Gorgon Gas Development and Jansz Feed Gas Pipeline:

Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 2: 2012–2013

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Terminology, 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 Ministerial Implementation Statement No. 800 (Statement No. 800) and the Commonwealth Gorgon Gas Development Ministerial Approvals (EPBC Reference: 2003/1294 and 2008/4178).

#	Number
µm	Micrometre. 1 µm = 10^{-6} metre = 0.000001 metre or one millionth of a metre.
ABU	Australasia Business Unit
AHC	Ah Chong monitoring site
ANOSIM	Analysis of Similarity; a non-parametric test of significant difference between two or more groups, based on any distance measure.
ANOVA	Analysis of Variance; 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.
ANT	Ant Point Reef monitoring site
Anthropogenic	Caused by, or related to, the influence of humans
ARI	Assessment on Referral Information (for the proposed Jansz Feed Gas Pipeline dated September 2007) as amended or supplemented from time to time.
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 statistical design
BAT	Batman Reef monitoring site
BB	Bandicoot Bay
Benthic	Living upon or in the seabed.
Benthic Habitats	Areas of the seabed that support living organisms. Examples include limestone pavement, reefs, sand, and soft sediments.
Berm	A narrow ledge or shelf typically at the top or bottom of a slope.
BIG	Biggada Reef monitoring site

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.
Bombora	Raised, dome-shaped, limestone feature, >1 m high, often formed by coral of the genus *Porites*.
Bray-Curtis dissimilarity	In ecology and biology, the Bray-Curtis dissimilarity is a statistic used to quantify the compositional dissimilarity between two different sites, based on counts at each site.
BRUV	Baited Remote Underwater Video system
BvA	A comparison of data collected at sampling time before (Marine Baseline Program) and after (Post-Development Survey)
BvA × IvR	Interaction term used in the statistical analysis; a comparison of data collected at sampling time before (Marine Baseline Program) and after (Post-Development Survey), and at (potential) Impact and Reference Sites
BvA × Zone	Interaction term used in the statistical analysis; a comparison of data collected at sampling time before (Marine Baseline Program) and after (Post-Development Survey), and at different Zones (e.g. ZoHI, ZoMI etc.)
CA	Coralline algae
CAP	Canonical Analysis of Principal coordinates
Caisson	A large watertight chamber used for construction under water.
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.
CDEEP	Construction Dredging Environmental Expert Panel
CFR1, CFR2, CFR3, CFR4	Monitoring sites
CI	Confidence Interval
CI1, CI2, CI3	Monitoring sites
CL	Confidence Limit
cm	Centimetre
CN1, CN2, CN3, CN4, CN5	Monitoring sites
CO_2	Carbon dioxide

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 Definitions	*Coral Assemblages* are benthic areas (minimum 10 m^2) or raised seabed features over which the average live coral cover is equal to or greater than 10%. *The Change in coral mortality* is determined by subtracting the baseline extent of Gross coral mortality from the extent of Gross coral mortality measured on a sampling occasion. *Detectable Net Mortality* is the result of subtracting the Change in coral mortality at the Reference Site(s) from the Change in coral mortality at the Monitoring Site. *Average Net Detectable Mortality* is the result of averaging the net detectable mortality of all monitoring sites within the Zone i.e. the mean of net detectable mortality of any Zone. *Gross coral mortality* at a site is expressed as a percentage of total coral cover at the time of sampling at that monitoring location. In determining the coral loss, measurement uncertainty is to be taken into consideration.
CPCe	Coral Point Count with Excel extensions (software for the determination of coral cover from photographs)
Crustose	Forming a crust which is firmly attached to the substrate over its entire area.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	Western Australian Department of Environment and Conservation
Demersal	Living on the seabed or just above it.
df	Degrees of freedom
DGI0, DGI3	Monitoring sites
Dominant	Most common (relating to the following ecological elements: macroalgae, seagrass, mangroves, non-coral benthic invertebrates and demersal fish).
Dominant Coral Species	Species with the highest relative percentage cover. Percentage cover is expressed as the proportion of total coral cover.

DS1, DS2, DSS1	Monitoring sites
DSI1, DSI2	Monitoring sites
DSN1, DSN3	Monitoring sites
DSR1, DSR3, DSR5, DSR6	Monitoring sites
DUG	Dugong Reef monitoring site
Ecological Element	Element listed in Condition 14.2 of Statement No. 800 and Condition 11.2 of EPBC Reference: 2003/1294 and 2008/4178.
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 Part 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.
Feed Gas Pipeline	Pipeline from the wells to the Gas Treatment Plant
GDA	Geocentric Datum of Australia
Globose	Having the shape of a sphere or ball.
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
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.

Hermatypic	Corals that contain and depend upon zooxanthellae (algae) for nutrients.
Interaction Term	An interaction term studies the effects of two factors together. An effect of interaction occurs when a relation between (at least) two variables is modified by (at least one) other variable. That is, 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).
ISO	International Organization for Standardization
ITIS	Integrated Taxonomic Information System (http://www.itis.gov)
IvR	A comparison of data collected from (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.
km	Kilometre
LADS	Laser Airborne Depth Sounder
LC1, LC2, LC4	Monitoring sites
LCT	Landing Craft Tank
LNG	Liquefied Natural Gas
LNG0, LNG1, LNG2, LNG3	East Barrow Ridge monitoring sites
LNGI2	Monitoring site
LNGR1, LNGR2, LNGR3	Monitoring sites
LONE	Lone Reef monitoring site
LOW	Southern Lowendal Shelf monitoring site
m	Metre
m^2	Square metre
m^3	Cubic metre
Macroalgae	Benthic marine plants which 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.

Mangrove	Tropical evergreen trees or shrubs with stilt-like roots and stems that grow in shallow coastal water.
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 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) as set out in the Coastal and Marine Baseline State Report required under Condition 14.2 of Statement No. 800, and Condition 11.2 of EPBC Reference: 2003/1294 and 2008/4178.
Marine Facilities	In relation to Condition 17.2 of Statement No. 800 and Condition 13.2 of EPBC Reference: 2003/1294 and 2008/4178, the Marine Facilities are the: • Materials Offloading Facility (MOF) • LNG Jetty For the purposes of Condition 17.2 of Statement No. 800, Marine Facilities also include: • Marine component of the Barge (WAPET) Landing upgrade.
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	Environmental Harm that is neither trivial nor negligible.
MaxN	Maximum number of individual 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
MBP	Marine Baseline Program
MDS	Non-metric multidimensional scaling ordination; a statistical output from the PRIMER package
MFR1, MFR3, MFR4, MFR5	Monitoring sites
MGA 50, GDA 94	Map Grid of Australia Zone 50 (WA); projection based on the Geocentric Datum of Australia 1994.
MI1, MI2	Monitoring sites
mL	Millilitre
mm	Millimetre
MN1, MN2, MN3, MN4	Monitoring sites

MOF	Materials Offloading Facility
MOF1	Materials Offloading Facility monitoring site
Motile	Capable of movement.
MS	Mean squares
MTN	Mattress Bay North
MTPA	Million Tonnes Per Annum
MTS	Mattress Bay South
N/A	Not Applicable
Nearshore	Close to shore
NEBWI1_A	Monitoring site
nMDS	Non-metric Multidimensional Scaling
OE	Operational Excellence
OEMS	Operational Excellence Management System
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.
P(MC)	p-value based on Monte Carlo bootstrapping
P(perm)	p-value generated via permutations
P2N	Perentie II North
P2S	Perentie II South
PAV	Pavement/Rock/Rubble
PDS	Post-Development Survey
PDS1	Post-Development Survey Year 1
PDS2	Post-Development Survey Year 2
PER	Public Environmental Review for the Gorgon Gas Development Revised and Expanded Proposal dated September 2008, as amended or supplemented from time to time.

Percentile	The value of a variable below which a certain percentage of observations fall
PERMANOVA	Permutational Multivariate Analysis of Variance; a process for testing the simultaneous response of one or more variables to one or more factors in an ANOVA experimental design on the basis of any distance measure, using permutation methods
Perms	Number of unique permutations
PI	Pelican Island
PIO	Pilbara Offshore Marine Bioregion
Pneumatophore	An aerial root specialised for gaseous exchange
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 geographical 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
PSD	Particle-size Distribution
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.
Ref	Reference Site
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.

