimeda discoidea*
		Subdominant	NS[4]	*Halimeda discoidea* Turf algae[1,2] *Sporochnus comosus*	*Sporochnus comosus* Various red algae[6] *Sargassum* sp.
	BR	Dominant	*Halimeda discoidea*	*Sirophysalis trinodis*	*Sargassum* spp.

Area	Site	Species	Baseline	FGPDSY1	FGPDSY2
		Subdominant	*Sirophysalis trinodis*[3] *Sargassum* spp. *Lobophora variegata*	*Sargassum* spp. *Dictyopteris* spp. *Sporochnus comosus* *Halimeda discoidea*	*Sirophysalis trinodis* *Sporochnus comosus* *Halimeda discoidea*
	HDDRS2	Dominant	*Sargassum* spp.	*Sargassum* spp.	*Sargassum* spp.
		Subdominant	*Sporochnus* sp. *Lobophora variegata* *Padina* sp.	*Halimeda discoidea* *Padina sanctae-crucis* *Sporochnus comosus*	*Sargassopsis decurrens* *Sporochnus comosus* *Halimeda discoidea* *Sirophysalis trinodis*
	NEBWI1	Dominant	*Sargassum* spp.	*Dictyopteris* spp.	*Sargassum* spp.
		Subdominant	*Halimeda discoidea*[1] *Sporochnus* sp. *Chondria* sp.	*Sargassum* spp. *Halimeda discoidea*	*Halimeda discoidea* *Galaxaura rugosa*

Notes:

1 *Species/taxa were visually identified from photoquadrats by BMT Oceanica's nominated taxonomic expert; these species were not collected and therefore identities have not been confirmed by Dr John Huisman.*

2 *Turf algae are likely to include several species of small-sized macroalgae.*

3 *Known as* Cystoseira trinodis *in the Baseline.*

4 *Site not surveyed due to poor weather conditions.*

5 *No dominant/subdominant macroalgal taxa recorded.*

6 *Various red algae refers to a mixture of red algal species, larger in stature than turf algae, that collectively were subdominant.*

In general, sand was the dominant benthic category, followed by macroalgae and turf algae within the MDF and at the Reference Sites across all surveys (Figure 5-5). The percent cover of seagrass, coral, benthic macroinvertebrates, rubble, and pavement comprised ≤4% of the benthic cover at both the MDF and Reference Sites across all surveys (Figure 5-5). The MDF had a greater percent cover of sand than the Reference Sites across all survey years, including the Baseline (Figure 5-5). Sand cover increased between the Baseline and FGPDSY1, and declined between FGPDSY1 and FGPDSY2 at both the MDF and Reference Sites (Figure 5-5). Turf algae declined between the Baseline and FGPDSY1, and increased between FGPDSY1 and FGPDSY2 at both the MDF and Reference Sites (Figure 5-5).

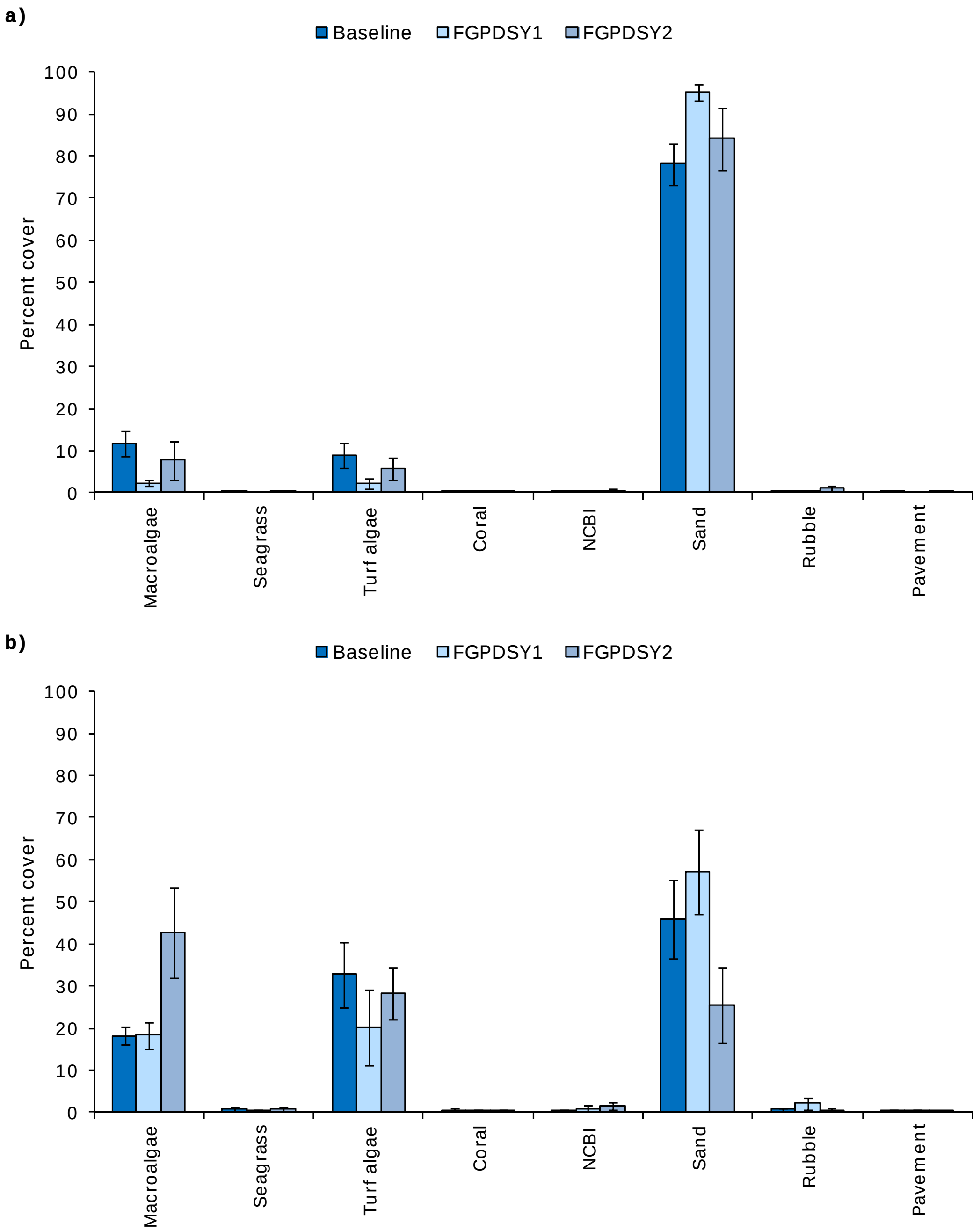


Figure 5-5 Benthic Cover (mean ± SE) during the Baseline and Post-Development Surveys at a) MDF Sites and b) Reference Sites

Note: Means and standard errors based on Site as replicate pooled into MDF or Reference areas

5.5.2 Statistical Comparison

5.5.2.1 Macroalgal Percent Cover

The 'Survey × IvR' interaction term was significant at Step 1 of the stepwise approach (three-factor design: Figure 5-2; Table 5-2). Post-hoc tests on the 'Survey × IvR' interaction term (undertaken on both factor 'Survey' (Table 5-14a) and factor 'IvR' (Table 5-14b)), only revealed a significant difference between MDF and Reference Sites in FGPDSY1 and FGPDSY2 for factor 'IvR'.

At MDF Sites, macroalgal percent cover was higher during the Baseline (11.9%), compared with FGPDSY1 (2.4%) and FGPDSY2 (7.8%) (Figure 5-6). Macroalgal percent cover at the

Reference Sites increased from the Baseline (18.2%) to FGPDSY2 (42.7%), as well as from FGPDSY1 (18.9%) to FGPDSY2 (42.7%) (Figure 5-6). Macroalgal percent cover varied among sites (both MDF and Reference), declining at all sites between the Baseline and FGPDSY1, except for Reference Site NEBWI1, which increased, and Reference Site HDDRN, which was not sampled in the Baseline (Figure 5-7). Macroalgal percent cover increased between FGPDSY1 and FGPDSY2 at all sites except MDF Site HDD4 (Figure 5-7).

Table 5-13 Results of Three-Factor Statistical Analyses of Macroalgal Percent Cover within the Baseline and Post-Development Surveys

Source	df	SS	MS	Pseudo-F	p-value
Survey	2	3.2749	1.6374	4.1438	0.0463
IvR	1	11.763	11.763	25.568	0.0087
Site(IvR)	6	2.8152	0.46921	9.2579	0.0001
Survey × IvR	**2**	**3.1048**	**1.5524**	**3.9286**	**0.0455**
Survey × Site(IvR)	11	4.3474	0.39522	7.7981	0.0001
Residual	459	23.263	5.0681E-2		
Total	481	50.035			

Note: Bold font = statistically significant difference for term of interest at α=0.05

Table 5-14 Results of Post-hoc Tests for Changes in Macroalgal Percent Cover for Significant Term of Interest Survey × IvR for the Factors a) Survey and b) IvR

a) Survey	df	t	p-value
MDF Sites			
Baseline, FGPDSY1	3	3.3334	0.0719
Baseline, FGPDSY2	3	1.1772	0.3282
FGPDSY1, FGPDSY2	3	1.293	0.2937
Reference Sites			
Baseline, FGPDSY1	2	0.50273	0.642
Baseline, FGPDSY2	2	1.9473	0.1803
FGPDSY1, FGPDSY2	3	2.5685	0.1041
b) IvR	**df**	**t**	**p-value**
Baseline			
Impact, Reference	5	1.7947	0.1404
FGPDSY1			
Impact, Reference	**6**	**7.6272**	**0.0117**
FGPDSY2			
Impact, Reference	**6**	**3.5005**	**0.0324**

Note: Bold font = statistically significant difference for term of interest

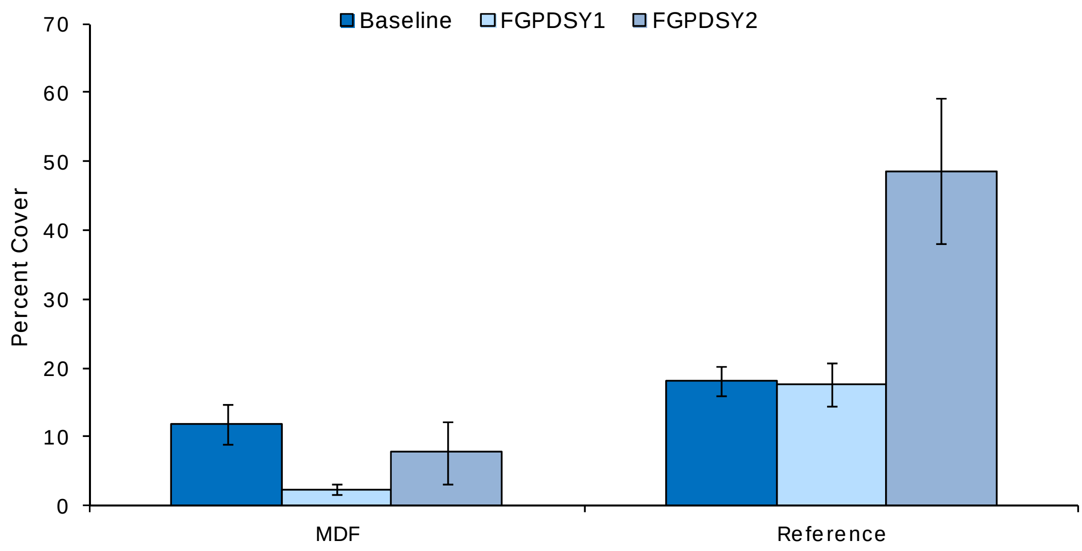


Figure 5-6 Percent Cover (mean ± SE) of Macroalgae at MDF and Reference Sites during the Baseline and Post-Development Surveys

Note: Means and standard errors based on Site as replicate pooled into MDF or Reference areas

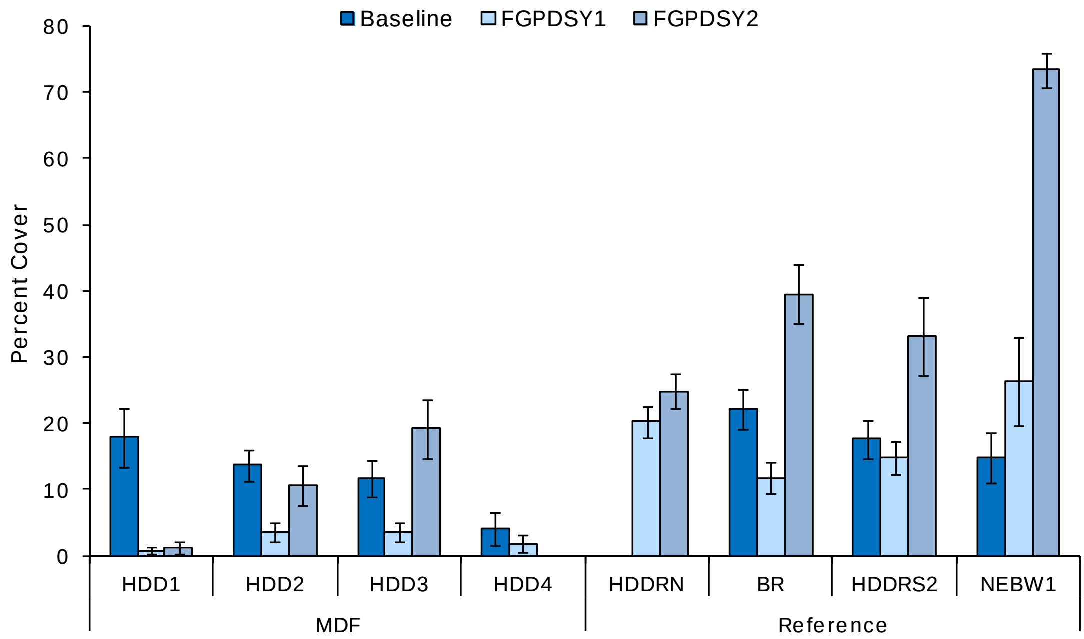


Figure 5-7 Percent Cover (mean ± SE) of Macroalgae at Each Site during the Baseline and Post-Development Surveys

Notes:

Means and standard errors based on quadrats as replicates within sites.

Site HDDRN not sampled in the Baseline due to poor weather conditions.

5.5.2.2 Macroalgal and Seagrass Combined Biomass

The ‘Survey × IvR’ interaction term was significant at Step 1 of the stepwise approach (three-factor design: Figure 5-2; Table 5-2). Post-hoc tests on the ‘Survey × IvR’ interaction term (undertaken on both factor ‘Survey’ [Table 5-16a] and factor ‘IvR’ [Table 5-16b]), only revealed a significant difference between MDF and Reference Sites in FGPDSY2 for factor ‘IvR’.

At MDF Sites, the mean biomass increased from the Baseline (420.6 g/m^2) to FGPDSY1 (612.9 g/m^2), and declined in FGPDSY2 (212.4 g/m^2) (Figure 5-8). At the Reference Sites, mean biomass was higher in FGPDSY2 (1559.6 g/m^2) compared with the Baseline (663.0 g/m^2) and FGPDSY1 (764.2 g/m^2) (Figure 5-8). Macroalgal and seagrass combined biomass varied among sites (both MDF and Reference), with no consistent pattern across sites from the Baseline to FGPDSY1 (Figure 5-9). Macroalgal and seagrass combined biomass increased between FGPDSY1 and FGPDSY2 at all sites except MDF Sites HDD1 and HDD4 (Figure 5-9).

Table 5-15 Results of Three-Factor Statistical Analyses of Macroalgal and Seagrass Combined Biomass during the Baseline and Post-Development Surveys

Source	df	SS	MS	Pseudo-F	p-value
Survey	2	3.0729E5	1.5364E5	1.8078	0.2076
IvR	1	7.3593E5	7.3593E5	3.1126	0.0542
Site(IvR)	6	1.5769E6	2.6281E5	10.909	0.0001
Survey × IvR	**2**	**8.6582E5**	**4.3291E5**	**5.0937**	**0.0282**
Survey × Site(IvR)	11	1.0068E6	91523	3.799	0.0002
Residual	178	4.2883E6	24092		
Total	200	9.4079E6			

Note: Bold font = statistically significant difference for term of interest at α=0.05

Table 5-16 Results of Post-hoc Tests for Changes in Macroalgal and Seagrass Combined Biomass for Significant Term of Interest Survey × IvR for the Factors a) Survey and b) IvR

a) Survey	**df**	**t**	**p-value**
MDF Sites			
Baseline, FGPDSY1	3.01	0.4405	0.7376
Baseline, FGPDSY2	3.05	0.9027	0.4317
FGPDSY1, FGPDSY2	3.08	1.1970	0.4327
Reference Sites			
Baseline, FGPDSY1	2.01	0.6951	0.5299
Baseline, FGPDSY2	2	3.1801	0.1216
FGPDSY1, FGPDSY2	2.01	2.8747	0.0826
b) IvR	**df**	**t**	**p-value**
Baseline			
Impact, Reference	5	0.8771	0.4219
FGPDSY1			
Impact, Reference	6.59	0.4632	0.5203
FGPDSY2			
Impact, Reference	**6.59**	**2.6598**	**0.0377**

Note: Bold font = statistically significant difference for term of interest

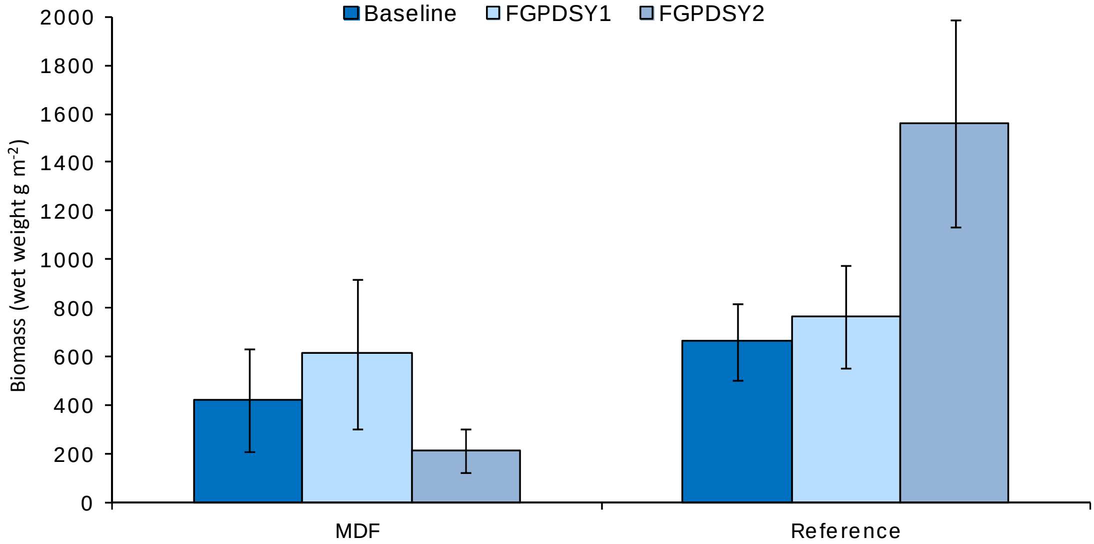


Figure 5-8 Combined Biomass (mean ± SE) of Macroalgae and Seagrass from the Baseline and Post-Development Surveys at MDF and Reference Sites

Notes:

1 *Biomass values scaled to 1 m^2.*

2. *Means and standard errors based on Site as replicate pooled into MDF or Reference areas.*

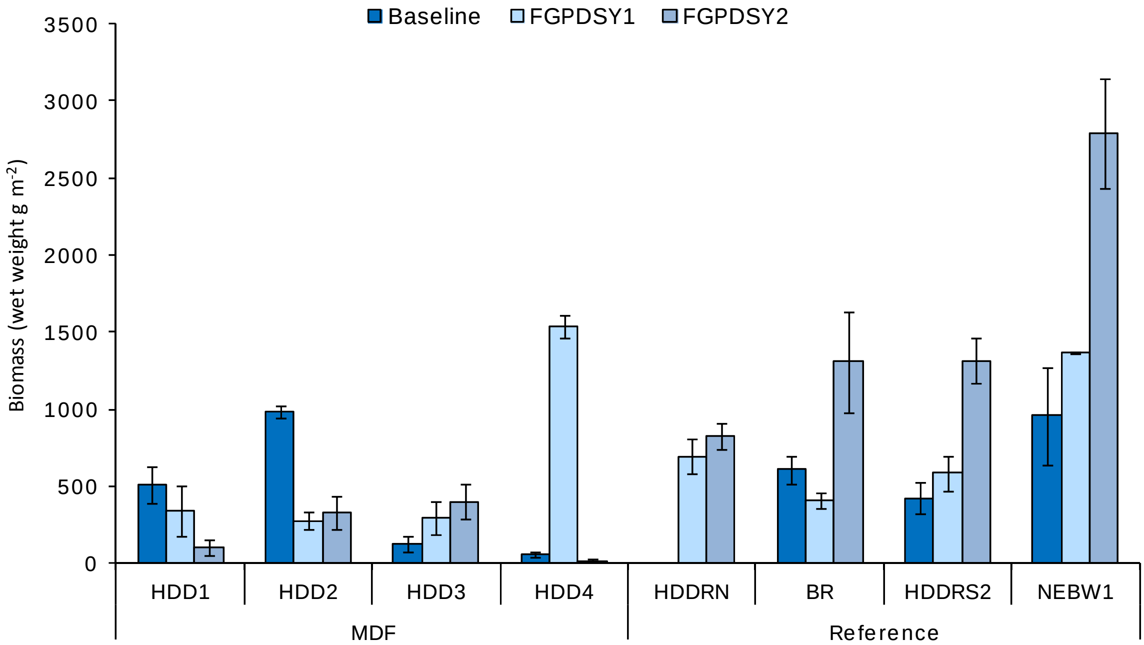


Figure 5-9 Combined Biomass (mean ± SE) of Macroalgae and Seagrass at Each Site during the Baseline and Post-Development Surveys

Notes:

Biomass values scaled to 1 m^2.

Means and standard errors based on quadrats as replicates within sites.

Site HDDRN not sampled in the Baseline due to poor weather conditions.

5.6 Discussion and Conclusions

Although the methods used in this study were consistent with the Scope of Works (RPS 2009, amended 2014), the results need to be placed in the context of some of the broader limitations inherent in the methods and analyses, which may have had an influence on the interpretations. Firstly, the locations of Reference Sites were spatially segregated around Barrow Island. Site NEBWI1 was located on the north-east side, sites HDDRS and BR were located on the south-west side, while site HDDRN was located on the north-west side of Barrow Island. As such, spatial differences between survey sites cannot be ruled out as driving observed change. Secondly, the three transects at each site all had the same start point and were laid out at 90° to each other and were not truly random. Due to this layout, the transects do not represent truly independent samples. Lastly, within the MDF, >50% of the habitat was characterised by unvegetated or bare sand habitat with a patchy distribution of macroalgae (Chevron Australia 2012b). Generally, most species of macroalgae require hard substrates to attach and grow, unlike seagrasses, which have root systems to anchor to sand habitats (Walker and Kendrick 1998). The percent cover and biomass of macroalgal cover within the MDF has historically been lower than in the Reference Sites, which mostly comprise shallow limestone pavement habitats with sand veneer that are likely to be more favourable for macroalgal attachment (Chevron Australia 2013a; Walker and Kendrick 1998). As such, the MDF Sites contain more sand than the Reference Sites, and thus initially less macroalgae than Reference Sites, and the greater natural movement of sand at these MDF Sites also potentially increased the susceptibility of their macroalgal communities.

Nonetheless, the diversity of macroalgal assemblages on the west coast of Barrow Island was higher in FGPDSY2 (115 taxa) compared with the Baseline (59 taxa) and FGPDSY1 (97 taxa) at both MDF and Reference Sites, with Rhodophyta containing the highest number of taxa across all surveys. A previously undescribed taxon was collected during FGPDSY2, which was provisionally assigned the name *Dudresnaya barrowense* (Dr John Huisman, pers. comm.). In general, changes in the dominant macroalgal taxa were recorded, and no sites had the same taxa (or suite of taxa) dominating the macroalgal flora in all surveys, although at some sites a subset of taxa was common among the three surveys. *Sargassum* spp., *Halimeda discoidea*, *Lobophora variegata*, *Sirophysalis trinodis*, and *Sporochnus comosus* featured across all surveys and most sites. One notable change between FGPDSY2 and the earlier surveys (Baseline and FGPDSY1) was that no macroalgae was recorded at site HDD4, which previously supported various large algal species such as *Dictyopteris serrata*, *Sargassum* spp., and *Halimeda discoidea*. However, the macroalgal percent cover at site HDD4 was only ~4% in the Baseline and ~2% in FGPDSY1, and because site HDD4 is the MDF Site furthest from the offshore pipe-laying activities, the absence of macroalgae in FGPDSY2 is likely due to natural temporal variability of macroalgae and sand movement and not Project-attributable change. Although increased sedimentation (both natural and anthropogenic origin) has been shown to affect the structure and diversity of macroalgal assemblages (Airoldi 2003; Eriksson and Johansson 2005; Balata *et al.* 2007), the variation in diversity in terms of the number and identity of taxa likely result from a combination of environmental factors including seasonality, exposure to cyclones and wave action, and strong currents and shifting sands that may expose then inundate the reef substratum.

A significant difference in macroalgal percent cover was observed for the interaction term ‘Survey × IvR’; however, the post-hoc tests showed no significant differences for factor ‘Survey’ and only revealed a significant difference between the MDF and Reference Sites in FGPDSY1 and FGPDSY2 for factor ‘IvR’. Within the MDF Sites, macroalgal cover was higher during the Baseline compared with FGPDSY1 and FGPDSY2, and macroalgal cover was higher in FGPDSY2 compared with FGPDSY1, while at the Reference Sites macroalgal percent cover remained stable between the Baseline and FGPDSY1, and increased in FGPDSY2. However, this result should be treated with caution, because the decline in macroalgal cover between the Baseline and FGPDSY1 within the MDF was influenced by a large decline at one site (HDD1), whereas the lack of a decline between the Baseline and FGPDSY1 at the Reference Sites was influenced by an increase at one site (NEBWI1; all other Reference Sites declined in cover in

FGPDSY1 compared with the Baseline). During FGPDSY1, sites HDD1 and NEBWI1 were sampled ~40 m and ~90 m from the Baseline site locations, respectively, whereas both sites were sampled within one metre of the Baseline site locations in FGPDSY2. Macroalgal assemblages are known to be patchy (e.g. Pihl *et al.* 1996; Pederson and Borum 1997; Karez 2004), and therefore, the large distance between the Baseline and FGPDSY1 locations for sites HDD1 and NEBWI1 may have resulted in sampling of a different habitat in FGPDSY1, which has influenced the results within the MDF and Reference Sites.

Although the decline in macroalgal cover between the Baseline and FGPDSY1 suggests a potential change associated with the offshore pipe-laying activities, it would be expected that the cause of this change would be an increase in sand habitat at MDF Sites that was not present at Reference Sites. However, sand cover increased between the Baseline and FGPDSY1 at both the MDF and Reference Sites. Additionally, the rationale behind the stepwise approach purposely ignored standard pooling rules (Winer *et al.* 1991) so as to increase conservatism and in doing so increased the likelihood of Type I error (i.e. conclusion of change when actually no change has occurred) in an effort to decrease Type II error (i.e. conclusion of no change when change has actually occurred) (Lazic 2010). The macroalgal percent cover was also consistently higher at the Reference Sites compared with MDF Sites across all surveys (including the Baseline), which was reflected in the significant 'IvR' main effect. There was also large variability in macroalgal percent cover across sites among surveys, which was reflected in the significant 'Survey' main effect, suggesting a high level of natural temporal and spatial variation.

The macroalgal and seagrass combined biomass was also higher at the Reference Sites compared with sites within the MDF among surveys. A significant difference in macroalgal and seagrass combined biomass was observed for the interaction term 'Survey × IvR'; however, the post-hoc tests showed no significant differences for factor 'Survey' and only revealed a significant difference between the MDF and Reference Sites in FGPDSY2 for factor 'IvR'. The macroalgal and seagrass combined biomass increased from the Baseline to FGPDSY1 within the MDF, largely due to a large increase at site HDD4. Interestingly, this increase in macroalgal and seagrass combined biomass was recorded despite the decline in macroalgal percent cover within the MDF between the Baseline and FGPDSY1. Moreover, the large increase in the macroalgal and seagrass combined biomass at the Reference Sites in FGPDSY2 was largely influenced by a single site (NEBWI1). Thus, there was large variability in macroalgal and seagrass combined biomass across sites among surveys, which was reflected in the significant 'Survey' main effect, suggesting these detected changes were largely a result of natural temporal and spatial variation.

Therefore, although there is weak evidence to suggest that offshore pipe-laying activities may have resulted in a change in the macroalgal assemblages within the MDF Sites between the Baseline and FGPDSY1, a significant increase in macroalgal percent cover was recorded between FGPDSY1 and FGPDSY2 within the MDF, and no significant differences in macroalgal percent cover and macroalgal and seagrass combined biomass were recorded between the Baseline and FGPDSY2 within the MDF. The variability in the macroalgal percent cover and macroalgal and seagrass combined biomass was large at the site level, reflecting natural spatial and temporal variability. Sand cover also increased at both the MDF and Reference Sites after the offshore pipe-laying activities, suggesting that the construction activities did not result in an anthropogenic increase in sand cover within the MDF Sites. Therefore, factors such as natural spatial and temporal variability may have contributed to the observed changes in the macroalgal assemblages within the MDF Sites. Ephemeral species often display large variation in percent cover in response to environmental conditions such as light or temperature (e.g. Pihl *et al.* 1996; Pederson and Borum 1997; Karez 2004). Moreover, some genera such as *Sargassum* show considerable natural variation in percent cover that is related to life history stage, and the timing of changes in cover (and biomass) varies between species (McCourt 1984; Kendrick and Walker 1994; Ateweberhan *et al.* 2008).

6.0 Seagrass

6.1 Introduction

The diversity and distribution of seagrass species on the North West Shelf are not well documented. Huisman and Borowitzka (2003) identified nine species of seagrass in the Dampier Archipelago, from the families Hydrocharitaceae and Cymodoceaceae. Seven species have been recorded to date from the Montebello Islands/Barrow Island region: *Cymodocea angustata, Halophila ovalis, H. spinulosa, Halodule uninervis*, *Thalassia hemprichii*, *Thalassodendron ciliatum*, and *Syringodium isoetifolium* (DEC 2007). Of these, *Halophila* spp. are the most common on shallow soft substrates and sand veneers throughout the region (DEC 2007). Seagrass do not appear to form extensive beds in the area, but rather are sparsely interspersed between macroalgae, extending from the intertidal zone to approximately 15 m water depth (DEC 2007).

Seagrass distribution in the waters surrounding Barrow Island is even less well known, though six species of seagrass have previously been identified—*Cymodocea serrulate*, *Syringodium isoetifolium*, *Halodule* sp., *Halophila decipens*, *Halophila ovalis*, and *Halophila spinulosa* (Chevron Australia 2012b). Seagrass have been observed across a range of benthic substrates, including soft sediments at depths of 14 to 18 m and on veneers of sand covering limestone pavement at depths of 5 to 10 m (Chevron Australia 2012b). Non-coral benthic macroinvertebrates and coral were occasionally recorded co-occurring with seagrass in the macroalgal-dominated assemblages on the shallow limestone pavement east of Barrow Island. Seagrass were also occasionally recorded co-occurring with non-coral benthic macroinvertebrates in deeper soft sediment habitats. Seagrass diversity was also low during the Baseline, with four species recorded—*Syringodium isoetifolium*, *Halophila decipens*, *Halophila ovalis*, and *Halophila spinulosa* (Chevron Australia 2014a).

Additionally, seagrass (*Halodule* sp.) has been reported to occur at low densities in the shallow subtidal zone on sand veneers that cover areas of pavement reef off North Whites Beach on the west coast of Barrow Island (RPS Bowman Bishaw Gorham 2007).

Seagrass beds in the Montebello Islands/Barrow Island region make an important contribution to local productivity, are an important direct food source for some animals (e.g. Dugongs [*Dugong dugon*] and Green Turtles [*Chelonia mydas*]), and provide refuge for fish and invertebrates (Chevron Australia 2005; DEC 2007). Seagrass habitats in the Montebello Islands/Barrow Island region vary seasonally in response to water temperature, day length, reproductive cycles, physical disturbance, and regrowth (DEC 2007; Chevron Australia 2012b).

6.2 Scope

This section is in two parts. The first part describes the seagrass recorded during the FGPDSY2:

- at sites within the MDF (area at risk of Material or Serious Environmental Harm due to the OFGPS)
- at References Sites not at risk of Material or Serious Environmental Harm due to the OFGPS.

The second part compares the Post-Development Surveys with the Baseline to identify any detected changes to marine ecological elements as per Condition 15.3 of Statement No. 769.

6.3 Methods

6.3.1 Site Locations

Baseline surveys were conducted at four sites within the MDF (HDD1, HDD2, HDD3, and HDD4), and at three Reference Sites (NEBWI2, BR, and HDDRS2) (Table 6-1; Figure 6-1). FGPDSY2 sampling was undertaken at the same sites as the Baseline surveys and FGPDSY1 (Table 6-1; Figure 6-1). Reference Site HDDRN could not be accessed during Baseline surveys due to poor weather, but was surveyed in FGPDSY1 and FGPDSY2 (Table 6-1; Figure 6-1).

Table 6-1 Baseline and Post-Development Survey Sites for Seagrass

Area	Site	Baseline[1]		FGPDSY1[1]		FGPDSY2[1]	
		Easting[2]	Northing[2]	Easting[2]	Northing[2]	Easting[2]	Northing[2]
MDF	HDD1	334655	7711392	334656	7711361	334666	7711398
	HDD2	334678	7711541	334677	7711541	334677	7711541
	HDD3	334549	7711352	334546	7711353	334548	7711351
	HDD4	334739	7711539	334753	7711551	334738	7711539
Reference	HDDRN	NS[3]	NS[3]	334972	7712174	334965	7712144
	BR	329877	7704929	329874	7704922	329877	7704929
	HDDRS2	329675	7705354	329675	7705357	329675	7705354
	NEBWI2	343137	7713599	343157	7713588	343137	7713599

Notes:

1 *Eastings and northings are the start of transects.*

2 *Datum used: GDA94 Projection MGA Zone 50.*

3 *Site not sampled due to poor weather conditions.*

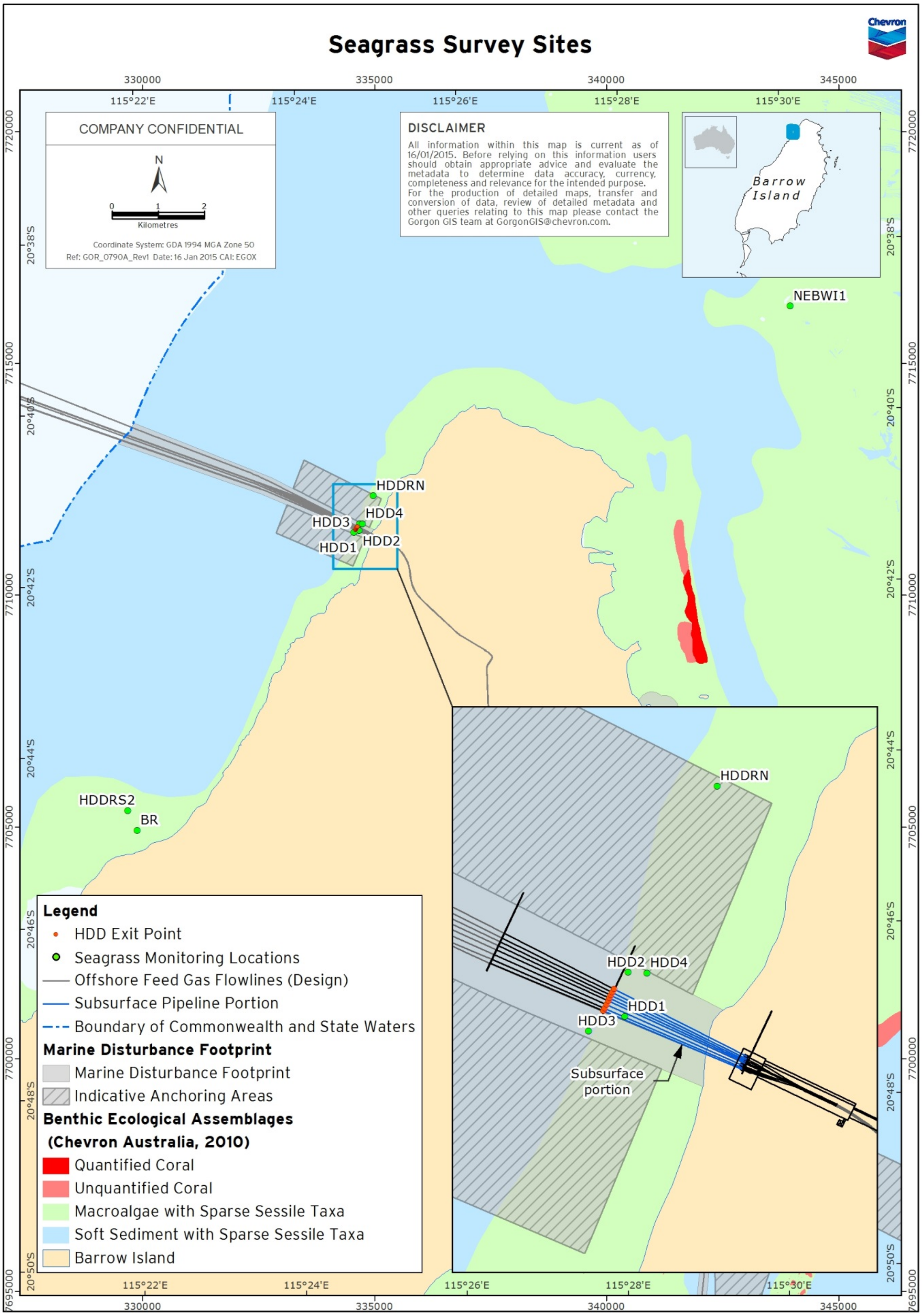


Figure 6-1 FGPDSY2 Sites for Seagrass

6.3.2 Timing of Sampling

The FGPDSY2 was undertaken in November 2014.

6.3.3 Methods

Seagrass data collection methods were consistent with the Scope of Works (RPS 2009, amended 2014). Minor differences exist in the methods used during the Baseline and Post-Development Surveys; these differences are explained in this Section and in Section 6.3.4.

At each site, three 30 m long transects were laid out from a randomly placed central clump weight. The first transect was oriented parallel to the anchor line and the two others were laid at approximately 90° to the first. Coordinates of the start point of each transect were recorded using GPS and the transect bearing was noted. These survey transects were also used for non-coral benthic macroinvertebrate surveys (see Section 4.3.3) and macroalgae surveys (see Section 5.3.3).

Benthic cover was surveyed by positioning seven 1 m^2 quadrats at 5 m intervals along the right side of each transect. Each 1 m^2 quadrat was divided into four subquadrats of 0.25 m^2 (0.5 × 0.5 m) and individually photographed for percent cover analyses. Seagrass voucher specimens were collected from within the quadrats positioned at 0 m, 10 m, 20 m, and 30 m along each transect.

Seagrass biomass samples were collected within 0.25 m^2 (0.5 × 0.5 m) quadrats positioned at 10 m, 10.5 m, 20 m, and 20.5 m along the left side of each transect (the opposite side of the transect line used for sampling benthic cover). All above- and below-ground biomass of seagrass were harvested. Two photographs of each quadrat were taken prior to and after harvesting. Biomass samples were blot dried and wet weighed, then combined with macroalgae biomass to record the total wet weight to the nearest gram.

Minor differences exist in the methods used to measure biomass during the Baseline and Post-Development Surveys. During the Baseline, samples with zero biomass were excluded from analyses, causing insufficient replication for statistical analyses at some sites. As such, during FGPDSY1 and FGPDSY2, a minimum of three non-zero replicate quadrats were required per site to enable sufficient replication for statistical analysis of biomass. If fewer than three samples were collected over the three transects (i.e. the quadrats had no macroalgae or seagrass), additional sampling was undertaken at 1 m intervals from the start of the transect until three replicate biomass samples were obtained at the site. If no biomass samples were collected over the three transects, a new biomass transect was established where patches of seagrass or macroalgae were present. If no seagrass or macroalgal patches were observed after five minutes of searching, the site was deemed to support no seagrass or macroalgae, and thereafter was excluded from sampling and statistical analyses. During FGPDSY2, combined biomass samples at all sites were collected from established transects to achieve sufficient replication for statistical analyses. Any quadrats with zero values were excluded from statistical comparison as outlined in the statistical approach (Section 6.3.5). For reporting of the descriptive biomass results for seagrass only (Section 6.4), similar sample methods to those outlined above were used where a minimum of three non-zero quadrats were required per site for each ecological element (macroalgae and seagrass). If quadrats on established transects did not support seagrass biomass samples, extra seagrass biomass samples were sought, as per the above methods. During FGPDSY2, extra seagrass biomass samples were sought at sites HDD2, HDD3, HDDRN, and HDD1 to achieve sufficient replication for descriptive analyses. Despite diver search efforts, no seagrass biomass could be located at sites HDD4 and NEBWI1. Quadrats with zero values were excluded in the descriptive analyses (Section 6.4).

Seagrass were identified to the lowest taxonomic level possible (generally, to genus and species) for assessment of seagrass diversity and dominant taxa at all sites. Taxa identification of seagrass present at FGPDSY2 sites was undertaken on voucher specimens that were forwarded to Dr John Huisman (Murdoch University) for formal identification. The dominant and subdominant seagrass taxa at each site were determined by qualitative assessment of seagrass percent cover as observed in the photoquadrat images, in conjunction with the list of verified taxa identified by Dr Huisman.

6.3.4 Treatment of Survey Data

6.3.4.1 Benthic Cover

The percent cover of major benthic categories (macroalgae, seagrass, turf algae, coral, benthic macroinvertebrates, sand, rubble, pavement) was estimated by photoquadrat images using the computer software program Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006).

All CPCe classifications, video analyses, and QA/QC were undertaken by BMT Oceanica scientists. To reduce inter-observer variability that is generally present in monitoring programs when two or more scientists make quantitative observations, analysts did not classify more than two of the three transects from each site. A taxonomic expert from BMT Oceanica was appointed to perform calibration classifications, against which the analysts were required to be within 10% accuracy.

Eight points per subquadrat image (32 points per 1 m^2 quadrat) were randomly generated and each point was visually classified by trained observers into one of eight major benthic cover categories (macroalgae, seagrass, turf algae, coral, benthic macroinvertebrates, sand, rubble, pavement, or where accurate identification was not possible, as unidentifiable). Note: The sparse distribution of some benthic cover categories meant they were not always scored in an image even when present in that image.

Estimates of the percent cover of benthic categories were then calculated as the number of points classified into each individual category divided by the total number of points classified. Points falling into the unidentifiable category were removed from the total prior to calculation of percent cover. This resulted in a slight overestimate of the percent cover of the remaining categories, but as only a few points were unidentifiable, the overestimation was expected to be negligible.

6.3.4.2 Biomass

For FGPDSY1 and FGPDSY2, the sampling method allowed the recording of seagrass wet weight (when observed) at each site separately from macroalgae wet weight, and thus provided a dataset by which to estimate seagrass biomass (as per RPS 2009, amended 2014). However, during Baseline surveys, seagrass and macroalgal biomass from two sites within the MDF (HDD1 and HDD2), one replicate transect at site HDD4 within the MDF, and one of the Reference Sites (NEBWI1) were not easily separated and so a combined weight was measured (Chevron Australia 2014a). To allow for statistical comparison between the Baseline and Post-Development Surveys, analysis was performed on the combined macroalgal and seagrass biomass.

The 0.25 m^2 quadrats were used as replicates for statistical analyses of the combined macroalgal and seagrass biomass. Quadrats with a zero value for macroalgal and seagrass biomass were excluded in the descriptive results of the FGPDSY2 (Sections 5.4 and 6.4), for consistency with the Baseline (Chevron Australia 2014a). For statistical comparisons of Baseline and Post-Development Survey data, quadrats and sites with zero values for the combined macroalgal and seagrass biomass were excluded from the analysis to stratify the analysis to areas of seabed supporting seagrass and/or macroalgae (Section 6.3.3). Mean macroalgal biomass per square metre (excluding zero values) at each site (g/m^2) was calculated for graphing purposes (Section 6.4).

6.3.5 Statistical Approach for Comparison against Baseline

A summary of the statistical treatment and analyses used to assess any detected changes on seagrass, consistent with the Scope of Works (RPS 2009, amended 2014) as per Condition 15.1 of Statement No. 769, is presented in Table 6-2 and further explained in Sections 6.3.5.1 and 6.3.5.2.

Table 6-2 Statistical Treatment and Analyses used for Seagrass Cover, and Macroalgae and Seagrass Combined Biomass

Random Transects	
Pre-treatment of data	Site comparison test done because an uneven number of sites were sampled between the Baseline and FGPDSY1 and FGPDSY2, to determine whether the additional site should be retained or removed
Sites used in statistical analyses	Seagrass cover, and macroalgae and seagrass combined biomass: Baseline: • MDF1: HDD1, HDD2, HDD3, HDD4 • Reference: BR, HDDRS2, NEBWI1 FGPDSY1 and FGPDSY2: • MDF1: HDD1, HDD2, HDD3, HDD4 • Reference: HDDRN, BR, HDDRS2, NEBWI1
Stepwise approach	Stepwise approach adopted (see flow chart: Figure 6-2)
Main statistical design	Three-factor statistical design: • Survey (fixed, orthogonal) • Impact vs Reference [IvR] (fixed, orthogonal) • Site (random, nested within IvR)
Terms of interest	Survey × IvR
Statistical program	PERMANOVA[1]
Statistical tests (PERMANOVA[1])	• Percent cover of seagrass (Univariate) • Macroalgae and seagrass combined biomass (Univariate)
Transformation	Seagrass cover: • Square-root arcsine transformed Macroalgae and seagrass combined biomass: • No transformation
Distance measure	Macroalgal cover: • Euclidean dissimilarity Macroalgae and seagrass combined biomass: • No distance measure

Notes:

1 PERMANOVA = Non-parametric analysis of variance (Version 1.0.1, Primer-E Ltd) (Anderson 2001a, 2001b)

6.3.5.1 Pre-treatment of Data for Statistical Analysis

For MDF and Reference Sites, if a site was sampled during only one or two surveys (and not all three), steps were taken to minimise the effect of this uneven replication of sites on statistical analyses. The solution to this problem was to only include extra sites that fell within the range of variation of sites sampled during both surveys (hereafter termed comparative sites). This was determined by independent statistical tests that compared extra sites against each of the comparative sites, within their respective survey period. The extra sites were excluded from subsequent analyses if the ecological element differed significantly from all the comparison sites. This reduced the likelihood that differences in the number of sites from Baseline to the Post-Development Surveys could drive any significant results of statistical analyses.

Quadrats and/or transect replicates that had zero values for combined macroalgal and seagrass biomass for Baseline and/or Post-Development Surveys were excluded from analyses (see Section 6.3.3 for details on stratification of samples).

Following pre-treatment, the final list of sites used for assessing the potential impact of offshore pipe laying on seagrass was determined, and is provided in Table 6-3.

Table 6-3 Sites Included in Statistical Analyses of Seagrass Cover, and Combined Macroalgae and Seagrass Biomass

Area	Baseline	FGPDSY1	FGPDSY2
MDF	HDD1	HDD1	HDD1
	HDD2	HDD2	HDD2
	HDD3	HDD3	HDD3
	HDD4	HDD4	HDD4
Reference	–	HDDRN	HDDRN
	BR	BR	BR
	HDDRS2	HDDRS2	HDDRS2
	NEBWI1	NEBWI1	NEBWI1

Note: Site HDDRN not sampled during the Baseline due to poor weather conditions.

For univariate analysis of the percent cover of seagrass, data were square-root arcsine transformed prior to analysis as this is a standard transformation for proportional datasets that are often binomially distributed (Underwood 1997). For univariate analysis of combined macroalgal and seagrass biomass, data were not transformed prior to analysis. Euclidean distance was used as a dissimilarity measure for univariate analyses. By using the Euclidean measure, PERMANOVA returns an equivalent test statistic to a standard ANOVA (Anderson *et al*. 2008).

6.3.5.2 Statistical Design and Analysis

Following pre-treatment of data, a BACI approach was used to assess changes between the Baseline and Post-Development Surveys. This approach is required as per the Scope of Works (RPS 2009, amended 2014) and is one of the most powerful statistical designs for detecting changes caused by anthropogenic disturbances (Keough and Mapstone 1995) and thus for assessing detected changes in seagrass associated with offshore pipe laying.

A stepwise approach was adopted for assessing potential environmental impacts to seagrass. The purpose of this approach was to address the most common form of statistical error in environmental impact assessment studies: Type II error (statistical conclusion of no change when change has actually occurred [Schmitt and Osenberg 1996]). Each step of the approach was designed to address potential issues in the datasets (i.e. statistical power and high variance), thus reducing the chance of a Type II error. Steps to improve power were achieved by pooling terms in the analysis.

Pooling was done by removing factors in the test that had no interpretive value towards identifying whether impacts had occurred. This approach incorporated the replication from those pooled factors into the remaining terms to potentially improve the power of tests. Where pooling of factors was required, this sometimes occurred regardless of the p-value of any terms that included the factor in question. Pooling of factors when the p-value is <0.25 can increase the chance of Type I error (conclusion of change when actually no change occurred; Winer *et al*. 1991). If the pooled analysis fails to detect change despite the increased risk of Type I error, then the interpretation of no change is strengthened. If the pooled analysis detects change, Type I error cannot be ruled out, but, as a minimum, taxa and places of potential concern are identified.

A flow chart (Figure 6-2) outlines the stepwise approach and three-factor design adopted for assessment of change in seagrass before and after offshore pipe laying. The interpretation of results for statistical designs in this flow chart (Figure 6-2) focused on the 'Survey × IvR' interaction term that was potentially indicative of a change. If the interaction term of interest was significant at any stage in the flow chart (Figure 6-2), it was interpreted using post-hoc, pairwise comparisons combined with graphing to determine the direction of any changes. A significant 'Survey × IvR' interaction term indicated that ecological elements had changed differently between surveys at MDF Sites compared with Reference Sites.

If the interaction term of interest was non-significant, the next step in the flow chart was followed and factors were pooled. After the conclusion of Step 2, if the 'Survey × IvR' interaction term remained non-significant, it could be concluded that no change associated with offshore pipe laying had occurred.

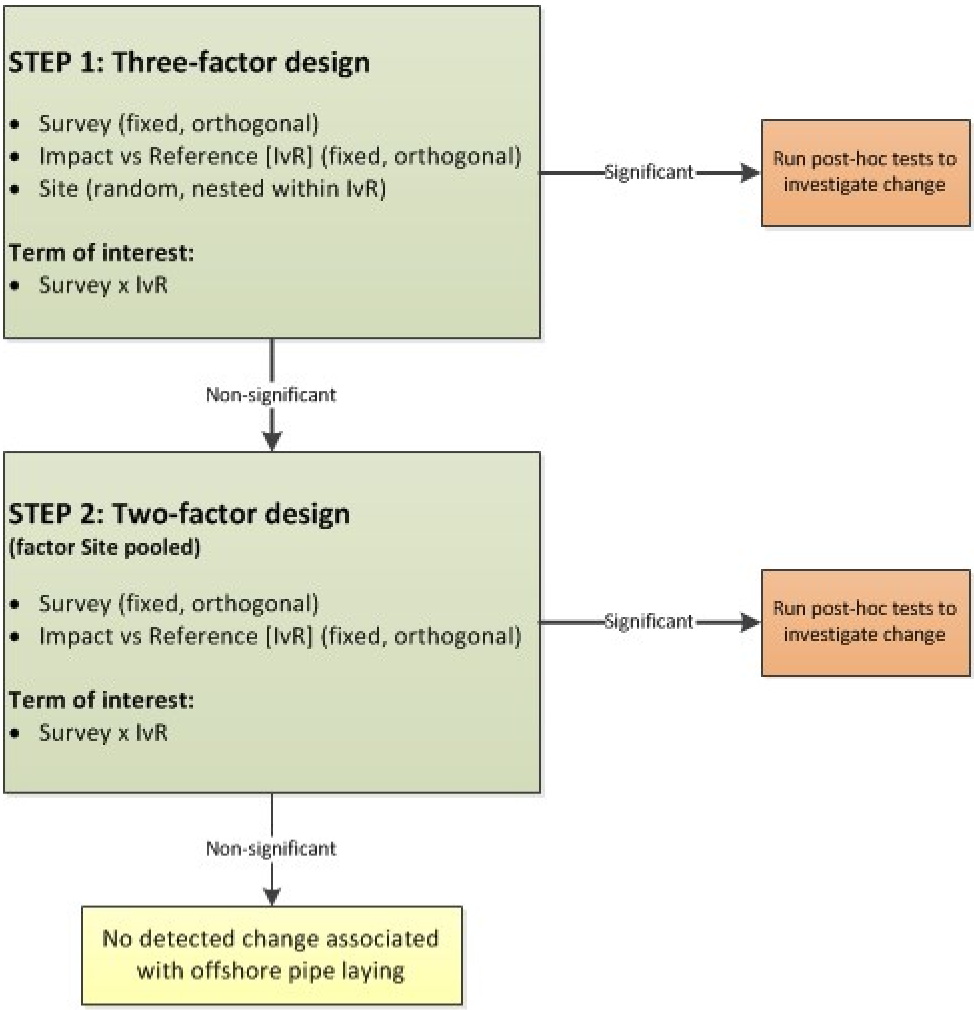


Figure 6-2 Statistical Design and Stepwise Approach for Assessment of Change in Seagrass Before and After Offshore Pipe Laying

6.4 Results of Post-Development Survey

6.4.1 Seagrass in West Coast Barrow Island Waters

Only two seagrass taxa (*Halophila ovalis*, *Syringodium isoetifolium*) were identified in the waters around Barrow Island during FGPDSY2 (Table 6-4).

Table 6-4 Seagrass Species Recorded during FGPDSY2

Species (or taxon)	No. of sites where species recorded	MDF Sites				Reference Sites			
		HDD1	HDD2	HDD3	HDD4	HDDRN	BR	HDDRS2	NEBWI1
Halophila ovalis,	1							X	
Syringodium isoetifolium	3			X			X	X	
Total (all seagrass)		**0**	**0**	**1**	**0**	**0**	**1**	**2**	**0**

6.4.2 Dominant Seagrass in West Coast Barrow Island Waters

Only *Halophila ovalis* and *Syringodium isoetifolium* were recorded in FGPDSY2.

6.4.3 Description of Seagrass Assemblages in the MDF (Area at Risk of Material or Serious Environmental Harm due to the OFGPS)

Seagrass cover in the MDF Sites ranged from 0.0% (HDD4) to 0.3% (HDD1, HDD2) (Table 6-5; Figure 6-3). Seagrass biomass in the MDF Sites ranged from 0.0 g/m^2 (HDD4) to 95.3 g/m^2 (HDD1) (Figure 6-4). *Syringodium isoetifolium* was the only seagrass taxon identified within the MDF Sites in FGPDSY2 (Table 6-4).

Table 6-5 Percent Cover (mean ± SE) of Major Benthic Cover Categories at MDF Sites during FGPDSY2

Site	Major Benthic Cover Categories							
	Seagrass	Macroalgae	Turf algae	Coral	Benthic macro-invertebrates	Sand	Rubble	Pavement
HDD1	0.30 (0.30)	1.19 (0.85)	2.53 (1.17)	–	0.15 (0.15)	95.68 (1.80)	0.15 (0.15)	–
HDD2	0.30 (0.21)	10.71 (2.96)	11.16 (2.72)	–	1.04 (0.62)	73.07 (5.28)	2.53 (1.17)	1.19 (0.73)
HDD3	0.15 (0.15)	19.20 (4.48)	9.23 (1.80)	0.30 (0.30)	1.34 (0.85)	69.79 (4.96)	–	–
HDD4	–	–	0.15 (0.15)	–	–	98.07 (1.63)	1.64 (1.64)	0.15 (0.15)

Notes:

SE are shown in parentheses.

– = zero value recorded.

Seagrass percent cover values are rounded to one decimal place in the text.

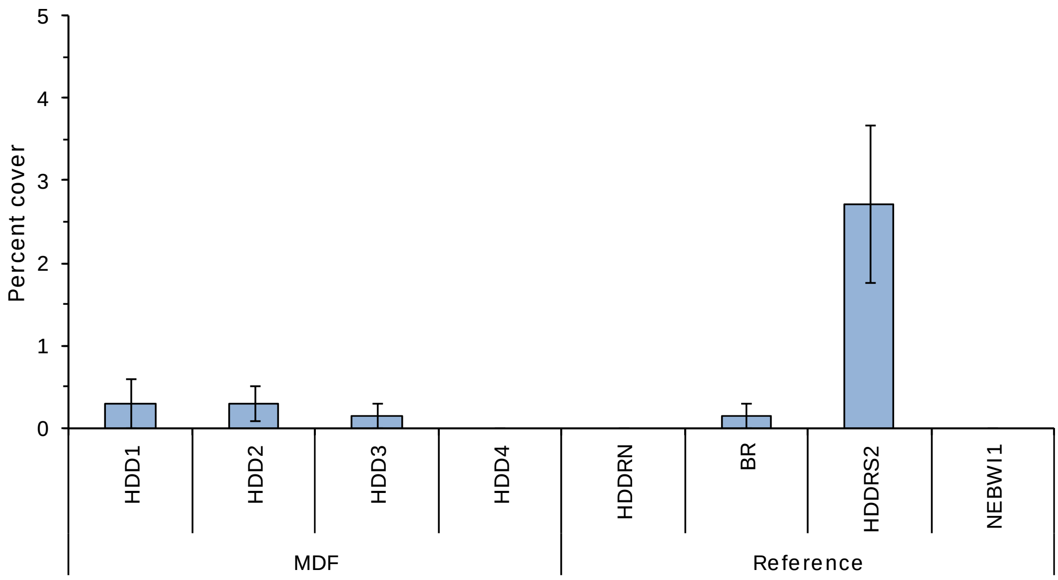


Figure 6-3 Mean (± SE) of Seagrass Percent Cover during FGPDSY2 at MDF and Reference Sites

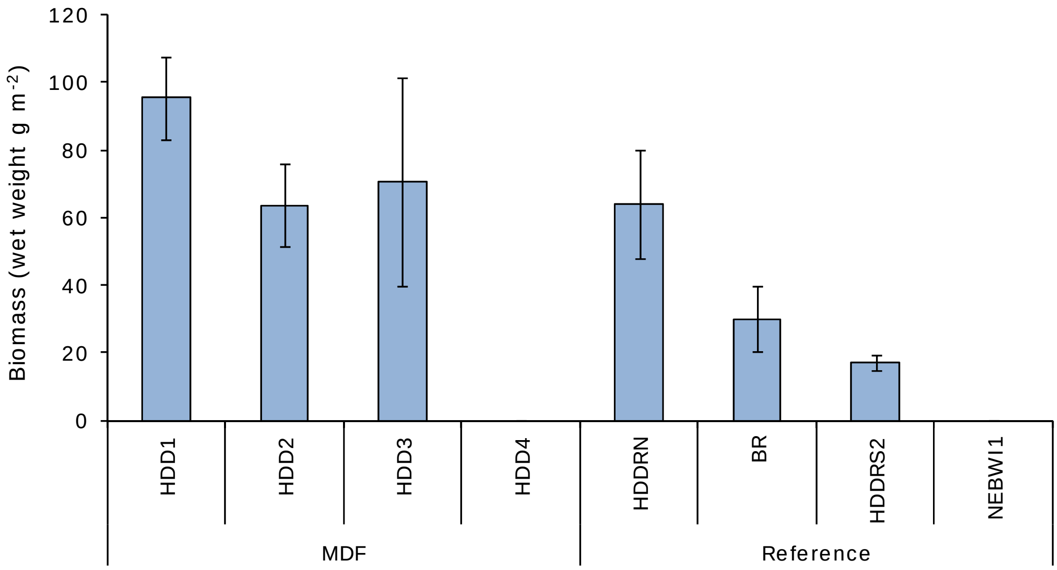


Figure 6-4 Mean (± SE) of Seagrass Biomass during FGPDSY2 at MDF and Reference Sites

Notes:

Quadrats that had zero values for biomass were excluded in calculation of mean and SE (see Section 6.3.4.2).

No seagrass biomass samples were located at sites HDD4 and NEBWI1.

6.4.4 Description of Seagrass Assemblages at Reference Sites not at Risk of Material or Serious Environmental Harm due to the OFGPS

Seagrass cover at the Reference Sites was low and ranged from 0.0% (HDDRN, NEBWI1) to 2.7% (HDDRS2) (Table 6-6; Figure 6-3). Seagrass biomass at the Reference Sites ranged from 0.0 g/m^2 (NEBWI1) to 64.0 g/m^2 (HDDRN) (Figure 6-4). *Halophila ovalis* and *Syringodium isoetifolium* were the only two seagrass taxa were identified at Reference Sites in FGPDSY2.

Table 6-6 Percent Cover (mean ± SE) of Major Benthic Cover Categories at Reference Sites during FGPDSY2

Site	Major Benthic Cover Categories							
	Seagrass	Macroalgae	Turf algae	Coral	Benthic macro-invertebrates	Sand	Rubble	Pavement
HDDRN	–	24.87 (2.57)	42.84 (3.20)	1.49 (0.60)	4.32 (1.04)	25.89 (2.40)	0.30 (0.21)	0.30 (0.30)
BR	0.15 (0.15)	39.52 (4.41)	33.44 (3.18)	–	0.45 (0.24)	24.51 (5.59)	1.64 (0.96)	0.30 (0.21)
HDDRS2	2.72 (0.95)	33.18 (5.96)	15.35 (3.57)	0.15 (0.15)	0.74 (0.43)	47.70 (6.10)	0.15 (0.15)	–
NEBWI1	–	73.32 (2.61)	21.02 (2.42)	–	0.89 (0.44)	4.17 (0.95)	0.30 (0.21)	0.30 (0.30)

Notes:
SE are shown in parentheses.
– = zero value recorded.
Seagrass percent cover values are rounded to one decimal place in the text.

6.5 Comparison Between the Post-Development Survey and the Marine Baseline Environmental State

6.5.1 Descriptive Comparison

Based on identification of collected specimens and seagrass visible in the photoquadrat images, the number of seagrass taxa recorded were lower in FGPDSY2 (two taxa) than in the Baseline (four taxa), and consistent with the number of taxa recorded in FGPDSY1 (two taxa) (Table 6-7). Comparison of seagrass diversity at the site level between the Baseline and FGPDSY2 indicated that the number of taxa declined at two MDF Sites (HDD1 and HDD2) and one Reference Site (NEWBWI1), and remained unchanged at the remaining four sites (Table 6-7).

Halophila ovalis and *Syringodium isoetifolium* were the dominant taxa in the Baseline and FGPDSY2.

Table 6-7 Seagrass Diversity (as Species Richness) observed in the Baseline and Post-Development Surveys

	Baseline	FGPDSY1	FGPDSY2
Seagrass diversity	4	2	2

Table 6-8 Seagrass Diversity (as Species Richness) Observed at Each Site in the Baseline and Post-Development Surveys

Area	Site	Baseline	FGPDSY1	FGPDSY2	Difference between Baseline and FGPDSY2
MDF	HDD1	1	0	0	-1
	HDD2	3	1	0	-3
	HDD3	1	1	1	0
	HDD4	0	1	0	0
Reference	HDDRN	NS[1]	0	0	n/a
	BR	1	1	1	0
	HDDRS2	2	2	2	0
	NEBWI1	1	0	0	-1

Note:

1 Site not surveyed due to poor weather conditions.

In general, sand was the dominant benthic category, followed by macroalgae and turf algae within the MDF and at the Reference Sites across all surveys (Figure 5-5). The percent cover of seagrass, coral, benthic macroinvertebrates, rubble, and pavement comprised ≤4% of the benthic cover at both the MDF and Reference Sites across all surveys (Figure 5-5). The MDF had a greater percent cover of sand than the Reference Sites across all surveys, including the Baseline (Figure 5-5). Sand cover increased between the Baseline and FGPDSY1, and declined between FGPDSY1 and FGPDSY2 at both the MDF and Reference Sites (Figure 5-5). Turf algae declined between the Baseline and FGPDSY1, and increased between FGPDSY1 and FGPDSY2 at both the MDF and Reference Sites (Figure 5-5).

6.5.2 Statistical Comparison

6.5.2.1 Seagrass Percent Cover

The 'Survey × IvR' interaction term was non-significant at Step 2 of the stepwise approach (two-factor design: Figure 5-2; Table 5-2), indicating that no detected change was observed in seagrass percent cover between the MDF and Reference Sites from the Baseline to FGPDSY2. This result suggests that there has been no impact on seagrass percent cover due to offshore pipe laying.

At MDF Sites, seagrass percent cover was the same between the Baseline (0.2%) and FGPDSY2 (0.2%) (Figure 6-5). No seagrass was recorded in the MDF in FGDPSY1 (Figure 6-5). Seagrass percent cover at the Reference Sites was lower in FGPDSY1 (0.5%) and FGPDSY2 (0.7%) compared with the Baseline (0.94%) (Figure 5-5). Seagrass percent cover varied among sites (both MDF and Reference), but seagrass percent cover was ≤1% across all sites and surveys, except for Reference Site HDDRS2, which ranged from 1.3% (FGPDSY1) to 2.7% (FGPDSY2) (Table 6-5; Table 6-6).

Table 6-9 Results of Two-Factor Statistical Analyses of Seagrass Percent Cover During the Baseline and Post-Development Surveys

Source	df	SS	MS	Pseudo-F	p-value
Survey	2	2.1645E-2	1.0822E-2	2.9483	0.0504
IvR	1	6.9372E-2	6.9372E-2	18.899	0.0001
Survey × IvR	2	3.7469E-3	1.8734E-3	0.51038	0.6048
Residual	476	1.7473	3.6707E-3		
Total	481	1.8351			

Note: No statistically significant term of interest was detected

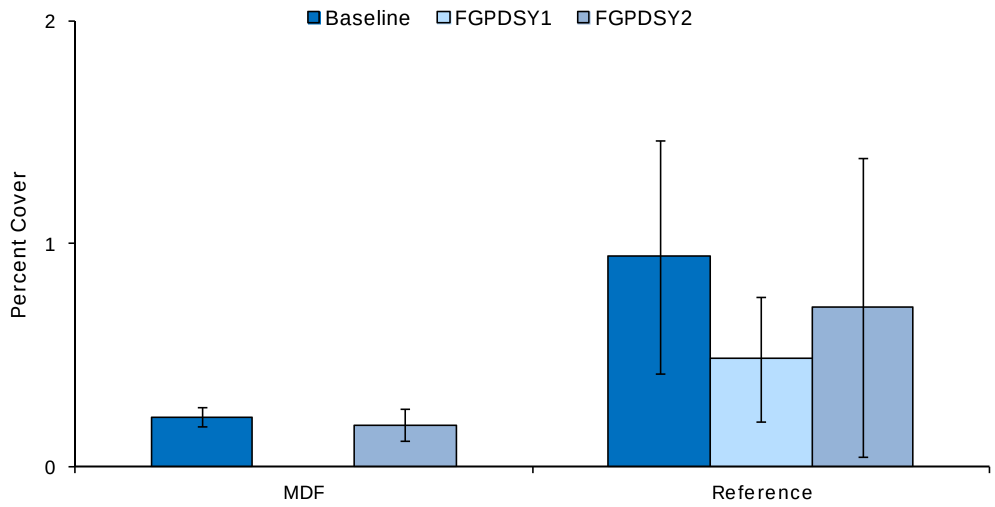


Figure 6-5 Percent Cover (mean ± SE) of Seagrass at MDF and Reference Sites during the Baseline and Post-Development Surveys

Note: Means and standard errors based on Site as replicate pooled into MDF or Reference areas.

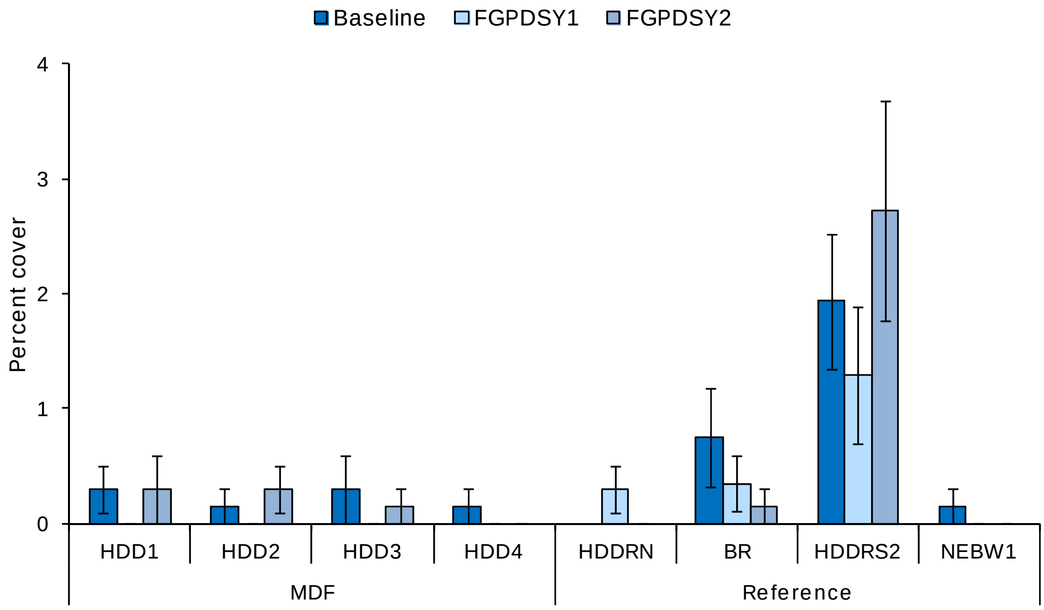


Figure 6-6 Percent Cover (mean ± SE) of Seagrass at Each Site during the Baseline and Post-Development Surveys

Notes:

Means and standard errors based on quadrats as replicates within sites.

Site HDDRN not sampled in the Baseline due to poor weather conditions.

6.5.2.2 Macroalgal and Seagrass Combined Biomass

The 'Survey × IvR' interaction term was significant at Step 1 of the stepwise approach (three-factor design: Figure 5-2; Table 5-2). Post-hoc tests on the 'Survey × IvR' interaction term (undertaken on both factor 'Survey' [Table 6-10a] and factor 'IvR' [Table 6-11b]), only revealed a significant difference between MDF and Reference Sites in FGPDSY2 for factor 'IvR'.

At MDF Sites, the mean biomass increased from the Baseline (420.6 g/m^2) to FGPDSY1 (612.9 g/m^2), and declined in FGPDSY2 (212.4 g/m^2) (Figure 6-7). At the Reference Sites, mean biomass was higher in FGPDSY2 (1559.6 g/m^2), compared with the Baseline (663.0 g/m^2) and FGPDSY1 (764.2 g/m^2) (Figure 6-7). Macroalgal and seagrass combined biomass varied among sites (both MDF and Reference), with no consistent pattern across sites from the Baseline to FGPDSY1 (Figure 6-8). Macroalgal and seagrass combined biomass increased between FGPDSY1 and FGPDSY2 at all sites except MDF Sites HDD1 and HDD4 (Figure 6-8).

Table 6-10 Results of Three-Factor Statistical Analyses of Macroalgal and Seagrass Combined Biomass during the Baseline and Post-Development Surveys

Source	df	SS	MS	Pseudo-F	p-value
Survey	2	3.0729E5	1.5364E5	1.8078	0.2076
IvR	1	7.3593E5	7.3593E5	3.1126	0.0542
Site(IvR)	6	1.5769E6	2.6281E5	10.909	0.0001
Survey × IvR	**2**	**8.6582E5**	**4.3291E5**	**5.0937**	**0.0282**
Survey × Site(IvR)	11	1.0068E6	91523	3.799	0.0002
Residual	178	4.2883E6	24092		
Total	200	9.4079E6			

Note: Bold font = statistically significant difference for term of interest at α=0.05

Table 6-11 Results of Post-hoc Tests for Changes in Macroalgal and Seagrass Combined Biomass for Significant Term of Interest Survey × IvR for the Factors a) Survey and b) IvR

a) Survey	df	t	p-value
MDF Sites			
Baseline, FGPDSY1	3.01	0.4405	0.7376
Baseline, FGPDSY2	3.05	0.9027	0.4317
FGPDSY1, FGPDSY2	3.08	1.1970	0.4327
Reference Sites			
Baseline, FGPDSY1	2.01	0.6951	0.5299
Baseline, FGPDSY2	2	3.1801	0.1216
FGPDSY1, FGPDSY2	2.01	2.8747	0.0826
b) IvR	**df**	**t**	**p-value**
Baseline			
Impact, Reference	5	0.8771	0.4219
FGPDSY1			
Impact, Reference	6.59	0.4632	0.5203
FGPDSY2			
Impact, Reference	**6.59**	**2.6598**	**0.0377**

Note: Bold font = statistically significant difference for term of interest

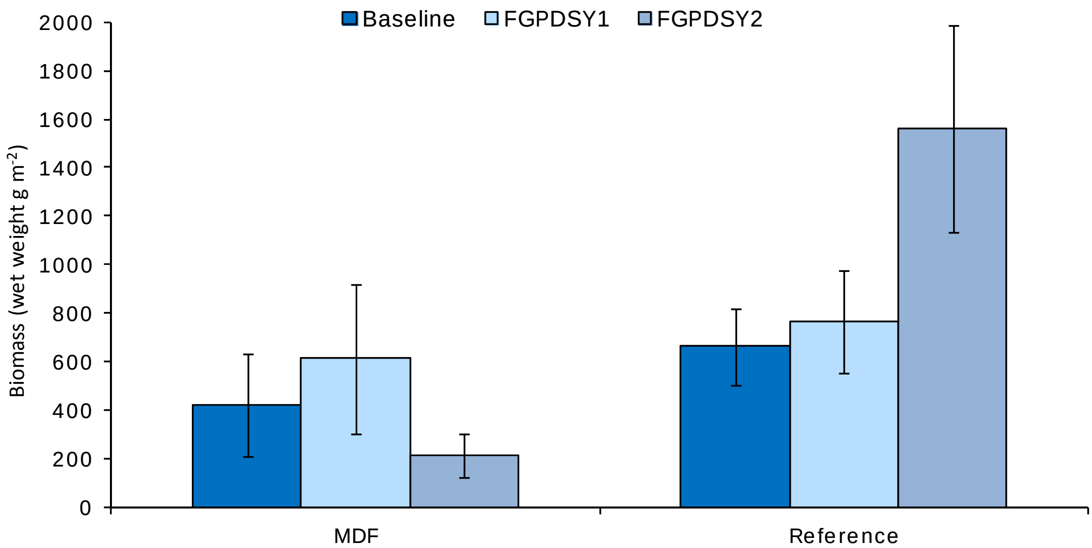


Figure 6-7 Combined Biomass (mean ± SE) of Macroalgae and Seagrass from the Baseline and Post-Development Surveys at MDF and Reference Sites

Notes:

1 *Biomass values scaled to 1 m^2.*

2. *Means and standard errors based on Site as replicate pooled into MDF or Reference areas.*

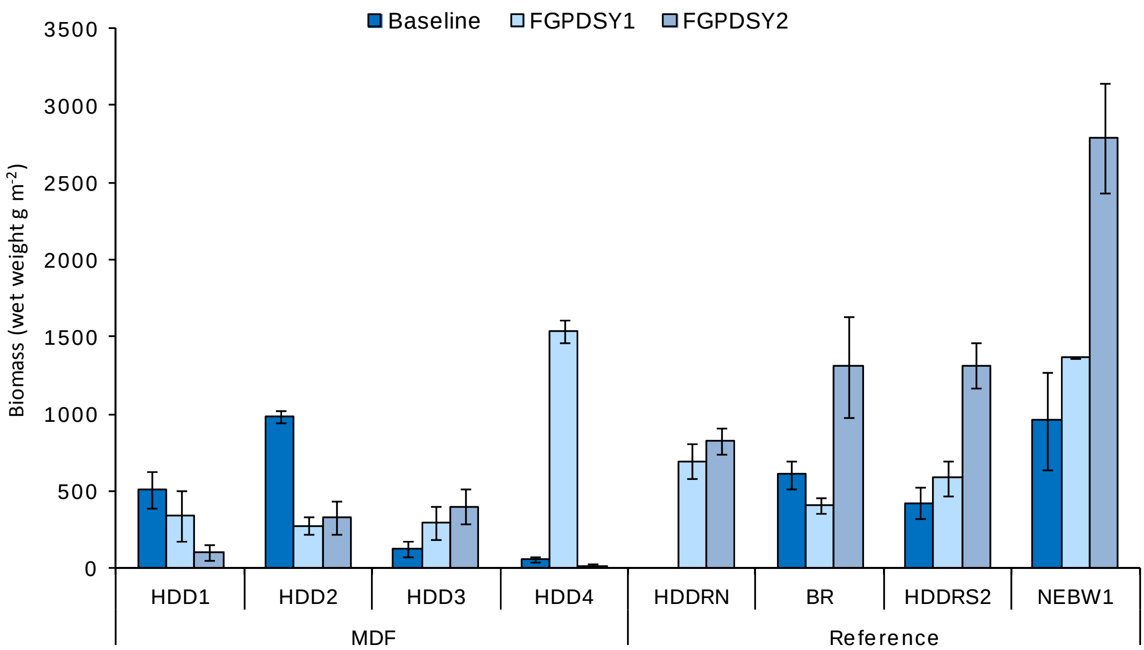


Figure 6-8 Combined Biomass (mean ± SE) of Macroalgae and Seagrass at Each Site during the Baseline and Post-Development Surveys

Notes:

Biomass values scaled to 1 m^2.

Means and standard errors based on quadrats as replicates within sites.

Site HDDRN not sampled in the Baseline due to poor weather conditions.

6.6 Discussion and Conclusions

Although the methods used in this study were consistent with the Scope of Works (RPS 2009, amended 2014), the results need to be placed in the context of some of the broader limitations inherent in the methods and analyses, which may have had an influence on the interpretations. Firstly, the locations of Reference Sites were spatially segregated around Barrow Island. Site NEBWI1 was located on the north-east side, sites HDDRS and BR were located on the south-west side, while site HDDRN was located on the north-west side of Barrow Island As such, spatial differences between survey sites cannot be ruled out as driving observed change. Secondly, the three transects at each site all had the same start point and were laid out at 90° to each other and were not truly random. Due to this layout, the transects do not represent truly independent samples.

The seagrass diversity was low during FGPDSY2 and comprised two species: *Halophila ovalis* and *Syringodium isoetifolium*. *Halophila ovalis* was the most common across all sites and surveys. The seagrass assemblages on the west coast of Barrow Island were sparsely distributed and the percent cover in FGPDSY2 was low (0% to 2.7%). Similar results were recorded in the waters immediately surrounding the east coast of Barrow Island, where seagrass cover between 1% and 3.7% was present over sandy areas (Chevron Australia 2014c). In general, the seagrass percent cover was higher at the Reference Sites compared with the MDF Sites across all surveys. No significant differences in seagrass percent cover were detected for the interaction term ‘Survey × IvR’, indicating that no detected change was evident among surveys at either the MDF Sites or the Reference Sites. However, a significant ‘IvR’ main effect was detected, indicating that seagrass percent cover differed significantly between the MDF and Reference Sites. These spatial differences were present among all surveys, and therefore, there is no evidence to suggest that the offshore pipe-laying activities resulted in any change in seagrass percent cover on the west coast of Barrow Island.

The macroalgal and seagrass combined biomass was higher at the Reference Sites compared with the MDF Sites across all surveys. However, seagrass is extremely sparse on both the west and east coasts of Barrow Island, and the macroalgal and seagrass combined biomass likely reflects the macroalgal biomass rather than the seagrass biomass. Nonetheless, a detected change in macroalgal and seagrass combined biomass was observed for the interaction term ‘Survey × IvR’; however, the post-hoc tests showed no significant differences for factor ‘Survey’ and only revealed a significant difference between the MDF and Reference Sites in FGPDSY2 for factor ‘IvR’. The macroalgal and seagrass combined biomass increased from the Baseline to FGPDSY1 within the MDF Sites, which was largely due to a large increase at site HDD4. Interestingly, this increase in macroalgal and seagrass combined biomass was recorded despite the decline in macroalgal percent cover within the MDF Sites between the Baseline and FGPDSY1. Moreover, the large increase in the macroalgal and seagrass combined biomass at the Reference Sites in FGPDSY2 was largely influenced by a single site (NEBWI1). Thus, there was large variability in macroalgal and seagrass combined biomass across sites among surveys, which was reflected in the significant ‘Survey’ main effect, suggesting that the detected change was largely due to natural temporal and spatial variation.

Therefore, there is no evidence to suggest that the offshore pipe-laying activities resulted in a detected change to seagrass cover on the west coast of Barrow Island. Although significant differences were detected in macroalgal and seagrass combined biomass in FGPDSY2 between the MDF and Reference Sites, this is more likely to reflect changes in macroalgal biomass, given the small contribution of seagrass to the combined biomass samples.

7.0 Demersal Fish

7.1 Introduction

Few ecological studies have been conducted on the fish species of north-western Australia, but the survey work to date has revealed a species-rich assemblage (Allen 1996; Hutchins 1999, 2001, 2003, 2004; Travers *et al.* 2006), with the North West Shelf in particular being considered a hotspot in terms of species richness (Fox and Beckley 2005). This reflects the strong biogeographic links with Indonesia and the west Pacific, facilitated by the Indonesian Throughflow and the diversity of available habitats in these waters (Department of Environment, Water, Heritage and the Arts [DEWHA] 2008). However, the degree of endemism in the fish fauna of the North West Shelf is low when compared with the temperate waters of southern Western Australia (Fox and Beckley 2005).

The Montebello Islands/Barrow Island region supports a rich diversity of fish fauna with 456 species from 75 families recorded during a Western Australian Museum survey in 1993 (Allen 2000), most of which exhibit wide distributions throughout the Indo–West Pacific region (DEC 2007). Two pipefish species recorded during this survey (*Doryrhamphus multiannulatus* and *Phoxocampus belcheri*) represent new records for Australia (DEC 2007). The region's fish fauna is considered to be closely related to that of the Dampier Archipelago (Hutchins 2004), which, along with other outer reef systems upstream in the Leeuwin Current, is thought to act as a supplementary recruitment source for the Montebello Islands/Barrow Island region (DEC 2007). Similarly, the Montebello Islands/Barrow Island region may act as a source of recruits for locations further south (DEC 2007).

Surveys undertaken in Barrow Island waters during 2008–2009 identified distinct fish assemblages in terms of species richness, relative abundance, composition, and size structure, in different key habitats (Chevron Australia 2012b). In general, fish assemblages in sand and soft sediments with sessile benthic invertebrate habitats were less species-rich than those in macroalgal habitats. Habitats dominated by macroalgae were characterised by high abundances of labrids (e.g. Bluespotted Tuskfish [*Choerodon cauteroma*], Blue Tuskfish [*Choerodon cyanodus*], Blackspot Tuskfish [*Choerodon schoenleinii*], lethrinids (e.g. Threadfin Emperor [*Lethrinus genivittatus*], Blue-lined Emperor [*Lethrinus* sp.]), nemipterids (e.g. Purple Threadfin Bream [*Pentapodus emeryii*], and Northwest Threadfin Bream [*Pentapodus porosus*]). In addition, macroalgae habitats were characterised by the presence of juveniles of many different species (particularly *Lethrinus* sp. and *Choerodon* spp.), indicating that macroalgae habitats act as important nursery grounds for numerous fish species, including those where adults were observed in different habitat types. Sandy areas were often visited by transient predators, including carangids (e.g. Yellowstripe Scad [*Selaroides leptolepis*]) and Scombridae spp. Also high in abundance in sandy areas were monacanthids (e.g. Pigface Leatherjacket [*Paramonacanthus choirocephalus*]), nemipterids (e.g. *Nemipterus* spp., Western Butterfish [*Pentapodus vitta*]), and tetraodontids (e.g. Rusty-spotted Toadfish [*Torquigener pallimaculatus*]). In contrast, fish assemblages in soft sediments with sessile benthic invertebrate communities were less species-rich, with high abundances of carangids (e.g. Gold-spotted Trevally [*Carangoides fulvoguttatus*], Golden Trevally [*Gnathanodon speciosus*], Yellowstripe Scad [*Selaroides leptolepis*]), lethrinids (e.g. Threadfin Emperor [*Lethrinus genivittatus*], Blue-lined Emperor [*Lethrinus* sp.]) and nemipterids (e.g. *Nemipterus* spp., Northwest Threadfin Bream [*Pentapodus porosus*], Western Butterfish [*Pentapodus vitta*]).

7.2 Scope

This section is in two parts. The first part describes demersal fish assemblages recorded during the FGPDSY2:

- at sites within the MDF (area at risk of Material or Serious Environmental Harm due to the OFGPS)

- at References Sites not at risk of Material or Serious Environmental Harm due to the OFGPS.

The second part compares the Post-Development Surveys with the Baseline to identify any detected changes to marine ecological elements as per Condition 15.3 of Statement No. 769.

7.3 Methods

7.3.1 Site Locations

Baseline surveys were conducted at six sites in March 2009 and 11 sites in February/March 2010, with 12 sites surveyed in total. Of these 12 sites, four are within the MDF (FGI1, FGI2, FGI4, and HDD1) and eight are Reference Sites. FGPDSY1 and FGPDSY2 surveys were undertaken at the same 12 sites as the Baseline surveys (Table 7-1; Figure 7-1).

Table 7-1 Demersal Fish Assemblage Survey Sites for the Baseline and Post-Development Surveys

Site Code	Easting	Northing	Latitude	Longitude	Mapped Habitat[1]	Dominant Habitat Observed On Stereo-BRUVs				Average Depth[1] (m)			
	(GDA94, MGA Zone 50)		(GDA94)			Mar 2009[2]	Feb/Mar 2010[2]	Oct 2013[3]	Oct/Nov 2014	Mar 2009[2]	Feb/Mar 2010[2]	Oct 2013[3]	Oct/Nov 2014
MDF Sites													
FGI1	333633	7711886	20°41.105' S	115°24.162' E	Sand/Sessile	Sand	Sand	Rock armour	Rock armour	19	18	16	17.1
FGI2	332102	7712403	20°40.816' S	115°23.284' E	Sand/Sessile	Sand	Sand	Sand	Sand	20.4	19.7	19.3	19.5
FGI4	330985	7712980	20°40.497' S	115°22.644' E	Sand/Sessile	-	Sand	Sand	Sand	-	21.9	21.5	20.3
HDD1	334650	7711425	20°41.360' S	115°24.745' E	Macroalgae	-	Macroalgae	Macroalgae	Sand	-	12.2	10.1	9.8
Reference Sites													
FGFR1	331682	7709028	20°42.643' S	115°23.022' E	Sand/Sessile	Sessile	Sand	Sessile	Sessile	18.7	17.8	18	17.9
FGFR2	334095	7715577	20°39.107' S	115°24.449' E	Sand/Sessile	Sand	Sand	Sand	Sand	12.5	13	11.8	10.8
FGFR3	330217	7710062	20°42.075' S	115°21.184' E	Sand/Sessile	Sessile	Sessile	Sessile	Sessile	20.4	21.3	22.1	19.4
FGFR4	335302	7714630	20°39.626' S	115°25.139' E	Sand/Sessile	-	Sand	Sand	Sand	-	12.1	10.7	10.7
FGN1	332603	7714032	20°39.936' S	115°23.581' E	Sand/Sessile	Sand	-	Sand	Sand	18.9	-	17.5	17.0
HDDN1	335552	7713012	20°40.504' S	115°25.274' E	Macroalgae	-	Macroalgae	Macroalgae	Macroalgae	-	13.2	11.3	10.5
HDDN2	335954	7713936	20°40.006' S	115°25.510' E	Macroalgae	-	Macroalgae	Sand	Sand	-	14.2	11.6	12.2
HDDN3	333646	7709907	20°42.177' S	115°24.159' E	Macroalgae	-	Sand	Sand	Sand	-	9.9	9.8	9.6

Notes:

1 Variations in tide height will have contributed to the minor variations in depths recorded at the time of sampling.

2 Chevron Australia 2014a

3 Chevron Australia 2014b

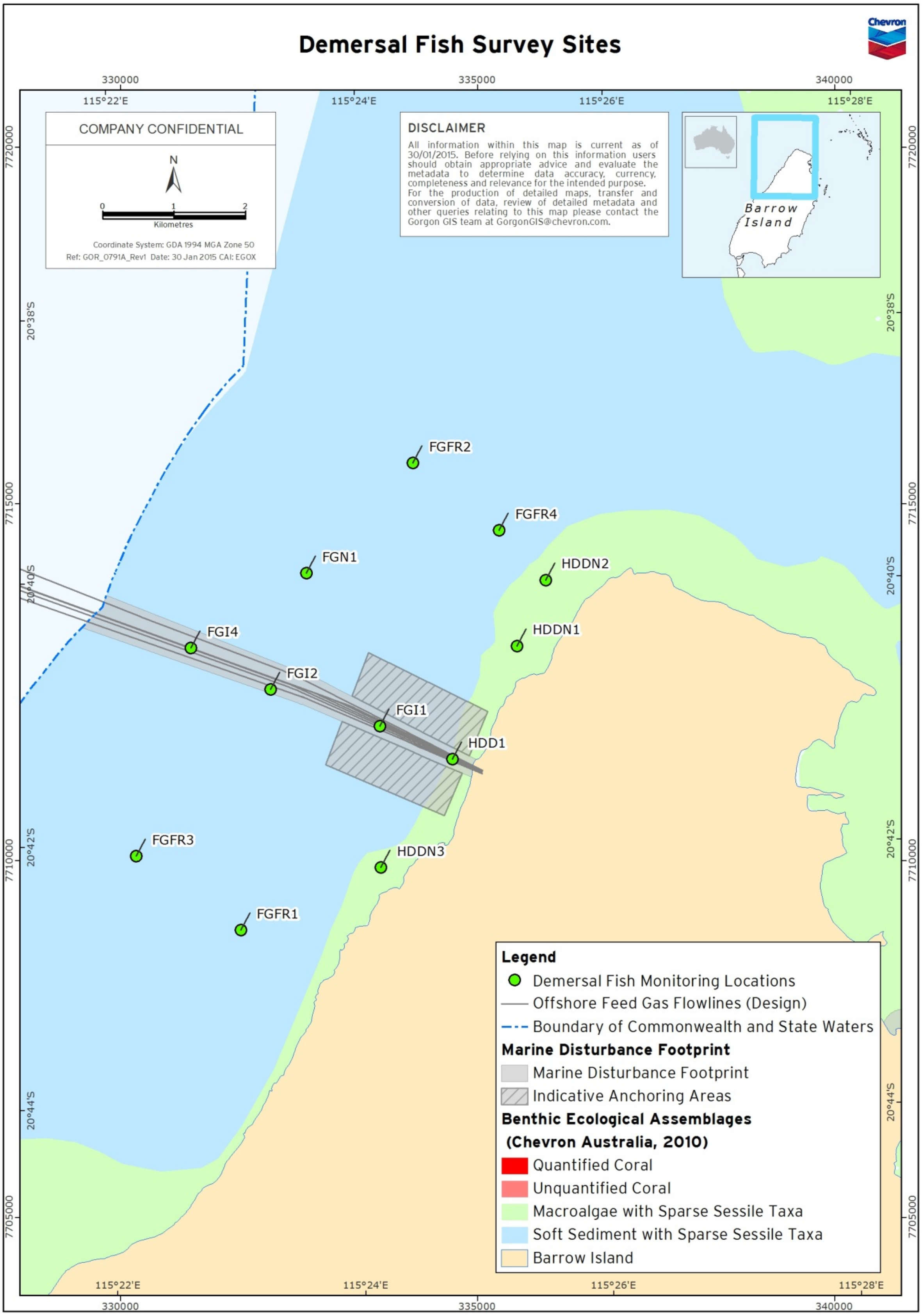


Figure 7-1 FGPDSY2 Sites for Demersal Fish

7.3.2 Timing of Sampling

The FGPDSY2 of the demersal fish assemblages was undertaken from 30 October to 1 November 2014 during daylight hours.