Regionally Significant Areas	These are the regionally significant areas outside the Zones of High Impact, Moderate Impact, and Influence on the eastern margins of the Lowendal Shelf to the southern boundary of the Montebello Islands Marine Park, and Dugong Reef, Batman Reef, and Southern Barrow Shoals.
R-statistic	Statistic generated by ANOSIM that reflects the observed differences among sampled groups, contrasted with differences within groups.
RVA	Rapid Visual Assessment
SAFR1, SAFR2, SAFR3	Monitoring sites
SAN1	Monitoring site
SBS	Southern Barrow Shoals monitoring site
Scleractinian	Corals that have a hard limestone skeleton and belong to the order Scleractinia.
SE	Standard Error
Seagrass	Benthic marine plants which have roots, stems, leaves and inconspicuous flowers with fruits and seeds much like terrestrial flowering plants. Unrelated to seaweed.
Serious Environmental Harm	Environmental harm that is: a) irreversible, of a high impact or on a wide scale; or b) significant or in an area of high conservation value or special significance and is neither trivial nor negligible.
Sessile	Permanently attached directly to the substratum by its base (i.e. immobile), without a stalk or stem.
SEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities
SI1, SI2	Monitoring sites
SIFR2, SIFR3, SIFR5	Monitoring sites
SIN1, SIN2, SIN3, SIN4, SIN5, SIN6, SIN7	Monitoring sites
sp. (plural: spp.)	Species
Speciose	Denotes a taxon that contains many species.
Spoil Disposal Ground	The area of the sea used for disposing of dredged and excavated material.
SQ	Square Bay
SS	Sum of squares

ST	Stokes Bay
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).
Subdominant Coral Species	Species, excluding Dominant Coral Species, that have greater than or equal to 5% cover. Percentage cover is expressed as the proportion of total coral cover.
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, is a name designating an organism or a group of organisms.
Temporal	Relating to, or limited by, time
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TP1, TP2, TP4, TP6, TP7, TP9, TP10	Monitoring sites
TPC1, TPC2, TPC3	Monitoring sites
Transect	The path along which a researcher moves, counts, and records observations.
TSS	Total Suspended Solids
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.
v.	Versus

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.
Vouchering	Collection of fauna specimens for scientific purposes.
WA	Western Australia (or Western Australian)
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 (PIO) 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 that is typical of the Indo–West Pacific flora and fauna.
ZoI Nth	Zones of Influence sites located north of the dredging and dredge spoil disposal activities
ZoI Sth	Zones of Influence sites located south of the dredging and dredge spoil disposal activities
Zones of High Impact (ZoHI)	An area where long-term impacts to corals are predicted to result directly from disturbance during Horizontal Directional Drilling, dredging or construction of infrastructure on the seabed and burial during dredge spoil disposal activities, or indirectly from smothering due to elevated sedimentation and/or from deterioration in water quality. As set out in Schedule 1 of Statement No. 800 and Schedule 5 of EPBC Reference: 2003/1294 and 2008/4178.
Zones of Influence (ZoI)	This area is predicted to be indirectly influenced by dredging and spoil disposal activities (e.g. marginal increases in turbidity and sedimentation), but at levels that will have no measurable impact on corals. As set out in Schedule 1 of Statement No. 800 and Schedule 5 of EPBC Reference: 2003/1294 and 2008/4178.
Zones of Moderate Impact (ZoMI)	An area where short-term moderate impacts (e.g. some partial mortality of corals) is predicted to result indirectly from Horizontal Directional Drilling, dredging, dredge spoil disposal activities, due to deterioration in water quality and/or an increase in sedimentation rates. Moderate impacts are likely to include some partial mortalities among fast-growing, more sensitive coral species (e.g. *Acropora* sp.) but less, if any, mortality of longer-living, generally more resilient species (e.g. *Porites* sp., *Turbinaria* sp.). As set out in Schedule 1 of Statement No. 800 and Schedule 5 of EPBC Reference: 2003/1294 and 2008/4178.

Executive Summary

This Post-Development Coastal and Marine State and Environmental Impact Survey Report, Year 2: 2012–2013, has been prepared to meet the requirements of Condition 24 of Ministerial Implementation Statement No. 800 and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178.The purpose of this Report is to determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with the pre-development baseline marine environmental state.

This is the second Post-Development Survey undertaken since completion of dredging and dredge spoil disposal activities. In the assessment of change in ecological elements between the Marine Baseline Program and Post-Development Surveys, the results from both Post-Development Survey Year 1 and Post-Development Survey Year 2 are included in the Report.

Coral Monitoring

Field sampling was undertaken to determine the proportion of mapped coral area in each of the Zones of High Impact (ZoHI), the Zones of Moderate Impact (ZoMI), and at the Reference Sites (including Regionally Significant Areas) that were classified as Coral Assemblages. The estimated net Area of Loss of Coral Assemblages in the ZoHI and ZoMI was 3.46 ha, and therefore did not exceed the Permanent Loss of Coral Assemblages limit of 8.47 ha, as per Condition 18.1ii.b of Ministerial Implementation Statement No. 800.

Coral monitoring was also undertaken at sites within the ZoHI and ZoMI, the Zones of Influence (ZoI), and at Reference Sites (including Regionally Significant Areas), and were sampled for a range of population parameters: identification of the dominant and subdominant taxa, size-class frequency, survival, growth, and recruitment success.

A number of hard coral families, including Faviidae, Poritidae, and Acroporidae, were dominant (where dominance is a measure based on abundance and coral cover of a particular coral taxa compared to other coral taxa) across most sites and zones in the Post-Development Survey. Subdominant families included Dendrophylliidae and Mussidae. Dominant and subdominant genera across most sites included *Montipora*, *Cyphastrea*, *Favia*, *Favites*, and *Porites*. There was no evidence to suggest a major change in the dominant coral taxa attributable to dredging and dredge spoil disposal activities between the dates of the Marine Baseline Program and the Post-Development Survey Year 2.

The size-class frequency distributions of 12 coral families showed no significant differences between Impact Sites (ZoHI and ZoMI) and Reference Sites from the Marine Baseline Program to Post-Development Survey Year 2. There was some variability in mean colony size among the 12 coral families (Acroporidae, Agariciidae, Dendrophylliidae, Faviidae, Fungiidae, Merulinidae, Milleporidae, Mussidae, Oculinidae, Pectiniidae, Pocilloporidae, Poritidae); however, in general the majority of all families fell within the 10–30 cm size range. The size-class frequency distributions at the Impact Sites and the Reference Sites were all positively skewed, which is encouraging given that size-class frequency distributions in degraded reef areas generally tend to show increased negative skewness. The standard deviation for several Families (e.g. Acroporidae, Dendrophylliidae, and Faviidae) did show reductions at the Impact Sites from the Marine Baseline Program to Post-Development Survey Year 2 compared to the Reference Sites. This result may indicate an impact associated with dredging and dredge spoil disposal activities, as coral colony size has been reported to vary less in degraded areas due to mortality of larger colonies. However, overall the results did not indicate a major change in the size-class frequency distributions of corals from the Marine Baseline Program to Post-Development Survey Year 2 that was attributable to dredging and dredge spoil disposal activities.

In the Post-Development Survey Year 2, live coral cover ranged from greater than 58.4% at two sites (one in the ZoI and one Reference Site), to less than 2% at a further two sites (one in the ZoI and one in the ZoMI). There was no significant difference in live coral cover in the ZoHI from Post-Development Survey Year 2 compared to the Marine Baseline Program; however, a significant decrease in live coral cover was detected from the Marine Baseline Program to Post-Development Survey Year 2 in the ZoMI. The percentage cover of live coral increased significantly from the Marine Baseline Program to Post-Development Survey Year 2 at the Reference Sites.

While there was a significant reduction in the percentage cover of live coral from the Marine Baseline Program to Post-Development Survey Year 2 in the ZoMI (and a non-significant decline in the ZoHI), coral cover increased from Post-Development Survey Year 1 to Post-Development Survey Year 2 in the ZoHI and ZoMI, suggesting a level of recovery.

There was no significant difference in the rate of change in live coral cover as measured from fixed transects between the ZoI and Reference Sites during the Marine Baseline Program and the Post-Development Survey Year 2. However, the rate of change in live coral tissue for tagged colonies did show significant differences in both the Acroporidae and the Mussidae at the Impact Sites. A significant difference was recorded in the rate of change in live coral cover from tagged colonies, with a significant reduction in the rate of change in live coral cover recorded at Impact Sites during the Marine Baseline Program compared to during the Post-Development Surveys. This result may be partly attributable to dredging and dredge spoil disposal activities, but should be interpreted with caution due to the low replication. However, the major trend across both coral genera sampled was a reduction in the rate of change in live coral tissue during the Post-Development Surveys at Impact and Reference Sites.

The discrepancy between the Area of Coral Assemblages results and the percentage live coral cover results is likely driven by the method used to calculate Coral Assemblage. According to the Scope of Works (RPS 2009, amended 2012), Coral Assemblage is classified as any transect with ≥10% coral cover. For example, 11% live coral cover is considered the same as 70% live coral cover. As such, the estimation of the live coral cover in the Area of Coral Assemblages calculations differs from the random survival transects method, which uses the actual percentage cover.

Coral growth rates were measured at four sites for branching colonies and twelve sites for non-branching coral colonies. For branching colonies, no significant differences or reduced growth rates were detected between the Marine Baseline Program and Post-Development Surveys between sites. For the non-branching Acroporidae, growth rates remained stable at the Impact Sites (ZoHI and ZoMI), whereas there was a significant increase in the growth rates in the Reference Sites during Post-Development Surveys compared to the Marine Baseline Program. No significant differences were recorded between the Marine Baseline Program and Post-Development Survey Year 2 and between sites for the Mussidae.

There was successful establishment and growth of juvenile corals recorded across all sites and zones in the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2. No significant differences between Impact Sites (ZoHI and ZoMI) and Reference Sites from the Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2 were detected in the total number of colonies ≤10 cm and in the size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm. Higher numbers of colonies in all three size-classes were recorded in Post-Development Survey Year 1 than in the Marine Baseline Program and Post-Development Survey Year 2, despite Post-Development Survey Year 1 being the sample period immediately following the dredging and dredge spoil disposal activities. No significant differences were detected in the number of colonies in the size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm between the Marine Baseline Program and Post-Development Survey Year 2 when their numbers were standardised for available recruitment substrate (Pavement/Rock/Rubble [PAV] and Coralline Algae [CA]: PAV/CA). Successful recruitment, as indicated by the successful establishment and growth of juvenile corals is important, as turbidity and sedimentation have been shown to affect reproductive success and the settlement and survival of coral larvae.