7.3.3 Methods

Demersal fish data collection methods were consistent with the Scope of Works (RPS 2009, amended 2014).

The demersal fish assemblages that characterised macroalgae, soft sediments with sessile benthic macroinvertebrates, and bare sand communities were surveyed using baited remote underwater stereo-video systems (stereo-BRUVs) in the same configuration and using the same high-definition video cameras as were used in the Baseline. Detailed information on the design and calibration of stereo-BRUVs was reported in Chevron Australia (2014c) and additional information can be found in the literature (e.g. Harvey and Shortis 1995, 1998; Harvey *et al.* 2001a, 2001b, 2002).

Five stereo-BRUVs were deployed synchronously at each site for a 60-minute period, with at least 250 m between each stereo-BRUVs to avoid overlap of bait plumes and reduce the likelihood of fish moving between deployments within the sampling period. The stereo-BRUVs used in this study used two full high-definition (1080i) SONY HDR CX12 handycams in underwater housings mounted 0.7 m apart and inwardly converged at 8° to gain an optimised field of view from approximately 0.5 m in front of the cameras. A synchronising diode and bait basket were positioned between the two cameras, in the field of view of both cameras at distances of approximately 0.75 m and 1.2 m respectively. Stereo-BRUVs were baited with approximately 800 g of Western Australian pilchard (predominantly *Sardinops sagaz*), crushed to maximise dispersal of the fish oil and flesh.

7.3.4 Treatment of Survey Data

7.3.4.1 Species Identification, Relative Abundance, and Length Measurements

High-definition stereo-BRUVs footage was converted from the proprietary HD MTS format to a general high-definition format using Xilisoft Video Converter Ultimate.

An extensive reference library of images and videos in combination with taxonomic literature (e.g. Randall *et al*. 1997; Allen *et al*. 2003; Randall 2002; Hutchins 2003; Allen 1998, 2004) were used to aid species identification. The supervising analyst verified the identification of any new species that had not been previously observed during the Baseline or Post-Development Surveys east of Barrow Island (Chevron Australia 2012a, 2013c, 2014c). Clear identification images and short video clips were collected for all species, where possible, and verified by the supervising analyst prior to being added to the reference library. A number of species could not be consistently identified to species level from the videos, so were identified to genus or family level. These were: scad (*Alepes* spp.), threadfin bream (*Nemipterus* spp.), unidentified cowtail stingrays (*Pastinachus* spp.), coral trout (*Plectropomus* spp.), fusiliers (*Pterocaesio* spp.), mackerels (Scombridae spp.), whiting (*Sillago* spp.), lizardfish (*Synodontidae* spp.), and razorfish (*Iniistius* spp.—previously a synonym to *Xyrichtys*, but not a distinct genus). The family grouping Scombridae spp. includes mackerel from the genera *Scomberomorus* and *Grammatorcynus*, but does not include tuna and bonito, which are in the same family. Blennies (*Blenniidae* spp.) were also pooled to family level except for two species of fang blennies (*Aspidontus taeniatus* and *Plagiotremus rhinorhynchos*) that were consistently identifiable to species level. One group—Pleuronectiformes (flounders)—was recorded at the Order level as further distinction was not possible from video.

Interrogation of each video was conducted using the custom interface EventMeasure (SeaGIS 2012). Relative abundance counts were obtained of the maximum number of fish belonging to each species, present in the field of view of the stereo-BRUVs at any one time (MaxN; Priede *et al*. 1994; Cappo *et al.* 2003). This measure avoids repeated counts of the same individual and provides a conservative measure of relative abundance, as only a portion of the total number of individuals in the area may be viewed at one time.

Measurements of fish fork length (snout to fork; FL) were made at the time of MaxN to avoid making repeated measurements of the same individuals. In contrast to the Baseline that measured fish length using the program PhotoMeasure (SeaGIS 2008), fish length in the Post-Development Surveys were measured using a stereo measuring component that has been integrated into EventMeasure since the Baseline (SeaGIS 2012). These two approaches use the same libraries and algorithms and result in no differences in the output data files, so the data produced is comparable. The merging of the two programs saves analysis time. Length measurements in millimetres (mm) were made by locating the snout and the caudal fork of the focal fish within each image of the synchronised video footage (Figure 7-2). The length from the snout of the fish to the central point between the camera lenses was also calculated automatically.

No measurements of fish length were made at distances greater than 7 m from the cameras. During the Baseline surveys, the maximum estimated horizontal visibility was 7 m, and only a single individual was recorded at a distance greater than 7 m from the camera. This individual measurement was excluded from the Baseline dataset so that the Baseline and Post-Development Survey data were entirely comparable. Although stereo-video systems using full high-definition cameras have been shown to measure accurately up to 9 m, accuracy and precision of length measurements begins to deteriorate at distances of 8 and 9 m (Harvey *et al*. 2010). Limiting measurements to a distance of 7 m also provides consistency between this dataset and those collected east of Barrow Island (Chevron Australia 2012a, 2013c, 2014c). Additionally, length measurements were not possible where other fish, the bait bag, or habitat, obstructed the snout or tail of a fish, so fewer total length measurements were made than the total numbers of individuals observed.

Dominant 'indicator' species—defined as the most numerically abundant fish species in each of the mapped habitats observed during the Baseline—were selected for further exploratory analysis as required by the Scope of Works (RPS 2009, amended 2014). Ten dominant species were selected from sand/sessile invertebrate habitat (from the 2009 and 2010 data combined) and from macroalgae habitats (2010 data only as no macroalgae was surveyed in 2009). However, it is not suggested that these dominant species are characteristic of certain habitats. For example, a species observed in a large school may be selected as a dominant species even if this species was only observed on a single deployment. Furthermore, as the 2010 Baseline survey was conducted in March, and FGPDSY1 and FGPDSY2 were conducted in October/November, there may be seasonal change in the abundance or size of dominant species, particularly for macroalgae habitats that were not sampled during the 2009 Baseline survey.

The overall fish assemblage was described in terms of the number and abundance of species, their commonality (% of deployments), and size structure. Following this initial overall description, further detailed examination of fish assemblage structure was conducted for each habitat associated with the OFGPS. Tables and graphs were used to illustrate richness, abundance, and length data for fish that occurred west of Barrow Island.

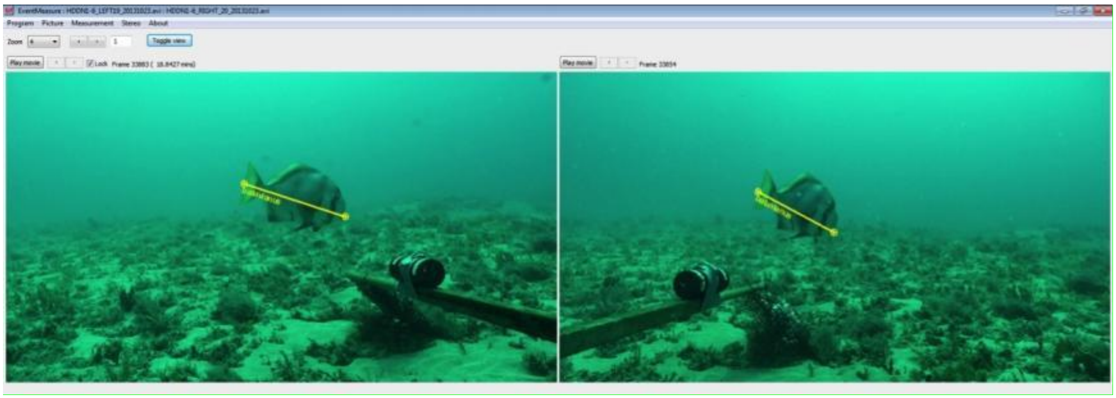


Figure 7-2 EventMeasure Software used to Obtain Measurements of Relative Abundance and Fish Length (example length measurement of a Humphead Batfish *Platax batavianus* is shown)

7.3.4.2 Visibility Estimates and Habitat Assessment

In addition to information on the fish assemblage, stereo-BRUVs footage was used to estimate visibility and verify habitat type. A single JPEG image was collected for every deployment. This image was collected when the stereo-BRUVs had settled on the seabed and any stirred up sediment had settled. Visibility and observed habitat was determined from this image. To avoid inter-observer variability, and to ensure comparability between surveys, a single observer scored visibility and observed habitat type from all stereo-BRUV deployments. Visibility was estimated using the bait bag as a reference point 1.2 m from the camera system, or measured to a distant object at the edge of visibility. The average visibility at each site ranged from 4.0 ± 0.2 m to 6.1 ± 0.8 m during FGPDSY2, from 4.0 ± 0.0 m to 8.2 ± 0.2 m during FGPDSY1, and from 2.6 ± 0.1 m to 5.8 ± 0.5 m during the Baseline. Estimates of visibility made for each deployment conducted during FGPDSY2 are presented in Appendix 2.

The habitat type was assessed for each stereo-BRUVs deployment and an overall ‘site’ habitat assigned. This site habitat was assigned according to the habitat type observed on most (three or more) deployments for that site. For example, a site that had three sand deployments and two sessile invertebrate deployments would be classified as ‘sand’. The habitat type viewed on footage depended on the orientation of the stereo-BRUVs. As such, a stereo-BRUVs facing away from the OFGPS might only record sand habitat despite being close to rock armour. Therefore, the assumption is made that by examining habitat on each of five deployments and assigning a dominant ‘site’ habitat, the dominant habitat in the area of the site is depicted. The four dominant habitat types are shown in Figure 7-3.

Although this process was applied to assign habitats that were used in describing the overall fish assemblage (Section 7.4), the habitat categories originally assigned during the Baseline habitat mapping (Table 7-1) were retained for visibility analysis, and to facilitate direct comparisons of the Baseline and Post-Development Surveys and allow statistical tests for change.

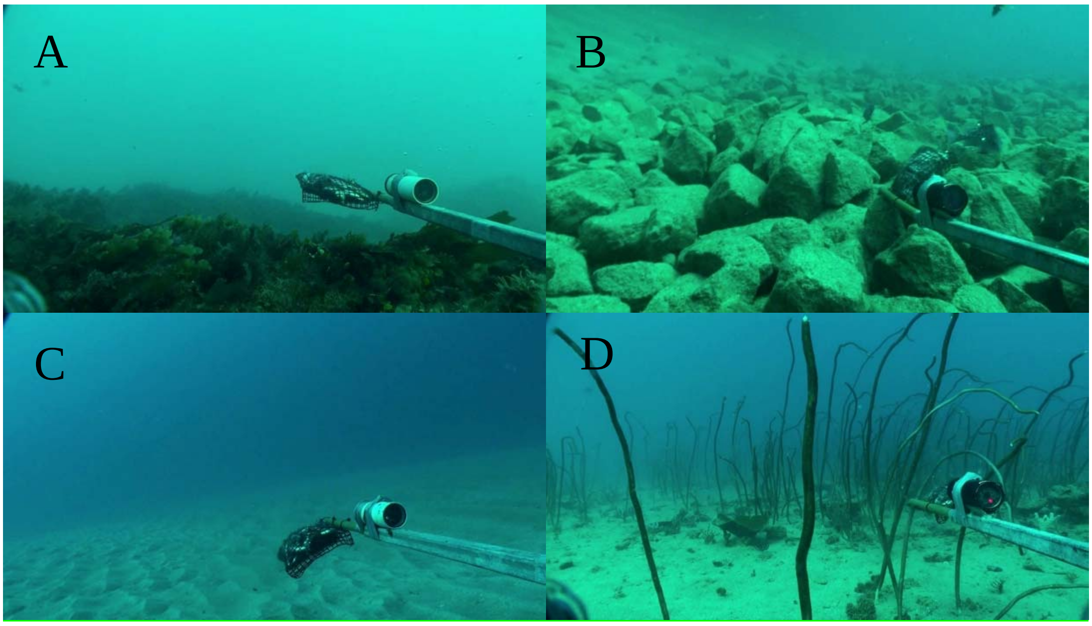


Figure 7-3 Dominant Habitats Surveyed West of Barrow Island during FGPDSY2: A) Macroalgae; B) Rock Armour Associated with MDF Site FGI1; C) Sand; and D) Sessile Invertebrates

7.3.5 Statistical Approach for Comparison against Marine Baseline

A summary of the statistical treatment and analyses used to assess any detected changes on demersal fish assemblages, consistent with the Scope of Works (RPS 2009, amended 2014) as per Condition 15.1 of Statement No. 769, is presented in Table 7-2 and further explained in Sections 7.3.5.1 to 7.3.5.2.

Table 7-2 Statistical Treatment and Analyses used for Demersal Fish

Random Stereo-BRUVs Deployments	
Sites used in statistical analyses	• MDF: FGI1, FGI2, FGI4, HDD1 • Reference: FGFR1, FGFR2, FGFR3, FGFR4, FGN1, HDDN1, HDDN2, HDDN3
Stepwise approach	Stepwise approach adopted: • PERMANOVA (see Figure 7-4; BMT Oceanica 2014) • PERMANOVA with covariate (Figure 7-5; BMT Oceanica 2014)
Main statistical design	Five-factor statistical design: • Survey (fixed, orthogonal) • MDF vs. Reference [IvR] (fixed, orthogonal) • Habitat (fixed, orthogonal) • Year (random, nested within Survey) • Site (random, nested within IvR) Covariate: • Visibility

Random Stereo-BRUVs Deployments	
Terms of interest	Interaction terms of interest • Survey × IvR × Habitat • Survey × IvR Covariate interactions of interest: • Visibility × Survey × IvR × Habitat • Visibility × Survey × IvR
Statistical program	PERMANOVA[1]
Statistical tests	• Relative abundance (Max N) – multivariate • Total number of individuals – univariate • Species richness – univariate • Fish length – multivariate • Dominant fish species – univariate
Transformation	Relative abundance: • Fourth-root Total number of individuals: • Fourth-root Species richness: • Fourth-root Fish length: • Untransformed, Length bins are standardised Dominant fish species: • Variable. Most untransformed; *Coris pictoides* macroalgae square-root transformed; *Pentapodus porosus* sand/sessile fourth-root transformed
Distance measure	Relative abundance: • Bray-Curtis Total number of individuals: • Euclidean distance Species richness: • Euclidean distance Fish length: • Manhattan distance Dominant fish species: • Euclidean distance

Notes:

1 PERMANOVA = Non-parametric analysis of variance (Version 1.0.3, Primer-E Ltd) (Anderson 2001a, 2001b)

7.3.5.1 Analysis to Assess Changes in Visibility

Visibility in front of the stereo-BRUVs was found to vary during FGPDSY2 (see Appendix 2) and when compared with the Baseline. Therefore, an assessment of the effects of visibility on surveyed fish was carried out. Visibility data were tested for homogeneity of dispersions using a distance-based test for homogeneity of multivariate dispersions (PERMDISP) on the factor IvR using Baseline data only. PERMDISP is analogous to a multivariate Levene's test (Anderson *et al*. 2006). This was to test the assumption that dispersion between groups was similar, but that a change in dispersion may be one effect of any impact of offshore pipe laying. The dispersion was not found to differ between groups, so untransformed visibility data were used for the analyses. A univariate PERMANOVA on untransformed visibility estimates was performed according to the five-factor design outlined in Table 7-2.

To provide an initial assessment of any relationship between visibility and the fish assemblage, distance-based linear modelling (DISTLM; Anderson 2001a; McArdle and Anderson 2001) of fourth-root transformed data (individual replicates from the Baseline and Post-Development Surveys) was carried out. DISTLM was also used to assess the strength of the relationship of species richness and total number of individuals to the predictor variable 'Visibility'. For species richness and total number of individuals, all PERMDISP tests of homogeneity of dispersions proved significant. Therefore, investigations of normality using Anderson-Darling tests were used to select the transformation. These indicated that fourth-root transformations generated normally distributed data compared to non-transformed and square-root transformations. The influence of visibility on measures of relative abundance (data from all surveys combined) was further examined using DISTLM, as the first step in the analysis of change with the statistical approach described in Section 7.3.5.2.

7.3.5.2 Statistical Design and Analysis

Data analysis and interpretation were undertaken following the approved Scope of Works (RPS 2009, amended 2014).

There were five replicate stereo-BRUVs deployments per site (except for the 2009 Baseline survey, where visibility issues and currents tipping the camera frame resulted in three sites with four deployments and one site with two).

Examination of changes in visibility and fish assemblage structure from the Baseline to FGPDSY1 and FGPDSY2 was conducted following the stepwise approach detailed in Figure 7-4 and detailed in BMT Oceanica (2014). Because visibility varied significantly between the terms of interest, each stage of analysis began with an assessment of any relationship between the variable being tested and visibility. The multivariate relative abundance dataset was analysed using PERMANOVA with 9999 permutations (Anderson 2001b) in the PRIMER-E statistical software package (Clarke and Gorley 2006) using the PERMANOVA+ add-on (Anderson *et al*. 2008). 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 Bray-Curtis dissimilarities of fourth-root transformed relative abundance data. This transformation resulted in a statistically insignificant difference in dispersion between the factor 'IvR' using Baseline data when tested using PERMDISP. Univariate analyses of species richness and total abundance were conducted using Euclidean distance dissimilarities of fourth-root transformed data as this transformation produced the distribution closest to normal.

A distance-based linear model (Anderson 2001a; McArdle and Anderson 2001) was first conducted to examine the relationship between visibility and each variable measured (using the dissimilarity matrices described above). The adjusted R^2 selection criterion was used with an 'all specified' selection procedure to determine how much of the variability in the fish data was explained by visibility. The statistical significance of visibility was assessed using marginal tests (from 9999 permutations) and its percent contribution to variability in fish data determined. If a significant DISTLM result was obtained, then statistical analyses for change progressed using visibility as a covariate (Figure 7-5; BMT Oceanica 2014). If the result was not significant (i.e. visibility had no influence), the analyses proceeded using the five-factor design outlined in Figure 7-4.

To provide additional power to statistically test the terms of interest and to reduce the chance of a Type II error (i.e. statistical conclusion of no change when change has actually occurred), a stepwise approach was used where, after the first test, factors were sequentially pooled in the analysis (Section 3.5; Figure 7-4). Pooling of factors occurred regardless of the p-value of terms containing those factors. Pooling when $p<0.25$ may increase the chance of a Type I error (i.e. conclusion of change when no change has occurred; Winer *et al*. 1991). If change was detected in these instances, then results were interpreted with caution as a Type I error could not be ruled out. Where significant terms of interest were detected, pairwise tests in PERMANOVA were performed to ascertain where differences occurred. Where necessary, these pairwise tests were conducted for pairs of levels of the factor 'Survey' for the significant interaction term of interest. This factor considers the two baseline sampling events together as a single level of the factor (Baseline), FGPDSY1 as a second level of the factor, and FGPDSY2 as a third.

A principal coordinate ordination (PCO; Anderson *et al*. 2008) was used to construct an unconstrained ordination of the data, and canonical analysis of principal coordinates (CAP; Anderson and Robinson 2003; Anderson and Willis 2003) was used to investigate the significant term of interest 'Survey × IvR'. Individual species likely to be responsible for any observed differences were determined by examining Spearman correlations of untransformed species counts with the canonical axes. For the CAP analysis, vectors were overlaid for those species with a correlation of $|r|\geq0.40$ to the canonical axes. Each of these selected species were analysed separately using the stepwise statistical model outlined above.

Dominant species were analysed following a modification of the stepwise approach described above. As species were selected separately for each habitat, the factor of habitat was not needed and therefore was removed from the design. In addition, macroalgae habitats were sampled during only one year (2010) in the Baseline, so the factor Year was removed from the design for these species. Thus sand/sessile invertebrate dominant species were analysed using a four-factor design, while macroalgae-dominant species were analysed using a three-factor design.

Species selected from the CAP and dominant species were tested for homogeneity of dispersions using PERMDISP as described above. If necessary, data were transformed until the dispersions between groups were not significantly different. *Coris pictoides* in macroalgae habitat was square-root transformed, and *Pentapodus porosus* in sand/sessile invertebrate habitat was fourth-root transformed. All other univariate species analyses were conducted on untransformed data. Mean relative abundance plots were produced for each species where a significant term of interest was detected. These plots graphically illustrated how their relative abundance changed from the Baseline to FGPDSY1 and FGPDSY2 at MDF and Reference Sites.

7.3.5.3 Fish Length Analyses

Histograms were used to display the length-frequency distribution of the fish assemblage for each survey and zone. Length-frequency histograms were also constructed for each site to allow comparison of the assemblage length-frequency distribution between the Baseline and Post-Development Surveys. These were tested using Kolmogorov-Smirnov (KS) tests.

Cumulative PERMANOVAs of standardised length bins, based on the Manhattan distance measure, were used to analyse the assemblage length data. This approach is sensitive to greatest difference between cumulative length-frequency distributions. Therefore, it is analogous to the KS test (Zar 1999) and is sensitive to differences in both shape and location (Hetrick and Bromaghin 2006; Neat and Burns 2010). An established direct plug-in method was used to select the appropriate bin width for each analysis and for constructing histograms (Wand 1995). The use of the Manhattan distance measure characterises the difference between the cumulative length bins. The cumulative PERMANOVA approach is adaptable and can be used for any complex ANOVA design. Therefore, as this length bin analysis is less sensitive when total numbers of fish within each replicate sample are low, a minimum threshold of 50 length measures was used within each replicate. Because this minimum was not reached from enough single deployments, length distributions were analysed using a modification of the stepwise approach (Figure 7-4). The factor Site within the analysis was removed, as Site was treated as the replicate and all length measurements within each Site were used to construct the length-frequency distributions.

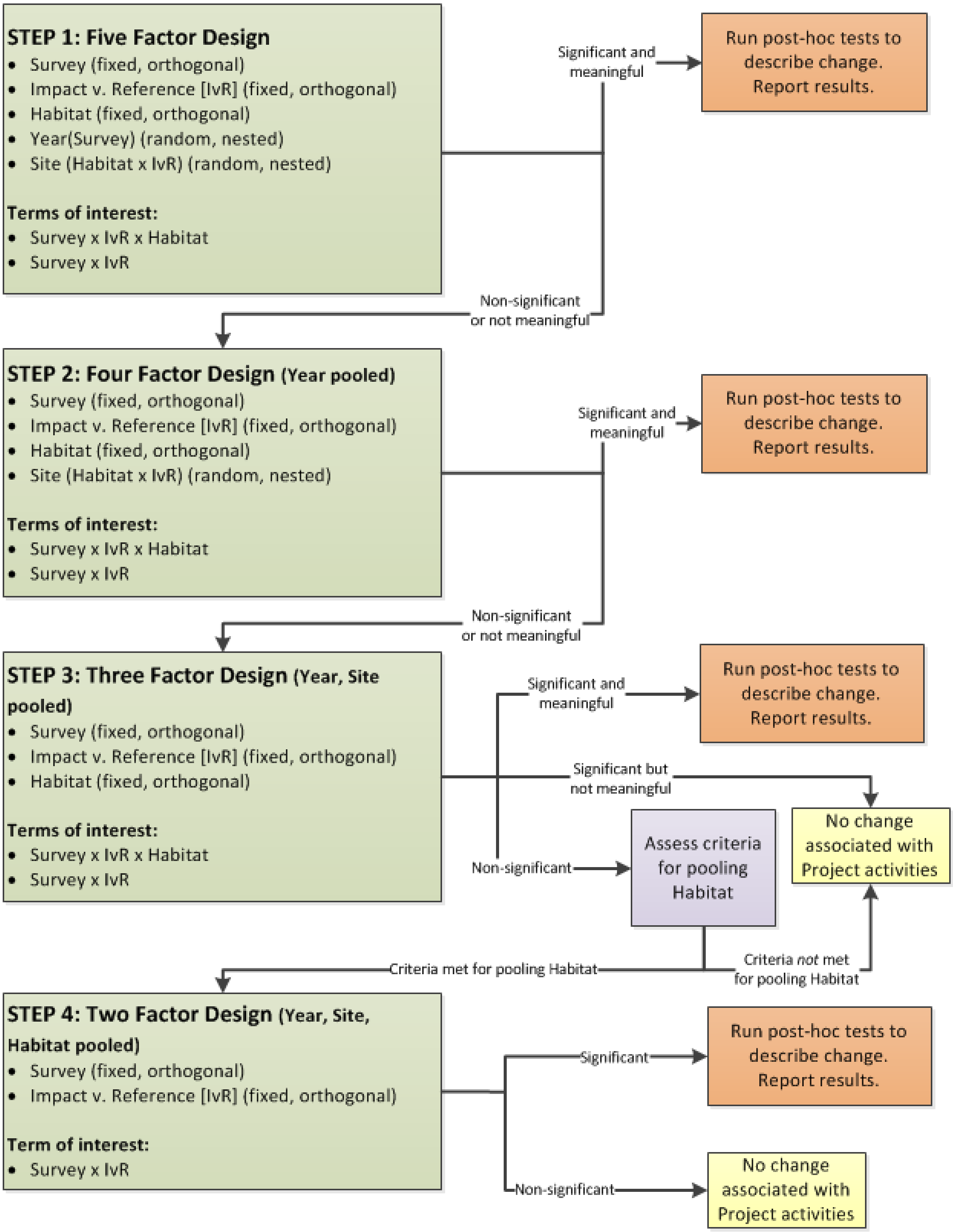


Figure 7-4 Statistical Design and Stepwise Approach for Assessment of Change in Demersal Fish Before and After Offshore Pipe Laying

Notes:

Meaningful = potentially indicative of impacts caused by offshore pipe laying.

Significant = statistically significant at α=0.05.

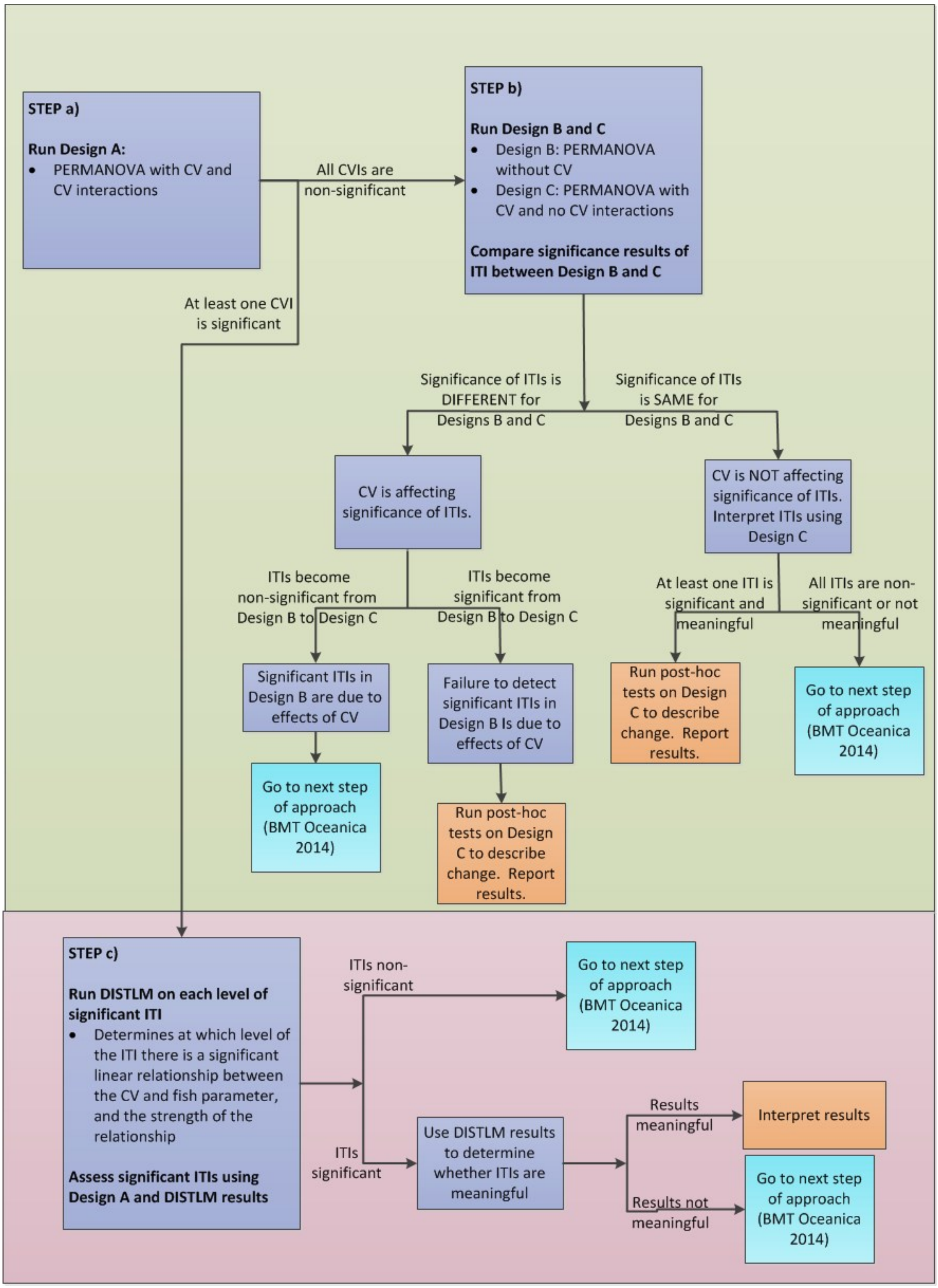


Figure 7-5 Covariate Decision Process for Assessment of Change in Demersal Fish Before and After Offshore Pipe Laying

Notes:

CV = covariate

CVI = covariate interaction of interest

ITI = interaction term of interest

DISTLM = Distance-based Linear Modelling (Anderson et al. *2008)*

Meaningful = potentially indicative of impacts caused by offshore pipe laying

Significant = statistically significant at α=0.05

7.4 Results of Post-Development Survey

7.4.1 Description of Demersal Fish Assemblages Characteristic of Soft Sediments with Sessile Benthic Macroinvertebrates, Macroalgae, and Sand Communities in West Coast Barrow Island Waters

In FGPDSY2, a total of 2162 individuals from 120 species and 36 families were recorded from the 60 stereo-BRUVs deployments (see Appendix 1 for full list). An average of 9.1 ± 1.1 species was observed on each deployment. The greatest species richness recorded on a single deployment was 31 at MDF Site FGI1, while the smallest was one species on single deployments at MDF Site HDD1 and Reference Sites HDDN2 and HDDN3. The 20 most common fish species observed on stereo-BRUVs deployments conducted for FGPDSY2 are listed in Table 7-3. The most common fish observed was mackerel (Scombridae spp.), which was recorded on 50% of all deployments and was most commonly observed in pairs or small groups. The Northwest Threadfin Bream (*Pentapodus porosus*) and whiting (*Sillago* spp.) were both commonly sighted and abundant on FGPDSY2 stereo-BRUVs deployments.

The five most numerically abundant families observed included: Nemipteridae (threadfin bream, n = 385), Lethrinidae (emperor, n = 355), Carangidae (trevally, n = 337), Scombridae (mackerel, n = 173) and Mullidae (goatfish, n = 144). The five most commonly observed families (present in the greatest percentage of deployments) included: Carangidae (53.3%), Nemipteridae (51.7%), Scombridae (51.7%), Mullidae (41.7%), and Labridae (36.7%). The most speciose family was Labridae (wrasses) with 16 species, followed by Serranidae (groupers, 11 species) and Carangidae (10 species). A summary of the contribution of the most numerically abundant families to the overall assemblage is shown in Figure 7-6.

During FGPDSY2, the lengths of 1587 individual fish were measured from 110 species and 33 families from the 60 deployments. The smallest individual measured overall was a 23.1 mm Neon Damselfish (*Pomacentrus coelestis*) and the largest was a 2.83 m Great Hammerhead (*Sphyrna mokarran*). The median fish length was 190.3 mm and the mean length of the fish measured was 272.0 ± 5.9 mm.

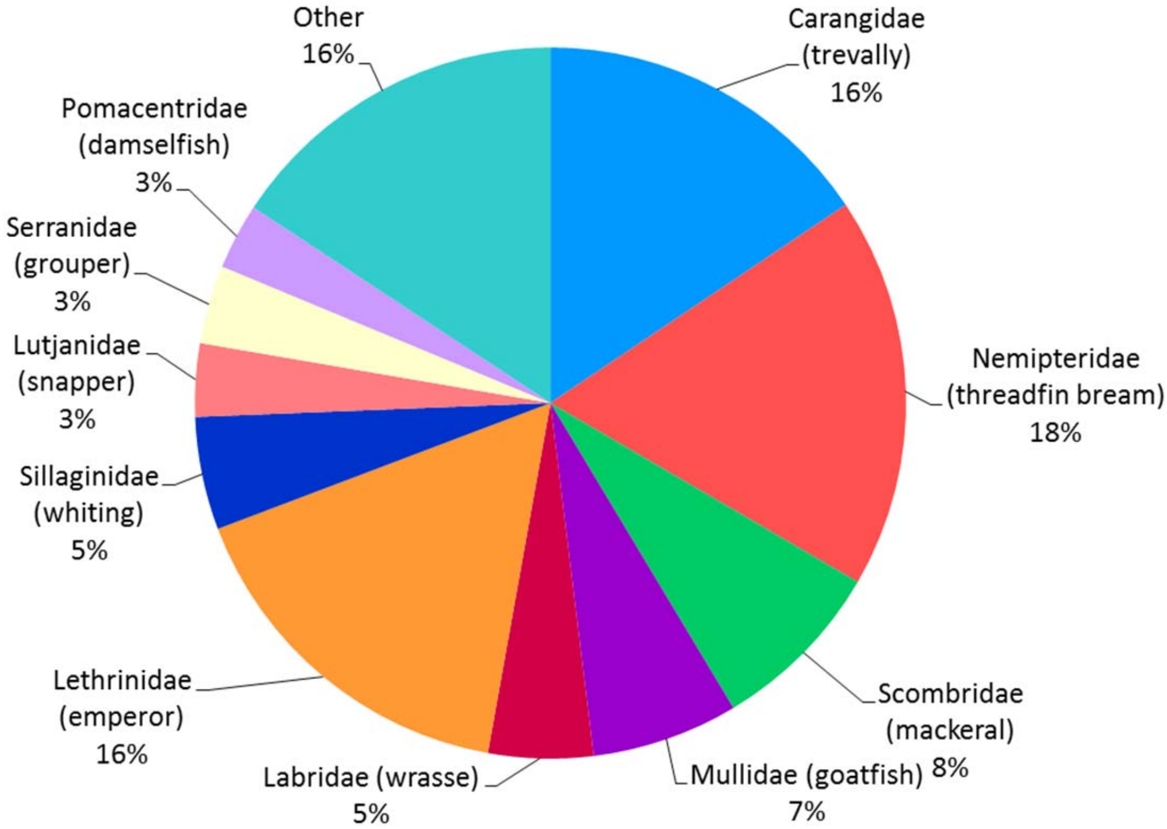


Figure 7-6 Contribution of the 10 Most Abundant Families to the Total Number of Fish Observed on Stereo-BRUVs Deployments Conducted West of Barrow Island During FGPDSY2

Table 7-3 Twenty Most Common Fish Species (viewed on the greatest number of stereo-BRUVs) Surveyed to the West of Barrow Island during FGPDSY2. Ordered from Most (1) to Least (20) Common

Species	Common name	Rank	% of deployments	Total #	Mean MaxN per deployment (± SE)	Mean length (± SE)
Scombridae spp.	Mackerel species	1	50.0	79	1.32 ± 0.38	836.31 ± 29.97
Pentapodus porosus	Northwest Threadfin Bream	2	33.3	244	4.07 ± 1.01	156.57 ± 1.86
Echeneis naucrates	Sharksucker	3	31.7	28	0.47 ± 0.12	551.83 ± 37.56
Abalistes stellatus	Starry Triggerfish	4	28.3	42	0.70 ± 0.20	286.82 ± 8.52
Sillago spp.	Whiting species	5	26.7	111	1.85 ± 0.50	117.48 ± 7.90
Upeneus tragula	Bartail Goatfish	6	26.7	92	1.53 ± 0.58	104.99 ± 5.41
Lagocephalus sceleratus	Silver Toadfish	7	26.7	27	0.45 ± 0.51	579.39 ± 14.42
Nemipterus spp.	Threadfin bream species	8	25.0	96	1.60 ± 0.48	198.74 ± 4.58
Gnathanodon speciosus	Golden Trevally	9	21.7	62	1.03 ± 0.37	666.43 ± 18.35
Scolopsis monogramma	Rainbow Monocle Bream	10	21.7	18	0.30 ± 0.37	209.34 ± 13.76
Atule mate	Yellowtail Scad	11	20.0	135	2.25 ± 0.95	193.33 ± 4.96
Choerodon cyanodus	Blue Tuskfish	12	18.3	22	0.37 ± 0.41	281.72 ± 0.73
Pentapodus emeryii	Purple Threadfin Bream	13	18.3	25	0.42 ± 0.45	216.39 ± 7.37
Synodontidae spp.	Lizardfish species	14	18.3	11	0.18 ± 0.25	186.57 ± 10.91
Epinephelus bilobatus	Frostback Rockcod	15	16.7	18	0.30 ± 0.35	223.78 ± 14.37
Feroxodon multistriatus	Ferocious Puffer	16	16.7	11	0.18 ± 0.24	461.96 ± 23.45
Lethrinus punctulatus	Australian Emperor	17	16.7	163	2.72 ± 1.06	198.56 ± 2.71
Carangoides fulvoguttatus	Yellowspotted Trevally	18	15.0	37	1.73 ± 0.94	632.47 ± 15.96
Lethrinus genivattatus	Longspine Emperor	19	15.0	104	0.62 ± 0.31	158.17 ± 2.57
*Parupeneus barberinoides**[1]	Bicolour Goatfish	20	15.0	36	0.60 ± 0.23	148.72 ± 5.97

Note:

An additional species, Scarus ghobban *(Bluebarred Parrotfish), was also observed in 15% of deployments, but had a lower total number of individuals so is not included in the top 20*

A summary of total relative abundance and species richness information for each of the four dominant habitats surveyed is shown in Table 7-4. Although the overall highest species richness was observed in sand habitat, the low mean total number of individuals and mean number of species per deployment indicates that the presence of certain species across deployments in sand habitat is highly varied. Rock armour habitat had high species richness, mean total number of individuals, and mean number of species per deployment despite the small sample size. Sessile invertebrate habitat displayed lower species richness, but a high mean total number of individuals and species per deployment. The lowest species richness was observed in macroalgae habitat, but the mean total number of individuals and species per deployment was higher than that of sand. The low total number of species reflects the low number of samples in macroalgae. The largest total numbers of individuals were observed in sessile invertebrate and sand habitats due to the schooling nature of species such as *Selaroides leptolepis* and *Atule mate*.

Table 7-4 Summary of Total Relative Abundance and Species Richness Information for the Four Habitats Surveyed West of Barrow Island during FGPDSY2

	Macroalgae	Rock Armour	Sand	Sessile Invertebrates
# of deployments	5	5	40	10
Total # individuals	146	371	769	876
Total # species	45	57	63	51
Total # families	22	24	26	21
Mean total # individuals (± SE) per deployment	29.20 ± 8.49	74.20 ± 13.44	19.23 ± 3.60	87.6 ± 17.35
Mean # species (± SE) per deployment	13.80 ± 4.55	23.40 ± 3.87	5.15 ± 0.64	15.30 ± 2.38

Note: The number of deployments conducted in each habitat influenced the numbers of individuals and species observed.

7.4.1.1 Fish Recorded within Macroalgae Habitat

In macroalgae habitat, a total of 146 individuals from 45 species and 22 families were recorded from the five stereo-BRUVs deployments. The total number of species observed on a single stereo-BRUVs deployment varied greatly, from four (HDDN1-5) to 25 (HDDN1-1), with an average of 13.8 ± 4.6 species per deployment. The total number of individual fish observed on a single stereo-BRUVs deployment ranged from 11 (HDDN1-5) to 54 (HDDN1-1), with an average of 29.2 ± 8.5 individuals per deployment. The ten most commonly sighted and abundant species and families in macroalgae habitat are listed in Table 7-5 and Table 7-6.

Macroalgae habitat was characterised by a relatively high commonality (observed in 60% of macroalgae deployments) of species such as *Acanthurus grammoptilus*, *Carangoides fulvoguttatus*, *Choerodon cyanodus*, *Lutjanus lemniscatus*, *Pentapodus emeryii*, Plectropomus spp., *Scarus ghobban*, and *Scolopsis monogramma*. Although commonly sighted across the macroalgae habitat deployments, the numerical abundances of these species were quite low.

The lengths of 107 fish individuals from 39 species and 18 families were measured from the five stereo-BRUVs deployments in macroalgae habitat. The smallest fish observed was a 33.4 mm *P. coelestis* and the largest was a 2.83 m *S. mokarran*. The median length of the fish measured was 246.3 mm and the mean length was 263.8 ± 29.6 mm.

7.4.1.2 Fish Recorded within Rock Armour Habitat

In rock armour habitat, a total of 371 individuals from 57 species and 24 families were recorded from the five stereo-BRUVs deployments. The total number of species observed on a single stereo-BRUVs deployment ranged from nine (FGI1-7) to 31 (FGI1-2), with an average of 23.40 ± 3.87 species per deployment. The total number of individual fish observed on a single stereo-BRUVs deployment ranged from 47 (FGI1-7) to 105 (FGI1-1), with an average of 74.2 ± 13.4 individuals per deployment. The ten most commonly sighted and abundant species and families in rock armour habitat are listed in Table 7-5 and Table 7-6. *Abalistes stellatus* (starry triggerfish) was the most numerically abundant species in this habitat and also the most commonly sighted, being present in 100% of deployments.

Macroalgae habitat was characterised by a relatively high commonality (observed in 60% of macroalgae deployments) of species such as *Acanthurus grammoptilus*, *Carangoides fulvoguttatus*, *Choerodon cyanodus*, *Lutjanus lemniscatus*, *Pentapodus emeryii*, Plectropomus spp., *Scarus ghobban*, and *Scolopsis monogramma*. Although commonly sighted across the macroalgae habitat deployments, the numerical abundances of these species were quite low.

The lengths of 289 fish individuals from 55 species and 22 families were measured from the five stereo-BRUVs deployments in rock armour habitat. The smallest fish observed was a 23.1 mm *P. coelestis* and the largest was a 1.34 m Scombridae spp. The median length of the fish measured was 246.18 mm and the mean length was 347.7 ± 15.3 mm.

7.4.1.3 Fish Recorded within Bare Sand Habitat

In sand habitat, a total of 769 individuals from 63 species and 26 families were recorded from the 40 stereo-BRUVs deployments. The total number of species observed on a single stereo-BRUVs deployment ranged from one (HDD1-5, HDD3N-1, and HDDN3-2) to 22 (FGI4-2), and the average of 5.2 ± 0.64 species per deployment was much lower than the other three habitats.

The total number of fish observed in a single stereo-BRUVs deployment in this habitat ranged from very low values (one each on HDDN3-1 and HDDN3-2) to much higher values (101 on FGI2-1), with an average of 19.2 ± 3.6 individuals per deployment. Although a number of species observed in this habitat were quite numerically abundant (e.g. *P. porosus*), most species appear to have been patchily distributed, with the highest commonality value at only 45%. This suggests the appearance of species in sand habitats is highly varied. The ten most commonly sighted and abundant species and families in sand habitat are listed in Table 7-5 and Table 7-6.

The lengths of 588 fish individuals from 55 species and 25 families were measured from the 40 stereo-BRUVs deployments in sand habitat. The smallest fish observed was a 24.7 mm *P. coelestis* and the largest was a 2.29 m *Rhynchobatus Australiae* (White-spotted Guitarfish). The median length of the fish measured was 214.2 mm and the mean length was 325.1 ± 11.0 mm.

7.4.1.4 Fish Recorded within Sessile Invertebrates Habitat

In sessile invertebrates habitat, 876 individual fish from 51 species and 21 families were observed in the ten stereo-BRUVs deployments. The total number of species observed on a single stereo-BRUVs deployment ranged from six (FGFR3-1) to 25 (FGFR1-2), and the average was the second highest of all habitats at 15.3 ± 2.4 species per deployment. The total number of fish observed in a single stereo-BRUVs deployment in this habitat ranged from 23 on FGFR3-1 to the very high value of 182 on FGFR3-1, with the highest average across all habitat types of 87.6 ± 17.4 individuals per deployment.

P. porosus was the most numerically abundant and commonly sighted species, present in 90% of deployments in this habitat. Other species that were commonly observed in this habitat included emperor species, such as *Lethrinus variegatus* (Slender Emperor) and *L. genivittatus*. The ten most commonly sighted and abundant species and families in sand habitat are listed in Table 7-5 and Table 7-6.

The lengths of 603 fish individuals from 51 species and 22 families were measured from the ten stereo-BRUVs deployments in sessile invertebrates habitat. The smallest fish observed was a 42 mm *Upeneus tragula* (Bartail Goatfish) and the largest was a 1.49 m *Carcharhinus plumbeus* (Sandbar Shark). The median length of the fish measured was 162.0 mm and the mean length was 185.5 ± 4.9 mm.

Table 7-5 Ten Most Abundant (largest combined relative abundance) and Common (observed on the greatest number of deployments) Fish Species Observed in Each Habitat During FGPDSY2, Ordered by Most Abundant/Common to Least

	Macroalgae		Rock Armour		Sand		Sessile Invertebrates	
10 most abundant species (Total #)	*Pomacentrus coelestis*	15	*Abalistes stellatus*	25	*Pentapodus porosus*	110	*Pentapodus porosus*	134
	Scarus ghobban	13	*Siganus fuscescens*	25	*Sarda orientalis*	94	*Lethrinus punctulatus*	129
	Acanthurus grammoptilus	12	Scombridae spp.	23	*Nemipterus* spp.	87	*Atule mate*	112
	Sillago spp.	11	*Epinephelus multinotatus*	21	*Sillago* spp.	83	*Lethrinus genivittatus*	102
	Parupeneus indicus	7	*Lutjanus sebae*	20	Scombridae spp.	43	*Selaroides leptolepis*	63
	Atule mate	6	*Gnathanodon speciosus*	18	*Gnathanodon speciosus*	38	*Lethrinus variegatus*	57
	Choerodon cyanodus	5	*Pomacentrus limosus*	18	*Upeneus tragula*	35	*Upeneus tragula*	57
	Pentapodus emeryii	5	*Lethrinus nebulosus*	17	*Carangoides fulvoguttatus*	28	*Parupeneus barberinoides*	33
	Plectropomus spp.	5	*Lethrinus punctulatus*	17	*Lagocephalus sceleratus*	25	*Lutjanus vitta*	32
	Carangoides fulvoguttatus[*4]	4	*Acanthurus mata*	16	*Echeneis naucrates*	21	*Sillago* spp.	17
10 most common species (% of deployments)	*Acanthurus grammoptilus*	60	*Abalistes stellatus*	100	Scombridae spp.	45	*Pentapodus porosus*	90
	Carangoides fulvoguttatus	60	*Choerodon cauteroma*	80	*Echeneis naucrates*	35	*Lethrinus variegatus*	80
	Choerodon cyanodus	60	*Choerodon cyanodus*	80	*Sillago* spp.	35	*Upeneus tragula*	80
	Lutjanus lemniscatus	60	*Epinephelus bilobatus*	80	*Lagocephalus sceleratus*	32.5	*Abalistes stellatus*	70
	Pentapodus emeryii	60	*Epinephelus multinotatus*	80	*Pentapodus porosus*	27.5	*Atule mate*	70
	Plectropomus spp.	60	*Heniochus acuminatus*	80	*Synodontidae* spp.	27.5	*Lethrinus genivittatus*	70
	Scarus ghobban	60	*Pentapodus emeryii*	80	*Nemipterus* spp.	25	*Parupeneus barberinoides*	70
	Scolopsis monogramma	60	*Scarus ghobban*	80	*Upeneus tragula*	20	Scombridae spp.	70
	Choerodon cauteroma	40	*Acanthurus grammoptilus*	60	*Gnathanodon speciosus*	17.5	*Lethrinus punctulatus*	60
	Choerodon schoenleinii[*6]	40	*Caranx papuensis*[*8]	60	*Iniistius* spp.	17.5	*Scolopsis monogramma*	60

Note: ** indicates the additional number of species present with the same relative abundance, or at the same number of sites, that are not presented in the top ten listed here (ordered alphabetically)*

Table 7-6 Ten Most Abundant (largest combined relative abundance) and Common (observed on the greatest number of deployments) Families of Fish Observed in each Habitat During FGPDSY2, Ordered by Most Abundant/Common to Least

	Macroalgae		Rock Armour		Sand		Sessile Invertebrates	
10 most abundant families (Total #)	Labridae	22	Serranidae	48	Nemipteridae	204	Lethrinidae	295
	Pomacentridae	20	Lethrinidae	37	Scombridae	137	Carangidae	183
	Acanthuridae	14	Carangidae	32	Carangidae	109	Nemipteridae	152
	Carangidae	13	Labridae	32	Sillaginidae	83	Mullidae	92
	Scaridae	13	Pomacentridae	26	Mullidae	41	Lutjanidae	38
	Nemipteridae	12	Lutjanidae	26	Labridae	37	Sillaginidae	17
	Sillaginidae	11	Balistidae	25	Tetraodontidae	33	Serranidae	16
	Serranidae	7	Siganidae	25	Lethrinidae	22	Caesionidae	15
	Lutjanidae	7	Scombridae	23	Echeneidae	21	Labridae	12
	Mullidae	7	Acanthuridae	20	Pomacentridae	19	Scombridae*1	10
10 most common families (% of deployments)	Carangidae	80	Lethrinidae	100	Scombridae	47.5	Lethrinidae	90
	Nemipteridae	80	Carangidae	100	Tetraodontidae	45	Nemipteridae	90
	Lutjanidae	80	Balistidae	100	Carangidae	37.5	Mullidae	90
	Labridae	60	Nemipteridae	100	Sillaginidae	35	Carangidae	80
	Acanthuridae	60	Serranidae	80	Echeneidae	35	Scombridae	70
	Scaridae	60	Labridae	80	Nemipteridae	32.5	Balistidae	70
	Serranidae	60	Lutjanidae	80	Mullidae	27.5	Lutjanidae	50
	Pomacentridae	40	Scaridae	80	Synodontidae	27.5	Labridae	50
	Mullidae	40	Chaetodontidae	80	Labridae	25	Serranidae	40
	Pomacanthidae*1	40	Pomacentridae*5	60	Lethrinidae	15	Siganidae*2	30

*Note: * indicates the additional number of families present with the same relative abundance, or at the same number of sites, that are not presented in the top ten listed here (ordered alphabetically).*

7.4.2 Description of Demersal Fish Assemblages Characteristic of Soft Sediments with Sessile Benthic Macroinvertebrates, Macroalgae, and Sand Communities in the MDF (Area at Risk of Material or Serious Environmental Harm due to the OFGPS)

At MDF Sites during FGPDSY2, a total of 886 individuals from 85 species and 27 families were recorded from the 20 stereo-BRUVs deployments. An average of 11.2 ± 2.2 species was observed on each deployment. The greatest species richness recorded on a single deployment was 31 species on deployment FGI1-2, while the least was one species on HDD1-5. The two most commonly observed species at the MDF Sites were Scombridae spp., which was observed on 65% of deployments, and Nemipterus spp., observed on 55% of deployments.

The five most abundant families observed at MDF Sites were Nemipteridae (n=216), Scombridae (n=150), Carangidae (n=102), Labridae (n=61), and Lethrinidae (n=58). These were also the most common observed families and were observed at 80%, 70%, 65%, 50%, and 50% of deployments at MDF Sites respectively. The most speciose families were Labridae (10 species) and Serranidae (10 species), followed closely by Carangidae (eight species).

At MDF Sites during FGPDSY2, the lengths of 697 individuals were measured from 76 species and 26 families from the 20 stereo-BRUVs deployments. The smallest individuals measured were a 23.1 mm and a 24.7 mm *P. coelestis* in rock armour and sand habitats respectively. The largest individuals measured were a 2.28 m *R. australiae* in sand habitat and a 1.34 m Scombridae spp. in rock armour habitat. The median fish length was 233.7 ± 9.3 mm and the mean fish length was 326.8 ± 9.3 mm.

Although the greatest numerical abundance of fish was in sand, the total number of species, the mean number of species, and the mean total number of individuals counted per deployment at MDF Sites was greatest in rock armour habitat (Table 7-7).

Table 7-7 Summary of the Relative Abundance, Species Richness and Length Information for each Habitat Type Sampled at MDF Sites during FGPDSY2

	Rock Armour	Sand
# of deployments	5	15
Total # individuals	371	515
Total # species	57	51
Total # families	24	19
Mean total # individuals (± SE) per deployment	74.2 ± 13.44	34.33 ± 7.98
Mean # species (± SE) per deployment	23.40 ± 3.87	7.07 ± 1.46
Total # lengths measured	289	408
Length range (mm)	23.06–1336.48	24.68–2282.38
Median length (mm)	246.18	213.04
Mean length (mm ± SE)	347.72 ± 15.28	232.63 ± 11.52
10 most abundant species (Total #)	*Abalistes stellatus* 25	*Pentapodus porosus* 105
	Siganus fuscescens 25	*Sarda orientalis* 93
	Scombridae spp. 23	*Nemipterus* spp. 87
	Epinephelus multinotatus 21	Scombridae spp. 34
	Lutjanus sebae 20	*Carangoides fulvoguttatus* 28
	Gnathanodon speciosus 18	*Carangoides gymnostethus* 19
	Pomacentrus limosus 18	*Lethrinus punctulatus* 17

	Rock Armour	Sand
	Lethrinus nebulosus 17	*Pomacentrus coelestis* 16
	Lethrinus punctulatus 17	*Gnathanodon speciosus* 15
	Acanthurus mata 16	*Thalassoma amblycephalum* 12
10 most common species (% of deployments)	*Abalistes stellatus* 100	*Nemipterus* spp. 66.67
	Epinephelus multinotatus 80	Scombridae spp. 66.67
	Pentapodus emeryii 80	*Pentapodus porosus* 60
	Scarus ghobban 80	*Carangoides fulvoguttatus* 26.67
	Choerodon cyanodus 80	*Iniistius* spp. 26.67
	Epinephelus bilobatus 80	*Abalistes stellatus* 26.67
	Choerodon cauteroma 80	*Echeneis naucrates* 26.67
	Heniochus acuminatus 80	*Carangoides gymnostethus* 20
	Scombridae spp. 60	*Gnathanodon speciosus* 20
	*Lutjanus sebae**8 60	*Lagocephalus sceleratus* 20

*Note: * indicates the additional number of species present with the same relative abundance, or at the same number of sites, that are not presented in the top ten listed here (ordered alphabetically)*

7.4.3 Description of Demersal Fish Assemblages Characteristic of Soft Sediments with Sessile Benthic Macroinvertebrates, Macroalgae, and Sand Communities not at Risk of Material or Serious Environmental Harm due to the OFGPS

At Reference Sites during FGPDSY2, a total of 1276 individuals from 93 species and 40 families were recorded from the 40 stereo-BRUVs deployments. An average of 43.2 ± 6.8 SE individuals and 8.1 ± 1.2 species were recorded for each deployment. The greatest species richness recorded on a single deployment was 25 each on deployment FGFR1-2 and HDDN1-1, while the least was one species on HDDN3-1 and HDDN3-2. The most commonly sighted species observed at Reference Sites was Scombridae spp. (present on 42.5% of deployments), followed by *Sillago* spp. and *U. tragula*, which were both recorded on 37.5% of deployments at Reference Sites.

The five most numerically abundant families at Reference Sites were Lethrinidae (n=297), Carangidae (n=235), Nemipteridae (n=169), Mullidae (n=131), and Sillaginidae (n=110), while the most commonly observed families (% of deployments) were Carangidae (50%), Mullidae (47.5%), Scombridae (45%), Tetraodontidae (42.5%), and Nemipteridae (40%). Family Sillaginidae was also observed at 40% of Reference Site deployments, but was not as numerically abundant as Nemipteridae. The most speciose family was Labridae (12 species), followed by Carangidae (nine species), and Serranidae (eight species).

At Reference Sites during FGPDSY2, the lengths of 890 fish were measured from 88 species and 31 families from the 40 deployments. The mean fish length was 229.1 ± 7.3 mm and the median fish length was 165.19 mm. The smallest fish measured at Reference Site deployments were a 33.4 mm *P. coelestis* in macroalgae, a 35.7 mm *U. tragula* in sand, and a 41.8 mm *U. tragula* in sessile invertebrates. The largest fish measured at a Reference Site was a 2.83 m *S. mokarran* in macroalgae habitat, while the largest fish measured in sand and sessile invertebrate habitats were a 2.29 m *R. australiae* and a 1.49 m *C. plumbeus* respectively.

Further information and descriptive statistics on the length of fish in each habitat sampled at Reference Sites is available in Table 7-8.

Table 7-8 Summary of the Relative Abundance, Species Richness, and Length Information for each Habitat Type Sampled at Reference Sites during FGPDSY2

	Macroalgae	Sand	Sessile Invertebrates
# of deployments	5	25	10
Total # individuals	146	254	876
Total # species	45	27	51
Total # families	22	19	21
Mean total # individuals (± SE) per deployment	29.2 ± 8.49	10.16 ± 1.48	87.6 ± 17.35
Mean # species (± SE) per deployment	13.8 ± 4.55	5 ± 0.41	15.30 ± 2.38
Total # lengths measured	107	180	603
Length range (mm)	33.35–2825.64	35.70–2293.30	41.82–1491.82
Median length (mm)	246.28	214.78	162.01
Mean length (mm ± SE)	263.82 ± 29.64	354.76 ± 24.57	185.46 ± 4.87
10 most abundant species (Total #)	*Pomacentrus coelestis* 15	*Sillago* spp. 82	*Pentapodus porosus* 134
	Scarus ghobban 13	*Upeneus tragula* 32	*Lethrinus punctulatus* 129
	Acanthurus grammoptilus 12	*Gnathanodon speciosus* 23	*Atule mate* 112
	Sillago spp. 11	*Lagocephalus sceleratus* 22	*Lethrinus genivittatus* 102
	Parupeneus indicus 7	*Echeneis naucrates* 17	*Selaroides leptolepis* 63
	Atule mate 6	*Atule mate* 14	*Upeneus tragula* 57
	Choerodon cyanodus 5	*Synodontidae* spp. 11	*Lethrinus variegatus* 57
	Pentapodus emeryii 5	Scombridae spp. 9	*Parupeneus barberinoides* 33
	Plectropomus spp. 5	*Pleuronectiformes* spp. 7	*Lutjanus vitta* 32
	Scolopsis monogramma 4	*Iniistius* spp. 6	*Sillago* spp. 17
10 most common species (% of deployments)	*Scarus ghobban* 60	*Sillago* spp. 56	*Pentapodus porosus* 100
	Acanthurus grammoptilus 60	*Synodontidae* spp. 48	*Upeneus tragula* 90
	Choerodon cyanodus 60	*Lagocephalus sceleratus* 44	*Lethrinus variegatus* 90
	Pentapodus emeryii 60	*Echeneis naucrates* 44	*Atule mate* 80
	Plectropomus spp. 60	Scombridae spp. 36	*Lethrinus genivittatus* 80
	Scolopsis monogramma 60	*Upeneus tragula* 32	*Parupeneus barberinoides* 80
	Carangoides fulvoguttatus 60	*Pleuronectiformes* spp. 24	Scombridae spp. 80
	Lutjanus lemniscatus 60	*Gnathanodon speciosus* 20	*Abalistes stellatus*. 80
	Parupeneus indicus 40	*Feroxodon multistriatus* 20	*Lethrinus punctulatus*. 70
	Labroides dimidiatus[*6] 40	*Rhynchobatus australiae* 20	*Scolopsis monogramma*. 70

*Note: * indicates the additional number of species present with the same relative abundance, or at the same number of sites, that are not presented in the top ten listed here (ordered alphabetically)*

7.5 Comparison between the Post-Development Survey and the Marine Baseline Environmental State

7.5.1 Visibility

The horizontal visibility during FGPDSY2 ranged from a mean of 4.0 ± 0.2 m at Site FGFR2 to 6.1 ± 0.8 m at Site FGI4, with an overall mean visibility of 5.0 ± 0.1 m (see Appendix 2 for the full list). During FGPDSY1, the horizontal visibility ranged from a mean of 4.0 ± 0.0 m at Site FGFR2 to 8.2 ± 0.2 m at Site FGI2, with an overall mean visibility of 6.4 ± 0.2 m. During the Baseline, the horizontal visibility ranged from a mean of 2.6 ± 0.1 m at Site FGI4 to 5.8 ± 0.5 m at Site HDD1, with an overall mean visibility of 3.9 ± 0.1 m.

A univariate PERMANOVA test comparing visibility data between the Baseline, FGPDSY1, and FGPDSY2 found a significant term of interest in the interaction of 'Survey × IvR × Habitat' (Table 7-9). During FGPDSY1 and FGPDSY2, visibility was significantly greater at sand/sessile invertebrates MDF Sites than during the Baseline (Table 7-10; Figure 7-7). Also, at sand/sessile invertebrates sites the visibility was significantly greater at MDF Sites than at Reference Sites during both FGPDSY1 and FGPDSY2 (Table 7-10; Figure 7-7). These changes in visibility are likely to confound the interpretation of results unless they are accounted for during analysis. Therefore, statistical analyses of relative abundance, total number of individuals, species richness, and dominant species (see Sections 7.5.2, 7.5.3, 7.5.4, and 7.5.6) were carried out taking changes in visibility into account following the procedure described in Section 7.3.5.

DISTLM on all data (Baseline, FGPDSY1, and FGPDSY2 combined) found that visibility explained 6% of the variation in the multivariate fish assemblage. This relationship was statistically significant (R^2 = 0.06; Pseudo-F = 12.13; P(perm) <0.001). A DISTLM found a significant relationship between horizontal visibility and species richness (R^2 = 0.16; Pseudo-F = 37.71; P(perm) <0.001; Figure 7-8A). A similar, although slightly weaker relationship was found between visibility and total number of individuals (R^2 = 0.14; Pseudo-F = 33.56; P(perm) <0.001; Figure 7-8B).

Table 7-9 Results of Five-Factor PERMANOVA Test for Changes in Visibility

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Survey	2	96.98	48.49	10.06	0.006	9971
IvR	1	10.50	10.50	1.13	0.453	9967
Habitat	1	0.14	0.14	0.02	0.871	9791
Year(Survey)	1	1.61	1.61	0.70	0.508	4705
Survey × IvR	*2*	*2.10*	*1.05*	*0.49*	*0.770*	*9959*
Survey × Habitat	2	21.26	10.63	3.46	0.057	9941
IvR × Habitat	1	0.10	0.10	0.02	0.898	9816
Site(Habitat × IvR)	8	57.06	7.13	2.72	0.245	9969
IvR × Year(Survey)	1	3.95	3.95	1.71	0.325	4798
Habitat × Year(Survey)**	0	0.00		No test		
Survey × IvR × Habitat	***2***	***57.83***	***28.91***	***9.42***	***0.005***	***9945***
Survey × Site(Habitat × IvR)	16	49.21	3.08	1.19	0.515	9976
IvR × Habitat × Year(Survey)**	0	0.00		No test		
Year(Survey) × Site(Habitat × IvR)**	3	7.13	2.38	4.19	0.009	9958
Residual	159	90.20	0.57			
Total	199	545.96				

Notes:

*** Term has one or more empty cells.*

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-10 Results of Pairwise Tests for Changes in Visibility for the Significant Term of Interest 'Survey × IvR × Habitat'. A) Tests for Pairs of Levels of the Factor 'Survey'. B) Tests for Pairs of Levels of the Factor 'IvR'

A) Term 'Survey × IvR × Habitat' for pairs of levels of factor 'Survey'				
Within level 'Reference' of factor 'IvR'				
Within level 'Sand/Sessile' of factor 'Habitat'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline, FGPDSY1	1.45	0.301	9968	0.319
Baseline, FGPDSY2	0.79	0.643	9964	0.685
FGPDSY1, FGPDSY2	1.46	0.215	2672	0.220
Within level 'Reference' of factor 'IvR'				
Within level 'Macroalgae' of factor 'Habitat'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline, FGPDSY1	3.10	0.116	38	0.089
Baseline, FGPDSY2	2.17	0.243	37	0.169
FGPDSY1, FGPDSY2	1.25	0.317	37	0.343
Within level 'MDF' of factor 'IvR'				
Within level 'Sand/Sessile' of factor 'Habitat'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline, FGPDSY1	**21.28**	**<0.001**	**3185**	**0.001**
Baseline, FGPDSY2	**6.51**	**0.009**	**3165**	**0.008**
FGPDSY1, FGPDSY2	**6.56**	**0.097**	**38**	**0.022**
Within level 'MDF' of factor 'IvR'				
Within level 'Macroalgae' of factor 'Habitat'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline, FGPDSY1	0.00	1	8	1.000
Baseline, FGPDSY2	1.98	0.127	8	0.089
FGPDSY1, FGPDSY2	**2.36**	**0.073**	**7**	**0.048**
B) Term 'Survey × IvR × Habitat' for pairs of levels of factor 'IvR'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline Sand/Sessile	1.54	0.209	9969	0.212
Baseline Macroalgae	1.96	0.505	2	0.187
FGPDSY1 Sand/Sessile	**2.74**	**0.052**	**24**	**0.031**
FGPDSY1 Macroalgae	0.30	1	3	0.793
FGPDSY2 Sand/Sessile	**2.88**	**0.039**	**17**	**0.031**
FGPDSY2 Macroalgae	0.19	1	3	0.863

Notes:

Bold text indicates a statistically significant term of interest at α=0.05

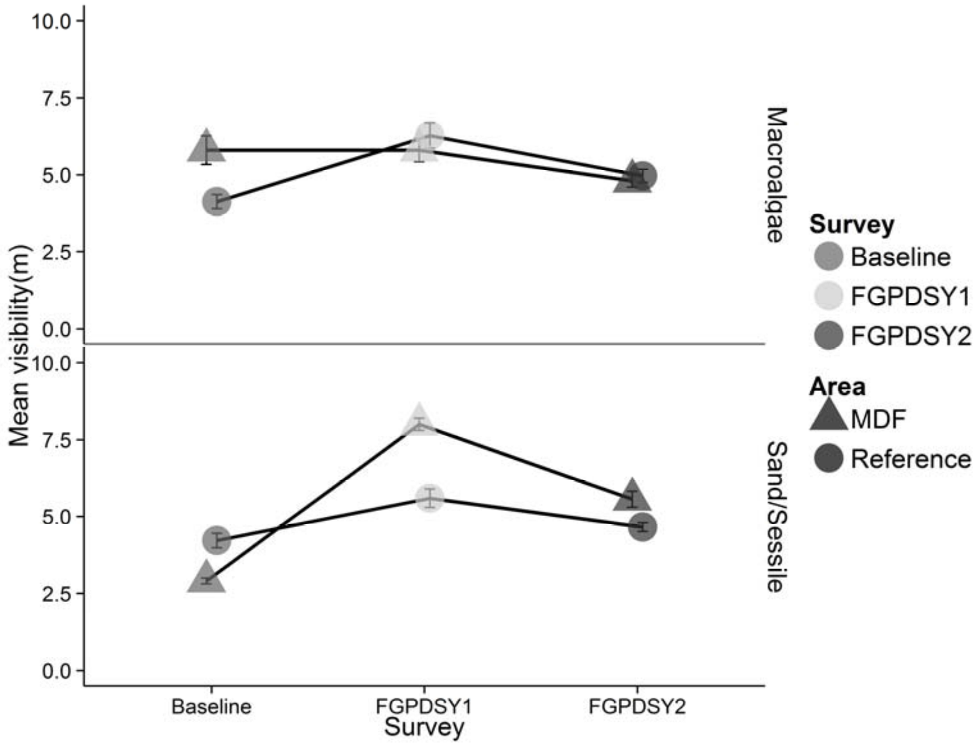


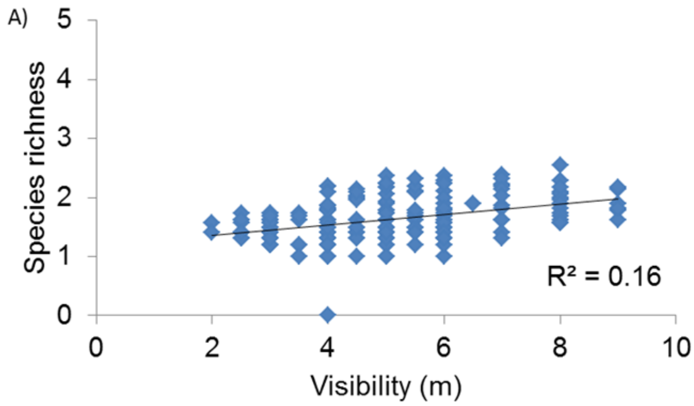
Figure 7-7 Mean Estimated Visibility (m) in Macroalgae and Sand/Sessile Invertebrate Habitats at MDF and Reference Sites during the Baseline, FGPDSY1, and FGPDSY2

Notes:

Error bars are to 1 SE.

Macroalgae: Baseline MDF n=5; Baseline Reference n=15; FGPDSY1, FGPDSY2 MDF n=5; FGPDSY1, FGPDSY2 Reference n=15.

Sand/Sessile: Baseline MDF n=22; Baseline Reference n=38; FGPDSY1, FGPDSY2 MDF n=15; FGPDSY1, FGPDSY2 Reference n=25.



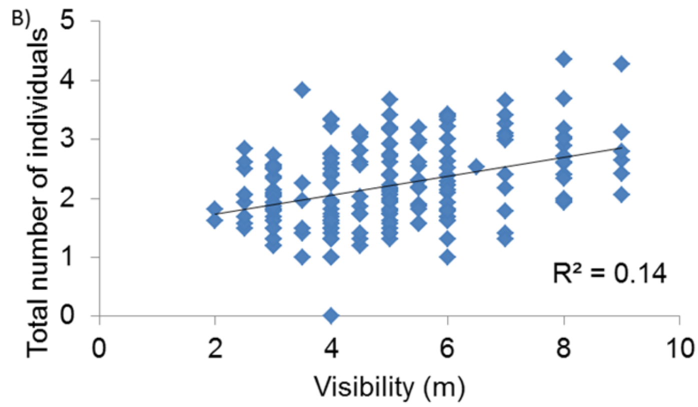


Figure 7-8 Linear Regression of Visibility (m) with Fourth-Root Transformed Species Richness (A) and Fourth-Root Transformed Total Number of Individuals (B) for Individual Stereo-BRUVs Deployments from the Baseline, FGPDSY1, and FGPDSY2

Note: R^2 from DISTLM

7.5.2 Relative Abundance

A statistically significant term of interest was detected for 'Survey × IvR' (Table 7-11). This test was not affected by the differences in visibility among levels of factors. Pairwise tests of 'Survey × IvR' were conducted (Table 7-12). The multivariate relative abundance data were found to change from the Baseline to FGPDSY1, and also from the Baseline to FGPDSY2 at Reference Sites, but not at MDF Sites (Table 7-12A). No statistically significant differences in the multivariate relative abundance data were detected between MDF and Reference Sites during any survey (Table 7-12B).

Table 7-11 Results of PERMANOVA Test with Visibility as a Covariate for Changes in the Multivariate Relative Abundance of the Fish Assemblage

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	41022.00	41022.00	9.28	<0.001	9910
Survey	2	27625.00	13813.00	3.07	<0.001	9917
IvR	1	14621.00	14621.00	1.01	0.413	9923
Habitat	1	17367.00	17367.00	1.27	0.269	9944
Survey × IvR	***2***	***14476.00***	***7238.00***	***1.68***	***0.045***	***9924***
Survey × Habitat	2	10851.00	5425.50	1.38	0.154	9928

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
IvR × Habitat	1	7601.00	7601.00	0.56	0.809	9917
Site(Habitat × IvR)	8	113040.00	14131.00	5.91	<0.001	9815
Survey × IvR × Habitat	*2*	*11951.00*	*5975.60*	*1.60*	*0.066*	*9909*
Survey × Site(Habitat × IvR)	16	62314.00	3894.60	1.63	<0.001	9736
Residual	163	390010.00	2392.70			
Total	199	710880.00				

Notes:

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-12 Results of Pairwise Tests for Changes in the Multivariate Relative Abundance of the Fish Assemblage for the Significant Term of Interest 'Survey × IvR'. A) Tests for Pairs of Levels of the Factor 'Survey'. B) Tests for Pairs of Levels of the Factor 'IvR'

A) Term 'Survey × IvR' for pairs of levels of factor 'Survey'			
Within level 'Reference' of factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	**1.57**	**0.020**	**9918**
Baseline, FGPDSY2	**1.88**	**0.017**	**9947**
FGPDSY1, FGPDSY2	1.39	0.128	9945
Within level 'MDF' of factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	1.38	0.184	8804
Baseline, FGPDSY2	1.29	0.250	8800
FGPDSY1, FGPDSY2	1.13	0.252	7883
B) Term 'Survey × IvR' for pairs of levels of factor 'IvR'			
'MDF' vs 'Reference'			
Groups	**t**	**P(perm)**	**Perms**
Baseline	0.69	0.832	9932
FGPDSY1	1.14	0.262	9939
FGPDSY2	1.46	0.053	9933

Note: Bold text indicates a statistically significant term of interest at α=0.05.

The statistically significant term of interest 'Survey × IvR' was investigated graphically using multivariate ordinations. The unconstrained PCO (Figure 7-9) illustrates much overlap between the different groups within 'Survey × IvR'. However, a grouping of Reference Sites from FGPDSY1 and FGPDSY2 can been seen in the lower left quadrant of the plot (Figure 7-9). A constrained CAP ordination (Figure 7-10) illustrates the significant term of interest 'Survey × IvR' more clearly. Baseline samples group to the right of the plot and MDF and Reference Site samples overlap (Figure 7-10). In contrast, FGPDSY1 and FGPDSY2 samples tend to be grouped to the left (Figure 7-10). Samples from both FGPDSY1 and FGPDSY2 show separation between MDF and Reference Site samples that is not observed in Baseline samples. FGPDSY1 and FGPDSY2 MDF Site samples are clustered more towards the upper left quadrant of the CAP plot, while Reference Site samples from FGPDSY1 and FGPDSY2 cluster more towards the bottom left quadrant (Figure

7-10). Post-hoc pairwise tests detected this significant change between the Baseline and Post-Development Surveys only at Reference Sites. The separation of MDF and Reference Sites during FGPDSY1 and FGPDSY2 may indicate an impact of construction of the OFGPS, so further investigation of individual species was conducted.

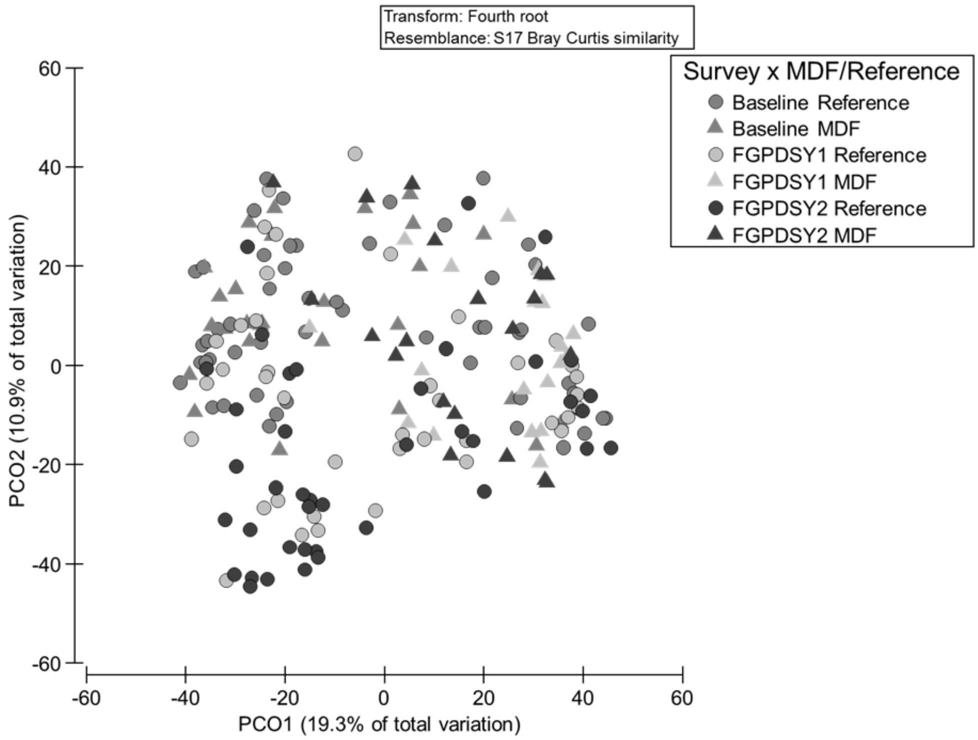


Figure 7-9 Principal Component Ordination Illustrating Patterns in the Relative Abundance of the Multivariate Fish Assemblage for the Interaction of 'Survey × IvR'

Note: MDF/Reference = IvR

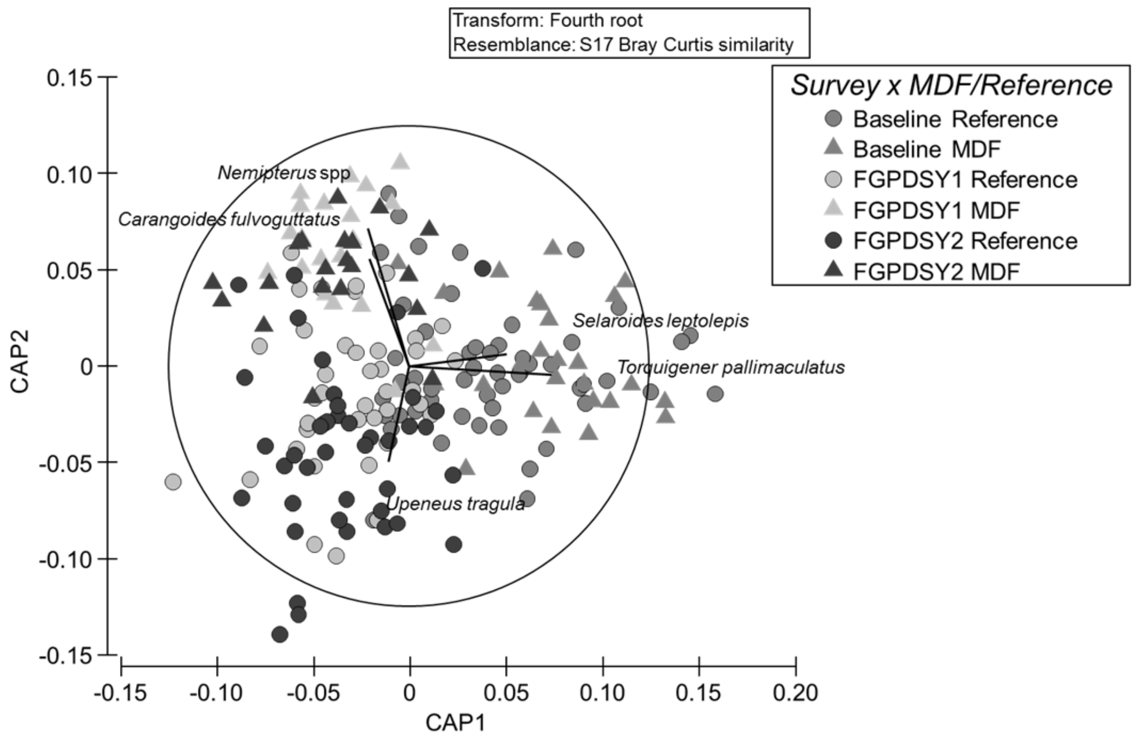


Figure 7-10 Canonical Analysis of Principal Coordinates (CAP; using Bray-Curtis similarity measure) Illustrating the Grouping of Deployments for the Interaction of 'Survey × IvR'

Notes:

MDF/Reference = IvR

Species with Spearman correlations of |r| ≥ 0.40 to either PCO axis are overlaid with vectors indicating the strength and direction of their association.

To further investigate which species may be contributing to the statistically significant results found in the multivariate fish assemblage, individual species were selected for further analyses. These species had a Spearman rank correlation to either CAP axis of |r|≥0.40 and were: *C. fulvoguttatus*, *Nemipterus* spp., *S. leptolepis*, *Torquigener pallimaculatus* (Rusty-spotted Toadfish), and *U. tragula*. The abundance of *S. leptolepis* and *T. pallimaculatus* was correlated in the direction of the Baseline MDF and Reference Site data. The abundance of *U. tragula* was correlated in the direction of FGPDSY1 and FGPDSY2 Reference Site data and the greatest abundance of *C. fulvoguttatus* and *Nemipterus* spp. was correlated in the direction of FGPDSY1 and FGPDSY2 MDF Site data. No significant change indicating an impact was detected for *S. leptolepis*, *T. pallimaculatus*, or *U. tragula* (Table 7-13, Table 7-14, Table 7-15).

Table 7-13 Results of Two-Factor PERMANOVA Test for Changes in Relative Abundance of *Selaroides leptolepis*

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Survey	2	1826.10	913.06	1.77	0.16	9941
IvR	1	581.97	581.97	1.13	0.32	9863
Survey × IvR	*2*	*1060.10*	*530.03*	*1.03*	*0.38*	*9957*
Residual	194	100090.00	515.92			
Total	199	103290.00				

Notes:
Italicised text indicates terms of interest.
No statistically significant term of interest was detected.

Table 7-14 Results of a PERMANOVA Test with Visibility as a Covariate for Changes in the Relative Abundance of *Torquigener pallimaculatus*

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	125.22	125.22	4.71	0.031	9821
Survey	2	411.70	205.85	7.74	<0.001	9949
IvR	1	22.79	22.79	0.86	0.375	9850
Survey × IvR	*2*	*28.24*	*14.12*	*0.53*	*0.601*	*9939*
Residual	193	5133.20	26.60			
Total	199	5721.20				

Notes:
Italicised text indicates terms of interest.
No statistically significant term of interest was detected.

Table 7-15 Results of Two-Factor PERMANOVA Test for Changes in Relative Abundance of *Upeneus tragula*

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Survey	2	25.05	12.53	1.33	0.270	9962
IvR	1	69.82	69.82	7.44	0.004	9841
Survey x× IvR	*2*	*21.30*	*10.65*	*1.13*	*0.328*	*9952*
Residual	194	1821.00	9.39			
Total	199	1952.10				

Notes:
Italicised text indicates terms of interest.
No statistically significant term of interest was detected.

The abundance of *C. fulvoguttatus* was found to change significantly with the term of interest 'Survey × IvR × Habitat' (Table 7-16). The abundance of *Nemipterus* spp. was found to change significantly with the term of interest 'Survey × IvR' (Table 7-17). At sand/sessile invertebrate habitat sites, a change indicative of an impact was detected for *C. fulvoguttatus*. *C. fulvoguttatus* was significantly more abundant at sand/sessile invertebrate MDF Sites than at sand/sessile invertebrate Reference Sites during FGPDSY1 (Table 7-18, Figure 7-11). This species was also significantly more abundant at MDF Sites during FGPDSY2 than at Reference Sites. This pattern is consistent with a positive impact of OFGPS construction on the abundance of this species in sand/sessile invertebrate habitat.

However, in macroalgal habitat, pairwise tests of the abundance of *C. fulvoguttatus* showed that significant changes in abundance of this species in macroalgal habitat were not likely to indicate an impact. For the term 'Survey × IvR × Habitat', a significant decrease from the Baseline to FGPDSY1 at macroalgal MDF Site HDD1 was detected (Table 7-18, Figure 7-11). However, during both FGPDSY1 and FGPDSY2, *C. fulvoguttatus* was found to be significantly more abundant at macroalgal MDF Site HDD1 than at macroalgal Reference Site HDDN1 (Table 7-18, Figure 7-11). These patterns are unlikely to represent an impact of OFGPS construction in macroalgal habitat for this species.

The abundance of *Nemipterus* spp. was found to change significantly with the term of interest 'Survey × IvR' (Table 7-17). However, pairwise tests on the abundance of *Nemipterus* spp. conducted for the significant term of interest 'Survey × IvR' detected no significant differences (Table 7-19). With visibility included as a covariate in the analysis, the apparent increase in abundance of this species at MDF Sites in all habitats (Figure 7-12) was not statistically significant (Table 7-19). The lack of a significant statistical test result is because these patterns of change closely follow the patterns of change in visibility when data collected from all habitat types are considered together (Figure 7-13). Therefore, the apparent pattern does not indicate a change in abundance of *Nemipterus* spp. across all habitat types.

Table 7-16 Results of a PERMANOVA Test with Visibility as a Covariate for Changes in the Relative Abundance of *Carangoides fulvoguttatus*

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	25.22	25.22	3.22	0.137	9956
Survey	2	4.51	2.25	0.41	0.828	9965
IvR	1	46.85	46.85	7.51	0.021	9968
Habitat	1	41.40	41.40	13.52	0.006	9918
Year(Survey)	1	9.57	9.57	3.39	0.075	9886
Survey × IvR	*2*	*8.06*	*4.03*	*1.90*	*0.319*	*9963*
Survey × Habitat	2	9.10	4.55	3.59	0.050	9961
IvR × Habitat	1	83.23	83.23	31.64	<0.001	9903
Site(Habitat × IvR)	8	19.92	2.49	0.69	0.709	9977
IvR × Year(Survey)	1	2.39	2.39	0.75	0.443	9878
Habitat × Year(Survey)**	0	0.00		No test		
Survey × IvR × Habitat	***2***	***16.14***	***8.07***	***5.58***	***0.016***	***9946***
Survey × Site(Habitat × IvR)	16	16.41	1.03	0.34	0.902	9981
IvR × Habitat × Year(Survey)**	0	0.00		No test		
Year(Survey) × Site(Habitat × IvR)**	3	11.38	3.79	1.09	0.333	9951
Residual	158	551.15	3.49			
Total	199	845.36				

Notes:

*** Term has one or more empty cells.*

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-17 Results of a PERMANOVA Test with Visibility as a Covariate for Changes in the Relative Abundance of *Nemipterus* spp.

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	126.24	126.24	14.62	<0.001	9837
Survey	2	22.37	11.19	1.08	0.352	9962
IvR	1	212.43	212.43	6.03	0.033	9882
Habitat	1	81.96	81.96	2.47	0.171	9863
Survey × IvR	***2***	***72.15***	***36.07***	***3.62***	***0.047***	***9954***
Survey × Habitat	2	5.81	2.90	0.33	0.732	9940

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
IvR × Habitat	1	85.16	85.16	2.59	0.161	9806
Site(Habitat × IvR)	8	273.82	34.23	10.40	<0.001	9942
Survey × IvR × Habitat	*2*	*22.65*	*11.32*	*1.37*	*0.280*	*9939*
Survey × Site(Habitat × IvR)	16	141.91	8.87	2.70	0.001	9927
Residual	163	536.39	3.29			
Total	199	1580.90				

Notes:

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

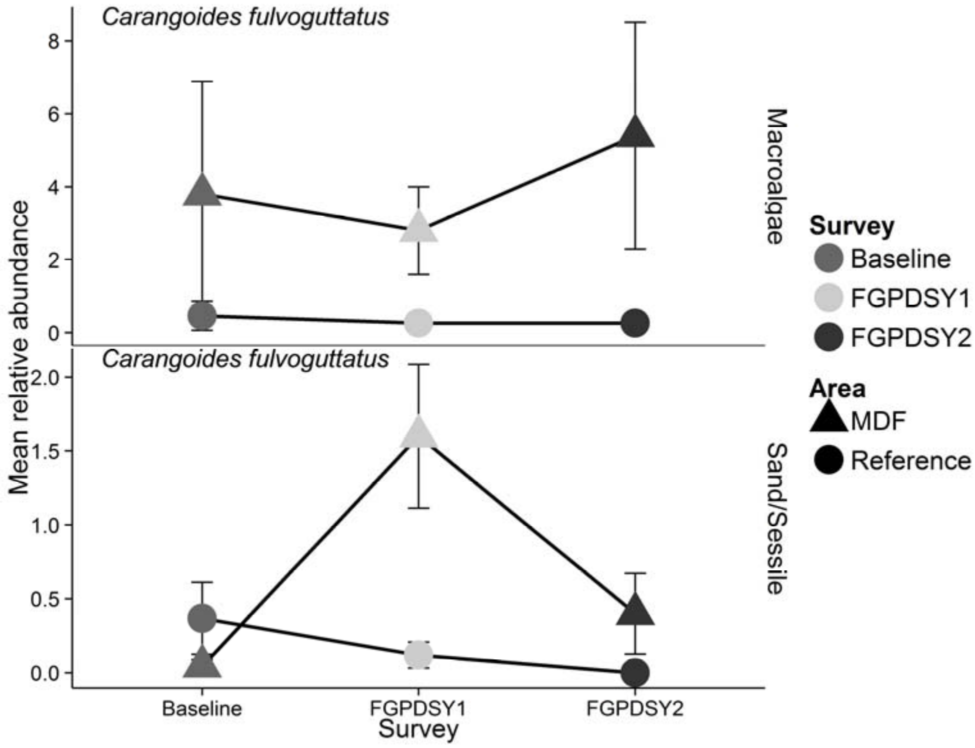


Figure 7-11 Patterns of Change in the Mean Relative Abundance per Deployment of *Carangoides fulvoguttatus* for the Interaction Term 'Survey × IvR × Habitat'

Notes:

Error bars to 1 SE.