Non-coral Benthic Macroinvertebrates

There were no clear differences in the top ten most abundant taxonomic groups between limestone and soft sediment substrates, based on average abundance. Eight of the dominant taxonomic groups; Ascidians (colonial), 'Other' hard corals, 'Other' soft corals, Sea whips, Sponges (branching), Sponges (cup), Sponges (variable), *Turbinaria* spp. were shared across the two substrate types. Subdominant non-coral benthic macroinvertebrates on limestone included Crinoids, Sponges (barrel), Sponges (fan), and Sponges (tubular). Subdominant benthic macroinvertebrates on soft sediment included Ascidians (solitary), Bivalves, Crinoids, Gorgonians, Nudibranchs, Sea cucumbers, Sea stars, Sea urchins, Sponges (digitate), Sponges (globular), Sponges (tubular), and Zoanthids. Besides the Gastropods and Sea pens, all the benthic macroinvertebrate taxonomic groups that were recorded during the Marine Baseline Program and Post-Development Survey Year 1 were also recorded during Post-Development Survey Year 2, with the Bivalves and Zoanthids recorded as additional taxonomic groups in Post-Development Survey Year 2.

To assess potential changes in the benthic macroinvertebrate community structure, separate analyses were conducted on the full (soft sediment and limestone) dataset, the soft sediment dataset, and the limestone dataset. If the statistical term(s) of interest was non-significant, the statistical analyses were re-run using a separate dataset for dredging sites, and a separate dataset for dredge spoil disposal sites to increase the probability of detecting impacts associated with either dredging activities or dredge spoil disposal activities. However, the same Reference Sites were used for both datasets.

No significant difference in the non-coral benthic macroinvertebrate community structure was evident between the Marine Baseline Program and Post-Development Survey Year 2 when the soft sediment and limestone dredging dataset and the soft sediment dredging dataset were used. For both datasets, the analyses suggested that natural temporal variation was greater than any potential change associated with the dredging and dredge spoil disposal activities.

The soft sediment dredge spoil disposal dataset showed a significant change between the Marine Baseline Program and Post-Development Survey Year 2 at the Impact Sites, which was largely driven by an increase in abundance of many of the taxonomic groups. For example, the abundance of Ascidians (colonial) and 'Other' hard corals increased significantly at Impact Sites from the Marine Baseline Program to Post-Development Survey Year 2. Sponges (fan) and Sponges (variable) showed a similar trend.

For limestone substrates, the assessment of change was limited to a comparison of benthic macroinvertebrate assemblages from two potential impact zones: ZoHI and the Zones of Influence South (ZoI Sth).[1] This assessment showed a significant difference in the ZoHI between the Marine Baseline Program and Post-Development Survey Year 2. In the ZoHI, there was a significant decline in the abundance of Sea cucumbers from the Marine Baseline Program (three individuals) to Post-Development Survey Year 2 (no individuals recorded). In the ZoI Sth, all taxonomic groups (except Ascidians (colonial) and Sponges (fan)) increased in abundance in Post-Development Survey Year 2 compared to the Marine Baseline Program. While both the ZoHI and ZoI Sth were considered to be 'influenced' by the dredging and dredge spoil disposal activities, the degree of influence between the two zones differed. As such, the significant change in the ZoHI between the Marine Baseline Program and Post-Development Survey Year 2, and the lack of a significant change in the ZoI Sth suggests that the observed changes in the benthic macroinvertebrate community structure for the limestone dredging dataset may potentially be due to the dredging activities. However, the significant change within

[1] Where appropriate, the Zones of Influence were split into two sub-zones: Zone of Influence South and Zone of Influence North. The sites within the Zone of Influence North were not impacted by the generation of turbidity and sediment deposition from construction or dredging and dredge spoil disposal activities; thus, where no Reference Sites were available, this sub-zone was used as a 'pseudo-Reference zone' in an assessment of change. For non-coral benthic macroinvertebrates, the analysis for limestone pavement habitat was restricted to the comparison of the two potential impact sites: Zones of High Impact and Zones of Influence South.

the ZoHI was largely driven by a decrease of three Sea cucumbers from the Marine Baseline Program to the Post-Development Survey Year 2.

Mangroves

Overall, the mangrove communities across all sites appeared in good condition. Statistical analysis showed no significant difference in mean percentage cover and tree abundance between ZoI and Reference Sites from the Marine Baseline Program to the Post-Development Surveys. However, mean percentage cover of mangrove trees showed significant differences between site, survey date, and the interaction between these factors, within both the ZoI and Reference Sites. This suggests that mangrove communities across Barrow Island are changing similarly over time regardless of their location. *Avicennia* spp. are considered sensitive biological indicators of coastal environmental change owing to their well-known ecological properties, in particular a tendency to sudden mortality resulting from changes in the daily duration and amplitude of flooding (Blasco *et al*. 1996). Given that the condition of mangroves appears to be similar to that recorded during the Marine Baseline Program with some improvements in health, the dredging and dredge spoil disposal activities are unlikely to have had any impact on the mangrove communities on the east coast of Barrow Island.

Demersal Fish

The Post-Development Survey Year 2 recorded the largest abundance of fish in coral habitats followed by macroalgae, sand, seagrass, and sessile invertebrate habitats. Species richness followed a similar pattern and was greatest in coral habitats followed by macroalgae, seagrass, sand, and then sessile invertebrates. The most common fish species observed in Barrow Island waters were mackerel (Scombridae spp), tuskfish (*Choerodon cyanodus, Choerodon schoenleinii*), trevally (*Carangoides fulvoguttatus, Gnathanodon speciosus*) and butterfish (*Pentapodus porosus, Pentapodus emeryii*).

No significant changes were recorded in the length frequency distributions of the fish assemblages between the Marine Baseline Program and Post-Development Surveys. A significant reduction in species richness was observed in the ZoHI between Marine Baseline Surveys and Post-Development Survey Year 1. However, at the time of this Post-Development Survey (Year 2), species richness had increased to the extent that it no longer differed to that recorded during the Marine Baseline Program. This pattern is suggestive of a 'pulse' response of species richness to a disturbance in this zone, which is now recovering.

Suggestion of a 'discrete pulse' perturbation reflected in the species richness data is supported by changes in the abundance of three indicator species all of which recorded a decrease in Post-Development Survey Year 1 compared to the Marine Baseline Program, followed by an increase, or no significant difference in abundance in Post-Development Survey Year 2. The abundance of one indicator, and two common fish species have shown a decrease in the Post-Development Surveys at Impact Sites compared to the Marine Baseline Program, and have not shown a recovery in Post-Development Survey Year 2. This pattern is consistent with a 'protracted pulse' perturbation, however given the recovery of other species with similar life characteristics, it is likely these species will also recover and exhibit increased abundance in Post-Development Survey Year 3.

Surficial Sediment

Six sediment classifications were observed in the Barrow Island region during the Post-Development Survey Year 2. These were the same sediment classifications observed during the Marine Baseline Program, except that sandy mud was observed during the Post-Development Survey Year 2 instead of muddy sandy gravel, observed during the Marine Baseline Program. This contrasts with the eight sediment classifications observed during the Post-Development Survey Year 1, which also included the categories gravel and gravelly mud.

Overall, across the predicted ZoHI, ZoMI, and ZoI and potentially the Reference Sites, the dredging and dredge spoil disposal activities may have caused a change in the sediment characteristics towards a finer particle size distribution near and to the south of the LNG Jetty.

However, it was also apparent that the surficial sediments in the region around Barrow Island were naturally variable; this was observed to a greater extent during Post-Development Survey Year 2 compared to Post-Development Survey Year 1. Therefore, the changes observed near and to the south of the LNG Jetty may, in part, be attributable to natural variability. Immediately north of the Materials Offloading Facility (MOF), sediments were observed to be coarser than those in the Marine Baseline Program were. Sediments with finer particle size distributions were also observed in a localised area south-west of the Dredge Spoil Disposal Ground. There were no other major trends in sediment change observed in the Barrow Island region.

Summary of Findings for each Ecological Element for the Post-Development Survey Year 2

Ecological Element	Conclusions
Coral	• The estimated net Area of Loss of Coral Assemblages in the ZoHI and ZoMI in the worst case was estimated to be 3.46 ha (adopting the upper 95% Confidence Limit [CL]) and therefore did not exceed the Permanent Loss of Coral Assemblages limit of 8.47 ha (95% CL), as per Condition 18.1ii.b of Statement No. 800. • No significant difference in the size-class frequency of corals between Impact Sites (ZoHI and ZoMI) and Reference Sites from the Marine Baseline Program to and Post-Development Survey Year 2. • No indication of a major shift in the dominant coral taxa between the Marine Baseline Program and Post-Development Survey Year 2; however, some of the variation in certain coral families may be associated with the dredging and dredge spoil disposal activities. • No significant difference in recruitment success was observed between the Marine Baseline Program and the Post-Development Survey Year 2. • A significant decline in the percentage live coral cover detected in the ZoMI between the Marine Baseline Program and the Post-Development Survey Year 2 is likely to be associated with the dredging and dredge spoil disposal activities. However, signs of recovery are evident in both the ZoHI and ZoMI as the Post-Development Survey Year 2 live coral cover has increased from Post-Development Survey Year 1. • No significant decline in coral growth was observed between the Marine Baseline Program and the Post-Development Survey Year 2 that may be associated with dredging and dredge spoil disposal activities.
Non-coral Benthic Macroinvertebrate	• The change in benthic macroinvertebrate assemblage for soft sediment substrates between the Marine Baseline Program and the Post-Development Survey Year 2 was an increase in abundance, and is not considered to be associated with the dredging and dredge spoil disposal activities. • The change in benthic macroinvertebrate assemblage for limestone pavement in the ZoHI between the Marine Baseline Program and Post-Development Survey Year 2 was driven by a decline of three individuals from one taxonomic group and is based only on sites within two potential Impact zones: ZoHI and ZoI Sth.
Mangroves	• Overall, the mangrove communities across all sites appeared in good condition. • No significant changes were detected in the mean percentage cover and abundance of mangroves attributable to dredging and dredge spoil disposal activities.
Demersal Fish	• Species richness in the ZoHI may be recovering from the significant decrease detected during Post-Development Survey Year 1 in comparison to that recorded during the Marine Baseline Program. • A single (one of 20) indicator species for coral habitat showed a decline in

Ecological Element	Conclusions
	abundance in the ZoHI between the Marine Baseline Program and the Post-Development Survey Year 2 and is likely to be associated with the dredging and dredge spoil disposal activities. • Two species of fish, commonly observed at Impact and Reference Sites showed a decline in abundance in Impact Sites between the Marine Baseline Program and Post-Development Survey Year 1 and Year 2 that is likely to be associated with dredging and dredge spoil disposal activities.
Surficial Sediment	• For those sites within the vicinity of, and south of, the LNG Jetty, the changes in composition of surficial sediment to finer sediments in the Post-Development Survey Year 2 relative to that recorded during the Marine Baseline Program is likely to be associated with the dredging and dredge spoil disposal activities.