Macroalgae: Baseline MDF n=5; Baseline Reference n=15; FGPDSY1, FGPDSY2 MDF n=5; FGPDSY1, FGPDSY2 Reference n=15.

Sand/Sessile: Baseline MDF n=22; Baseline Reference n=38; FGPDSY1, FGPDSY2 MDF n=15; FGPDSY1, FGPDSY2 Reference n=25.

Table 7-18 Results of Pairwise Tests for Changes in the Relative Abundance of *Carangoides fulvoguttatus*, for the Significant Term of Interest 'Survey × IvR × Habitat'. A) Tests for Pairs of Levels of the Factor 'Survey'. B) Tests for Pairs of Levels of the Factor 'IvR'

A) Term 'Survey × IvR × Habitat' for pairs of levels of factor 'Survey'			
Within level 'Reference' of factor 'IvR'			
Within level 'Sand/Sessile' of factor 'Habitat'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.79	0.641	9957
Baseline, FGPDSY2	0.77	0.694	9966
FGPDSY1, FGPDSY2	0.38	0.697	9788
Within level 'Reference' of factor 'IvR'			
Within level 'Macroalgae' of factor 'Habitat'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	2.2	0.086	359
Baseline, FGPDSY2	1.73	0.160	360
FGPDSY1, FGPDSY2	1.84	0.211	359
Within level 'MDF' of factor 'IvR'			
Within level 'Sand/Sessile' of factor 'Habitat'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	**2.33**	**0.042**	**5211**
Baseline, FGPDSY2	0.77	0.610	5157
FGPDSY1, FGPDSY2	2.79	0.104	359
Within level 'MDF' of factor 'IvR'			
Within level 'Macroalgae' of factor 'Habitat'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.30	0.811	8777
Baseline, FGPDSY2	1.33	0.228	9203
FGPDSY1, FGPDSY2	0.54	0.607	8675

B) Term 'Survey × IvR × Habitat' for pairs of levels of factor 'IvR'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline Sand/Sessile	1.07	0.427	9953	n/a
Baseline Macroalgae	0.21	0.788	24	0.849
FGPDSY1 Sand/Sessile	1.91	0.094	8738	n/a
FGPDSY1 Macroalgae	**4.31**	**0.124**	**24**	**0.049**
FGPDSY2 Sand/Sessile	**1.80**	**0.022**	**7203**	**n/a**
FGPDSY2 Macroalgae	**6.16**	**0.257**	**24**	**0.022**

Note: Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-19 Results of Pairwise Tests for Changes in the Relative Abundance of *Nemipterus* spp., for the Significant Term of Interest 'Survey × IvR'. A) Tests for Pairs of Levels of the Factor 'Survey'. B) Tests for Pairs of Levels of the Factor 'IvR'

A) Term 'Survey × IvR' for pairs of levels of factor 'Survey'			
Within level 'Reference' of factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.76	0.441	9807
Baseline, FGPDSY2	1.53	0.165	9856
FGPDSY1, FGPDSY2	0.90	0.383	9848
Within level 'MDF' of factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.47	0.713	8740
Baseline, FGPDSY2	0.78	0.503	8720
FGPDSY1, FGPDSY2	1.83	0.107	7734
B) Term 'Survey × IvR' for pairs of levels of factor 'IvR'			
MDF vs Reference			
Groups	**t**	**P(perm)**	**Perms**
Baseline	0.84	0.438	9858
FGPDSY1	1.93	0.104	9878
FGPDSY2	2.16	0.061	9873

Note: No statistically significant term of interest was detected.

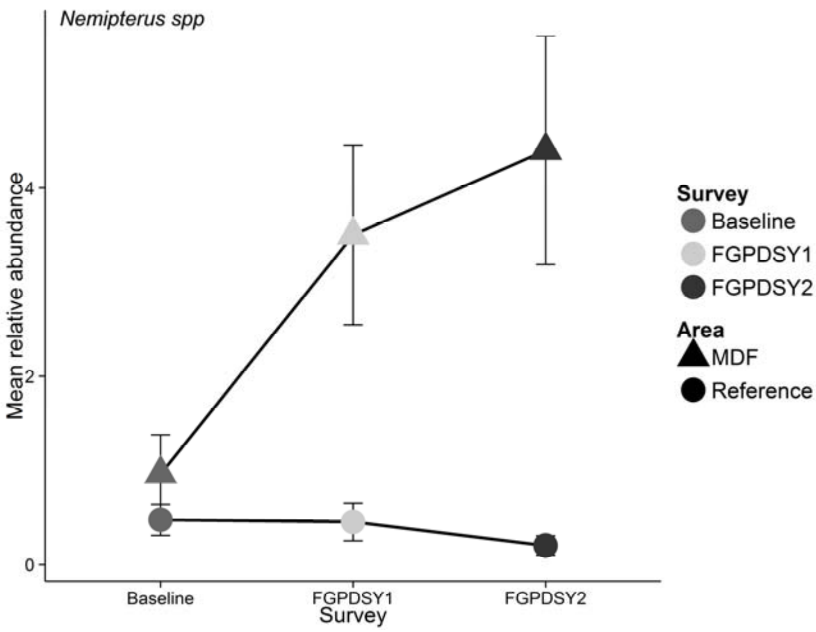


Figure 7-12 Patterns of Change in the Mean Relative Abundance per Deployment of *Nemipterus* spp. across all Habitat Types

Notes:

These patterns were not found to be statistically significant.

Error bars to 1 SE.

Baseline MDF n=27; Baseline Reference n=53; FGPDSY1, FGPDSY2 MDF n=20; FGPDSY1, FGPDSY2 Reference n=40.

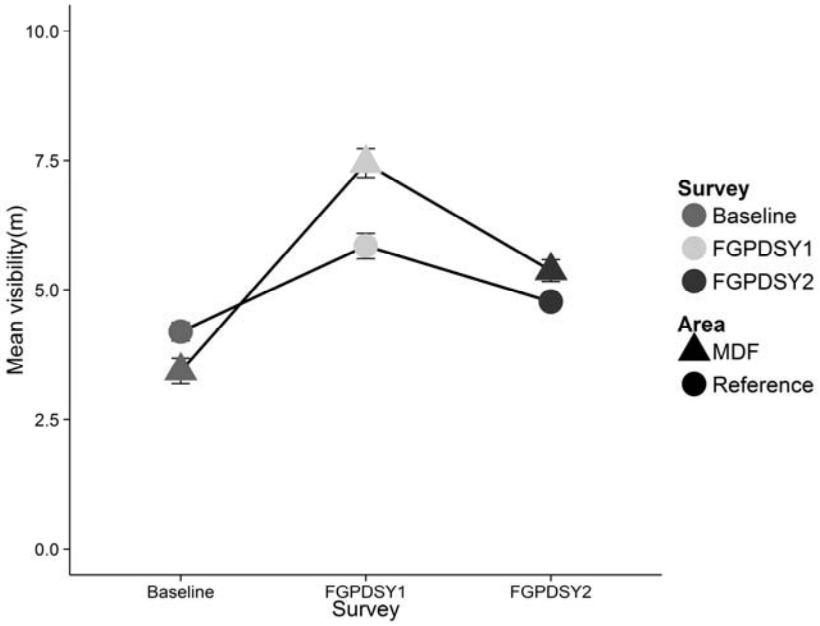


Figure 7-13 Patterns of Change in the Mean Horizontal Visibility per Deployment across all Habitat Types

Notes:

Error bars to 1 SE.

Baseline MDF n=27; Baseline Reference n=53; FGPDSY1, FGPDSY2 MDF n=20; FGPDSY1, FGPDSY2 Reference n=40.

7.5.3 Total Number of Individuals

Visibility was shown to influence the total number of individuals recorded throughout the stages of the stepwise approach. However, following the stepwise analysis, no statistically significant change in the total number of individuals was detected over and above the influence of visibility (Table 7-20).

Table 7-20 Results of a PERMANOVA Test with Visibility as a Covariate for Changes in the Total Number of Individuals

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	13.91	13.91	40.64	<0.001	9843
Survey	2	9.76	4.88	14.25	<0.001	9953
IvR	1	0.87	0.87	2.55	0.110	9848
Habitat	1	2.00	2.00	5.85	0.016	9846
Survey × IvR	*2*	*0.33*	*0.17*	*0.49*	*0.619*	*9953*
Survey × Habitat	2	3.33	1.67	4.87	0.009	9953
IvR × Habitat	1	0.15	0.15	0.43	0.508	9846
Survey × IvR × Habitat	*2*	*1.62*	*0.81*	*2.36*	*0.100*	*9948*
Residual	187	64.02	0.34			
Total	199	96.01				

Notes:

No statistically significant term of interest was detected.

Italicised text indicates terms of interest.

7.5.4 Species Richness

Visibility was shown to influence species richness at various stages through the stepwise approach, but a final statistically significant term of interest in 'Survey × IvR × Habitat' was detected over and above influence of visibility (Table 7-21). Pairwise tests of 'Survey × IvR × Habitat' detected a number of statistically significant changes (Table 7-22). At Reference Sites within macroalgal habitat, the species richness was significantly lower during FGPDSY1 and FGPDSY2 than it was during the Baseline (Table 7-22A, Figure 7-14). In addition, during FGPDSY1 species richness was significantly greater at MDF Sites than at Reference Sites (Table 7-22B). However, during FGPDSY2 macroalgal Reference and MDF Sites were no longer different (Table 7-22B, Figure 7-14). This indicates greater species richness at macroalgal MDF Sites compared with macroalgal Reference Sites during FGPDSY1. During FGPDSY2, the species richness at macroalgal Reference Sites had increased significantly from that recorded during FGPDSY1, and at MDF Sites decreased slightly (not statistically significant) so that the species richness at macroalgal MDF and Reference Sites was again similar.

A statistically significant increase in species richness at sand/sessile invertebrate Reference Sites was detected from the Baseline to FGPDSY1 (Table 7-22A). However, this is unlikely to be attributable to pipeline construction. This is because no significant differences were detected between MDF and Reference Sites in sand/ sessile invertebrate habitat during any survey (Table 7-22B). In addition, the species richness also increased at sand/sessile invertebrate MDF Sites, although this increase was not statistically significant (Table 7-22A, Figure 7-14). The apparent increase in species richness at sand/sessile invertebrate MDF Sites (Figure 7-14) can be statistically attributed to increased visibility at these sites during FGPDSY1.

Table 7-21 Results of a PERMANOVA Test with Visibility as a Covariate for Changes in Species Richness

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	4.08	4.08	43.38	<0.001	9838
Survey	2	1.85	0.93	9.87	<0.001	9944
IvR	1	0.10	0.10	1.05	0.310	9847
Habitat	1	0.49	0.49	5.18	0.023	9824
Survey × IvR	*2*	*0.13*	*0.06*	*0.68*	*0.500*	*9934*
Survey × Habitat	2	0.39	0.20	2.09	0.127	9948
IvR × Habitat	1	0.13	0.13	1.35	0.248	9860
Survey × IvR × Habitat	***2***	***0.74***	***0.37***	***3.96***	***0.022***	***9943***
Residual	187	17.57	0.09			
Total	199	25.48				

Notes:

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-22 Results of Pairwise Tests for Changes in Species Richness for the Significant Term of Interest ‘Survey × IvR × Habitat’. A) Tests for Pairs of Levels of the Factor ‘Survey’. B) Tests for Pairs of Levels of the Factor ‘IvR’

A) Term 'Survey × IvR × Habitat' for pairs of levels of factor 'Survey'			
Within level ‘Reference’ of factor ‘IvR’			
Within level ‘Sand/sessile’ of factor ‘Habitat’			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	**3.23**	**0.002**	**9840**
Baseline, FGPDSY2	0.97	0.341	9837
FGPDSY1, FGPDSY2	1.53	0.137	9824
Within level ‘Reference’ or factor ‘IvR’			
Within level ‘Macroalgae’ of factor ‘Habitat’			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	**5.44**	**<0.001**	**9835**
Baseline, FGPDSY2	**2.22**	**0.037**	**9804**
FGPDSY1, FGPDSY2	**2.22**	**0.031**	**9808**
Within level 'MDF' of factor 'IvR’			
Within level 'Sand/Sessile' of factor ‘Habitat'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	1.31	0.195	9830
Baseline, FGPDSY2	1.38	0.175	9825
FGPDSY1, FGPDSY2	0.53	0.601	9859
Within level 'MDF' of factor 'IvR’			
Within level 'Macroalgae' of factor ‘Habitat'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.19	0.864	9603
Baseline, FGPDSY2	0.68	0.527	9681
FGPDSY1, FGPDSY2	1.48	0.178	9542
B) Term 'Survey × IvR × Habitat' for pairs of levels of factor 'IvR’			
Groups	**t**	**P(perm)**	**Perms**
Baseline Sand/Sessile	0.68	0.508	9846
Baseline Macroalgae	1.63	0.118	9843
FGPDSY1 Sand/Sessile	1.46	0.149	9806
FGPDSY1 Macroalgae	**2.57**	**0.019**	**9818**
FGPDSY2 Sand/Sessile	0.91	0.376	9836
FGPDSY2 Macroalgae	0.32	0.756	9841

Note: Bold text indicates a statistically significant term of interest at α=0.05.

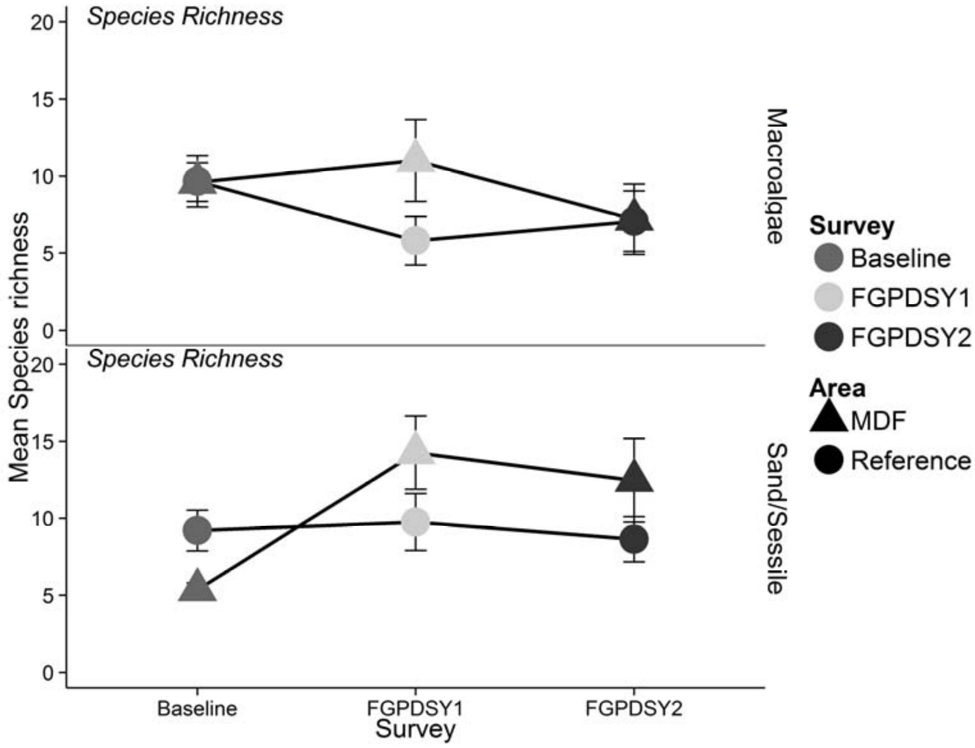


Figure 7-14 Patterns of Change in the Mean Species Richness per Deployment for the Interaction Term 'Survey × IvR × Habitat'

Notes:

Error bars to 1 SE.

Macroalgae: Baseline MDF n=5; Baseline Reference n=15; FGPDSY1, FGPDSY2 MDF n=5; FGPDSY1, FGPDSY2 Reference n=15.

Sand/sessile: Baseline MDF n=22; Baseline Reference n=38; FGPDSY1, FGPDSY2 MDF n=15; FGPDSY1, FGPDSY2 Reference n=25.

7.5.5 Fish Length

No relationship between visibility and fish length was detected using DISTLM. A modified stepwise approach (sites used as replicates) was used to assess change in the length-frequency distribution of the fish assemblages at MDF and Reference Sites between the Baseline, FGPDSY1, and FGPDSY2. No statistically significant change in the terms of interest 'Survey × IvR × Habitat' or 'Survey × IvR' were detected through the stepwise approach (Table 7-23). The length-frequency histograms for the interaction term 'Survey × IvR' were plotted (Figure 7-15) with no changes evident in these length-frequency distributions. The length-frequency distributions of fish assemblages were similar, with each showing a trend for most fish measured being between 80 mm and 280 mm long, with a secondary increase in the frequency of fish recorded with lengths between 460 mm and 700 mm.

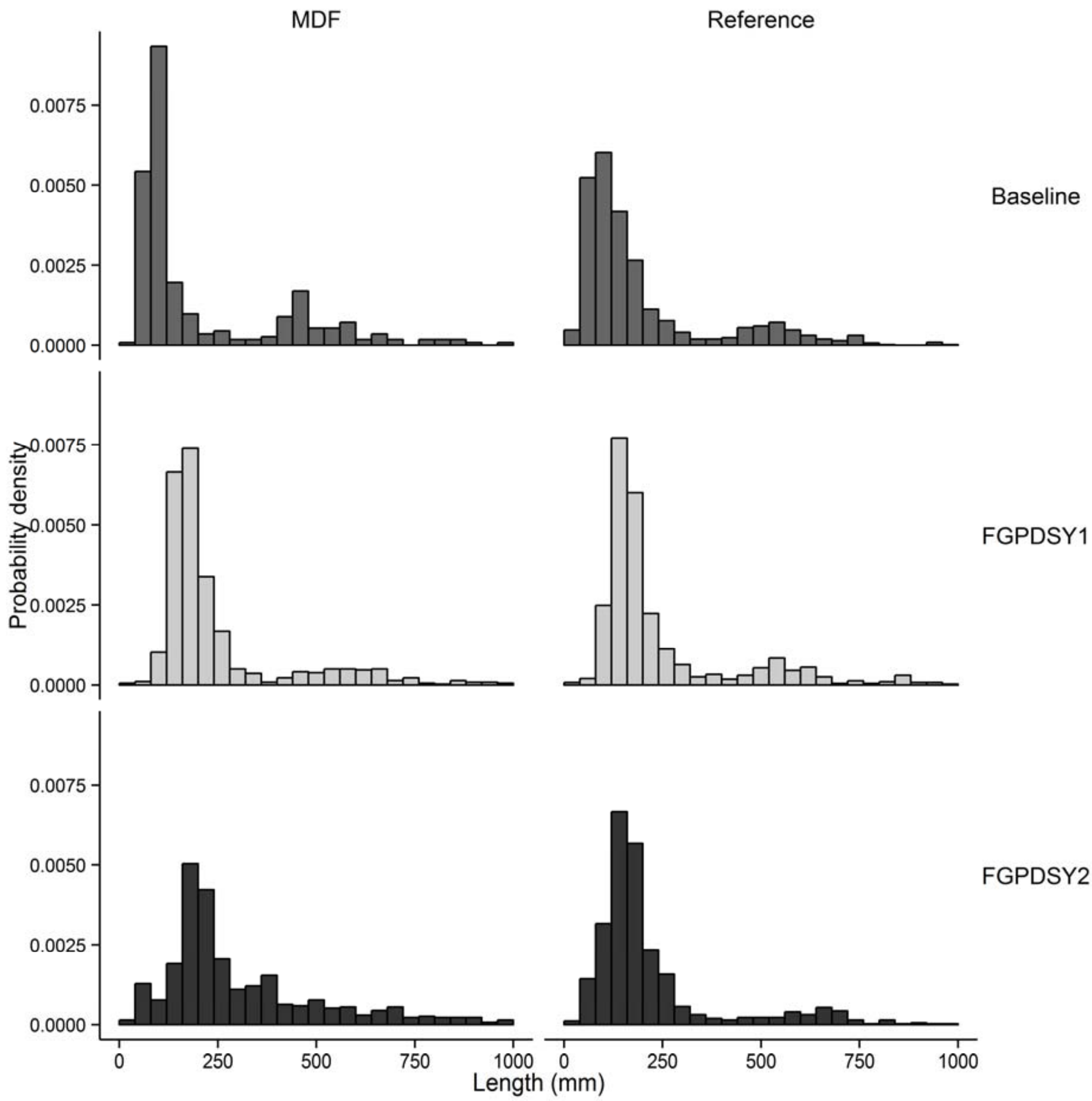


Figure 7-15 Length-Frequency Distributions of Fish Assemblages at MDF and Reference Sites Measured during the Baseline, FGPDSY1, and FGPDSY2

Table 7-23 Results of a Two-factor PERMANOVA Test for Changes in the Length-Frequency Distribution of the Fish Assemblage

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Survey	2	654860.00	327430.00	3.97	0.014	9947
IvR	1	77488.00	77488.00	0.94	0.349	9953
Survey × IvR	*2*	*136540.00*	*68272.00*	*0.83*	*0.468*	*9946*
Residual	35	2883800.00	82393.00			
Total	40	3841300.00				

Notes:

Italicised text indicates terms of interest.

No statistically significant term of interest was detected.

Length-frequency distribution histograms were produced for all macroalgal sites and all sand/sessile invertebrate sites during the Baseline, FGPDSY1, and FGPDSY2 (Figure 7-16). In macroalgae habitat, the general trend of change between surveys was dominated by a decrease in the frequency of fishes in the 40–120 mm length classes from the Baseline to FGPDSY1 and FGPDSY2. During FGPDSY1 and FGPDSY2, the 200–320 mm length classes had greater frequencies of fish than during the Baseline (Figure 7-16). In sand/sessile invertebrate habitat the general pattern of length-frequency distribution appeared similar between surveys (Figure 7-16).

Histograms of the length-frequency distributions of fish in MDF and Reference Sites were constructed for each survey in both macroalgae habitat (Figure 7-17) and sand/sessile invertebrate habitat (Figure 7-18). In general, the length-frequency distributions do not differ between surveys or between MDF and Reference Sites. The exception is in macroalgae habitat where at Reference Sites during FGPDSY1 a peak in frequency can be seen in length classes between 440 and 640 mm (Figure 7-17). Also in macroalgae habitat during the Baseline there was a peak in frequency of fish recorded between 400 and 480 mm at MDF Sites that was not seen at Reference Sites (Figure 7-17).

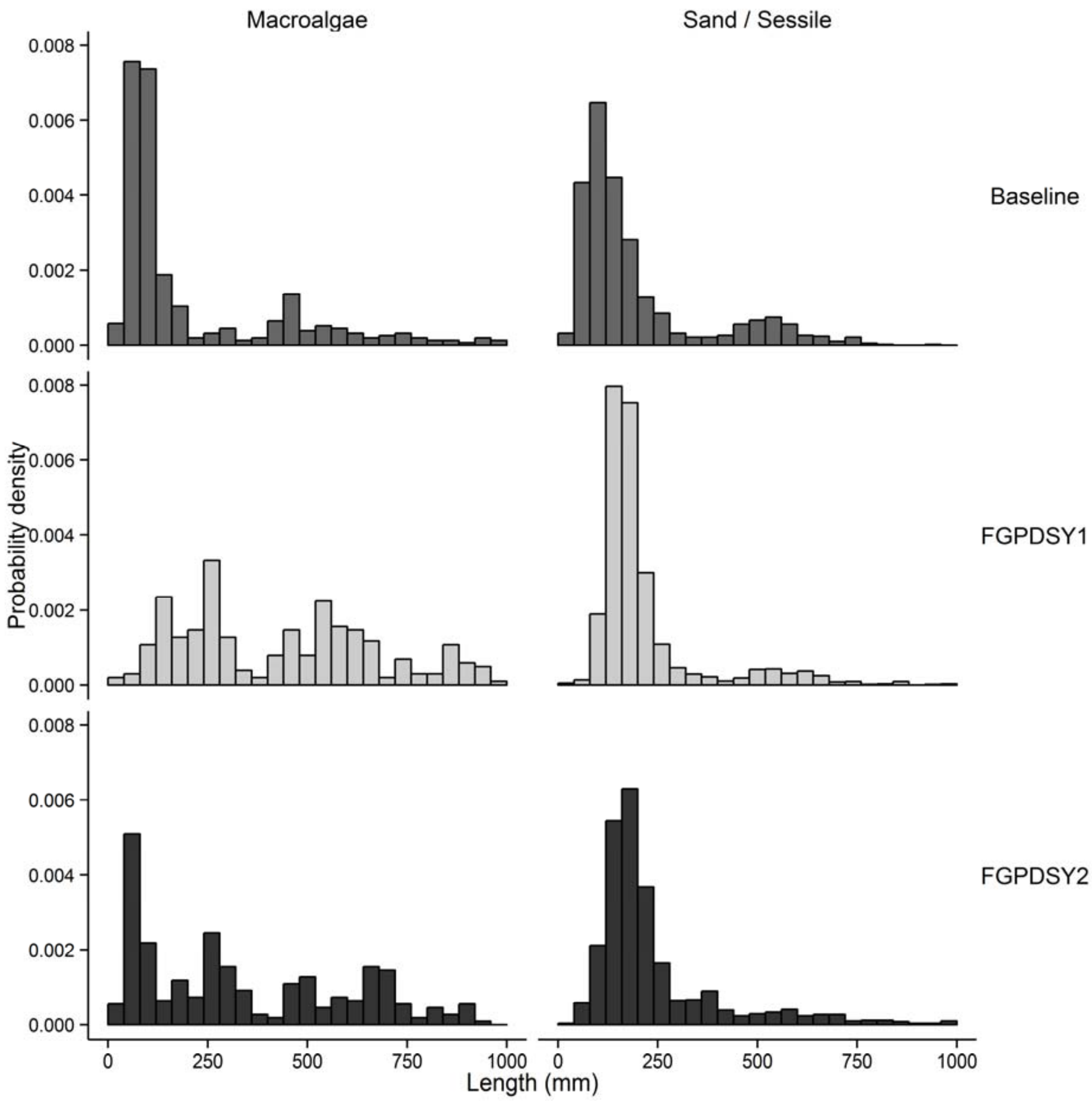


Figure 7-16 Length-frequency Histograms of all Observed Demersal Fish During the Baseline, FGPDSY1, and FGPDSY2 at Macroalgal Sites and Sand/Sessile Invertebrates Sites

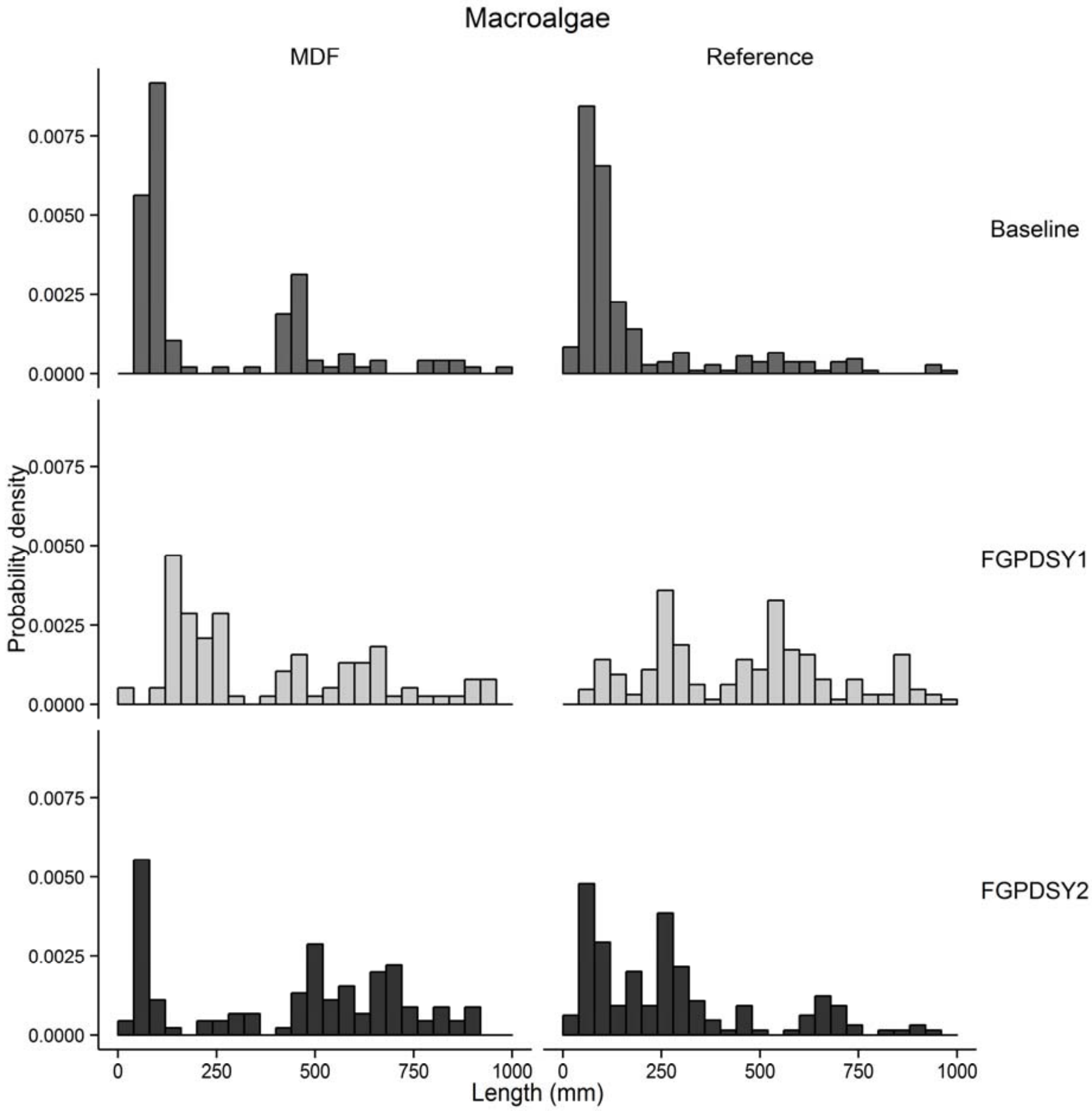


Figure 7-17 Length-frequency Histograms of all Observed Demersal Fish During the Baseline, FGPDSY1, and FGPDSY2 at Macroalgal MDF Sites and Macroalgal Reference Sites

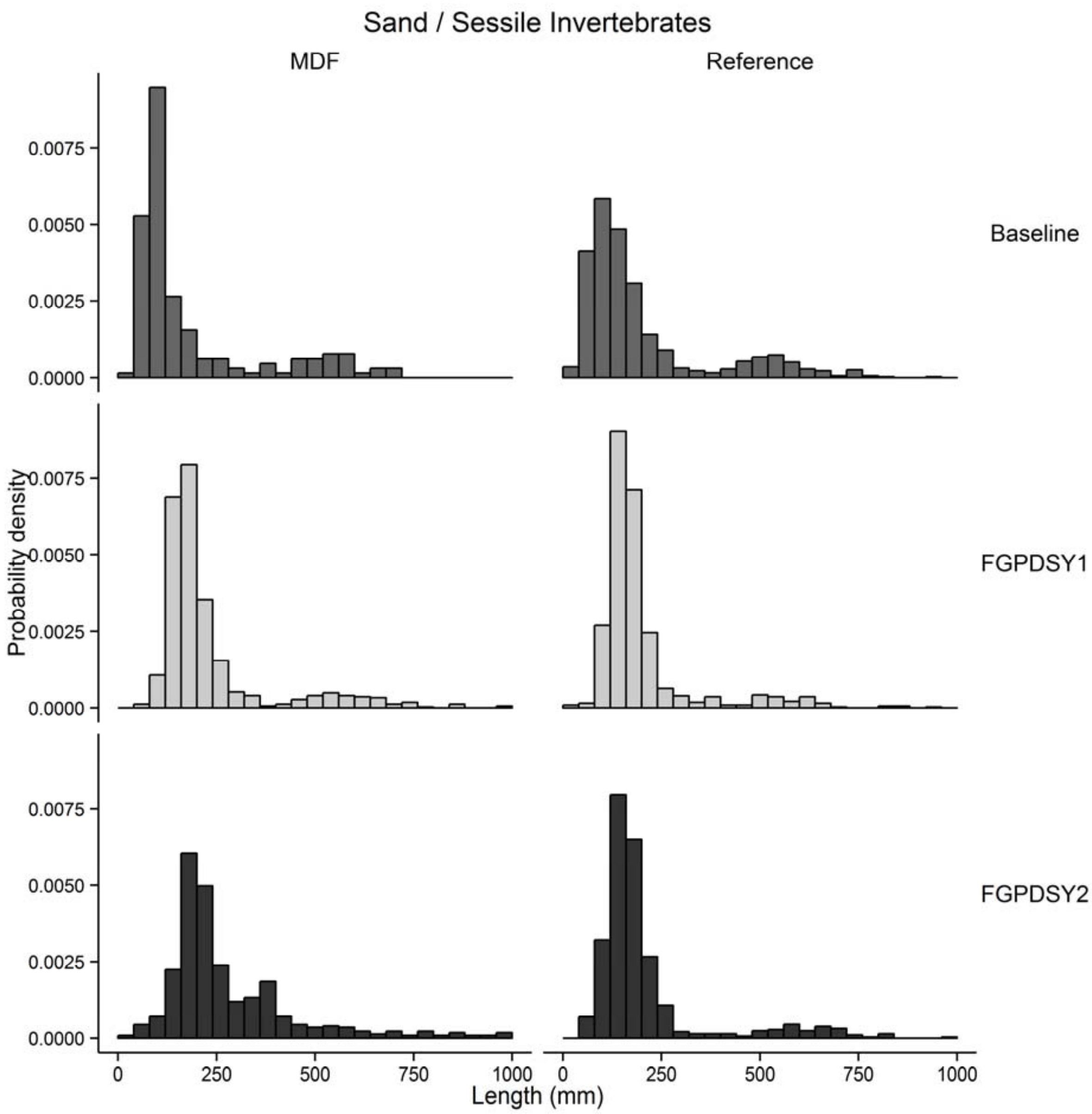


Figure 7-18 Length-frequency Histograms of all Observed Demersal Fish During the Baseline, FGPDSY1, and FGPDSY2 at Sand/Sessile Invertebrate MDF Sites and Sand/Sessile Invertebrate Reference Sites

7.5.6 Dominant Species

7.5.6.1 Macroalgae Habitat

The ten dominant (numerically abundant) species in macroalgae habitat included: *C. fulvoguttatus*, *C. pictoides*, *Gnathanodon Speciosus* (Golden Trevally), *Leptojulis Cyanopleura* (Shoulder-spot Wrasse), *P. barberinoides*, *P. porosus*, *P. coelestis*, *S. leptolepis*, *Sillago* spp., and *T. pallimaculatus*. A summary of relative abundance and length information for each of these species is presented in Table 7-24 and Table 7-25. Most species appear to exhibit a decline in total abundance and commonality (% of deployments) from the Baseline to FGPDSY2 (Table 7-24).

Despite this apparent decline in total abundance and commonality from the Baseline to FGPDSY2, none of the ten dominant species for macroalgal habitat showed a statistically significant change in abundance that might indicate an impact. For eight of the ten macroalgal dominant species no statistically significant terms of interest were detected (Table 7-26). For the remaining two species—*C. fulvoguttatus* and *C. pictoides*—a significant term of interest was detected in the interaction of 'Survey × IvR' (Table 7-27 and Table 7-29 respectively), but further investigation using pairwise tests illustrated that these changes did not indicate an impact. Although a significant interaction of the term 'Survey × IvR' was detected for *C. fulvoguttatus* in macroalgal habitat (Table 7-27), pairwise tests revealed that this species was recorded in significantly greater abundance at MDF Sites than Reference Sites during all surveys (Table 7-28, Figure 7-19) and therefore this pattern did not indicate an impact. Similarly, although a significant term of interest 'Survey × IvR' was detected for the macroalgal dominant species *C. pictoides* (Table 7-29) and this species was recorded in significantly lower abundance during FGPDSY1 and FGPDSY2 than during the Baseline (Table 7-30, Figure 7-20), this change was recorded at both MDF and Reference Sites so does not indicate an impact.

Table 7-25 lists the mean length and the range of length measurements for each of the dominant species for macroalgae habitats. The length-frequency distributions for 'Survey × IvR' are presented in Appendix 3. Length-frequency distributions are only presented for combinations of Survey and IvR where length measurements were made. In some cases the species was not recorded or could not be measured. In general, the abundances of these species and the number of replicate deployments were too low to allow for sufficient numbers of length measurements to be made to allow meaningful analyses or interpretation of any patterns of change.

Table 7-24 Relative Abundance and Commonality Information for the 10 Dominant Species (most numerically abundant) in Macroalgae Habitats (selected from 2010 Baseline data)

		Total # Individuals			% of Deployments			Mean MaxN per Deployment (± SE)		
Species (alphabetical order)	Common Name	2010 Baseline	FGPDS Y1	FGPDS Y2	2010 Baseline	FGPDS Y1	FGPDS Y2	2010 Baseline	FGPDSY1	FGPDSY2
Carangoides fulvoguttatus	Gold-spotted Trevally	26	18	31	25	5	10	1.30 ± 0.83	0.90 ± 0.40	1.55 ± 0.88
Coris pictoides	Pixy Wrasse	33	0	1	45	0	2	1.65 ± 0.56	0	0.02 ± 0.05
Gnathanodon speciosus	Golden Trevally	26	17	27	25	8	13	1.30 ± 0.83	0.85 ± 0.45	2.92 ± 0.65
Leptojulis cyanopleura	Shoulderspot Wrasse	23	1	0	25	1	0	1.15 ± 0.70	0.05 ± 0.05	0
Parupeneus barberinoides	Bicolour Goatfish	21	3	0	25	1	0	1.05 ± 0.55	0.15 ± 0.15	0
Pentapodus porosus	Northwest Threadfin Bream	195	17	4	70	4	2	9.75 ± 2.79	0.85 ± 0.41	0.20 ± 0.20
Pomacentrus coelestis	Neon Damsel	53	0	31	15	0	3	2.65 ± 1.87	0	1.55 ± 1.07
Selaroides leptolepis	Yellowstripe Scad	244	0	0	25	0	0	12.20 ± 7.75	0	0
Sillago spp.	Whiting	21	22	43	20	3	10	1.05 ± 0.55	1.10 ± 0.74	2.15 ± 0.87
Torquigener pallimaculatus	Rusty-spotted Toadfish	119	0	0	30	0	0	5.95 ± 3.07	0	0

Table 7-25 Summary of Length Information for the 10 Dominant Species (most numerically abundant) in Macroalgae Habitats (selected from 2010 Baseline data)

	# Individuals Measured for Length			Length Range (mm)			Mean Length (± SE)		
Species (alphabetical order)	**2010 Baseline**	**FGPDSY1**	**FGPDSY2**	**2010 Baseline**	**FGPDSY1**	**FGPDSY2**	**2010 Baseline**	**FGPDSY1**	**FGPDSY2**
Carangoides fulvoguttatus	19	15	25	250.1–1001.5	414.5–697.4	409.5 - 716.8	510.7 ± 56.8	551.6 ± 22.2	619.4 ± 16.94
Coris pictoides	18	0	1	46.6–186.2	–	-	107.3 ± 9.3	-	75.9
Gnathanodon speciosus	13	16	17	421.6–771.5	493.7–677.9	509.7 - 759.4	547.6 ± 37.3	599.7 ± 13.4	658.6 ± 16.1
Leptojulis cyanopleura	8	1	0	49.0–122.5	64.3–64.3	-	89.8 ± 9.7	-	-
Parupeneus barberinoides	5	3	0	72.3–88.7	141.0–148.2	-	82.7 ± 3.1	145.3 ± 2.2	-
Pentapodus porosus	79	12	4	45.2–194.1	22.3–168.8	80.4 - 110.2	102.4 ± 3.5	123.1 ± 14.3	89.5 ± 7.0
Pomacentrus coelestis	24	0	31	39.8–74.0	–	24.7 - 95.9	52.5 ± 1.8	-	54.8 ± 2.7
Selaroides leptolepis	39	0	0	52.5–94.0	–	-	76.3 ± 1.6	-	-
Sillago spp.	5	14	19	99.5–126.2	60.5–146.8	56.6 - 296.1	111.0 ± 4.7	104.7 ± 6.0	112.8 ± 13.0
Torquigener pallimaculatus	27	0	0	32.2–96.4	–	-	58.7 ± 2.5	-	-

Notes:

The number measured is not indicative of abundance.

'–' indicates species not recorded.

Table 7-26 Results of Two-factor PERMANOVA Tests for Eight Macroalgal Dominant Species

Note: *Carangoides fulvogattutus* and *Coris pictoides* are presented separately in Table 7-27 to Table 7-30.

		Gnathanodon speciosus					***Leptojulis cyanopleura***				
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**
Survey	2	13.23	6.62	0.78	0.457	9951	6.68	3.34	1.00	0.327	9939
IvR	1	24.20	24.20	2.84	0.083	9754	2.22	2.22	0.67	0.444	9823
Survey × IvR	*2*	*18.43*	*9.22*	*1.08*	*0.348*	*9957*	*3.81*	*1.91*	*0.57*	*0.492*	*9946*
Residual	54	460.67	8.53				179.47	3.32			
Total	59	506.33					202.40				
		Parupeneus barberinoides					***Pentapodus porosus***				
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**
Survey	2	5.34	2.67	1.23	0.288	9950	1287.10	643.57	13.00	0.001	9950
IvR	1	0.09	0.09	0.04	0.868	9814	172.09	172.09	3.48	0.065	9859
Survey × IvR	*2*	*4.08*	*2.04*	*0.94*	*0.385*	*9958*	*184.88*	*92.44*	*1.87*	*0.165*	*9952*
Residual	54	117.33	2.17				2672.50	49.49			
Total	59	134.40					4168.40				
		Pomacentrus coelestis					***Selaroides leptolepis***				
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**
Survey	2	38.21	19.11	0.61	0.513	9935	1166.40	583.20	1.39	0.269	9935
IvR	1	2.22	2.22	0.07	0.814	9821	39.20	39.20	0.09	0.797	9811
Survey × IvR	*2*	*62.74*	*31.37*	*1.00*	*0.366*	*9932*	*78.40*	*39.20*	*0.09*	*0.901*	*9955*
Residual	54	1692.50	31.34				22680.00	419.99			
Total	59	1828.40					24782.00				

		***Sillago* spp.**				
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**
Survey	2	4.14	2.07	0.20	0.824	9951
IvR	1	13.89	13.89	1.31	0.265	9814
Survey × IvR	*2*	*28.74*	*14.37*	*1.36*	*0.261*	*9937*
Residual	54	570.67	10.57			
Total	59	628.73				

Notes:

Italicised text indicates terms of interest.

No statistically significant terms of interest were detected.

Table 7-27 Results of Three-Factor PERMANOVA Test for Changes in the Relative Abundance of the Macroalgal Dominant Species *Carangoides fulvoguttatus*

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Survey	2	12.70	6.35	95.25	0.000	9951
IvR	1	151.25	151.25	37.19	0.247	4
Site(IvR)	2	8.13	4.07	0.43	0.667	9949
Survey × IvR	***2***	***13.30***	***6.65***	***99.75***	***0.001***	***9964***
Survey × Site(IvR)	4	0.27	0.07	0.01	1.000	9954
Residual	48	450.00	9.38			
Total	59	627.25				

Notes:

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-28 Results of Pairwise Tests for Changes in the Relative Abundance of the Macroalgal Dominant Species *Carangoides fulvoguttatus* for the Significant Term of Interest 'Survey × IvR'. A) Tests for Pairs of Levels of the Factor 'Survey'. B) Tests for Pairs of Levels of the Factor 'IvR'

A) Term 'Survey × IvR' for pairs of levels of factor 'Survey'			
Within level 'Reference' of factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	1.73	0.275	12
Baseline, FGPDSY2	1.73	0.270	12
FGPDSY1, FGPDSY2	Denominator is 0		
Within level 'MDF' or factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.30	0.929	16
Baseline, FGPDSY2	0.37	0.972	12
FGPDSY1, FGPDSY2	0.78	0.490	16

B) Term 'Survey × IvR' for pairs of levels of factor 'IvR'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline	**4.49**	**0.248**	**4**	**0.048**
FGPDSY1	**4.75**	**0.253**	**3**	**0.039**
FGPDSY2	**9.63**	**0.251**	**3**	**0.011**

Note: Bold text indicates a statistically significant term of interest at α=0.05.