1.0 Introduction

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 Ministerial Implementation Statement No. 800 (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 Ministerial Implementation Statement No. 769 (Statement No. 769) and EPBC Reference: 2005/2184.

1.2 Project

Chevron Australia proposes to develop the gas reserves of the Greater Gorgon Area (Figure 1-1).

Subsea gathering systems and subsea pipelines will be installed to deliver feed gas from the Gorgon and Jansz–Io gas fields to the west coast of Barrow Island. The feed gas pipeline system will be buried as it traverses from the west coast to the east coast of the Island where the system will tie in to the Gas Treatment Plant located at Town Point. The Gas Treatment Plant will comprise three Liquefied Natural Gas (LNG) trains capable of producing a nominal capacity of five Million Tonnes Per Annum (MTPA) per train. The Gas Treatment Plant will also produce condensate and domestic gas. Carbon dioxide (CO_2), which occurs naturally in the feed gas, will be separated during the production 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-northeast of the town of Onslow and 140 km west of Karratha. The 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.

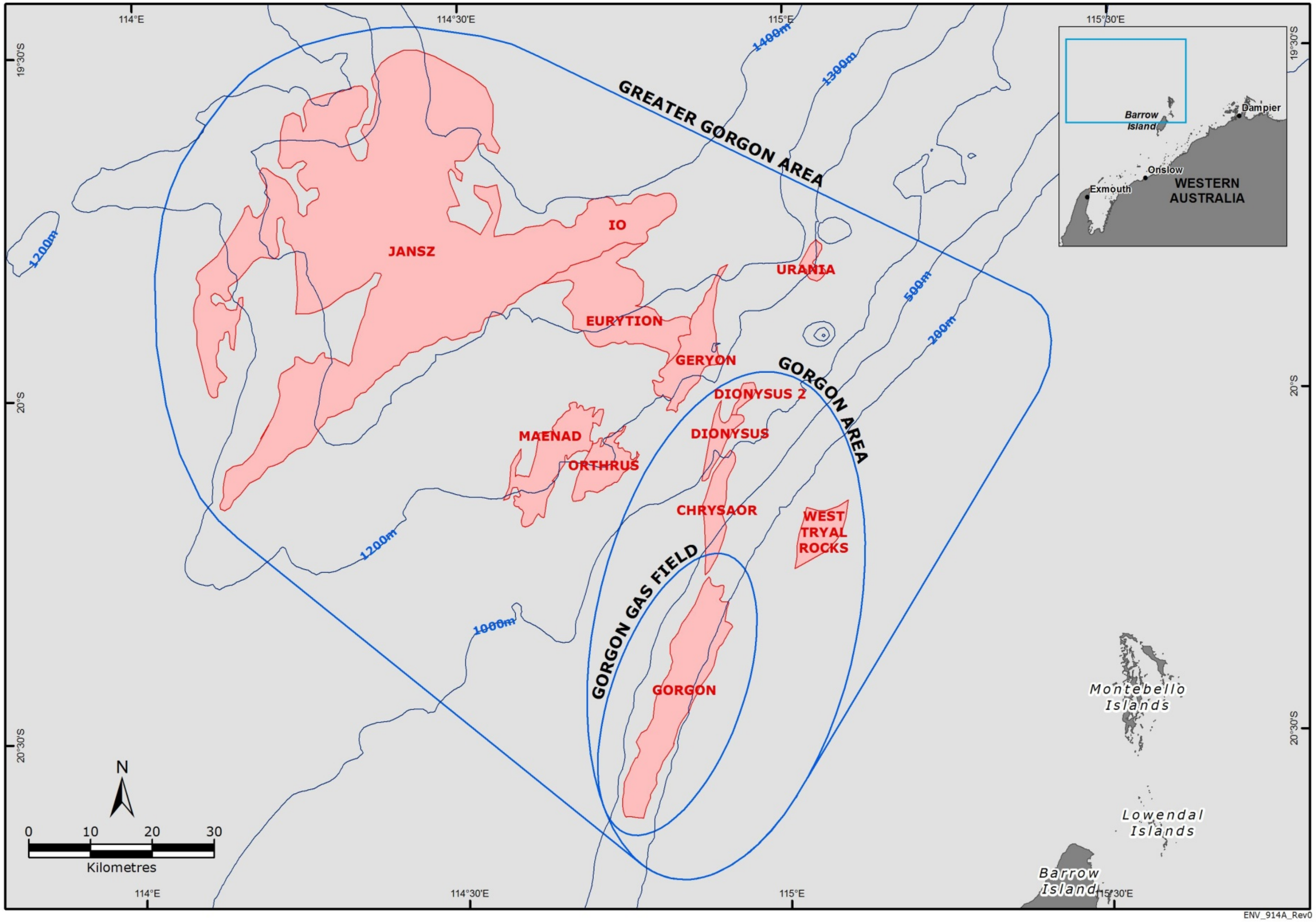


Figure 1-1 Location of the Greater Gorgon Area

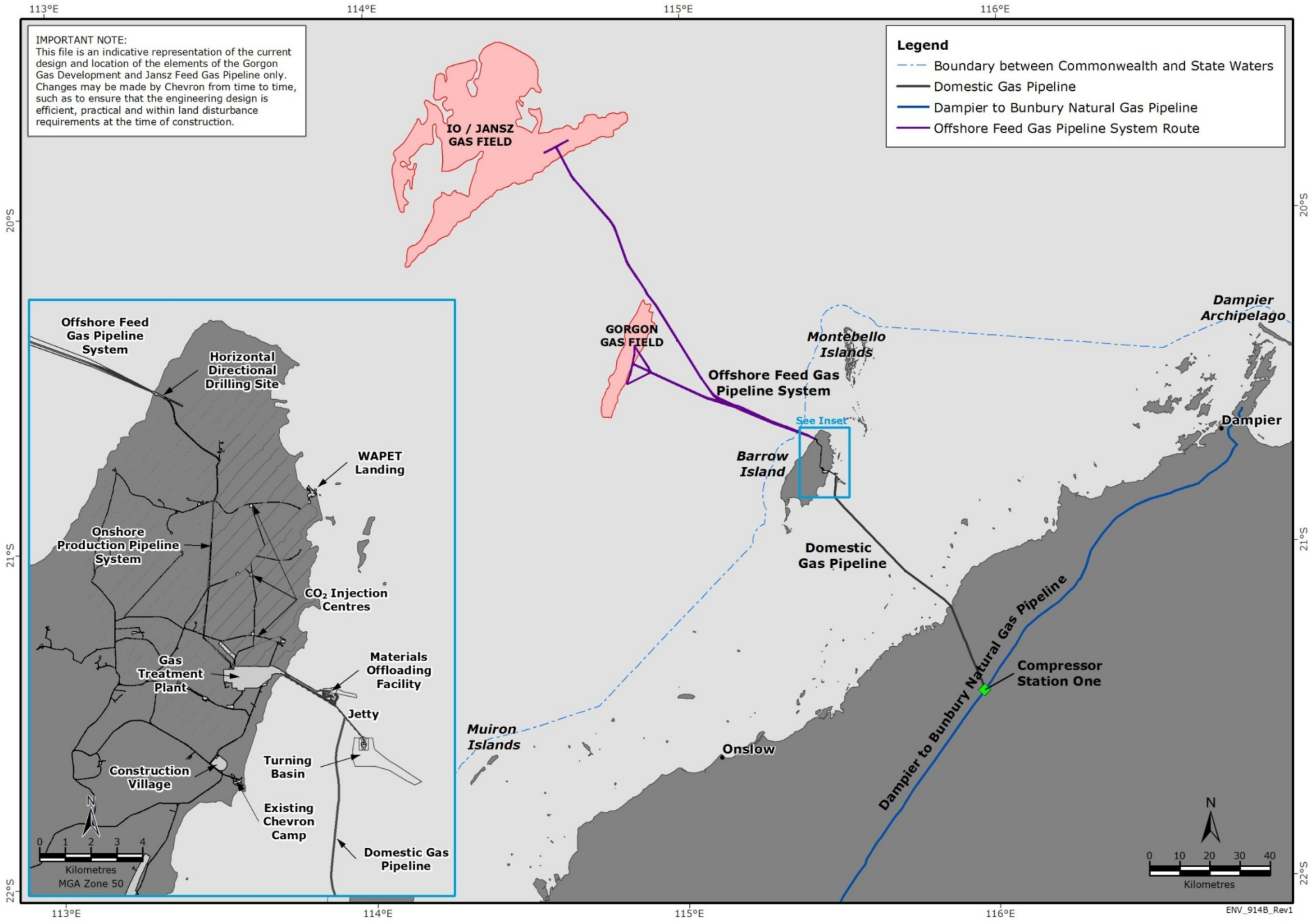


Figure 1-2 Location of the Gorgon Gas Development and Jansz Feed Gas Pipelines

1.4 Environmental 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' (Environmental Protection Authority [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 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). However, implementation of the Gorgon Gas Development will continue to be in accordance with Statement No. 800.

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). Since the Revised and Expanded Gorgon Gas Development was approved, further minor changes have also been made and/or approved to the Gorgon Gas Development and are now also part of the Development. Further changes may also be made/approved in the future.

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 Statement No. 769 and the Commonwealth Minister for the Environment and Water Resources on 22 March 2006 (EPBC Reference: 2005/2184).

This Report covers the Gorgon Gas Development as approved under Statement No. 800 and as approved by EPBC Reference: 2003/1294 and 2008/4178.

1.5 Purpose of this Report

1.5.1 Legislative Requirements

1.5.1.1 State Ministerial Conditions

This Report is required under Condition 24.3 of Statement No. 800, which is quoted below:

> *'Within 3 months of completion of each annual Post-Development Coastal and Marine State and Environmental Impact Survey required by Condition 24.1, the Proponent, on advice of the CDEEP, shall report the results of the survey to the Minister, including detected changes to marine ecological elements listed in Condition 14.2.'*

1.5.1.2 Commonwealth Ministerial Conditions

This Report satisfies the requirements of Condition 17.3 of EPBC Reference: 2003/1294 and 2008/4178, which is quoted below:

> *'Within 3 months of completion of each annual Post-Development Coastal and Marine State and Environmental Impact Survey, the person taking the action, on advice of the CDEEP, must report the results of the survey to the Minister, including detected changes to marine ecological elements listed in Condition 11.2.'*

1.5.2 Objectives

The objectives of this Report, as stated in Condition 24.2 of Statement No. 800 are to:

- determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with the pre-development baseline marine environmental state established in the Report required by Condition 14.2.

Note that the Post-Development Coastal and Marine State and Environmental Impact Survey required under Condition 24.1 of Statement No. 800 refers specifically only to those Marine Facilities listed in Condition 17.2, and as repeated below:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Marine component of the Barge (WAPET) Landing upgrade.

The objectives of this Report, as stated in Condition 17.2 of EPBC Reference: 2003/1294 and 2008/4178 are to:

- determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with the pre-development baseline marine environmental state established in the Report required by Condition 11.2.

Note that the Post-Development Coastal and Marine State and Environmental Impact Survey required under Condition 17.1 of EPBC Reference: 2003/1294 and 2008/4178, refers specifically only to those Marine Facilities listed in Condition 13.2, and as repeated below:

- Materials Offloading Facility (MOF)
- LNG Jetty.

1.5.3 Requirements

The requirements of this Report, as stated in Condition 24 of Statement No. 800 and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178 are listed in Table 1-1.

Table 1-1 Requirements of this Report

Ministerial Document	Condition No.	Requirement	Section Reference in this Report
Statement No. 800	24.1	The Proponent shall conduct Post-Development Coastal and Marine State Surveys associated with the construction of marine facilities listed in Condition 17.2 in accordance with the approved scope of works required by Condition 14.1, within three months following the date on which the Proponent issues a certificate of acceptance of the dredge and dredge spoil disposal program under the contract, issued for the Program. Surveys shall be repeated at the same time of the year (where practicable) for at least an additional two years, unless otherwise determined by the Minister.	See survey dates in Sections 4.3.1.2, 4.4.1.2, 4.5.1.2, 4.6.1.2,4.7.1.2, 4.8.1.2, 5.3.2, 6.3.2, 7.3.2, and 8.3.2.
Statement No. 800	24.2	The purpose of the Post-Development Coastal and Marine State and Environmental Impact Surveys is to determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with pre-development baseline marine environmental state established in the Report required by Condition 14.2.	Comparison between Marine Baseline and Post-Development is presented in Sections 4.3.3, 4.4.3, 4.5.3, 4.6.4, 4.7.3, 4.8.3, 5.5, 6.5, 7.5, and 8.5. Area of Loss of Coral Assemblages is presented in Section 4.3.
Statement No. 800	24.3	Within 3 months of the completion of each annual Post-Development Coastal and Marine State and Environmental Impact Survey required by Condition 24.1, the Proponent, on advice of the CDEEP, shall report the results of the survey to the Minister, including detected changes to marine ecological elements listed in Condition 14.2.	Field sampling completed 7 May 2013. Construction Dredging Environmental Expert Panel (CDEEP) consultation presented in Section 1.5.6.
EPBC Refs: 2003/1294 and 2008/4178	17.1	The person taking the action must conduct Post-Development Coastal and Marine State Surveys associated with the construction of marine facilities listed in Condition 13.2 in accordance with the approved scope of works required by Condition 11.1, within three months following the date on which the person taking the action issues a certificate of acceptance of the dredge and dredge spoil disposal program under the contract issued for the Program. Surveys must be repeated at the same time of year (where practicable) for at least an additional two years, unless otherwise determined by the Minister. In determining the need for additional surveys, the Minister will take	See Section 3.0 (General Approach to Methods) See survey dates in Sections 4.3.1.2, 4.4.1.2, 4.5.1.2, 4.6.1.2, 4.7.1.1.1, 4.8.1.2, 5.3.2, 6.3.2, 7.3.2, and 8.3.2. CDEEP consultation presented in Section 1.5.6.

Ministerial Document	Condition No.	Requirement	Section Reference in this Report
		into consideration any advice of the person taking the action, the CDEEP, and the Western Australian Minister.	
EPBC Refs: 2003/1294 and 2008/4178	17.2	The purpose of the Post-Development Coastal and Marine State and Environmental Impact Surveys are to determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with pre-development baseline marine environmental state established in the Report required by Condition 11.2.	See Section 3.0 (General Approach to Methods) Comparison between Marine Baseline and Post-Development is presented in Sections 4.3.3, 4.4.3, 4.5.3, 4.6.4, 4.7.3, 4.8.3, 5.5, 6.5, 7.5, and 8.5. Area of Loss of Coral Assemblages is presented in Section 4.3.
EPBC Refs: 2003/1294 and 2008/4178	17.3	Within 3 months of completion of each annual Post-Development Coastal and Marine State and Environmental Impact Survey, the person taking the action, on advice of the CDEEP, must report the results of the survey to the Minister, including detected changes to marine ecological elements listed in Condition 11.2.	Field sampling completed 7 May 2013. CDEEP consultation presented in Section 1.5.6.

Any matter specified in this Report is relevant to the Gorgon Gas Development only if that matter relates to the specific activities or facilities associated with that particular development.

1.5.4 Hierarchy of Documentation

This Report will be implemented for the Gorgon Gas Development 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 provides an overview of the overall hierarchy of environmental management documentation within which this Report exists.