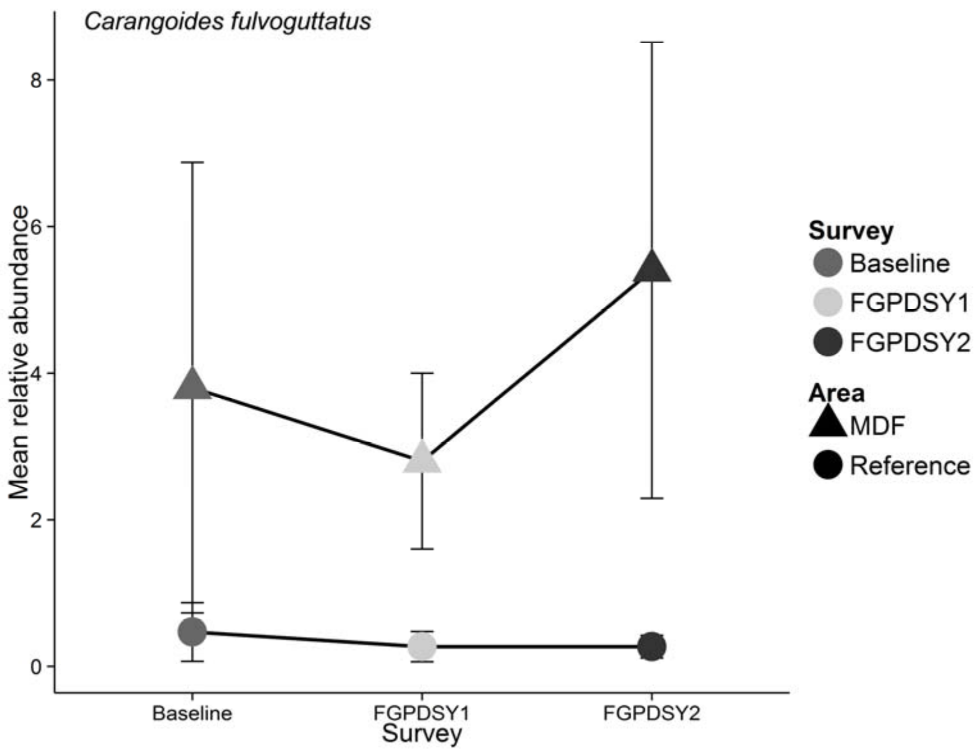


Figure 7-19 Mean Relative Abundance per Stereo-BRUVs Deployment Macroalgal Dominant Species *Carangoides fulvoguttatus* for the Interaction Term 'Survey × IvR'

Notes:

Error bars to 1 SE.

Baseline MDF n=5; Baseline Reference n=15; FGPDSY1, FGPDSY2 MDF n=5; FGPDSY1, FGPDSY2 Reference n=15.

Table 7-29 Results of Three-Factor PERMANOVA Test for Changes in the Relative Abundance of the Macroalgal Dominant Species *Coris pictoides*

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Survey	2	11.84	5.92	22.14	<0.001	9954
MDF/Reference	1	2.62	2.62	9.81	0.003	9790
Survey × IvR	***2***	***3.37***	***1.68***	***6.30***	***0.004***	***9942***
Residual	54	14.43	0.27			
Total	59	28.93				

Notes:

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-30 Results of Pairwise Tests for Changes in the Relative Abundance of the Macroalgal Dominant Species *Coris pictoides* for the Significant Term of Interest 'Survey × IvR'. A) Tests for Pairs of Levels of the Factor 'Survey'. B) Tests for Pairs of Levels of the Factor 'IvR'

A) Term 'Survey × IvR' for pairs of levels of factor 'Survey'				
Within level 'Reference' of factor 'IvR'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline, FGPDSY1	**2.60**	**0.043**	**5**	**0.013**
Baseline, FGPDSY2	**2.60**	**0.046**	**5**	**0.016**
FGPDSY1, FGPDSY2	Denominator is 0			
Within level 'MDF' or factor 'IvR'				
Groups	**t**	**P(perm)**	**Perms**	
Baseline, FGPDSY1	**3.34**	**0.045**	**8**	**0.010**
Baseline, FGPDSY2	**2.77**	**0.048**	**16**	**0.025**
FGPDSY1, FGPDSY2	1.00	1.000	1	0.351
B) Term 'Survey × IvR' for pairs of levels of factor 'IvR'				
Groups	**t**	**P(perm)**	**Perms**	**P(MC)**
Baseline	**2.78**	**0.012**	**64**	**0.012**
FGPDSY1	Denominator is 0			
FGPDSY2	1.84	0.247	2	0.081

Note: Bold text indicates a statistically significant term of interest at α=0.05.

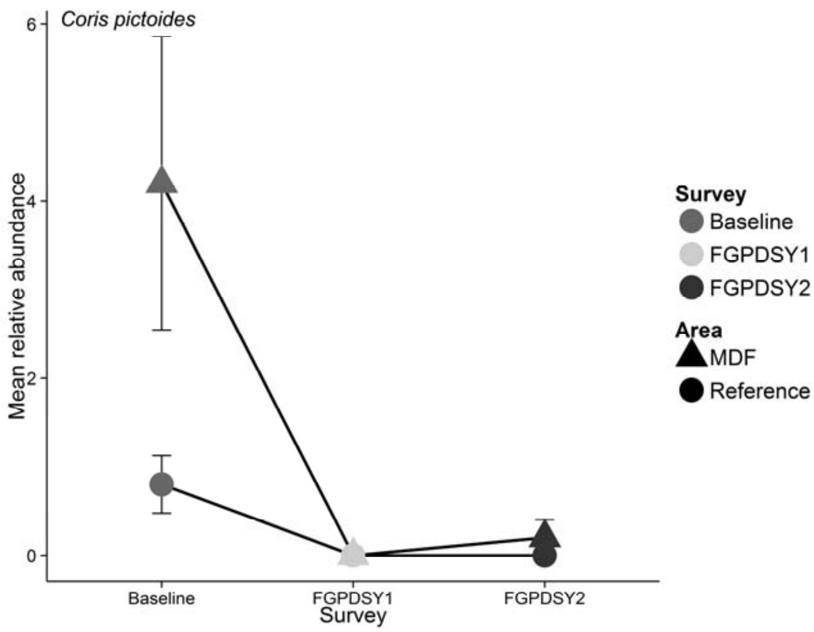


Figure 7-20 Mean Relative Abundance per Stereo-BRUVs Deployment Macroalgal Dominant Species *Coris pictoides* for the Interaction Term 'Survey × IvR'

Notes:

Error bars to 1 SE.

Baseline MDF n=5; Baseline Reference n=15; FGPDSY1, FGPDSY2 MDF n=5;, FGPDSY1, FGPDSY2 Reference n=15.

7.5.6.2 Sand/Sessile Invertebrates Habitat

The ten dominant (numerically abundant) species in sand/sessile invertebrates habitat included: *A. mate*, *C. gymnostethus*, *G. speciosus*, *L. genivittatus*, *Nemipterus* spp., *P. porosus*, *S. leptolepis*, *Siganus Fuscescens* (Black Rabbitfish), *Sillago* spp., and *T. pallimaculatus*. A summary of relative abundance and length information for each of these species is presented in Table 7-31 and Table 7-32.

No significant interaction terms of interest were detected for nine of the ten dominant species for sand/sessile invertebrate habitat (Table 7-33, Table 7-34). However, a significant interaction term of interest was detected in 'Survey × IvR' for *Nemipterus* spp. (Table 7-35). Pairwise tests showed that, at sand/sessile invertebrate MDF Sites, *Nemipterus* spp. was recorded at significantly greater abundance than at Reference Sites during both FGPDSY1 and FGPDSY2 (Table 7-36, Figure 7-21). During the Baseline, this species was recorded in similar abundance at MDF and Reference Sites (Table 7-36, Figure 7-21). This change indicates a positive impact of the construction of the OFGPS on the abundance of *Nemipterus* spp. in sand/sessile invertebrate habitat.

Table 7-32 lists the mean length and the range of length measurements for each of the dominant species for sand/sessile invertebrate habitat. The length-frequency distributions for 'Survey × IvR' are presented in Appendix 4. In general, the abundances of these species and the number of replicate deployments were too low to allow for sufficient numbers of length measurements to be made to allow meaningful analyses or interpretation of any patterns of change.

Table 7-31 Relative Abundance and Commonality Information for the 10 Dominant Species (most numerically abundant) in Sand/Sessile Invertebrate Habitats (selected from 2009 and 2010 Baseline data combined)

		Total # of Individuals				% of Deployments				Mean MaxN per Deployment (± SE)			
Species (alphabetical order)	Common Name	2009 Baseline	2010 Baseline	FGPDSY 1	FGPDSY 2	2009 Baseline	2010 Baseline	FGPDS Y1	FGPD SY2	2009 Baseline	2010 Baseline	FGPDSY1	FGPDSY2
Atule mate	Barred Yellowtail Scad	33	23	83	125	24	3	15	25	1.3 ± 0.6	0.7 ± 0.7	2.1 ± 1.4	3.13 ± 1.39
Carangoides gymnostethus	Bludger Trevally	0	49	32	3	0	20	23	7.5	0	1.4 ± 0.6	0.8 ± 0.4	0.08 ± 0.04
Gnathanodon speciosus	Golden Trevally	27	33	51	35	16	14	18	12.5	1.1 ± 0.7	0.9 ± 0.5	1.3 ± 1.1	0.88 ± 0.46
Lethrinus genivittatus	Threadfin Emperor	17	87	136	104	20	17	35	22.5	0.7 ± 0.3	2.5 ± 1.3	3.4 ± 1.2	2.6 ± 1.40
Nemipterus spp.	Threadfin Bream	15	33	86	93	24	26	45	35	0.6 ± 0.3	0.9 ± 0.3	2.2 ± 0.6	2.33 ± 0.69
Pentapodus porosus	Northwest Threadfin Bream	154	109	402	240	32	31	65	47.5	6.2 ± 2.2	3.1 ± 1.1	10.1 ± 1.8	6.00 ± 1.42
Selaroides leptolepis	Yellowstripe Scad	154	232	317	63	32	29	23	7.5	6.2 ± 2.8	6.6 ± 2.6	7.9 ± 6.3	1.58 ± 1.52
Siganus fuscescens	Dusky Rabbitfish	6	49	50	41	4	14	8	15	0.2 ± 0.2	1.4 ± 0.8	1.3 ± 1.0	1.03 ± 0.64
Sillago spp.	Whiting	15	64	17	68	20	29	18	25	0.6 ± 0.3	1.8 ± 1.4	0.4 ± 0.2	1.70 ± 0.62
Torquigener pallimaculatus	Rusty-spotted Toadfish	6	143	0	1	20	63	0	2.5	0.2 ± 0.1	4.1 ± 1	0	0.03 ± 0.03

Table 7-32 Summary of Length Information for the 10 Dominant Species (most numerically abundant) in Sand/Sessile Invertebrate Habitats (selected from 2009 and 2010 Baseline data combined)

	# Individuals Measured for Length				Length Range (mm)				Mean Length (± SE)			
Species (alphabetical order)	2009 Baseline	2010 Baseline	FGPDS Y1	FGPD SY2	2009 Baseline	2010 Baseline	FGPDSY1	FGPDSY2	2009 Baseline	2010 Baseline	FGPDSY1	FGPDSY2
Atule mate	8	7	44	59	101.5–283.1	224.2–285.0	135.7–213.9	105.2–277.3	212.0 ± 27.0	261.9 ± 6.9	176.9 ± 2.3	39.6 ± 5.2
Carangoides gymnostethus	0	39	30	3	-	203.1–639.0	198.9–355.7	139.5–322.0	-	393.4 ± 24.9	273.6 ± 7.2	252.8 ± 57.1
Gnathanodon speciosus	2	21	28	28	39.4–39.9	22.05–205.4	32.6–730.3	671.2–1035.0	39.7 ± 0.3	79.7 ± 10.2	207.4 ± 31.3	671.6 ± 128.1
Lethrinus genivittatus	9	37	88	68	59.2–163.6	92.49–214.0	107.9–206.9	105.4–207.1	99.3 ± 10.6	155.7 ± 5.0	152.0 ± 3.0	158.2 ± 2.6
Nemipterus spp.	7	16	74	85	207.4–273.0	94.2–283.4	154.7–271.7	99.6–295.9	240.5 ± 7.5	199.7 ± 14.5	215.6 ± 3.3	199.7 ± 4.7
Pentapodus porosus	71	57	314	4	62.6–212.9	99.27–252.9	93.6–259.6	80.4–110.2	148.7 ± 3.8	157.9 ± 3.8	161.0 ± 1.2	89.5 ± 7.0
Selaroides leptolepis	45	69	108	22	53.7–118.7	36.29–190.9	66.8–231.2	120.6–238.2	87.8 ± 3.0	90.7 ± 3.5	133.7 ± 2.5	194.4 ± 5.4
Siganus fuscescens	4	22	37	24	94.3–176.0	97.33–214.8	54.7–185.1	108.3–432.2	134.9 ± 20.7	127.5 ± 6.2	128.6 ± 3.9	195.7 ± 17.5
Sillago spp.	6	10	7	19	122.1–175.4	37.75–165.5	120.9–167.7	56.6–296.1	148.8 ± 7.1	93.8 ± 11.6	139.2 ± 6.8	112.8 ± 13.0
Torquigener pallimaculatus	5	80	0	1	64.3–93.0	34.49–118.8	-	-	78.2 ± 5.1	83.9 ± 2.3	-	134.1

Notes:

'–' indicates species not recorded.

The number of individuals measured does not indicate abundance.

Table 7-33 Results of Two-factor PERMANOVA Tests for Changes in the Relative Abundance of Sand/Sessile Invertebrates Habitat Dominant Species

		Atule mate					***Gnathanodon speciosus***				
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**
Survey	2	65.37	32.68	0.66	0.539	9967	14.73	7.36	0.37	0.754	9953
IvR	1	109.48	109.48	2.21	0.144	9839	29.14	29.14	1.47	0.249	9888
Survey × IvR	*2*	*122.55*	*61.27*	*1.24*	*0.303*	*9955*	*81.39*	*40.69*	*2.05*	*0.118*	*9962*
Residual	134	6624.70	49.44				2655.70	19.82			
Total	139	6952.20					2757.70				

		Selaroides leptolepis					***Sillago* spp.**				
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**
Survey	2	1397.80	698.91	1.24	0.300	9952	21.09	10.55	0.47	0.705	9950
IvR	1	880.63	880.63	1.57	0.223	9893	71.44	71.44	3.16	0.051	9919
Survey × IvR	*2*	*1234.30*	*617.14*	*1.10*	*0.367*	*9947*	*21.69*	*10.85*	*0.48*	*0.702*	*9952*
Residual	134	75401.00	562.69				3032.50	22.63			
Total	139	78423.00					3161.90				

		Torquigener pallimaculatus				
Source	**df**	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Perms**
Survey	2	194.64	97.32	9.17	<0.001	9955
IvR	1	0.03	0.03	0.00	0.962	9843
Survey × IvR	*2*	*0.01*	*0.01*	*0.00*	*0.999*	*9955*
Residual	134	1421.90	10.61			
Total	139	1631.30				

Notes:

Italicised text indicates terms of interest.

No statistically significant terms of interest were detected.

Table 7-34 Results of PERMANOVA Tests with Visibility at a Covariate for Changes in the Relative Abundance of Sand/Sessile Invertebrates Habitat Dominant Species

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Carangoides gymnostethus						
Visibility	1	41.65	41.65	9.37	0.003	9847
Survey	2	49.91	24.95	5.61	0.006	9950
IvR	1	3.12	3.12	0.70	0.419	9819
Survey × IvR	*2*	*5.62*	*2.81*	*0.63*	*0.545*	*9954*
Residual	133	591.30	4.45			
Total	139	691.60				
Lethrinus genivittatus						
Visibility	1	389.17	389.17	8.19	0.005	9834
Survey	2	35.43	17.71	0.37	0.695	9937
IvR	1	378.15	378.15	7.96	0.004	9823
Survey × IvR	*2*	*223.03*	*111.52*	*2.35*	*0.099*	*9938*
Residual	133	6321.00	47.53			
Total	139	7346.70				
Siganus fuscescens						
Visibility	1	180.50	180.50	9.08	0.002	9827
Survey	2	85.41	42.70	2.15	0.112	9957
MDF/Reference	1	5.99	5.99	0.30	0.600	9834
Survey × IvR	*2*	*11.89*	*5.95*	*0.30*	*0.750*	*9950*
Residual	133	2644.00	19.88			
Total	139	2927.70				
Pentapodus porosus						
Visibility	1	165.90	165.90	63.88	0.000	9834
Survey	2	6.94	3.47	1.34	0.264	9949
IvR	1	0.09	0.09	0.03	0.855	9824
Visibility × Survey	2	6.11	3.05	1.18	0.315	9953
Visibility × IvR	1	0.55	0.55	0.21	0.643	9837
Survey × IvR	*2*	*1.76*	*0.88*	*0.34*	*0.708*	*9958*
Visibility × Survey × IvR	***2***	***37.41***	***18.71***	***7.20***	***0.001***	***9941***
Residual	128	332.41	2.60			
Total	139	551.17				

Notes:

Italicised text indicates terms of interest.

Statistically significant interaction of visibility with 'Survey × IvR', but no statistically significant interaction term of interest was detected.

Table 7-35 Results of PERMANOVA Tests with Visibility at a Covariate for Changes in the Relative Abundance of the Sand/Sessile Invertebrate Dominant Species *Nemipterus* spp.

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	177.90	177.90	25.57	<0.001	9836
Survey	2	28.42	14.21	2.04	0.130	9941
IvR	1	241.98	241.98	34.78	<0.001	9823
Survey × IvR	***2***	***97.24***	***48.62***	***6.99***	***0.002***	***9938***
Residual	133	925.39	6.96			
Total	139	1470.90				

Notes:

Italicised text indicates terms of interest.

Bold text indicates a statistically significant term of interest at α=0.05.

Table 7-36 Results of Pairwise Tests for Changes in the Relative Abundance of Sand/Sessile Invertebrates Habitat Dominant Species *Nemipterus* spp., for the Significant Term of Interest 'Survey × IvR'. A) Tests for Pairs of Levels of the Factor 'Survey'. B) Tests for Pairs of Levels of the Factor 'IvR'

A) Term 'Survey × IvR' for pairs of levels of factor 'Survey'			
Within level 'Reference' of factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.40	0.695	9837
Baseline, FGPDSY2	1.57	0.121	9866
FGPDSY1, FGPDSY2	1.00	0.341	9852
Within level 'MDF' or factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline, FGPDSY1	0.74	0.435	9791
Baseline, FGPDSY2	0.14	0.882	9824
FGPDSY1, FGPDSY2	**2.03**	**0.047**	**9828**
B) Term 'Survey × IvR' for pairs of levels of factor 'IvR'			
Groups	**t**	**P(perm)**	**Perms**
Baseline	0.97	0.340	9848
FGPDSY1	**2.73**	**0.008**	**9831**
FGPDSY2	**3.66**	**0.001**	**9822**

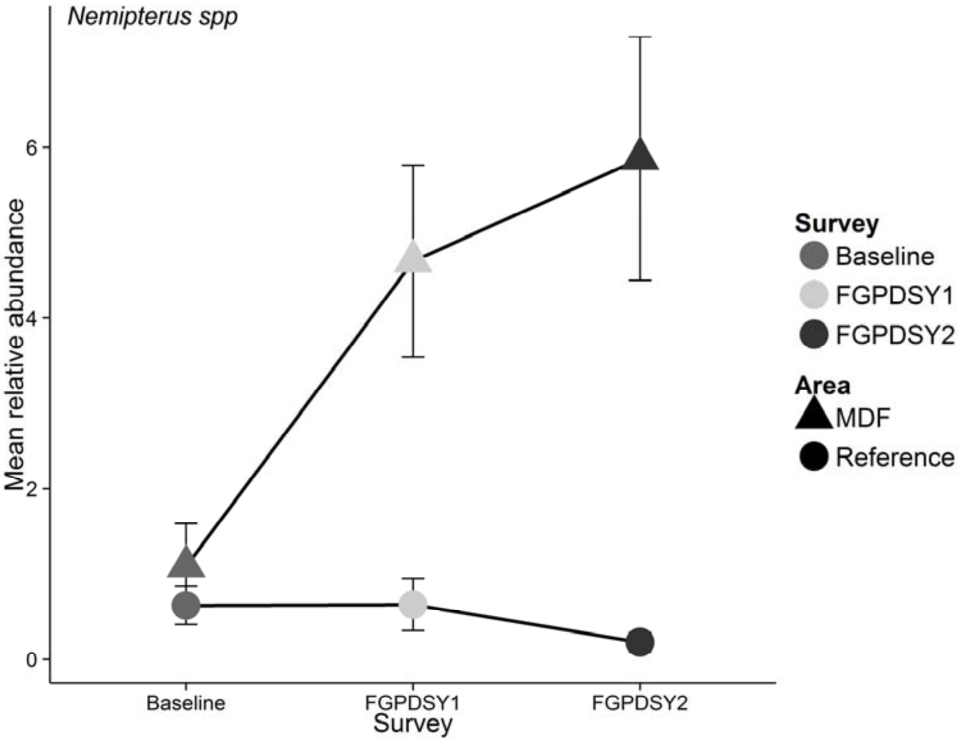


Figure 7-21 Mean Relative Abundance per Stereo-BRUVs Deployment of *Nemipterus* spp. in Sand/Sessile Invertebrates Habitats for the Interaction Term 'Survey × IvR'

Notes:

Error bars to 1 SE.

Baseline MDF n=22; Baseline Reference n=38; FGPDSY1, FGPDSY2 MDF n=15; FGPDSY1, FGPDSY2 Reference n=25.

7.5.7 Temporal and Seasonal Changes in Fish Assemblage Structure

In addition to the changes already presented (Sections 7.5.2 to 7.5.6), CAP analyses suggested there has been a change in the relative abundance of the fish assemblage between surveys, i.e. from the Baseline to FGPDSY1 and FGPDSY2. Some of the species analysed in Sections 7.5.2 to 7.5.6 showed a change in relative abundance between surveys, which is likely to reflect natural temporal variation. For example, *T. pallimaculatus* was correlated in the direction of Baseline surveys on the CAP plot (Figure 7-10) and so was a CAP selected species. The relative abundance of *T. pallimaculatus* decreased significantly at both Reference and MDF Sites from the Baseline to FGPDSY1 and FGPDSY2 (Table 7-37, Table 7-38, Figure 7-22). *T. pallimaculatus* was also selected as a dominant species in both sand/sessile invertebrate habitat and macroalgal habitat as it was abundant in both habitats during the Baseline. In addition, the macroalgae-dominant species *C. pictoides* was abundant in macroalgae habitat during the Baseline, but was not recorded in this habitat during FGPDSY1, and only one individual was recorded in this habitat during FGPDSY2 (Figure 7-20). Despite these observations, many of the individual species that were investigated did not show a significant change in abundance between surveys.

Table 7-37 Results of PERMANOVA Tests with Visibility at a Covariate for Changes in the Relative Abundance of the CAP Selected Species *Torquigener pallimaculatus*

Source	df	SS	MS	Pseudo-F	P(perm)	Perms
Visibility	1	125.22	125.22	4.71	0.031	9821
Survey	**2**	**411.70**	**205.85**	**7.74**	**<0.001**	**9949**
IvR	1	22.79	22.79	0.86	0.375	9850
Survey × IvR	*2*	*28.24*	*14.12*	*0.53*	*0.601*	*9939*
Residual	193	5133.20	26.60			
Total	199	5721.20				

Notes:

Italicised text indicates terms of interest.

'Survey' was statistically significant, but no statistically significant term of interest was detected.

Table 7-38 Results of Pairwise Tests for Changes in the Relative Abundance of the CAP Selected Species *Torquigener pallimaculatus*, for Pairs of Levels of the Factor 'Survey'.

Groups	t	P(perm)	Perms
Baseline, FGPDSY1	**2.55**	**0.012**	**9838**
Baseline, FGPDSY2	**2.98**	**0.002**	**9859**
FGPDSY1, FGPDSY2	1.25	0.189	9942

Note: Bold text indicates a statistically significant term of interest at α=0.05.

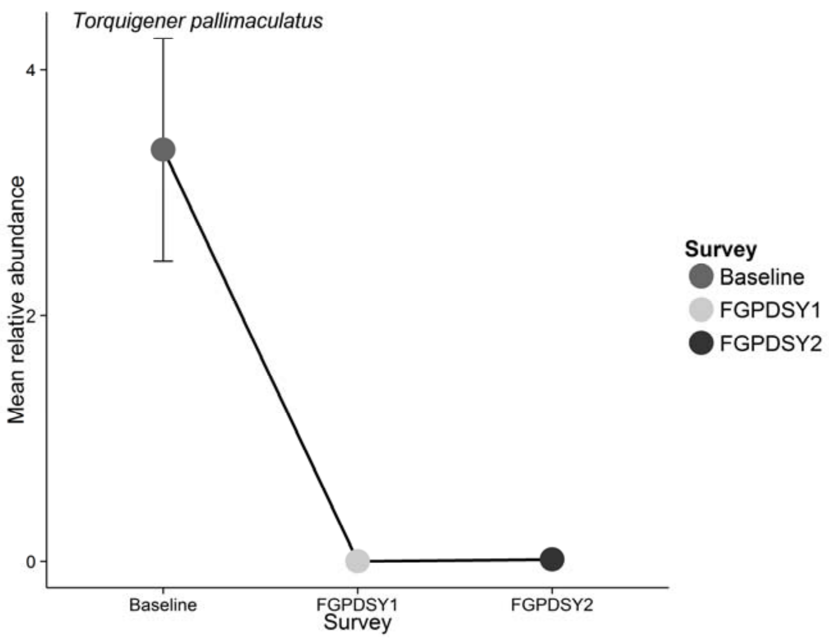


Figure 7-22 Mean Relative Abundance per Stereo-BRUVs Deployment of *Torquigener pallimaculatus*

Notes:

Error bars to 1 SE.

Baseline MDF n=27; Baseline Reference n=53; FGPDSY1, FGPDSY2 MDF n=20; FGPDSY1, FGPDSY2 Reference n=40.

7.6 Discussion and Conclusions

During FGPDSY2, distinct fish assemblage characteristics were described in each of four habitat types: macroalgae, bare sand, sand with sessile invertebrates, and rock armour. The rock armour classification describes the bermed rubble that protects the OFGPS. During FGPDSY2 this rock armour had been colonised by some macroalgae, but had not yet been colonised by large macroalgae or sessile invertebrate benthos. Rock armour habitat had the highest average species richness at 23 species per stereo-BRUVs deployment and second highest relative abundance of fish (behind sessile invertebrate habitat) at 74 individuals per deployment. Sessile invertebrate habitat had, on average, 15 species per deployment and the highest average abundance of fish at 88. Macroalgae habitat had, on average, 14 species and 26 individuals per deployment. Sand habitat had the lowest average number of species per deployment at five, and the lowest mean abundance at 19 fish per deployment. The most commonly observed fish during FGPDSY2 were Scombridae spp. (mackerel species), *Pentapodus porosus* (Northwest Threadfin Bream), *Echeneis naucrates* (Sharksucker), *Abalistes stellatus* (Starry Triggerfish), and *Sillago* spp. (whiting).

As FGPDSY1 and FGPDSY2 surveys were required to be conducted at a different time of year to the Baseline surveys (October–November instead of February–March), temporal and seasonal variability in habitats and fish assemblage is likely to have contributed to differences between the Baseline and Post-Development Surveys. However, temporal and/or seasonal differences are predicted to be consistent between MDF and Reference Sites. As a result, any change between the Baseline, FGPDSY1, and FGPDSY2 at MDF Sites is likely to reflect an impact of installation of the OFGPS and not be a result of temporal or seasonal variability.

Visibility has an influence on the number of species and individuals viewed. During the Baseline, visibility was lowest at MDF Sites due to a combination of strong currents and bare sand habitats (Watson *et al*. 2010). Visibility was particularly low during the 2009 Baseline survey (2–5 m), with a few deployments excluded from analyses with visibility <2 m (Watson *et al*. 2010). In contrast, visibility was improved during FGPDSY1 (4–9 m) and FGPDSY2 (3.5–9 m), particularly at MDF Sites (FGPDSY1, 6–9 m; FGPDSY2, 4.5–9 m). The potentially confounding influence of this change in visibility was taken into account during statistical analysis by including visibility as a covariate. In some cases, there appears to be change between the Baseline, FGPDSY1 and FGPDSY2 that is indicative of an impact (e.g. increases in species richness in sand/sessile invertebrate habitat and increases in *Nemipterus* spp. across all habitats), but this change was statistically attributable to the changes in visibility.

Over and above the effects of changes in visibility, fish assemblages as a whole were found to have changed significantly at Reference Sites between surveys. This change was not reflected in MDF Site data. The disparity in trajectories of change between MDF and Reference Sites may indicate an impact of installation of the OFGPS evident during FGPDSY1. Species richness was found to be significantly greater at macroalgal MDF Sites than at Reference Sites during FGPDSY1, but during FGPDSY2, species richness at MDF and Reference Sites in macroalgal habitat was again similar. This change is consistent with a positive pulse response to pipeline construction followed by a recovery to Baseline levels ('discrete pulse' [Glasby and Underwood 1996]). However, it seems more likely that the change is due to variation in observed habitat. Statistical analyses were based on mapped habitats rather than those habitats that were observed on video footage. Therefore, three Reference Sites were classed as macroalgae for these analyses and HDD1 was classified as a macroalgal MDF Site. However, during FGPDSY2, the dominant habitat observed at MDF Site HDD1 was sand, and only two of the five deployments had macroalgae habitat visible within the field of view. The recorded decrease in species richness during FGPDSY2 to a level similar to that at Reference Sites may be due to this change in the observed habitat. During both FGPDSY1 and FGPDSY2, macroalgae was recorded as the dominant habitat type at only one Reference Site, but during the Baseline, macroalgae was the dominant habitat observed at two of these three Reference Sites. This observed decline in dominant macroalgae habitat is likely to be associated with the measured decrease in species richness at macroalgal Reference Sites.

The observed variation in the classification of macroalgae as the dominant habitat may be due to the patchiness of this habitat and the orientation of the stereo-BRUVs upon deployment. However, during FGPDSY1 a statistically significant decline in the percent cover of macroalgae at MDF Sites was reported (Chevron Australia 2014b). It was concluded that installation of the OFGPS may have contributed to this detected decline in macroalgal percent cover at MDF Sites, or it may have been a result of natural temporal variation (Chevron Australia 2014b). If the change in macroalgal cover is shown to be a result of installation of the OFGPS, rather than natural variation or stereo-BRUVs orientation, the recorded positive pulse response in species richness may be a change due to the installation of the OFGPS.

A change that indicates a positive impact of installation of the OFGPS was detected for two species in sand/sessile invertebrate MDF Sites. *C. fulvoguttatus* and *Nemipterus* spp. were recorded in greater abundance at sand/sessile invertebrate MDF Sites than at Reference Sites during both FGPDSY1 and FGPDSY2. During the Baseline, the abundance of these species was similar at MDF and Reference Sites. *C. fulvoguttatus* was selected from the CAP analysis as being associated with FGPDSY1 and FGPDSY2 MDF Sites. *Nemipterus* spp. was selected as a dominant species in sand/sessile invertebrate habitat. These species are both mobile, but have known associations with reef (Allen *et al*. 2003; Allen 2004; Froese and Pauly 2014). However, both have also been observed over all habitats during the surveys (Appendix 1), showing that these species travel some distance from their preferred reef habitat. Therefore, the addition of rock armour habitat likely benefited these species, and their abundance increased throughout the MDF Sites even though rock armour was the dominant observed habitat only at Site FGI1. However, the stereo-BRUVs deployments at sand and sessile invertebrate MDF Sites were often deployed in bare sand habitat near the rock-armoured pipeline.

The addition of rock armour associated with the OFGPS installation has provided a more structurally complex habitat (previously, bare sand was prevalent). The creation of a new benthic habitat (rock armour) at the OFPGS is likely to have attracted species associated with that type of reef habitat. Increasing habitat complexity is known to facilitate higher species diversity and abundance by providing shelter (Hixon and Beets 1993; Harman *et al*. 2003; Gratwicke and Speight 2005a, 2005b; Graham *et al*. 2006) and greater availability of prey (Heck and Wetstone 1977; Gilinsky 1984; Harman *et al*. 2003). The rocky habitat that has been created along the pipeline does not yet show much colonisation by macroalgae or sessile invertebrates. However, as time passes, it is expected that benthic colonisation would continue, and the fish assemblage associated with the MDF Sites would continue to change with the benthos.

Fish assemblages were also found to differ significantly between the Baseline, FGPDSY1, and FGPDSY2 at both MDF and Reference Sites (significant result for factor ‘Survey’). Such changes indicate temporal or seasonal variation in habitats or fish assemblages. The relative abundance of two species was found to decrease significantly from the Baseline to FGPDSY1 and FGPDSY2. *C. pictoides* was abundant during the Baseline and was selected as a dominant species for macroalgal habitat. However, only one individual was recorded during each of the FGPDSY1 and FGPDSY2 surveys. Although there is little published information available for this species, seasonal variation in abundance has been reported for *Coris julis* (Rainbow Wrasse), a congener of *C. pictoides*. On an artificial reef in the Mediterranean, *C. julis* was found to increase in abundance during summer, before decreasing during winter and spring (Relini *et al*. 1994). It is possible that *C. pictoides* might show similar seasonal patterns in abundance at Barrow Island. Baseline surveys were conducted in late summer–autumn (March 2009 and February/March 2010), while FGPDSY1 and FGPDSY2 were conducted in spring (October/November).

A similar pattern was observed for *T. pallimaculatus*, which was abundant during the Baseline and was selected as a dominant species in both macroalgae and sand/sessile invertebrate habitats. A statistically significant change was detected for the factor ‘Survey’ for this species at both MDF and Reference Sites. It was not recorded at all during FGPDSY1, despite improved visibility, and only one individual was recorded during FGPDSY2. The abundance of this species varied between the 2009 and 2010 Baseline surveys, so it is possible that its abundance was very low during FGPDSY1 and FGPDSY2 due to natural processes such as seasonal variation in recruitment. Although there is little ecological information available for this species, marked annual variations in the abundance of *Torquigener pleurogramma* (Weeping Toadfish), a congener, have been recorded in the Swan Estuary, Western Australia, as a result of large differences in recruitment (Potter *et al*. 1988). It is also possible that a decline in the abundances of *T. pallimaculatus* may be linked to an increase in the prevalence of their predators. For example, *L. sceleratus* was one of the most commonly observed fish species during FGPDSY1 and is a known predator of pufferfish (Kalogirou 2013).

In summary, an increase in the relative abundance of some species from the Baseline to FGPDSY1 and FGPDSY2 at MDF Sites likely reflects a change as a consequence of offshore pipe laying. This potential impact may be linked to the provision of habitat (rock armour) at MDF Sites. Temporal and seasonal variability in fish assemblage structure likely influenced the structure of fish assemblages as multivariate relative abundance data were observed to change at both MDF and Reference Sites between the Baseline and Post-Development Surveys.

8.0 Conclusions and Recommendations

This Post-Development Coastal and Marine State and Environment Impact Report: Offshore Feed Gas Pipeline System and Marine Component of the Shore Crossing, Year 2: 2014 has been prepared to meet the requirements of Condition 15 of Statement No. 769. The purpose of this Report, as stated in Condition 15.3 of Statement No. 769, is to report the results to the Minister, including detecting changes to marine ecological elements.

Table 8-1 summarises the findings of this Report.

Table 8-1 Summary of Findings for each Ecological Element for FGPDSY2

Ecological Element	Conclusions
Non-coral Benthic Macroinvertebrates	• No change was detected in the abundance or composition of non-coral benthic macroinvertebrates at MDF or Reference Sites between the Baseline and Post-Development Surveys.
Macroalgae	• The number of macroalgal taxa recorded, and the diversity of all algal divisions, was higher in FGPDSY2 than in the Baseline. The dominant and subdominant macroalgal taxa were variable at most sites between surveys. These changes are likely to reflect natural variation and were not likely to be associated with offshore pipe-laying activities. • No significant differences in macroalgal percent cover and macroalgal and seagrass combined biomass were detected between the Baseline and FGPDSY2 within the MDF and at the Reference Sites, but a large increase in macroalgal percent cover at the Reference Sites during FGPDSY2 resulted in significant differences being detected between the MDF and Reference Sites in FGPDSY2. Although there was some evidence to suggest that offshore pipe-laying activities may have resulted in a detected change in macroalgae at the MDF Sites between the Baseline and FGPDSY1, a significant increase in macroalgal percent cover was recorded between FGPDSY1 and FGPDSY2, resulting in no detectable difference in macroalgal percent cover and macroalgal and seagrass combined biomass at MDF Sites between the Baseline and FGPDSY2. Therefore, if the detected changes between the Baseline and FGPDSY1 were an impact of offshore pipe-laying activities, these changes were only temporary, with a return to a state with no detectable difference to Baseline levels by FGPDSY2.
Seagrass	• Dominant seagrass taxa remained the same between the Baseline and FGPDSY2. • No change in seagrass percent cover was detected at MDF or Reference Sites among survey years or between MDF and Reference Sites within survey years. • A significant difference was detected in macroalgal and seagrass combined biomass between the MDF and Reference Sites in FGPDSY2, but not between FGPDSY2 and the Baseline within the MDF. There was little seagrass in the combined macroalgal and seagrass biomass samples, so this difference reflects changes in macroalgal biomass rather than seagrass biomass. • Because no significant difference was detected in seagrass percent cover among MDF and Reference Sites, there is no evidence to suggest that offshore pipe-laying activities resulted in any change in seagrass within the MDF between the Baseline and FGPDSY2.

Ecological Element	Conclusions
Demersal Fish	• No changes in total number of individuals, species richness, fish length, or abundance of dominant species within macroalgal habitat were detected at MDF Sites between the Baseline and FGPDSY2. • Detected changes (decrease) in relative abundance of the overall fish assemblage were observed at Reference Sites from the Baseline to FGPDSY1 and FGPDSY2, but were not observed at MDF Sites. However, none of the species that were investigated individually showed statistically significant changes between surveys at Reference Sites. • Species richness was found to be significantly greater at macroalgal MDF Sites than at Reference Sites during FGPDSY1, but during FGPDSY2, species richness at MDF and Reference Sites in macroalgal habitat was again similar. This detected change may indicate a positive ‘pulse’ response to pipeline construction followed by a return to Baseline levels. • Sand/sessile invertebrate dominant species *Nemipterus* spp. (Threadfin Bream) and *Carangoides fulvoguttatus* (Gold-spotted Trevally) were significantly more abundant at sand/sessile invertebrate MDF Sites during FGPDSY1 and FGPDSY2 than during the Baseline; likely due to the creation of an additional benthic habitat (rock armour) through installation of the OFGPS.

Although some minor changes in ecological elements were detected between the Baseline and FGPDSY1 at MDF Sites, by FGPDSY2 ecological elements appear to have returned to a state where there is no detectable difference to Baseline levels. The only potential remaining effects of the OFGPS at sites within the MDF are i) an increased abundance of two demersal fish species potentially as a result of increased habitat complexity (rock armour), and ii) minor differences in macroalgal cover and biomass when compared to Reference Sites, which may have been caused by natural spatial or temporal variation and may not be project-attributable.

This is the second Post-Development Survey undertaken since completing offshore pipe-laying activities for the OFGPS. Condition 14.4(vi) of Statement No. 769 requires three Post-Development Surveys for the OFGPS, unless otherwise determined by the Minister. In light of the evidence presented in this Report, further surveys to monitor recovery will be of limited usefulness. Already, minor impacts that may have been associated with the OFGPS on ecological elements detected in FGPDSY1 were not detected in FGPDSY2, and any remaining effects (i.e. increased presence of two demersal fish species) are likely to persist over time due to the increased habitat complexity created by the rock armour.

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Appendix 1 Demersal Fish Species

Table A1.1 List of all fish species recorded from 140 stereo-BRUVs deployments conducted west of Barrow Island from the 2009 and 2010 Baseline surveys, 2013 FGPDSY1, and 2014 FGPDSY2

Information on the relative abundance of fish is presented as well as the habitats where they were observed (M = macroalgae, R = rock armour, S = sand, Ses = sessile invertebrates). In the Authority column, parentheses indicate where this was not the original taxonomic authority.