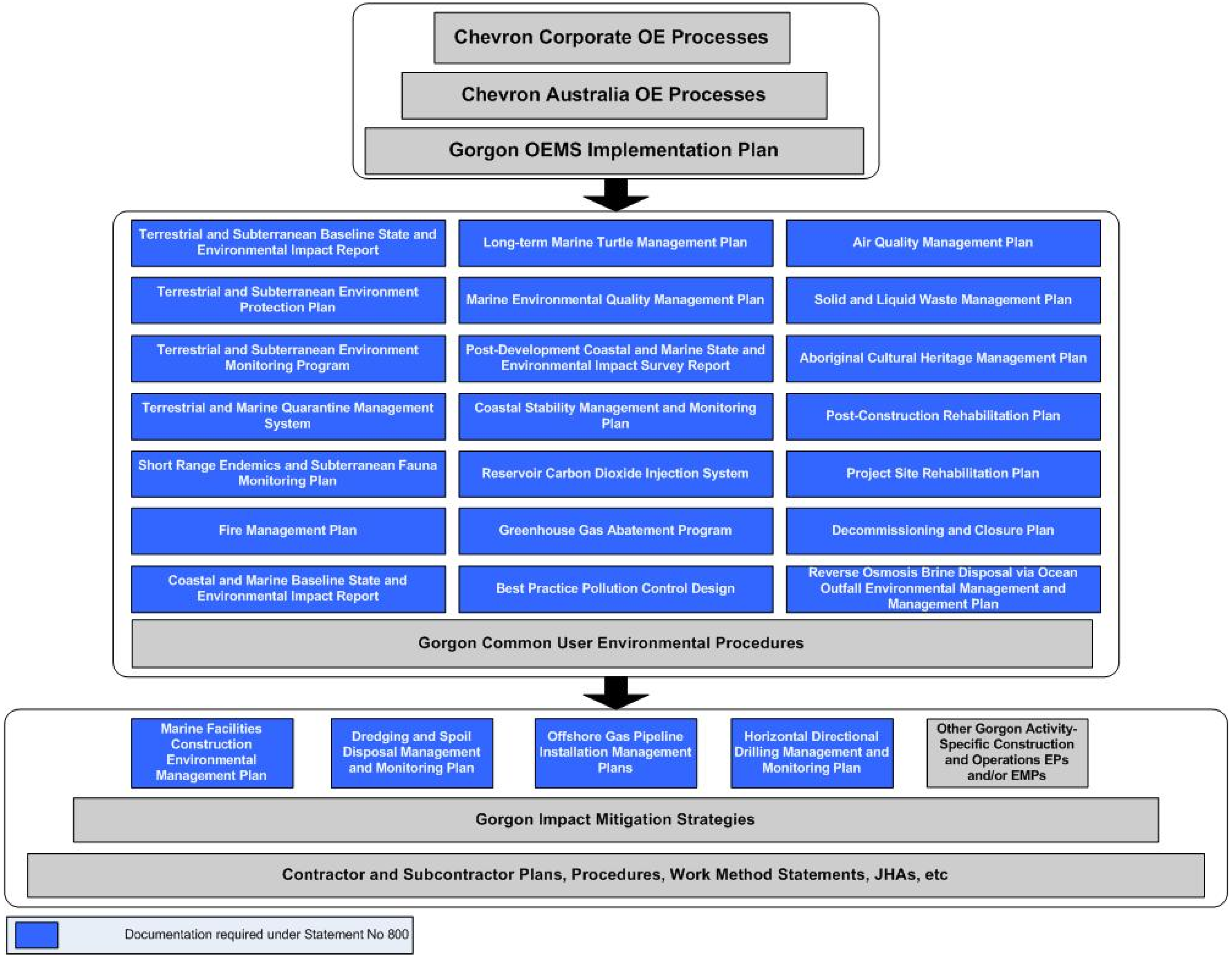


Figure 1-3 Hierarchy of Gorgon Gas Development Environmental Documentation

1.5.5 Scientific Expertise

The field component of this Post-Development Survey was primarily managed and undertaken by Sinclair Knight Merz and supported by Oceanic Offshore Commercial Diving Services and Gun Marine Services Pty Ltd. Field sampling for the demersal fish scope was supported by the Marine Ecology Group (University of Western Australia).

The data analysis and reporting component of this Post-Development Survey was undertaken by Oceanica Consulting Pty Ltd (for these ecological elements: corals, non-coral benthic macroinvertebrates, and surficial sediment); 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 Marine Ecology Group (University of Western Australia). Oceanica Consulting Pty Ltd provided advice on statistical design for the subtidal demersal fish analyses.

The field sampling, data analysis, and reporting components for the mangrove element of this Post-Development Survey were undertaken by Astron Environmental Services. Oceanica Consulting Pty Ltd provided advice on statistical design for mangrove abundance and percentage cover analyses.

1.5.6 Stakeholder Consultation

In accordance with Condition 24.3 of Statement No. 800 and Condition 17.3 of EPBC Reference: 2003/1294 and 2008/4178, this Report was prepared with advice from the Construction Dredging Environmental Expert Panel (CDEEP). The CDEEP has reviewed and been provided with verbal briefings on this Report and their comments have been incorporated or otherwise resolved.

1.5.7 Public Availability

This Report will be made public as and when determined by the Minister, under Condition 35 of Statement No. 800 and Condition 22 of EPBC Reference: 2003/1294 and 2008/4178.

2.0 Relevant Facilities and Areas

2.1 Marine Facilities

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 and Figure 2-1. The Gorgon Gas Development Marine Facilities, relevant to this Report, are defined in Condition 17.2 of Statement No. 800 as the:

- Materials Offloading Facility (MOF)
- LNG Jetty
- Marine component of the Barge (WAPET) Landing upgrade.

The Marine Facilities, relevant to this Report, for the Gorgon Gas Development as defined in Condition 13.2 of EPBC Reference: 2003/1294 and 2008/4178 are the:

- Materials Offloading Facility (MOF)
- LNG Jetty.

The sections that follow summarise the main activities associated with construction of the Marine Facilities that are required by this Report (i.e. the MOF, the LNG Jetty, and the marine component of the Barge [WAPET] Landing upgrade). Additional details on these Marine Facilities can be found in the Draft EIS/ERMP (Chevron Australia 2005), the section 45C approval (EPA 2008), the PER (Chevron Australia 2008), and the Marine Facilities Construction Environmental Management Plan (Chevron Australia 2012d).

A range of construction vessels is required for these marine construction activities. In addition, a number of ancillary vessels are required, including supply vessels, refuelling vessels, crew change vessels, survey vessels, and marine construction support vessels. Works include the installation of navigation aids, channel markers, and lead lights. Moorings will also be installed for the marine construction activities as required.

2.1.2 Dredging and Dredge Spoil Disposal

Dredging was required to provide access channels and berths associated with the MOF, and an access channel, berths, and a turning basin associated with the LNG Jetty. Dredge spoil generated was either used for reclamation and development of the MOF or disposed in the designated Dredge Spoil Disposal Ground. Further information on the dredging and dredge spoil disposal activities and associated monitoring can be found in the Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011).

The dredging and dredge spoil disposal activities commenced on 19 May 2010 and were completed by 7 November 2011. The total dredge volume for the LNG Jetty and MOF was approximately 7.7 million m^3.

2.1.3 Materials Offloading Facility (MOF)

The MOF is being constructed in the following stages:

- construction of the Pioneer MOF Platform
- construction of the Pioneer MOF Causeway
- extension of the Pioneer MOF to complete the Full MOF.

The full MOF (causeway and offloading facilities) is approximately 2120 m long.

The Pioneer MOF is required for offloading equipment and materials for the construction of the onshore Gas Treatment Plant and associated facilities on Barrow Island, via large barges and Roll-on/Roll-off vessels. Construction activities for the Pioneer MOF Platform included:

- constructing a Pioneer MOF perimeter berm using a combination of suitably-sized dredged material and rock transported from the mainland
- placing dredged material within the perimeter berm to form the Pioneer MOF Platform. Primary and secondary armour rock sourced from the mainland was then installed on the external face of the Pioneer MOF Platform.

A causeway was constructed to connect the Pioneer MOF Platform to Town Point on the east coast of Barrow Island, using material excavated from Barrow Island. A roadway was constructed on the surface of the Pioneer MOF Causeway.

Following construction of the Pioneer MOF Platform, work commenced on extending the MOF platform seaward and raising part of the existing MOF Causeway, including:

- extending the MOF platform seaward, forming a breakwater to protect tug pen moorings, the heavy lift facility, and other berths. Material excavated from Barrow Island and dredge material was used for this extension
- constructing a Heavy Lift Facility and tug pens
- raising the existing MOF Causeway by adding an upper causeway section to accommodate an all-weather access road to the LNG Jetty and a pipe rack containing LNG, condensate, and other pipelines for export and operations of the jetty offloading facilities. At the time of this Report, this work was under construction using material excavated from Barrow Island and installing armour comprising precast concrete units. Suitable dredged material has been used in place of core fill material from Barrow Island.

2.1.4 LNG Jetty

A two-kilometre long jetty (under construction at the time of this Report) will extend from the MOF platform head (Figure 2-1). The LNG Jetty is required to support a series of LNG, condensate, vapour return, firewater, and utilities pipelines that connect the onshore LNG Plant to the loading platforms. The design of the LNG Jetty is based on an open structure with gravity-based concrete caissons founded on the seabed. The caissons typically have four piles each, which are embedded in the caisson and which support the jetty superstructure.

Construction of the LNG Jetty will include:

- seabed preparation, levelling, and placement of the foundation gravel layer for the caissons
- offsite prefabrication of jetty elements
- transportation to site, floating into position, and immersion to the rock foundation of gravity-based concrete jetty supports
- lifting the offsite prefabricated superstructures (including pipe racks, buildings, and pre-assembled units for firewater pumps, emergency shutdown, and product loading) on to the jetty supports.

2.1.5 Marine Upgrade of the Existing WAPET Landing

Prior to the construction of the MOF, WAPET Landing handled marine vessel and freight movements for import to and export from Barrow Island; it continues to be used as a materials offloading facility. WAPET Landing has been in use since the 1960s and the area along the Land-backed Wharf and the boat ramps has been disturbed by regular marine supply vessel activity. While the facilities have been expanded slightly, the area of disturbance is similar to the area of historical disturbance of the WAPET Landing facilities.

The existing material offloading facilities at WAPET Landing that were upgraded were the:

- Landing Craft Tank (LCT) Landing and Barge Berth
- Land-backed Wharf
- Groyne Barge Berth.

As the area of disturbance is similar to the historical disturbance, and as data related to the WAPET Landing from the Marine Baseline Program is primarily qualitative, no further specific discussion about this Marine Facility or the description of the ecological elements in the vicinity of WAPET Landing are presented in this Report.

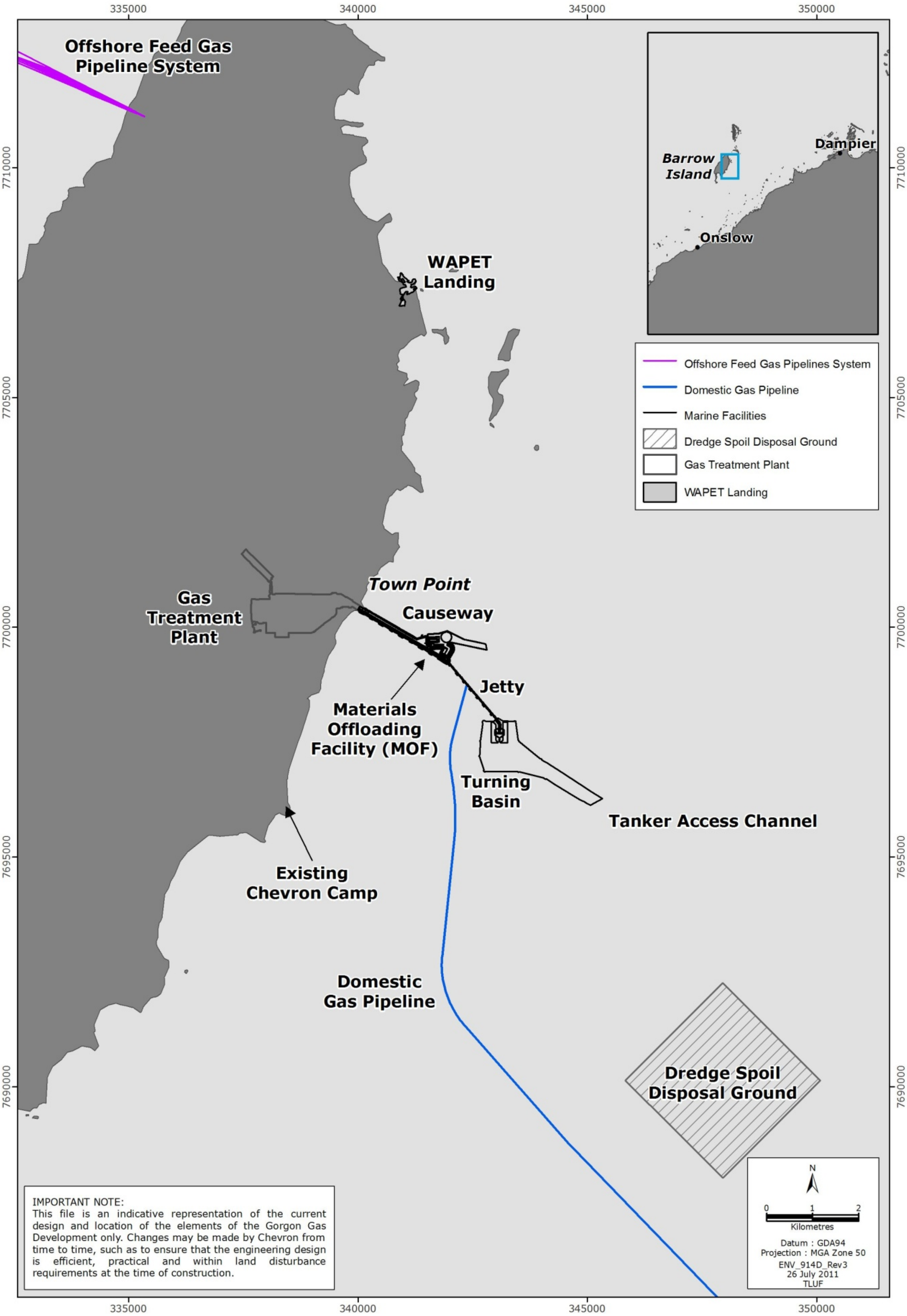


Figure 2-1 Gorgon Gas Development and Jansz Feed Gas Pipeline Marine Facilities on Barrow Island

2.2 Marine Areas

2.2.1 Marine Disturbance Footprint

The Gorgon Gas Development Marine Disturbance Footprint is defined in Statement No. 800 as:

> *'The area of the seabed to be disturbed by construction or operations activities associated with the marine facilities listed in Condition 14.3 (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and spoil disposal).'*

The Gorgon Gas Development Marine Disturbance Footprint is defined in EPBC Reference: 2003/1294 and 2008/4178 as:

> *'The area of the seabed to be disturbed by construction or operations activities associated with the marine facilities listed in Condition 11.3 (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and spoil disposal).'*

The Marine Disturbance Footprint includes the Marine Facilities Footprint (the areas of the seabed associated with the physical footprint of the Marine Facilities [the MOF, the LNG Jetty, and the marine upgrade of the existing WAPET Landing]) and the extent of the surrounding seabed in which the planned construction and operations activities could be expected to disturb the seabed. The stressors include vessel propeller wash, vessel anchoring and mooring facilities, pipe laying, rock and fill material placement, and pile and navigational aid installation. The boundary of the Marine Disturbance Footprint for the east coast Marine Facilities is shown in Figure 2-2; it encompasses an area extending 300 m from the toe of the facilities.

The Marine Disturbance Footprint does not include areas that were predicted to be disturbed by the generation of turbidity and sedimentation from dredging and dredge spoil disposal activities. However, it does include areas of the seabed that were directly affected (i.e. removed) by these activities and the impacts of plumes from non-dredging construction activities. Disturbance to the seabed within the Marine Disturbance Footprint may include changes in seabed profile and seabed type; sedimentation and smothering of benthic assemblages; and wastewater discharge. The Marine Disturbance Footprint also includes areas that were not or will not be disturbed; e.g. areas between anchor positions and between the anchor positions and the vessel where no anchors or chains contact the seabed. The levels of disturbance within the Marine Disturbance Footprint vary from negligible to Material Environmental Harm to Serious Environmental Harm (see Section 2.2.3 for further details on these levels).

In addition, the Marine Disturbance Footprint to the east of Barrow Island includes indicative areas where operational and cyclone moorings have and will be installed (see hatched areas on Figure 2-2). Note that it is not proposed to disturb the entire area of the Marine Disturbance Footprint identified for the installation of moorings in Figure 2-2. Each mooring will create localised disturbance at the points of contact with the seabed, and when anchors or clump weights are used instead of moorings, some additional disturbance will be created by anchor chain sweep of the seabed. However, it is anticipated that approximately 50 to 60% of the indicative Marine Disturbance Footprint will be directly disturbed (see the Marine Facilities Construction Environmental Management Plan [Chevron Australia 2012d] for details on the management of mooring installation).

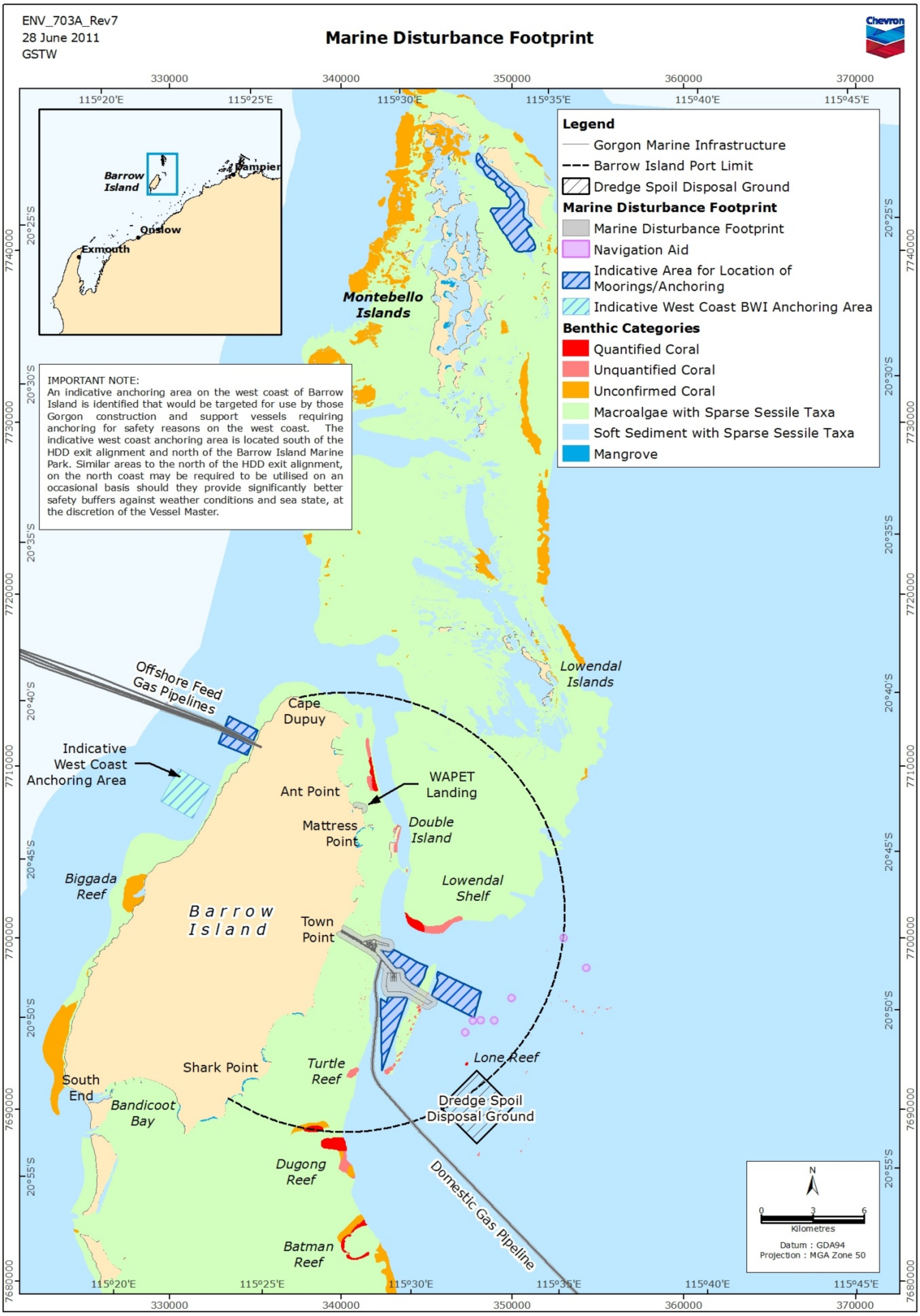


Figure 2-2 Marine Disturbance Footprint

2.2.2 Dredge Management Areas and Plume Modelling

Hydrodynamic modelling was undertaken for the EIS/ERMP (Chevron Australia 2005, 2006) and refined in the Revised and Expanded Proposal PER (Chevron Australia 2008). Models were developed to predict how sediments released during dredging and dredge spoil disposal activities would disperse through the marine environment under the influence of oceanographic processes.