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Abalistes stellatus	Balistidae	Starry Triggerfish	(Anonymous, 1798)	14	32	2	19	18.2	14	42	36.7	4	42	28.3	4	M, R, S, Ses
Abudefduf bengalensis	Pomacentridae	Bengal Sergeant	(Bloch, 1787)							4	3.3	63	2	3.3	65	R
Acanthurus dussumieri	Acanthuridae	Pencil Surgeonfish	(Valenciennes, 1835)										2	1.7	76	M
Acanthurus grammoptilus	Acanthuridae	Inshore Surgeonfish	Richardson, 1843							10	5	47	16	10.0	29	M, R
Acanthurus mata	Acanthuridae	Pale Surgeonfish	(Cuvier, 1829)										16	1.7	77	R
Acreichthys tomentosus	Monacanthidae	Bristle-Tail Leatherjacket	(Linnaeus, 1758)										1	1.7	78	Ses
Alepes spp.	Carangidae	Small Mouthed Scad								107	8.3	31				M, Ses
Aluterus scriptus	Monacanthidae	Scrawled Leatherjacket	(Osbeck, 1765)				1	1.8	64							Ses
Amphiprion clarkii	Pomacentridae	Clark's Anemonefish	(Bennett, 1830)	1	4	29										Ses
Anampses lennardi	Labridae	Blue-and-Yellow Wrasse	Scott, 1959				3	1.8	65	2	1.7	83				M, R
Arius thalassinus	Ariidae	Giant Sea Catfish	(Rüppell, 1837)	2	4	30										Ses
Arothron stellatus	Tetraodontidae	Starry Puffer	(Bloch & Schneider, 1801)				1	1.8	66				1	1.7	79	M, S
Aspidontus taeniatus	Blenniidae	False Cleanerfish	Quoy & Gaimard, 1834	6	12	17	4	3.6	51							M, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Atule mate	Carangidae	Barred Yellowtail Scad	(Cuvier, 1833)	33	24	5	23	1.8	67	96	13.3	25	135	20.0	11	M, R, S, Ses
Balistoides viridescens	Balistidae	Titan Triggerfish	(Bloch & Schneider, 1801)										1	1.7	80	M
Blenniidae spp.	Blenniidae	Blenny Species					1	1.8	68	1	1.7	84				M, S
Bodianus bilunulatus	Labridae	Saddleback Pigfish	(Lacépède, 1801)				2	1.8	69							Ses
Bodianus perditio	Labridae	Goldspot Pigfish	(Quoy & Gaimard, 1834)				2	1.8	70				1	1.7	81	S, Ses
Caesio cuning	Caesionidae	Yellowtail Fusilier	(Bloch, 1791)										11	1.7	82	R
Carangoides caeruleopinnatus	Carangidae	Onion Trevally	(Rüppell, 1830)				1	1.8	71							S
Carangoides ferdau	Carangidae	Blue Trevally	(Forsskål, 1775)				2	3.6	52	8	6.7	38	4	3.3	66	M, S, Ses
Carangoides fulvoguttatus	Carangidae	Gold-Spotted Trevally	(Forsskål, 1775)	14	20	8	27	10.9	25	45	26.7	8	37	15.0	18	M, R, S, Ses
Carangoides gymnostethus	Carangidae	Bludger Trevally	(Cuvier, 1833)				49	12.7	21	37	18.3	13	21	8.3	32	M, R, S, Ses
Carangoides orthogrammus	Carangidae	Thicklip Trevally	(Jordan & Gilbert, 1882)	4	4	31										Ses
Caranx ignobilis	Carangidae	Giant Trevally	(Forsskål, 1775)	2	4	32	4	7.3	37	5	8.3	32	3	3.3	67	M, R, S, Ses
Caranx lugubris	Carangidae	Black Trevally	Poey, 1860				1	1.8	72							S
Caranx papuensis	Carangidae	Brassy Trevally	Alleyne & Macleay, 1877				2	1.8	73	2	3.3	64	7	5.0	48	R, S
Carcharhinus amblyrhynchos	Carcharhinidae	Grey Reef Shark	(Bleeker, 1856)							1	1.7	85	1	1.7	83	M, S
Carcharhinus amboinensis	Carcharhinidae	Pigeye Shark	(Müller & Henle, 1839)							1	1.7	86	1	1.7	84	R, S

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Carcharhinus melanopterus	Carcharhinidae	Blacktip Reef Shark	(Quoy & Gaimard, 1824)				1	1.8	74	5	6.7	39	1	1.7	85	M, Ses
Carcharhinus plumbeus	Carcharhinidae	Sandbar Shark	(Nardo, 1827)										3	5.0	49	S, Ses
Cephalopholis boenak	Serranidae	Brownbarred Rockcod	(Bloch, 1790)	1	4	33							1	1.7	86	R, Ses
Cephalopholis miniata	Serranidae	Coral Rockcod	(Forsskål, 1775)				1	1.8	75	1	1.7	88	2	3.3	68	R, S, Ses
Chaetodon assarius	Chaetodontidae	Western Butterflyfish	Waite, 1905				10	9.1	31	3	3.3	65				M, R, S, Ses
Chaetodon aureofasciatus	Chaetodontidae	Goldstripe Butterflyfish	Macleay, 1878							1	1.7	89				R
Chaetodontoplus duboulayi	Pomacanthidae	Scribbled Angelfish	(Günther, 1867)	1	4	34	2	3.6	53	8	6.7	40	6	6.7	41	R, Ses
Chaetodontoplus personifer	Pomacanthidae	Yellowtail Angelfish	(McCulloch, 1914)				4	5.5	42	3	5	48	5	5.0	50	M, R, Ses
Cheilinus trilobatus	Labridae	Tripletail Maori Wrasse	(Lacepède, 1801)										1	1.7	87	M
Chelmon marginalis	Chaetodontidae	Margined Coralfish	Richardson, 1842				3	3.6	54	12	10	29	8	6.7	42	M, R, Ses
Chlorurus microrhinos	Scaridae	Steephead Parrotfish	(Bleeker, 1854)							1	1.7	90				R
Choerodon cauteroma	Labridae	Bluespotted Tuskfish	Gomon & Allen, 1987				3	3.6	55	30	21.7	11	16	13.3	22	M, R, S, Ses
Choerodon cephalotes	Labridae	Purple Tuskfish	(Castelnau, 1875)	2	8	22	6	9.1	32	14	18.3	14	6	10.0	30	M, R, S, Ses
Choerodon cyanodus	Labridae	Blue Tuskfish	(Richardson, 1843)	1	4	35	4	5.5	43	19	20	12	22	18.3	12	M, R, S, Ses
Choerodon schoenleinii	Labridae	Blackspot Tuskfish	(Valenciennes, 1839)	1	4	36	3	5.5	44	13	16.7	16	7	11.7	25	M, R, S, Ses
Choerodon vitta	Labridae	Redstripe Tuskfish	Ogilby, 1910				5	3.6	56				1	1.7	88	Ses
Chromis fumea	Pomacentridae	Smoky Puller	(Tanaka, 1917)	6	4	37	25	7.3	38							M, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Coradion altivelis	Chaetodontidae	Highfin Coralfish	(McCulloch, 1916)										1	1.7	89	R
Coradion chrysozonus	Chaetodontidae	Orangebanded Coralfish	(Cuvier, 1831)	1	4	38	6	7.3	39	6	8.3	33	2	3.3	69	R, S, Ses
Coris caudimacula	Labridae	Spot-Tail Wrasse	(Quoy & Gaimard, 1834)				3	1.8	76	1	1.7	91	3	5.0	51	M, S, Ses
Coris pictoides	Labridae	Pixy Wrasse	Randall & Kuiter, 1982	2	4	39	41	25.5	6	1	1.7	92	1	1.7	90	M, S, Ses
Diagramma labiosum	Haemulidae	Painted Sweetlips	Macleay, 1883							3	5	49	6	5.0	52	M, R, S
Diploprion bifasciatum	Grammistidae	Barred Soapfish	Cuvier, 1828				1	1.8	77	1	1.7	93	1	1.7	91	R, Ses
Echeneis naucrates	Echeneidae	Sharksucker	Linnaeus, 1758	9	20	9	21	25.5	7	37	41.7	3	28	31.7	3	M, R, S, Ses
Elops hawaiensis	Elopidae	Hawaiian Giant Herring	Regan, 1909				1	1.8	78	4	6.7	41	4	5.0	53	M,R, S
Epinephelus bilobatus	Serranidae	Frostback Rockcod	Randall & Allen, 1987				16	12.7	22	14	13.3	26	18	16.7	15	M, R, S, Ses
Epinephelus coioides	Serranidae	Goldspotted Rockcod	(Hamilton, 1822)				1	1.8	79				4	6.7	43	M, R, Ses
Epinephelus fasciatus	Serranidae	Blacktip Rockcod	(Forsskål, 1775)	1	4	40				3	1.7	94	8	8.3	33	R, Ses
Epinephelus lanceolatus	Serranidae	Queensland Groper	(Bloch, 1790)							1	1.7	95				S
Epinephelus malabaricus	Serranidae	Blackspotted Rockcod	(Bloch & Schneider, 1801)							3	3.3	66	1	1.7	92	M
Epinephelus multinotatus	Serranidae	Rankin Cod	(Peters, 1877)				2	1.8	80	11	6.7	42	23	8.3	34	R, S
Epinephelus quoyanus	Serranidae	Longfin Rockcod	(Valenciennes, 1830)							4	3.3	67	4	6.7	44	R, Ses
Epinephelus rivulatus	Serranidae	Chinaman Rockcod	(Valenciennes, 1830)				3	5.5	45	6	8.3	34	4	5.0	54	M, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Feroxodon multistriatus	Tetraodontidae	Ferocious Puffer	(Richardson, 1854)	2	8	23	7	12.7	23	3	5	50	11	16.7	16	M, R, S, Ses
Fistularia commersonii	Fistulariidae	Smooth Flutemouth	(Rüppell, 1838)										1	1.7	93	S
Galeocerdo cuvier	Carcharhinidae	Tiger Shark	(Péron & Lesueur, 1822)				1	1.8	81	2	3.3	68	1	1.7	94	M, S, Ses
Glaucosoma magnificum	Glaucosomatidae	Threadfin Pearl Perch	(Ogilby, 1915)	28	4	41	17	5.5	46							M, Ses
Gnathanodon speciosus	Carangidae	Golden Trevally	(Forsskål, 1775)	27	16	14	59	18.2	15	68	25	9	62	21.7	9	M, R, S, Ses
Halichoeres melanochir	Labridae	Orangefin Wrasse	(Fowler & Bean, 1928)										1	1.7	95	M
Halichoeres nebulosus	Labridae	Cloud Wrasse	(Valenciennes, 1839)				18	10.9	26	4	3.3	69	2	1.7	96	M, S
Halichoeres trimaculatus	Labridae	Threespot Wrasse	(Quoy & Gaimard, 1834)										3	1.7	97	M
Hemipristis elongata	Hemigaleidae	Fossil Shark	(Klunzinger, 1871)				1	1.8	82							Ses
Heniochus acuminatus	Chaetodontidae	Longfin Bannerfish	(Linnaeus, 1758)				1	1.8	83	3	5	51	7	8.3	35	M, R
Himantura fai	Dasyatidae	Pink Whipray	Jordan & Seale, 1906				8	1.8	84	1	1.7	96	3	5.0	55	R, S
Himantura granulata	Dasyatidae	Mangrove Whipray	(Macleay, 1883)				1	1.8	85							M
Himantura jenkinsii	Dasyatidae	Jenkins' Whipray	(Annandale, 1909)							3	5	52				M, R
Iniistius spp.	Labridae	Razorfish Species		7	20	10	17	23.6	9	12	11.7	27	13	11.7	26	S, Ses
Kyphosus vaigiensis	Kyphosidae	Brassy Drummer	(Quoy & Gaimard, 1825)							50	1.7	97				M
Labroides dimidiatus	Labridae	Common Cleanerfish	(Valenciennes, 1839)				7	7.3	40	1	1.7	98	9	8.3	36	M, R, S, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Lagocephalus lunaris	Tetraodontidae	Rough Golden Toadfish	(Bloch & Schneider, 1801)	2	8	24				5	5	53	1	1.7	98	S
Lagocephalus sceleratus	Tetraodontidae	Silver Toadfish	(Gmelin, 1789)				17	14.5	19	43	36.7	5	27	25.0	7	M, R, S, Ses
Leptojulis cyanopleura	Labridae	Shoulderspot Wrasse	(Bleeker, 1853)				23	9.1	33	1	1.7	99				M
Lethrinus atkinsoni	Lethrinidae	Yellowtail Emperor	(Seale, 1910)										2	1.7	99	R
Lethrinus genivittatus	Lethrinidae	Threadfin Emperor	Valenciennes, 1830	17	20	11	97	18.2	16	136	23.3	10	104	15.0	19	M, R, S, Ses
Lethrinus laticaudis	Lethrinidae	Grass Emperor	Alleyne & Macleay, 1877	4	8	25	2	3.6	57	8	5	54	4	5.0	56	Ses
Lethrinus microdon	Lethrinidae	Smalltooth Emperor	(Valenciennes, 1830)										2	3.3	70	Ses
Lethrinus nebulosus	Lethrinidae	Spangled Emperor	(Forsskål, 1775)	2	8	26	8	9.1	34	14	15	22	22	11.7	27	M, R, S, Ses
Lethrinus olivaceus	Lethrinidae	Longnose Emperor	Valenciennes, 1830							1	1.7	100	1	1.7	100	R, Ses
Lethrinus punctulatus	Lethrinidae	Blue-Lined Emperor	(Carpenter, pers comm)				5	1.8	86	301	31.7	6	163	16.7	17	R, S, Ses
Lethrinus variegatus	Lethrinidae	Variegated Emperor	Valenciennes, 1830	10	8	27	18	10.9	27	42	16.7	17	57	13.3	23	M, S, Ses
Loxodon macrorhinus	Carcharhinidae	Sliteye Shark	Müller & Henle, 1839							1	1.7	101				S
Lutjanus carponotatus	Lutjanidae	Stripey Snapper	(Richardson, 1842)							6	8.3	35	2	3.3	71	M, R, Ses
Lutjanus lemniscatus	Lutjanidae	Darktail Snapper	(Valenciennes, 1828)							3	5	55	7	8.3	37	M, R
Lutjanus lutjanus	Lutjanidae	Bigeye Snapper	Bloch, 1790				2	1.8	87				1	1.7	101	M, Ses
Lutjanus sebae	Lutjanidae	Red Emperor	(Cuvier, 1828)							2	1.7	102	22	8.3	38	R, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Lutjanus vitta	Lutjanidae	Brownstripe Snapper	(Quoy & Gaimard, 1824)	12	4	42	13	10.9	28	103	11.7	28	32	6.7	45	M, R, S, Ses
Malacanthus brevirostris	Malacanthidae	Flagtail Blanquillo	Guichenot, 1848				4	1.8	88							M
Monacanthus chinensis	Monacanthidae	Fanbelly Leatherjacket	(Osbeck, 1765)				6	5.5	47							S, Ses
Naso annulatus	Acanthuridae	Ringtail Unicornfish	(Quoy & Gaimard, 1825)				5	5.5	48							M, Ses
Naso unicornis	Acanthuridae	Bluespine Unicornfish	(Forsskål, 1775)							2	3.3	70				M, R
Nebrius ferrugineus	Ginglymostomatidae	Tawny Shark	(Lesson, 1830)							2	3.3	71	1	1.7	102	M, R, S
Nemipterus spp.	Nemipteridae	Threadfin Bream Species		15	24	6	36	20	12	88	31.7	7	96	25.0	8	M, R, S, Ses
Neopomacentrus cyanomos	Pomacentridae	Regal Demoiselle	(Bleeker, 1856)										4	1.7	103	M
Neotrygon kuhlii	Dasyatidae	Bluespotted Maskray	(Müller & Henle, 1841)				1	1.8	89	1	1.7	103				M
Odonus niger	Balistidae	Redtooth Triggerfish	(Rüppell, 1836)	1	4	43										Ses
Ostracion cubicus	Ostraciidae	Yellow Boxfish	Linnaeus, 1758							1	1.7	104				Ses
Parachaetodon ocellatus	Chaetodontidae	Ocellate Butterflyfish	(Cuvier, 1831)							3	5	56				R, Ses
Paramonacanthus choirocephalus	Monacanthidae	Pigface Leatherjacket	(Bleeker, 1852)	8	16	15	21	23.6	10	1	1.7	105	3	5.0	57	M, S, Ses
Parapercis nebulosa	Pinguipedidae	Pinkbanded Grubfish	(Quoy & Gaimard, 1825)	4	16	16	7	9.1	35	2	1.7	106	3	5.0	58	S, Ses
Parupeneus barberinoides	Mullidae	Bicolour Goatfish	(Bleeker, 1852)	10	12	18	51	18.2	17	52	16.7	18	36	15.0	20	M, R, S, Ses
Parupeneus heptacanthus	Mullidae	Opalescent Goatfish	(Lacépède, 1802)	10	4	44	13	9.1	36	30	16.7	19	6	5.0	59	M, R, S, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Parupeneus indicus	Mullidae	Yellowspot Goatfish	(Shaw, 1803)				1	1.8	90	22	6.7	43	8	5.0	60	M, R, S,
Parupeneus spilurus	Mullidae	Blacksaddle Goatfish	(Bleeker, 1854)	2	4	45	24	14.5	20	10	5	57	2	3.3	72	M, R, Ses
Pastinachus spp.	Dasyatidae	Cowtail Stingray Species					1	1.8	91							M
Pentapodus emeryii	Nemipteridae	Purple Threadfin Bream	(Richardson, 1843)				2	1.8	92	16	16.7	20	25	18.3	13	M, R, S, Ses
Pentapodus porosus	Nemipteridae	Northwest Threadfin Bream	(Valenciennes, 1830)	154	32	3	304	45.5	3	419	50	2	244	33.3	2	M, R, S, Ses
Pentapodus vitta	Nemipteridae	Western Butterfish	Quoy & Gaimard, 1824	4	12	19	3	1.8	93	3	5	58	2	3.3	73	M, S, Ses
Plagiotremus rhinorhynchos	Blenniidae	Bluestriped Fangblenny	(Bleeker, 1852)	1	4	46	5	5.5	49							M, Ses
Platax batavianus	Ephippidae	Humphead Batfish	Cuvier, 1831	3	12	20	2	3.6	58	1	1.7	107	1	1.7	104	M, Ses
Platax orbicularis	Ephippidae	Round Batfish	(Forsskål, 1775)							2	3.3	72				M
Platax teira	Ephippidae	Roundface Batfish	(Forsskål, 1775)							1	1.7	108	1	1.7	105	M, S
Plectorhinchus gibbosus	Haemulidae	Brown Sweetlips	(Lacépède, 1802)							1	1.7	109	1	1.7	106	M, R
Plectorhinchus picus	Haemulidae	Dotted Sweetlips	(Cuvier, 1828)										1	1.7	107	Ses
Plectropomus spp.	Serranidae	Coral Trout					1	1.8	94	8	10	30	11	11.7	28	M, R, S, Ses
Pleuronectiforme s spp.	Bothidae, Pleuronectidae	Sand Flounder Species		1	2	56	4	2.7	63	4	2.5	82	7	8.3	39	S
Pomacanthus imperator	Pomacanthidae	Emperor Angelfish	(Bloch, 1787)										1	1.7	108	M
Pomacanthus sexstriatus	Pomacanthidae	Sixband Angelfish	(Cuvier, 1831)							3	3.3	73	3	3.3	74	M, Ses
Pomacentrus coelestis	Pomacentridae	Neon Damsel	Jordan & Starks, 1901				53	5.5	50				37	6.7	46	M, R, S

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Pomacentrus limosus	Pomacentridae	Muddy Damsel	Allen, 1992							2	3.3	74	19	6.7	47	M, R
Pomacentrus nagasakiensis	Pomacentridae	Blue Scribbled Damsel	(Tanaka, 1917)	1	4	47	20	12.7	24				3	1.7	109	M, S, Ses
Priacanthus blochii	Priacanthidae	Glasseye	Bleeker, 1853							12	3.3	75				R
Priacanthus hamrur	Priacanthidae	Lunartail Bigeye	(Forsskål, 1775)	1	4	48							1	1.7	110	R, Ses
Pristis clavata	Pristidae	Dwarf Sawfish	Garman, 1906				1	1.8	95							M
Pristotis obtusirostris	Pomacentridae	Gulf Damsel	(Günther, 1862)				29	3.6	59	1	1.7	110				M, S
Pseudobalistes flavimarginatus	Balistidae	Yellowmargin Triggerfish	(Rüppell, 1829)							1	1.7	111				M
Pseudomonacanthus peroni	Monacanthidae	Potbelly Leatherjacket	(Hollard, 1854)	1	4	49										S
Pterocaesio spp.	Caesionidae	Fusilier Species					3	3.6	60	22	5	59	15	1.7	111	M, S, Ses
Rachycentron canadum	Rachycentridae	Cobia	(Linnaeus, 1766)				3	3.6	61	3	3.3	76	1	1.7	112	R, S
Rhynchobatus australiae	Rhynchobatidae	Whitespotted Guitarfish	Whitely, 1939	2	8	28	12	21.8	11	4	6.7	44	5	8.3	40	M, S, Ses
Sarda orientalis	Scombridae	Oriental Bonito	(Temminck & Schlegel, 1844)										94	5.0	61	S
Scarus ghobban	Scaridae	Bluebarred Parrotfish	Forsskål, 1775							8	3.3	77	29	15.0	21	M, R, Ses
Scolopsis monogramma	Nemipteridae	Rainbow Monocle Bream	(Kuhl & van Hasselt, 1830)				8	10.9	29	29	18.3	15	18	21.7	10	M, R, S, Ses
Scomberoides commersonnianus	Carangidae	Giant Queenfish	Lacépède, 1801	2	4	50	5	7.3	41				3	5.0	62	M, S
Scombridae spp.	Scombridae	Mackerel Species		49	88	1	91	83.6	1	124	66.7	1	79	50.0	1	M, R, S, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Selaroides leptolepis	Carangidae	Yellowstripe Scad	(Kuhl & van Hasselt, 1833)	154	32	4	476	27.3	4	317	15	23	63	5.0	63	M, R, S, Ses
Seriola rivoliana	Carangidae	Highfin Amberjack	Valenciennes, 1833							1	1.7	112				S
Seriolina nigrofasciata	Carangidae	Blackbanded Amberjack	(Rüppell, 1829)	1	4	51				7	8.3	36	2	1.7	113	S, Ses
Siganus argenteus	Siganidae	Forktail Rabbitfish	(Quoy & Gaimard, 1825)							79	6.7	45				R, Ses
Siganus fuscescens	Siganidae	Dusky Rabbitfish	(Houttuyn, 1782)	6	4	52	53	10.9	30	50	5	60	41	10.0	31	M, R, S, Ses
Sillago spp.	Sillaginidae	Whiting Species	Whitley, 1943	15	20	12	85	25.5	8	39	16.7	21	111	26.7	5	M, S, Ses
Sphyraena forsteri	Sphyraenidae	Blackspot Barracuda	Cuvier, 1829							2	1.7	113				Ses
Sphyraena jello	Sphyraenidae	Pickhandle Barracuda	Cuvier, 1829				2	3.6	62	9	6.7	46	3	5.0	64	M, S, Ses
Sphyraena obtusata	Sphyraenidae	Striped Barracuda	Cuvier, 1829	21	4	53										Ses
Sphyraena qenie	Sphyraenidae	Blackfin Barracuda	Klunzinger, 1870							42	3.3	78				R, Ses
Sphyrna mokarran	Sphyrnidae	Great Hammerhead	(Rüppell, 1837)							2	3.3	79	1	1.7	114	M
Stegostoma fasciatum	Stegostomatidae	Zebra Shark	(Hermann, 1783)	1	4	54				2	3.3	80				S, Ses
Sufflamen chrysopterum	Balistidae	Eye-stripe Triggerfish	(Bloch & Schneider, 1801)										1	1.7	115	M
Sufflamen fraenatum	Balistidae	Bridled Triggerfish	(Latreille, 1804)							2	3.3	81	1	1.7	116	S, Ses
Symphorus nematophorus	Lutjanidae	Chinamanfish	(Bleeker, 1860)	1	4	55	13	20	13	3	5	61	8	13.3	24	M, R, S, Ses
Synodontidae spp.	Synodontidae	Lizardfish Species		6	24	7	18	27.3	5	5	8.3	37	11	18.3	14	M, S, Ses

Species (alphabetical order)	Family	Common Name	Authority	2009 Baseline Survey			2010 Baseline Survey			2013 FGPDSY1			2014 FGPDSY2			Habitat
				# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	# fish	% drops	Rank	
Thalassoma amblycephalum	Labridae	Bluehead Wrasse	(Bleeker, 1856)										12	1.7	117	S
Thalassoma lunare	Labridae	Moon Wrasse	(Linnaeus, 1758)				1	1.8	96	5	5	62	5	3.3	75	M, R
Torquigener pallimaculatus	Tetraodontidae	Rusty-spotted Toadfish	Hardy, 1983	6	20	13	262	50.9	2				1	1.7	75	M, R, S
Trichonotus setiger	Trichonotidae	Spotted Sand Diver	(Bloch & Schneider, 1801)				1	1.8	97							S
Variola louti	Serranidae	Yellowedge Coronation Trout	(Forsskål, 1775)										1	26.7	119	R
Upeneus tragula	Mullidae	Bartail Goatfish	Richardson, 1846	4	12	21	24	16.4	18	52	15	24	92	1.7	6	M, S, Ses
Zanclus cornutus	Zanclidae	Moorish Idol	(Linnaeus, 1758)							1	1.7	114				R

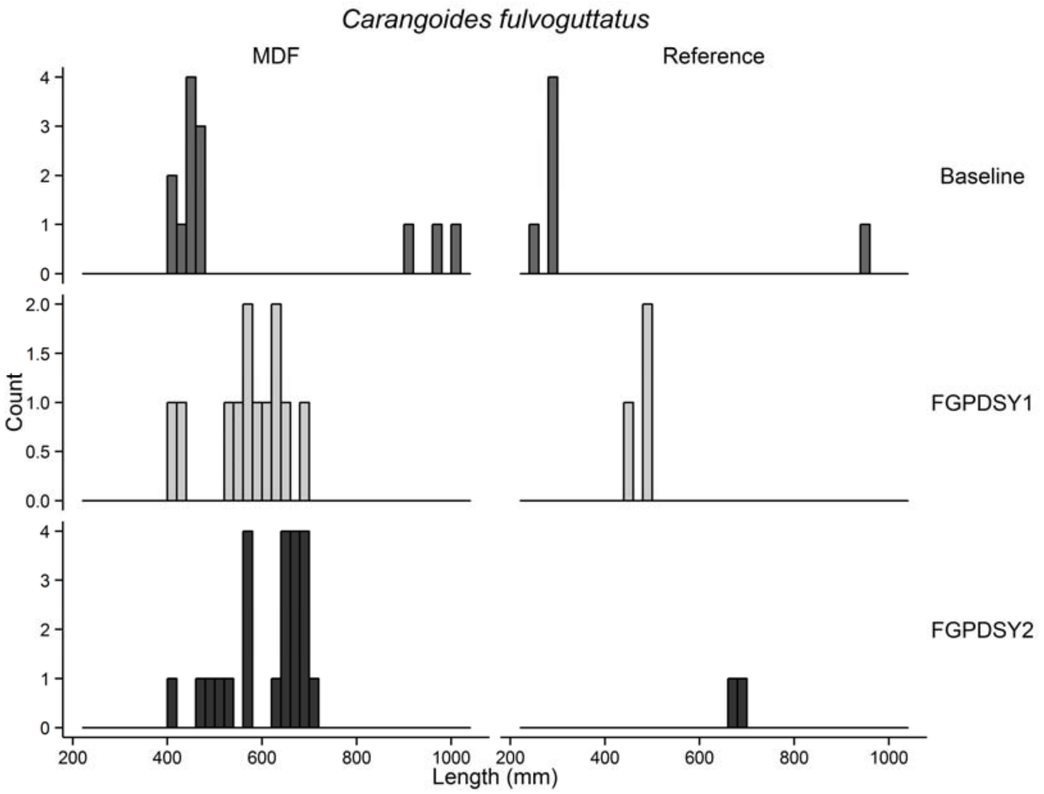
Appendix 2 Visibility Recorded During Demersal Fish Surveys

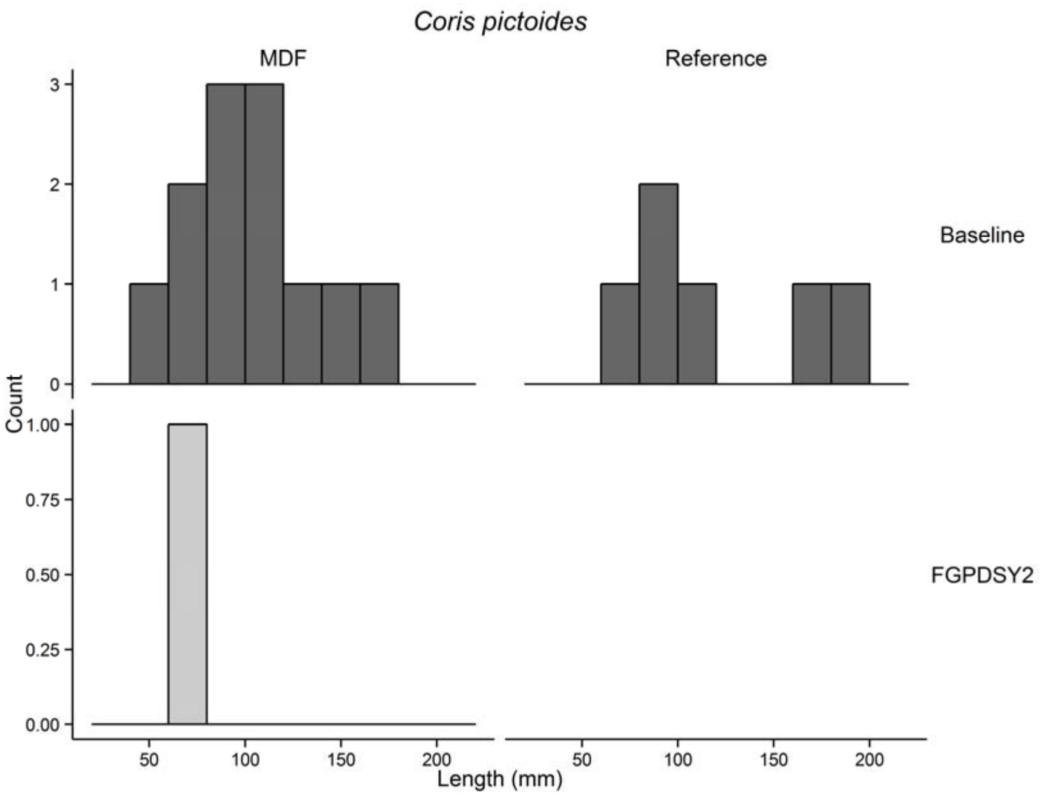
Table A2.1 Estimated visibility in front of the stereo-BRUVs on each of the 60 deployments conducted during FGPDSY2. Estimates were made immediately following settling of sediment when the system came to rest on the sea floor

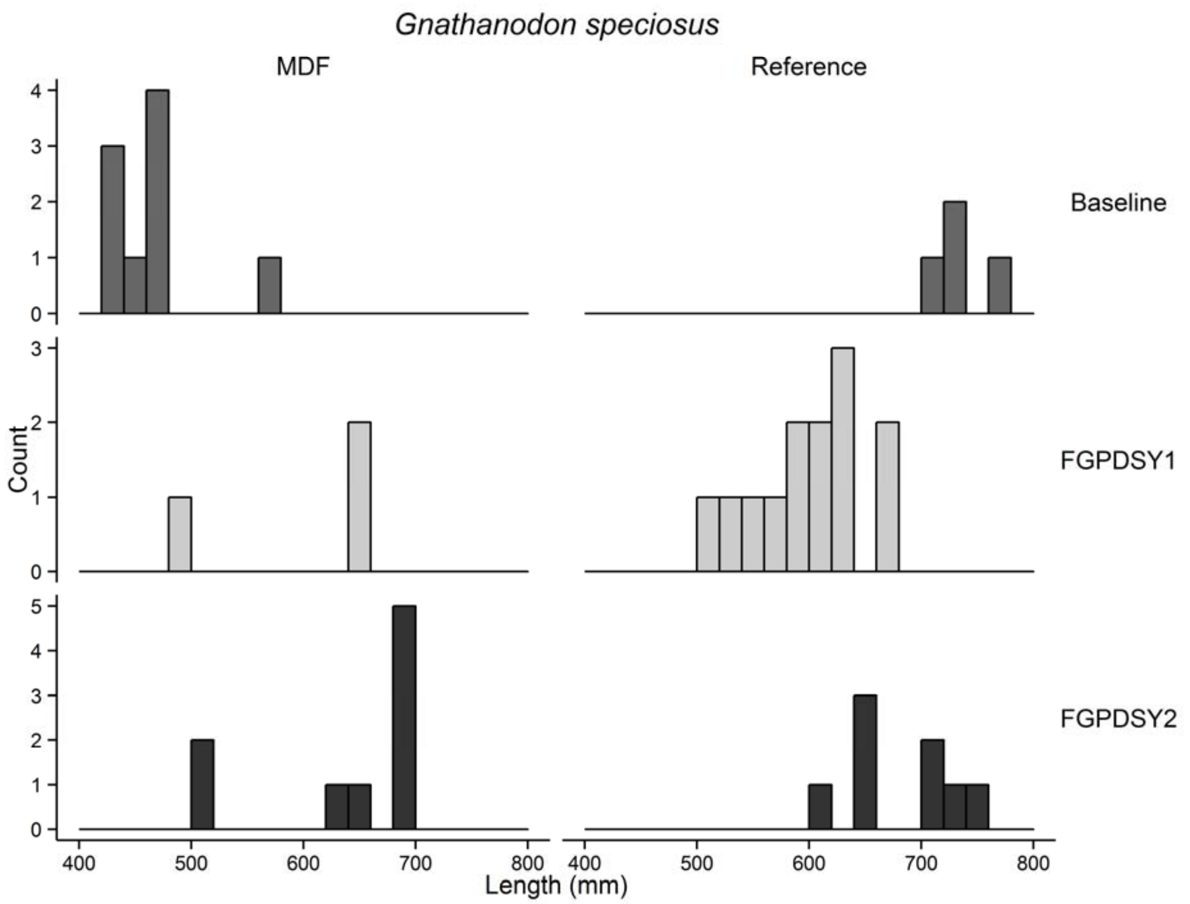
Stereo-BRUVs deployment	Visibility (m)	Stereo-BRUVs deployment	Visibility (m)
FGFR1-2	6	FGI4-1R	6
FGFR1-3	4	FGI4-2	5
FGFR1-4	4	FGI4-3	5.5
FGFR1-6	6	FGI4-4	5
FGFR1-7	3.5	FGI4-5R	9
FGFR2-2	4	FGN1-1	5
FGFR2-3	3.5	FGN1-2	5
FGFR2-4	4.5	FGN1-3	4.5
FGFR2-5	4	FGN1-4	4.5
FGFR2-6	4	FGN1-5	5.5
FGFR3-1	5.5	HDD1-1	4.5
FGFR3-2	5	HDD1-2	4.5
FGFR3-3	4.5	HDD1-3	4.5
FGFR3-4	4	HDD1-4	5.5
FGFR3-5	4	HDD1-5	5
FGFR4-1	5	HDDN1-1	5
FGFR4-2	5	HDDN1-2	4
FGFR4-3	5	HDDN1-3	4.5
FGFR4-4	5.5	HDDN1-4	5.5
FGFR4-5	5	HDDN1-5	5
FGI1-1	5	HDDN2-1	5.5
FGI1-2	5	HDDN2-2	6
FGI1-3	5.5	HDDN2-3	5.5
FGI1-4	5.5	HDDN2-5	6
FGI1-7	5.5	HDDN2-6	6
FGI2-1	5	HDDN3-1	3.5
FGI2-3	5	HDDN3-2	4
FGI2-4	5	HDDN3-3	4
FGI2-5	5.5	HDDN3-4	5
FGI2-6	6	HDDN3-5	5

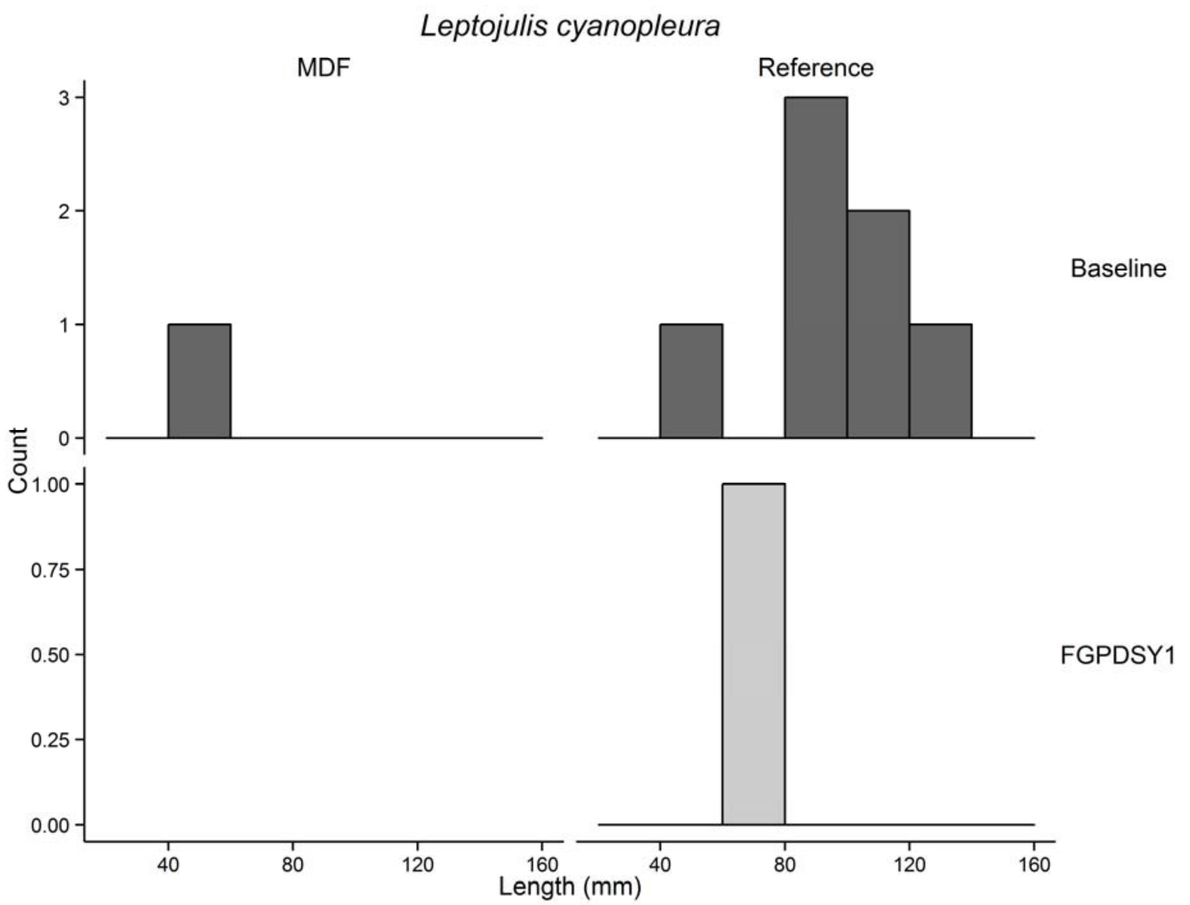
Appendix 3 Length-Frequency Histograms of each Macroalgal Habitat Dominant Species

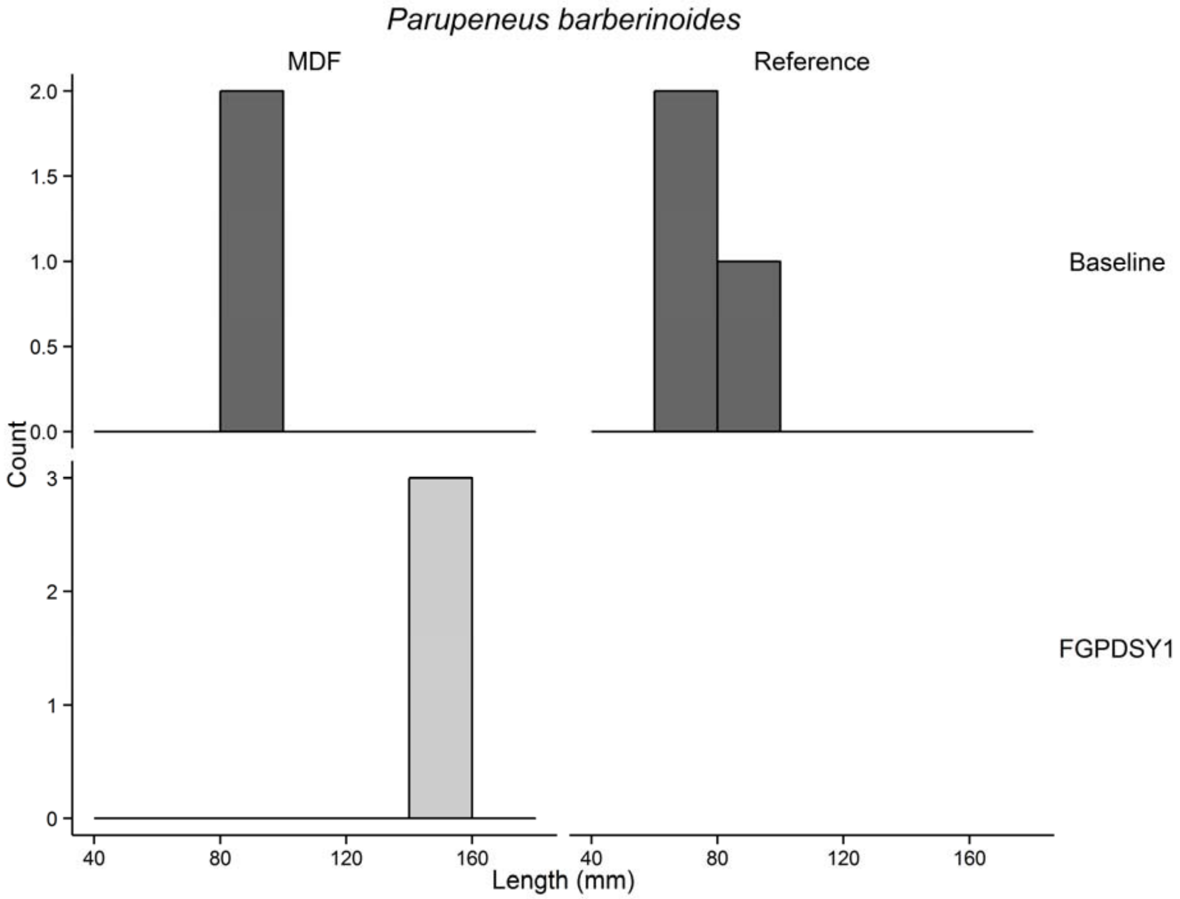
Length-frequency histograms for each of the dominant species in the macroalgal habitat. Data are presented only for combinations of 'Survey × IvR' where data were available (i.e. non-zero). Note: Scales on Y axes are variable.

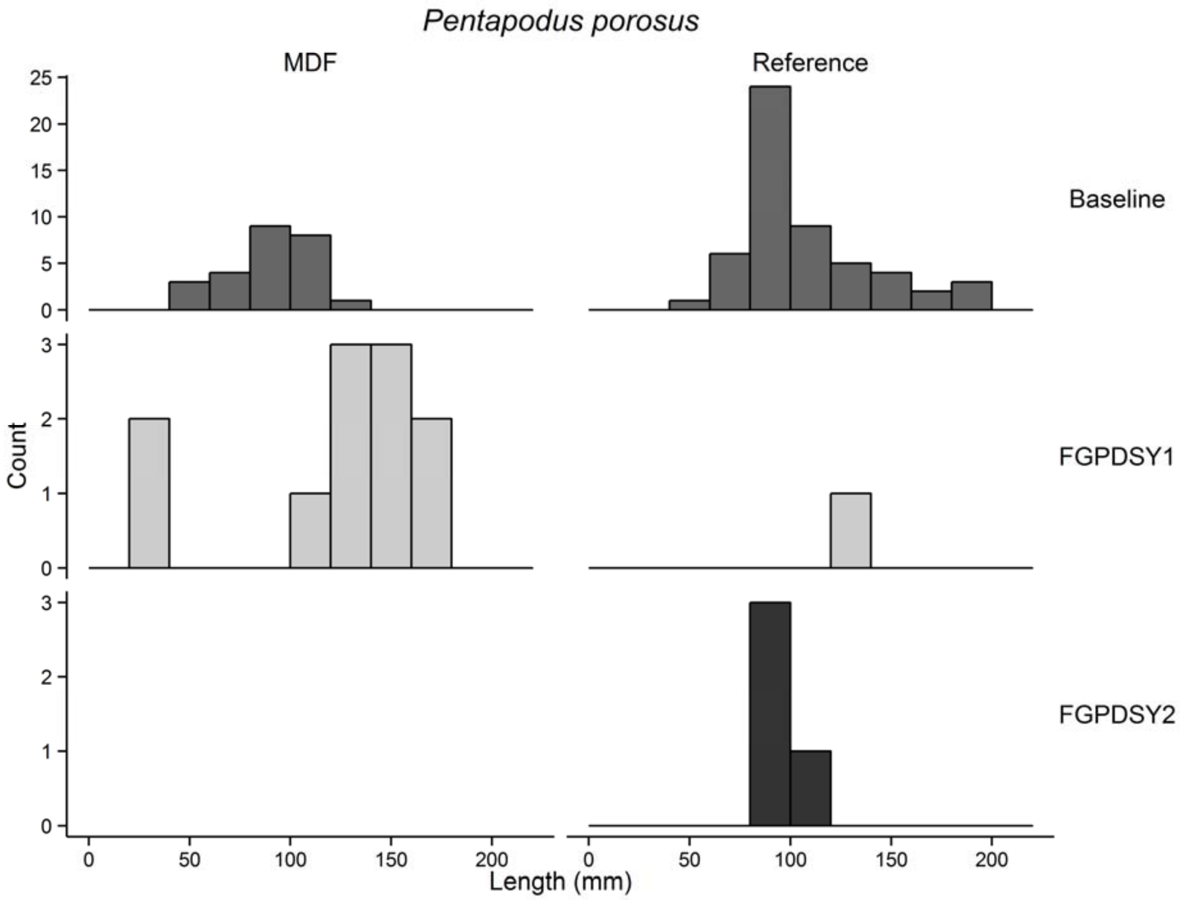


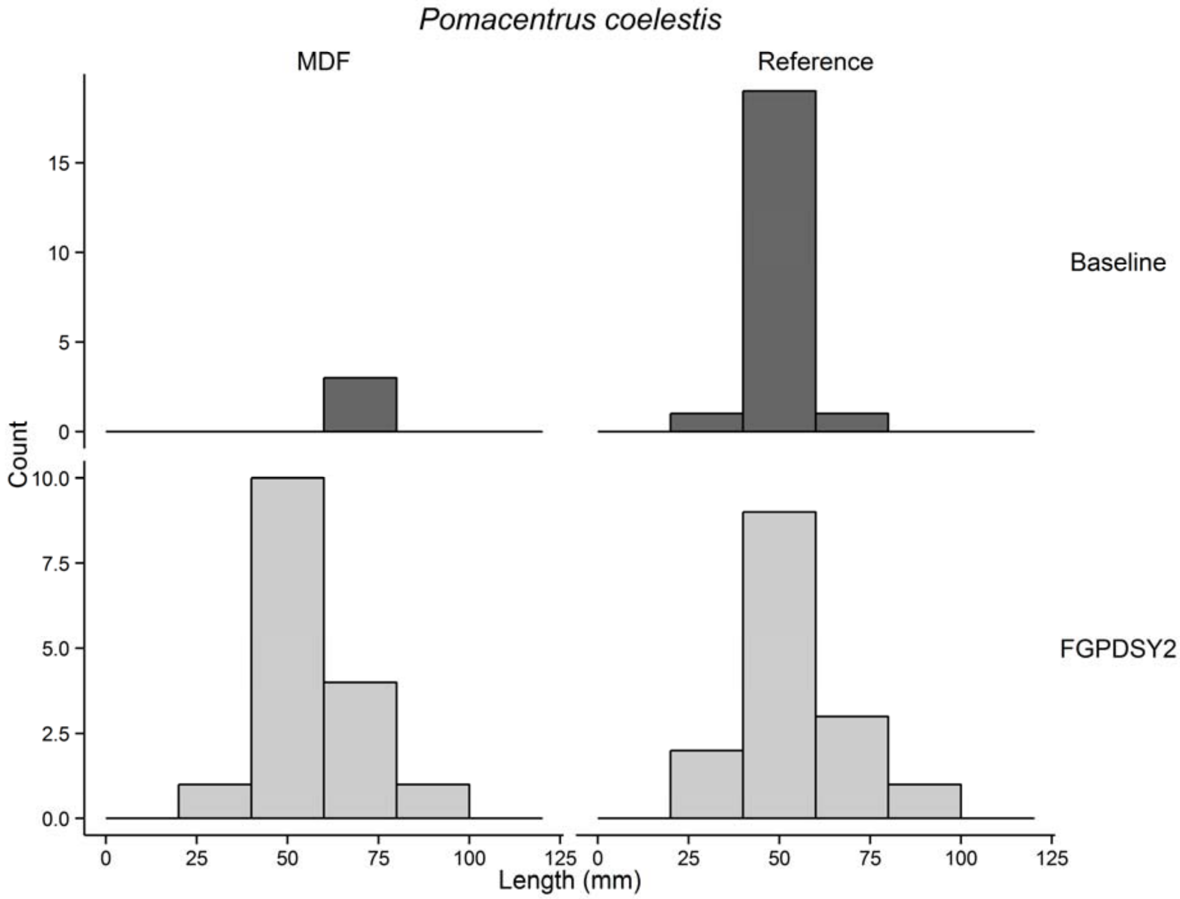


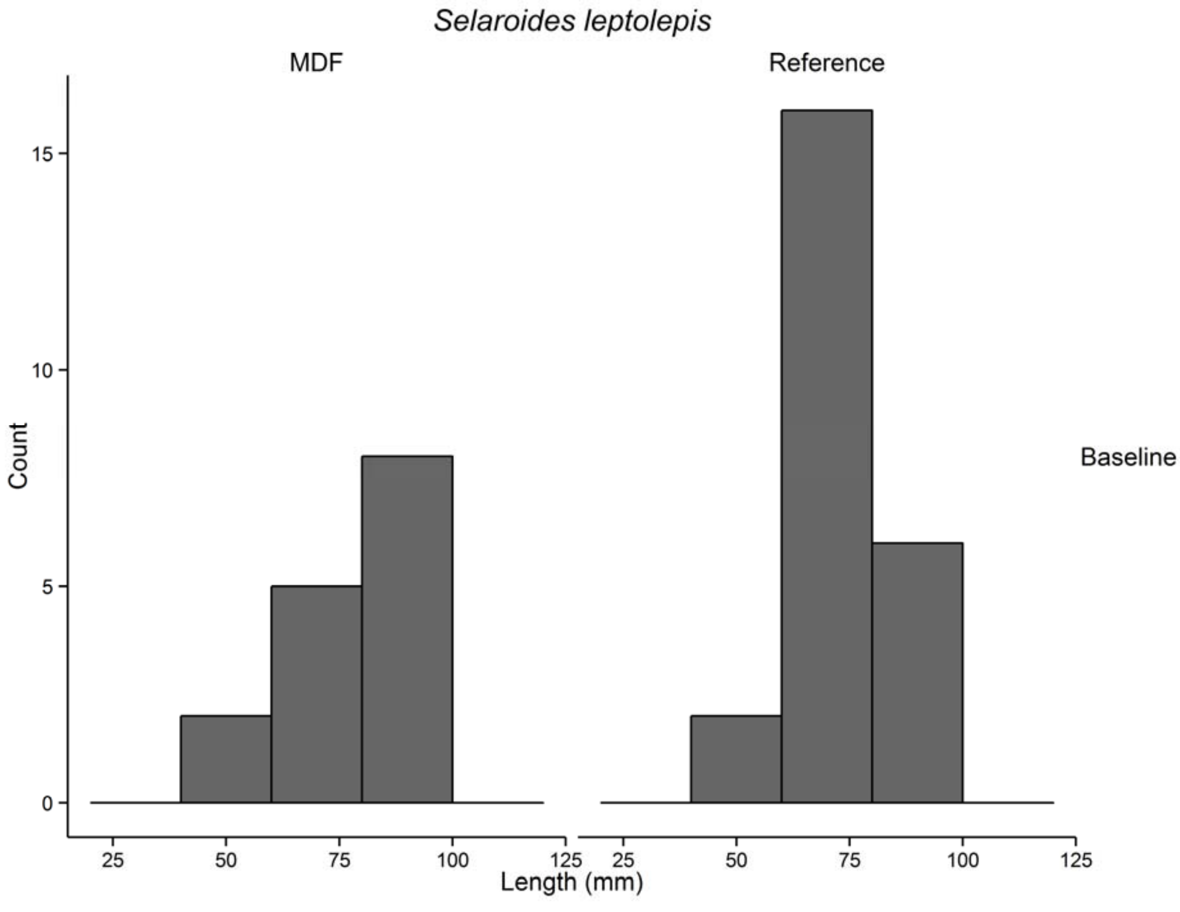

Gnathanodon speciosus
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)
400
500
600
700
800

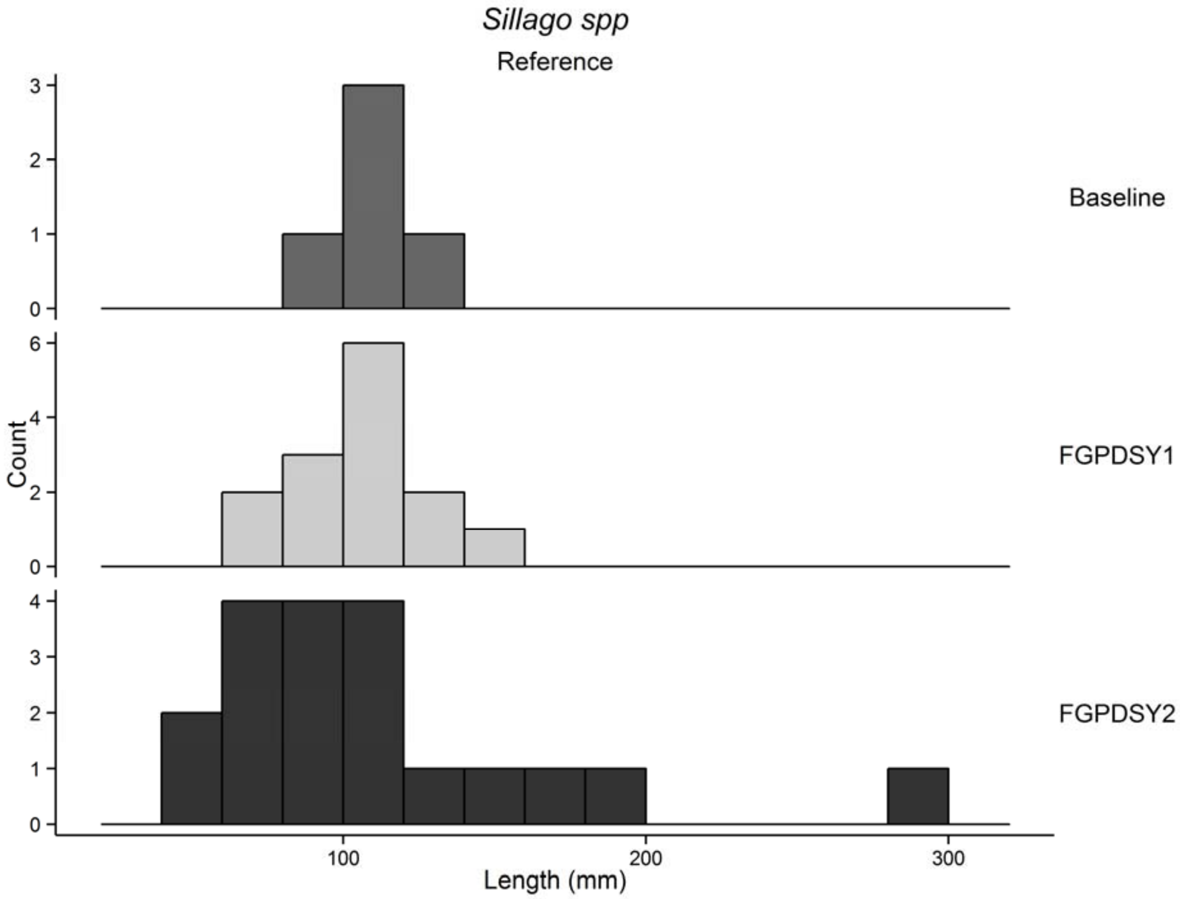

Leptojulis cyanopleura
MDF
Reference
Baseline
FGPDSY1
Count
Length (mm)
40
80
120
160

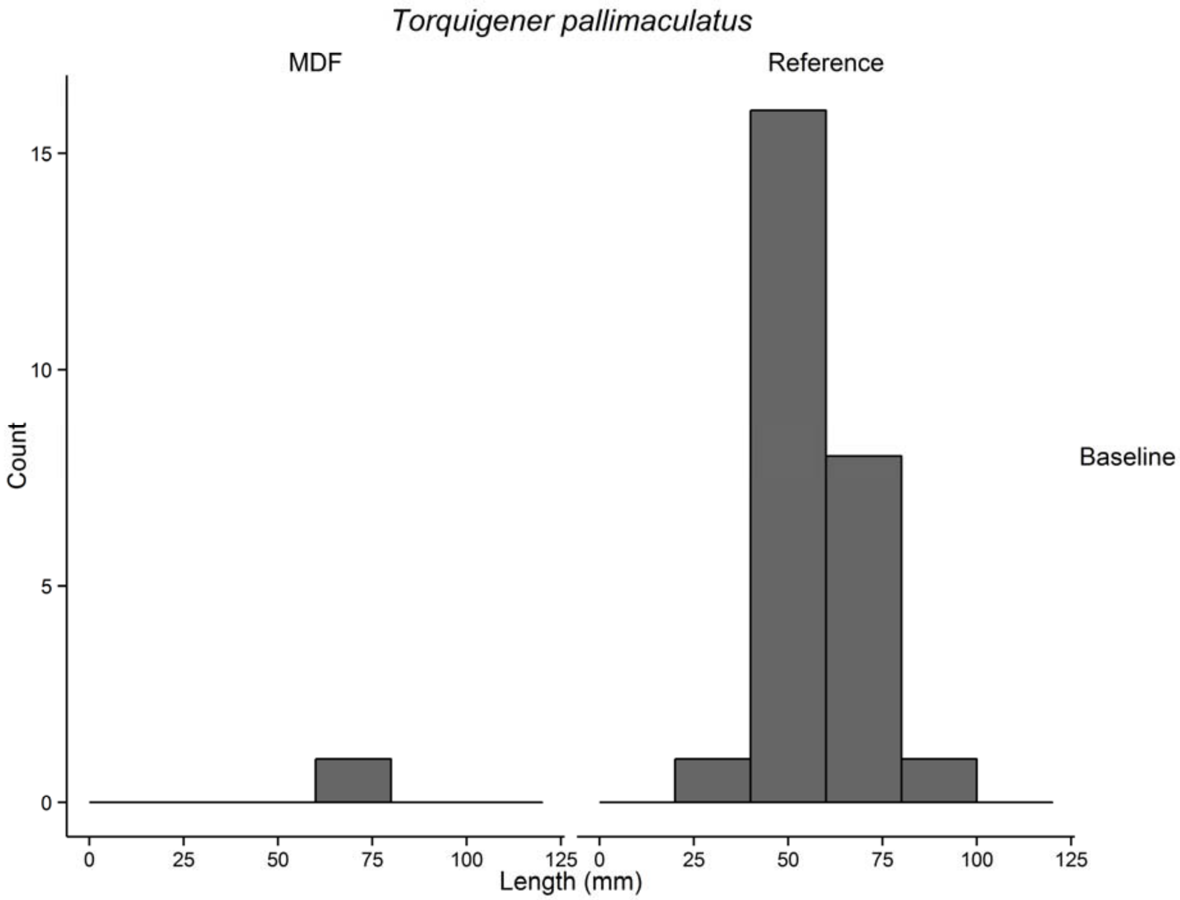

Parupeneus barberinoides
MDF
Reference
Baseline
FGPDSY1
Count
2.0
1.5
1.0
0.5
0.0
3
2
1
0
40
80
120
160
Length (mm)


Pentapodus porosus
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
25
20
15
10
5
0
3
2
1
0
50
100
150
200
Length (mm)


Pomacentrus coelestis
MDF
Reference
Baseline
FGPDSY2
Count
0
5
10
15
0.0
2.5
5.0
7.5
10.0
0
25
50
75
100
125
Length (mm)

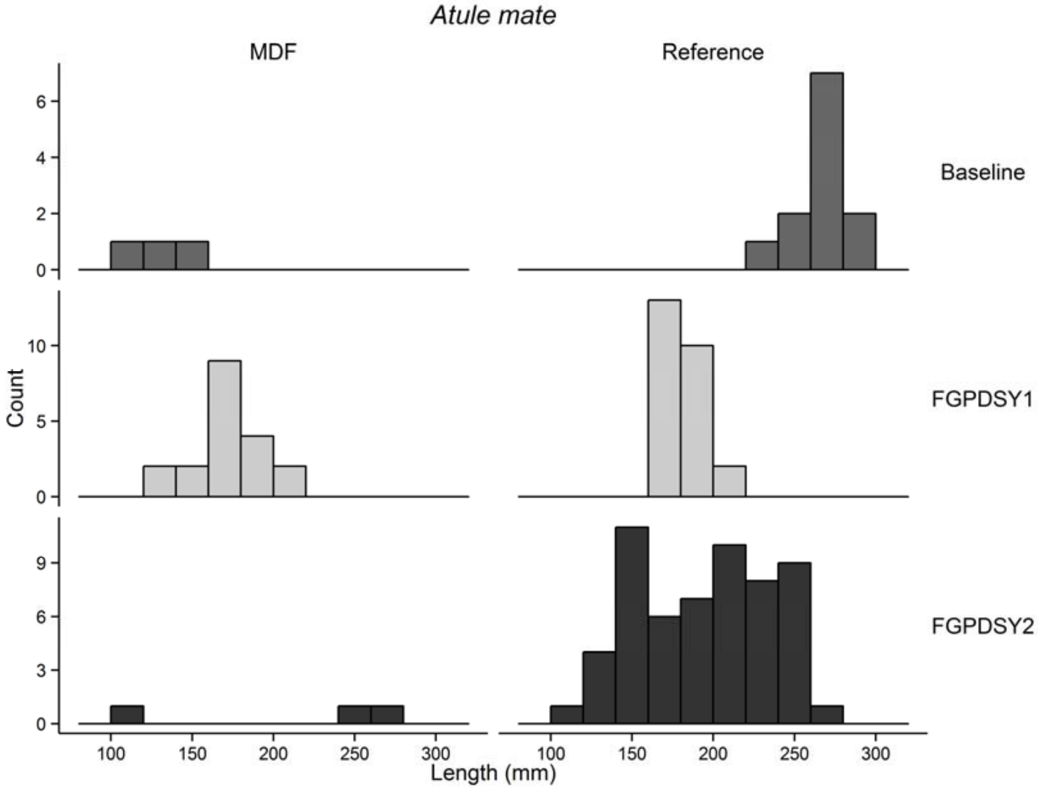

Selaroides leptolepis
MDF
Reference
Baseline
Count
0
5
10
15
25
50
75
100
125
Length (mm)

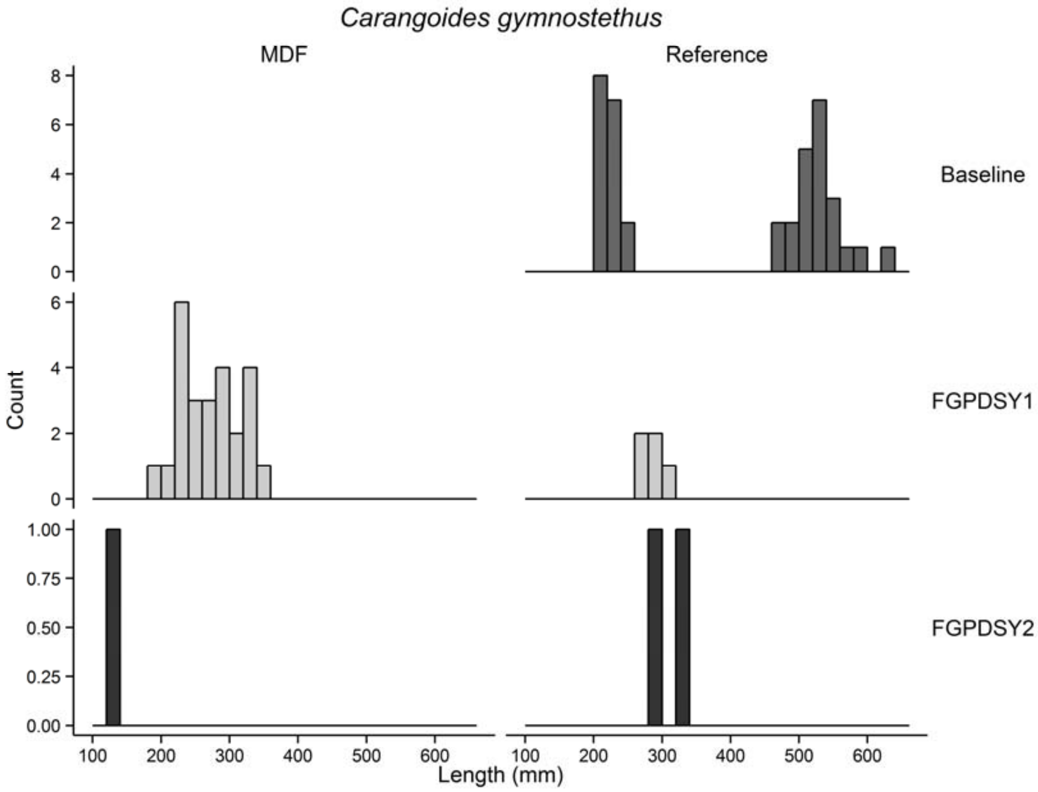

Sillago spp
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)
0
1
2
3
4
6
100
200
300

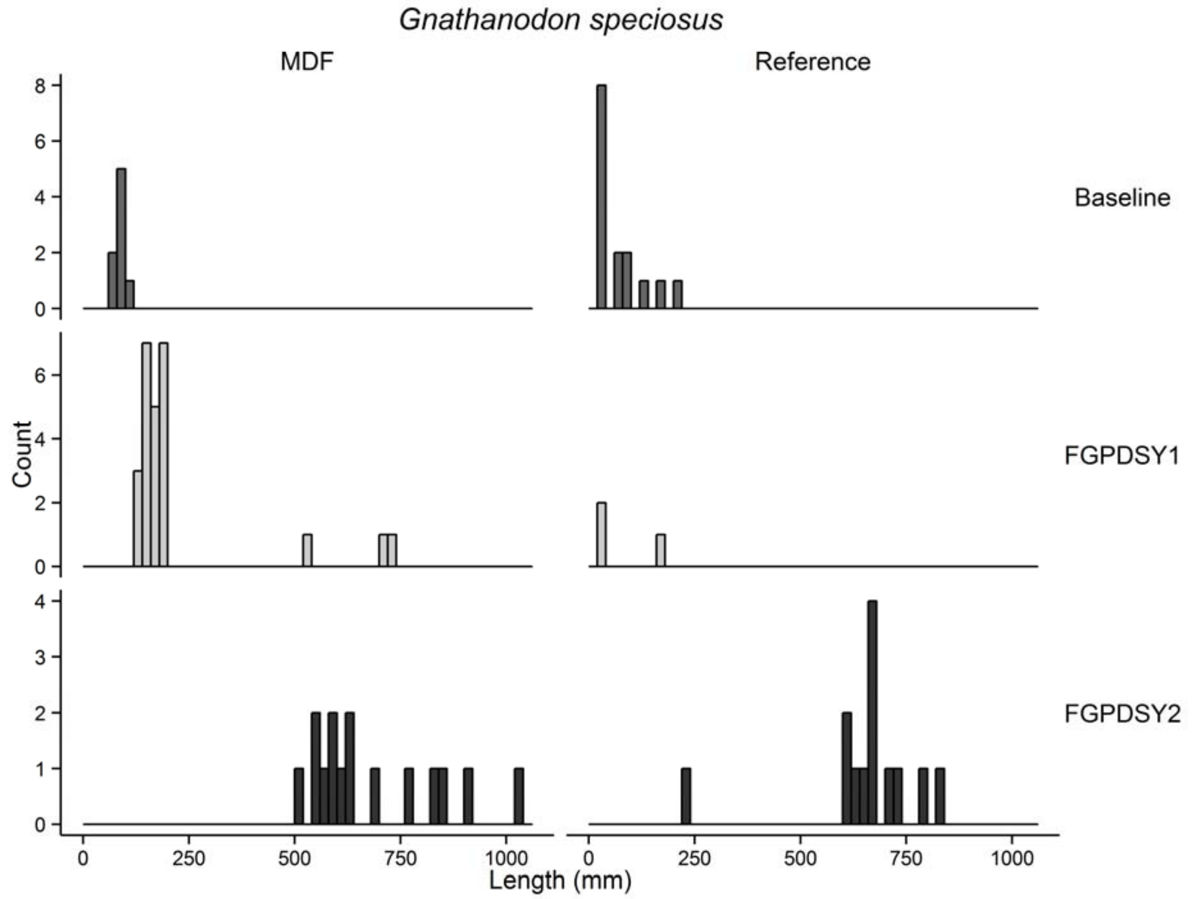

Torquigener pallimaculatus
MDF
Reference
Baseline
Count
Length (mm)
0
5
10
15
25
50
75
100
125

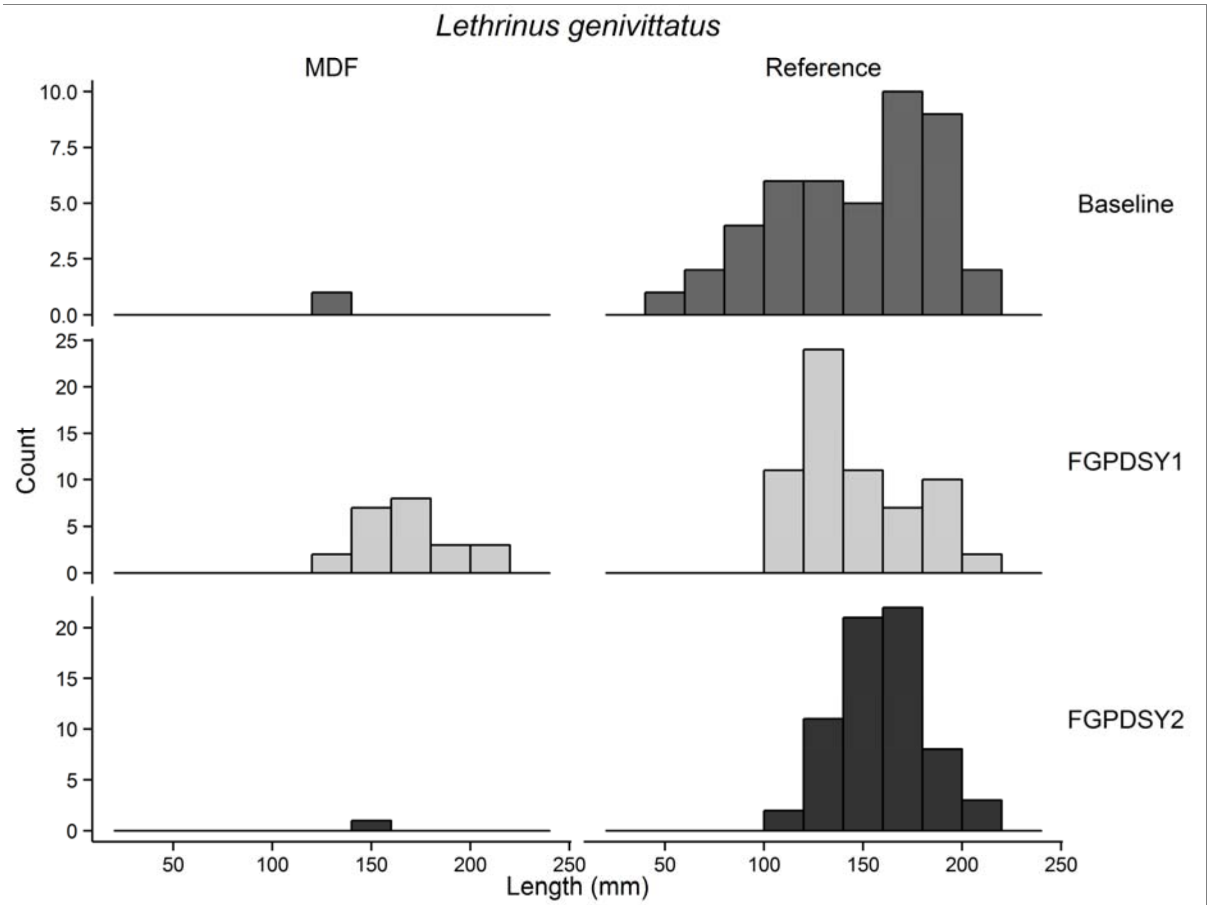
Appendix 4 Length-Frequency Histograms of each Sand/Sessile Invertebrate Habitat Dominant Species

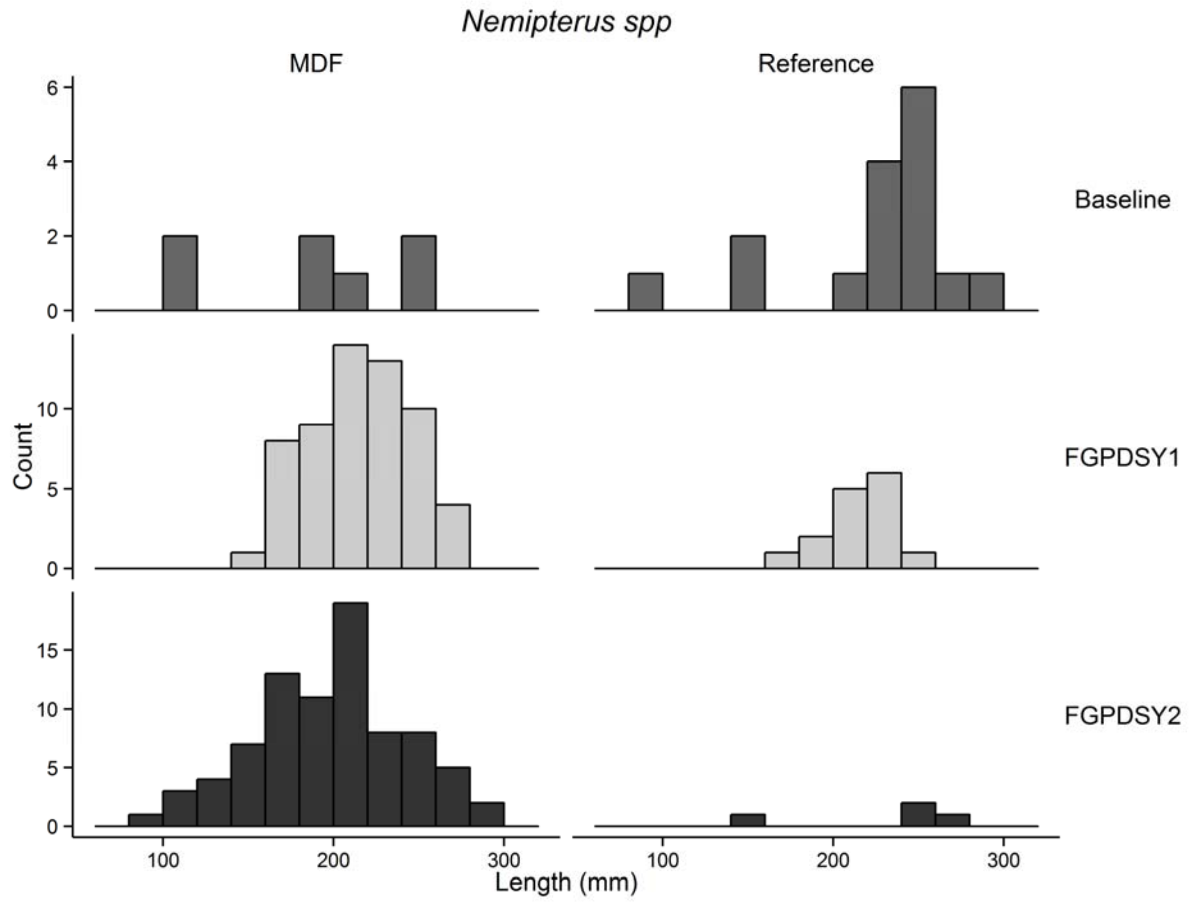
Length-frequency histograms for each of the dominant species in the sand/sessile invertebrates habitat. Data are presented only for combinations of 'Survey × IvR' where data were available (i.e. non-zero). Note: Scales on Y axes are variable.

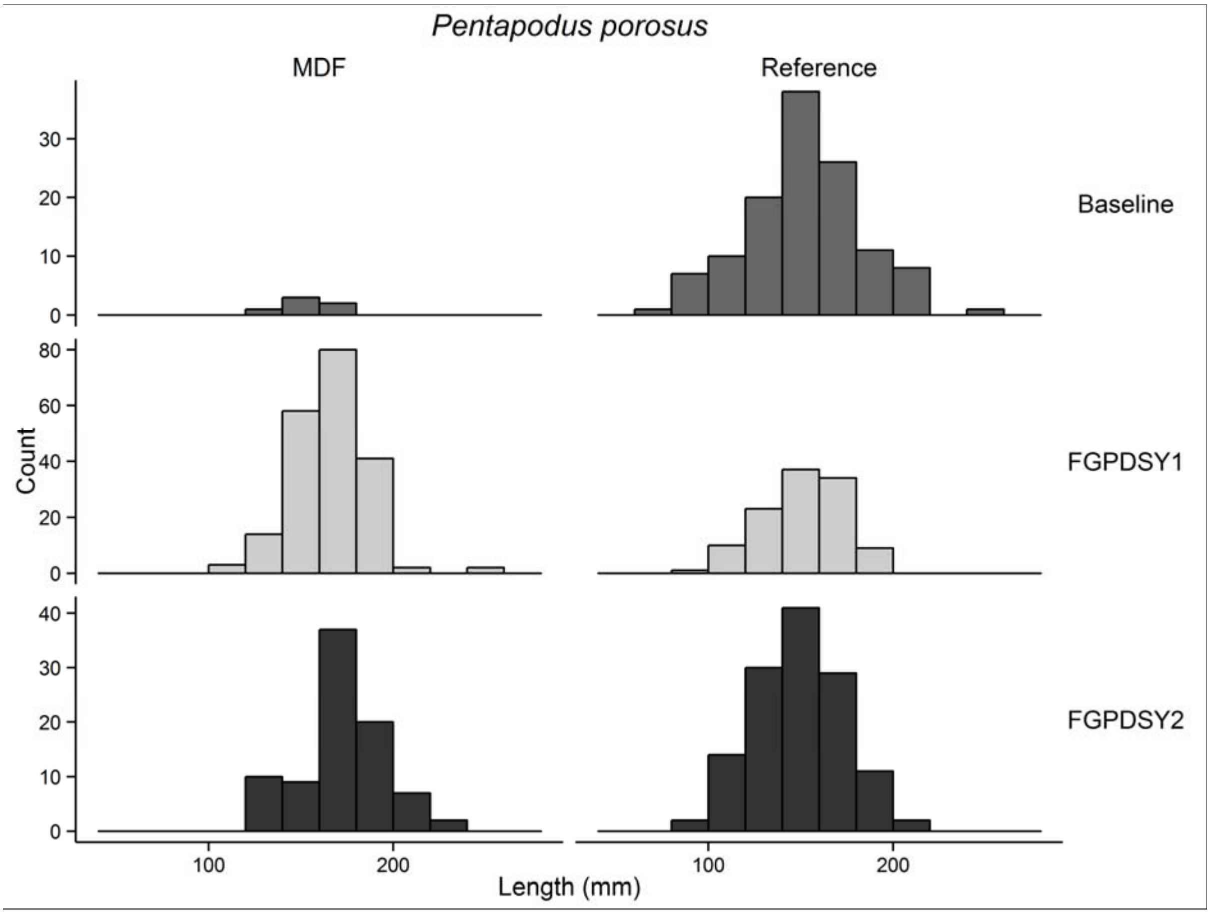


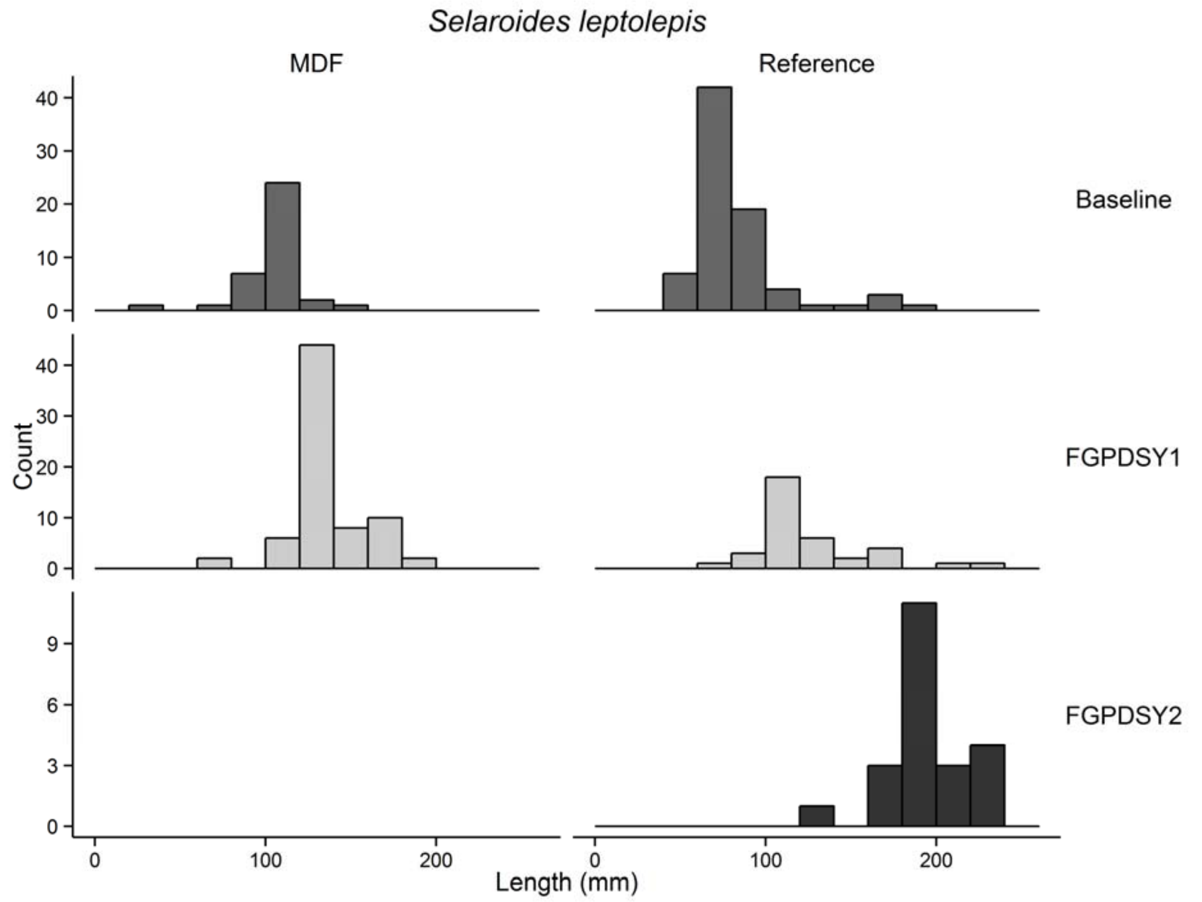


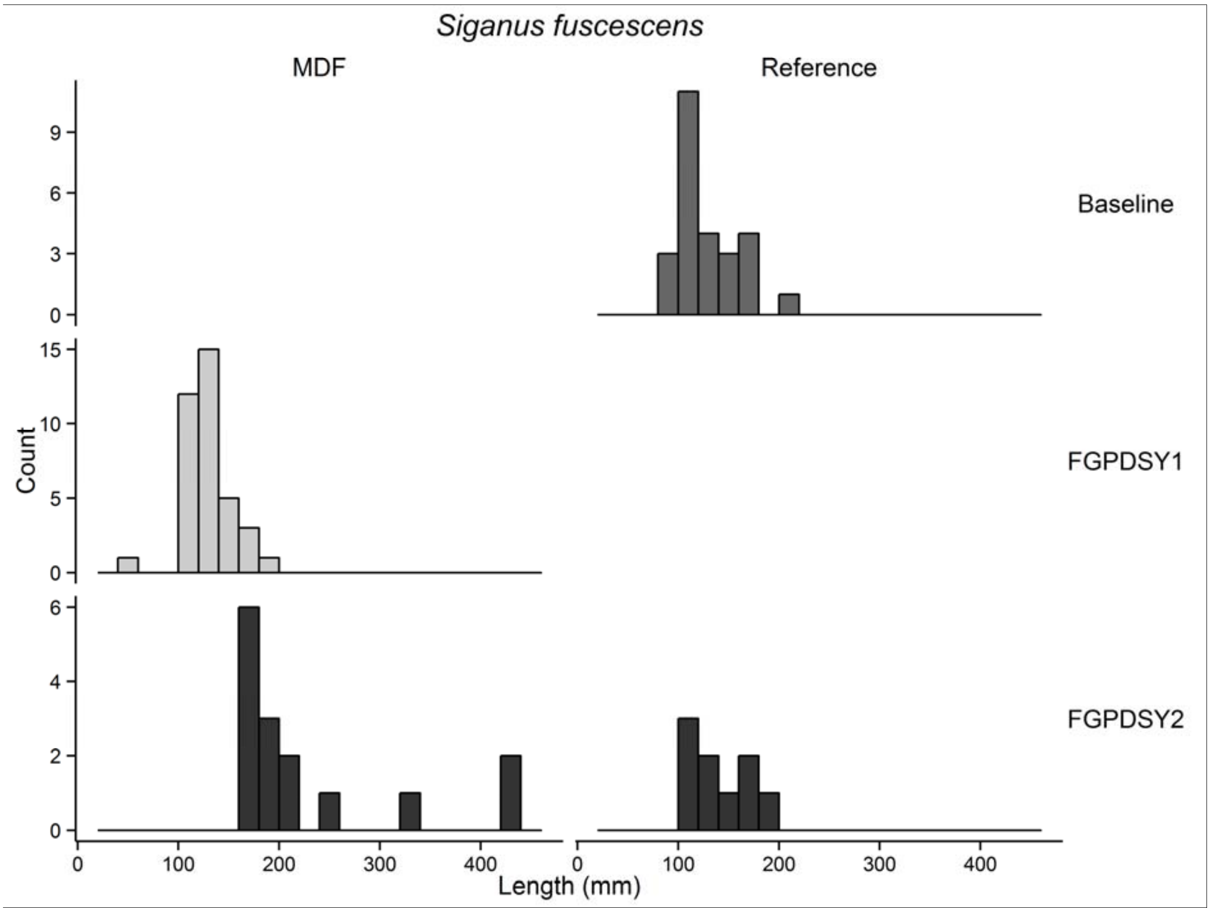

Gnathanodon speciosus
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)
0
250
500
750
1000

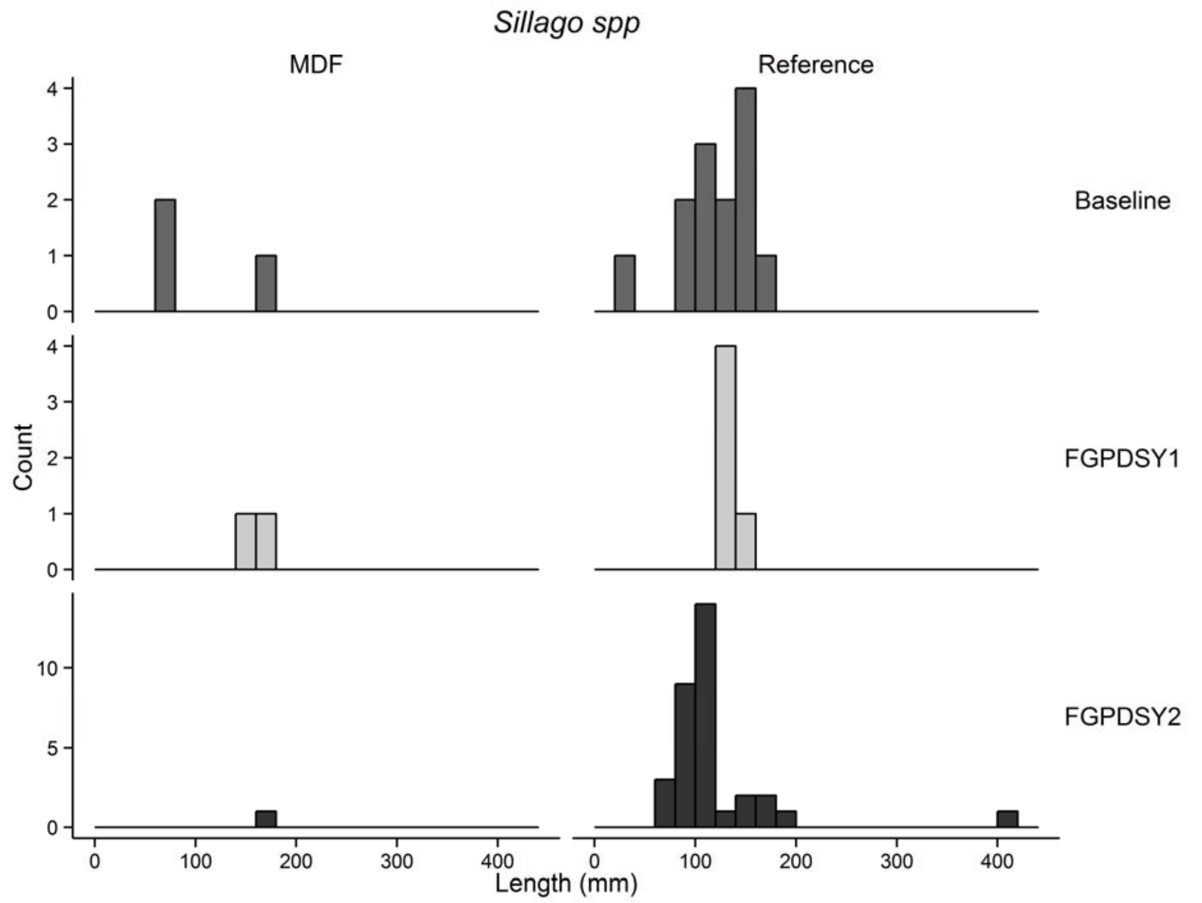

Lethrinus genivittatus
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)
50
100
150
200
250

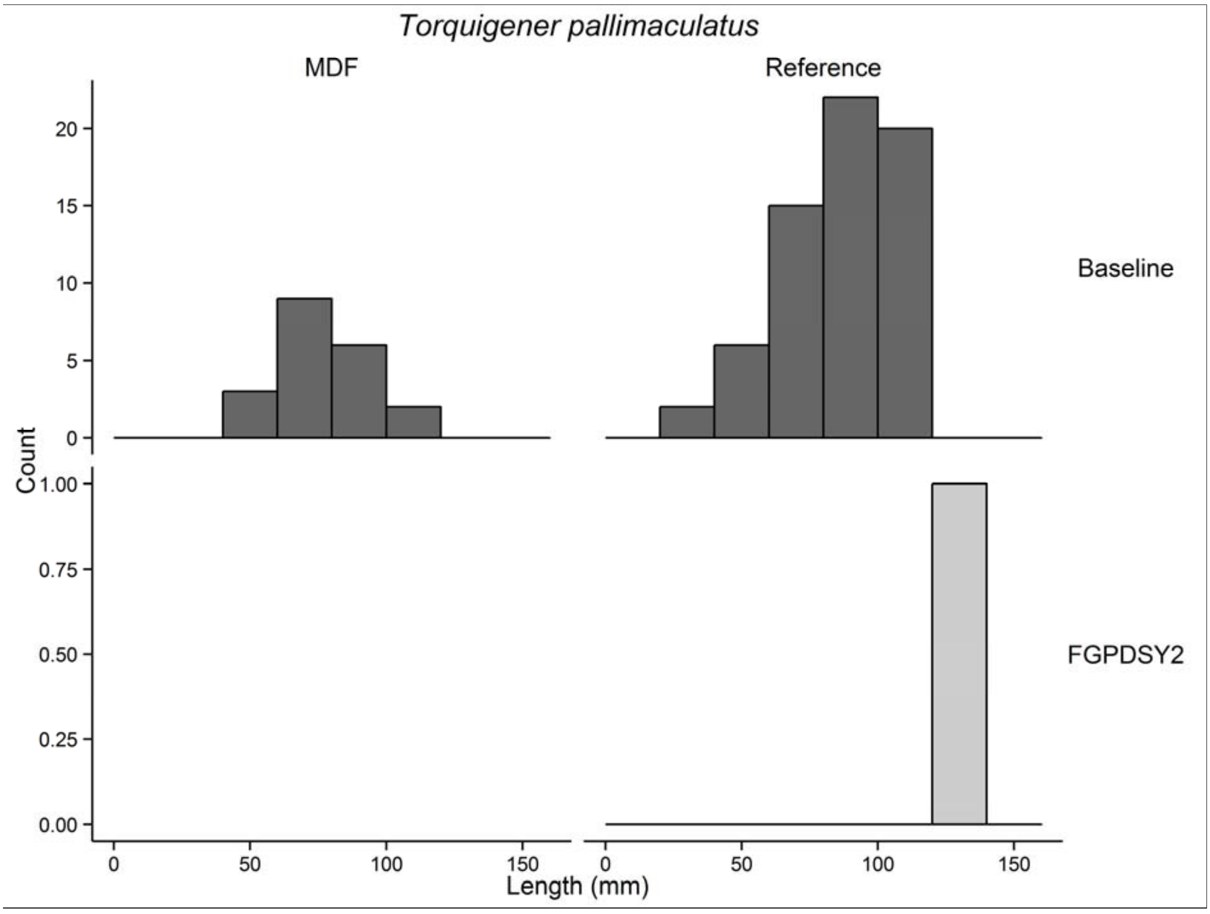

Nemipterus spp
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)
0
2
4
6
5
10
15
100
200
300


Pentapodus porosus
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)
0
10
20
30
40
60
80
100
200


Selaroides leptolepis
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)


Siganus fuscescens
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)


Sillago spp
MDF
Reference
Baseline
FGPDSY1
FGPDSY2
Count
Length (mm)


Torquigener pallimaculatus
MDF
Reference
Baseline
FGPDSY2
Count
Length (mm)