In undertaking the risk assessment for the EIS/ERMP (Chevron Australia 2005, 2006) and the Revised and Expanded Proposal PER (Chevron Australia 2008), three zones were established to reflect the different levels of predicted impact to corals (Figure 2-3). These zones were established based on sediment load and exposure time above background levels, and took into account published values for acute (short-term), medium-term, and chronic (long-term) responses to both sedimentation and elevated total suspended solids (TSS) (Chevron Australia 2005, 2006). These zones are shown in Figure 2-3 and are defined as:

- 'Zones of High Impact' (ZoHI) – the areas where long-term impacts on corals are predicted to occur directly, from direct disturbance during dredging or construction of infrastructure on the seabed and burial during dredge spoil disposal activities; or where complete, but short-term losses, are predicted to occur directly through increased sedimentation and/or deterioration in water quality.
- 'Zones of Moderate Impact' (ZoMI) – the areas where short-term moderate impacts (e.g. some partial mortality of corals) are predicted to result indirectly from dredging and/or dredge spoil disposal activities, due to an increase in sedimentation rates and/or a deterioration in water quality. Moderate impacts are likely to include some partial mortalities among fast-growing, more sensitive coral species (e.g. *Acropora* species.), but less, if any, mortality of longer-living, generally more resilient species (e.g. *Porites* species, *Turbinaria* species).
- 'Zones of Influence' (ZoI) – the areas that are predicted to be influenced by dredging and dredge spoil disposal activities such that marginal increases in sedimentation and turbidity will occur, but at levels that will have no measurable impact on corals.

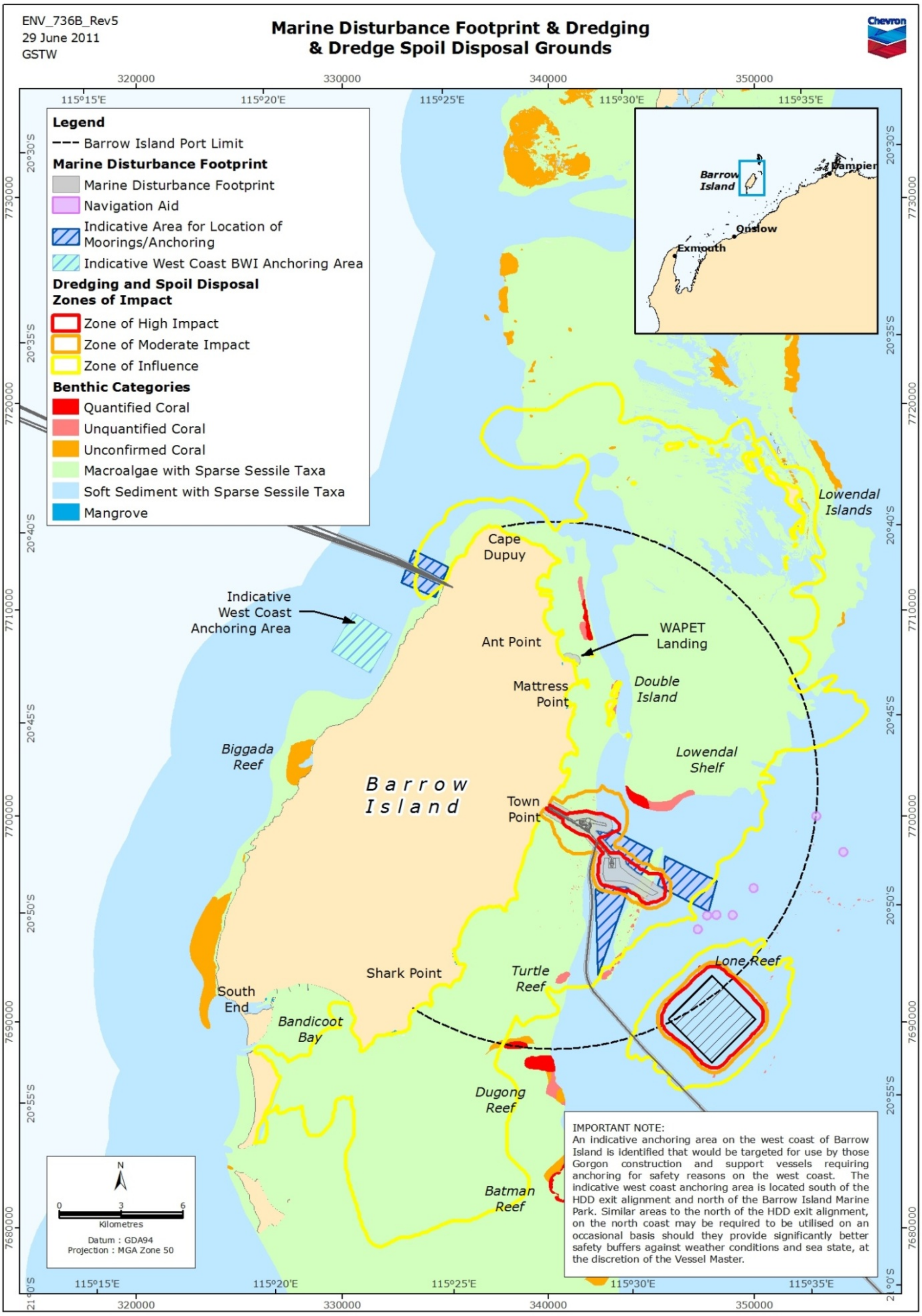


Figure 2-3 Marine Disturbance Footprint and Dredging and Dredge Spoil Disposal Zones of High Impact, Zones of Moderate Impact, and Zones of Influence

2.2.3 Areas at Risk of Material or Serious Environmental Harm

Material Environmental Harm is defined as:

> 'Environmental harm that is neither trivial nor negligible'.

Serious Environmental Harm is defined as:

> 'Environmental harm that:
>
> a. is irreversible, of a high impact or on a wide scale; or
>
> b. is significant or in an area of high conservation value or special significance and is neither trivial nor negligible'.

Material or Serious Environmental Harm due to the construction of the Marine Facilities may occur within the Marine Disturbance Footprint (described in Section 2.2.1) and the Dredge Management Areas (described in Section 2.2.2). The level of harm predicted at a particular location within the Marine Disturbance Footprint and the Dredge Management Areas depends on the types of stressors, the sensitivity of the benthic assemblages at any location, the likelihood of complete or partial recovery from the disturbance, and the management or mitigation measures taken to reduce impacts. Examples of seabed disturbances that were predicted to cause Material Environmental Harm include: localised or short-term (fewer than five years) impacts such as anchor scouring in a macroalgal bed, seagrass bed, or benthic macroinvertebrate assemblage; and disturbance or resuspension of unconsolidated sediments by vessel propeller wash and pipeline discharges. Examples of seabed disturbances that were predicted to cause Serious Environmental Harm include: permanent loss or removal of substrates (e.g. through the direct placement of the Marine Facilities on the seabed); shading by infrastructure; and physical removal of the substrate through dredging. These factors were used to determine the areas within the Marine Disturbance Footprint and the Dredge Management Areas that were, or still are, at risk of Material or Serious Environmental Harm (Figure 2-4, Figure 2-5).

The areas at risk of Material or Serious Environmental Harm are predicted to be different for hard and soft corals (Figure 2-4) compared to other ecological elements (Figure 2-5). For all ecological elements, Serious Environmental Harm will occur within the Marine Facilities Footprint as the existing substrate and associated ecological elements will be either removed or buried beneath the Marine Facilities. 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.

Within the Dredge Management Areas (beyond the Marine Facilities Footprint) there were likely to be temporary or sub-lethal impacts that may remove or reduce the existing ecological elements. Nevertheless, the substrate was expected to retain its ecological function as benthic habitat and the ecological elements other than coral were predicted to recover in the short term (fewer than five years). This was considered to represent Material Environmental Harm. Seagrass and macroalgae 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 were predicted to be temporarily affected (Chevron Australia 2006). Recovery of these assemblages was anticipated within two to five years following cessation of the disturbance, when water quality and sedimentation return to their natural range. This is not the case for all hard coral taxa. Some hard corals are predicted to recover or recolonise in the short term following cessation of the disturbance (e.g. corals such as the *Turbinaria* and *Acropora*), while others will take a long time to re-establish and regrow. Consequently, Material and Serious Environmental Harm to corals cannot easily be distinguished within the ZoHI and the ZoMI.

Reference Sites, those areas not at risk of Material or Serious Environmental Harm due to the construction of the Marine Facilities, include selected areas outside the Marine Disturbance Footprint and the ZoHI and ZoMI, including areas within the ZoI that are suitable for comparison with impacted areas. For ecological elements other than hard and soft corals, sites within the ZoI are considered to be Reference Sites because turbidity and sedimentation are not expected to cause Material or Serious Environmental Harm at these sites. Note that these sites will not be included as Reference Sites in any analysis if there is evidence that they have been impacted by the generation of turbidity and sediment deposition from construction of, or dredging and dredge spoil disposal activities required for, the MOF, LNG Jetty, Dredge Spoil Disposal Ground, or the marine upgrade of the existing WAPET Landing.

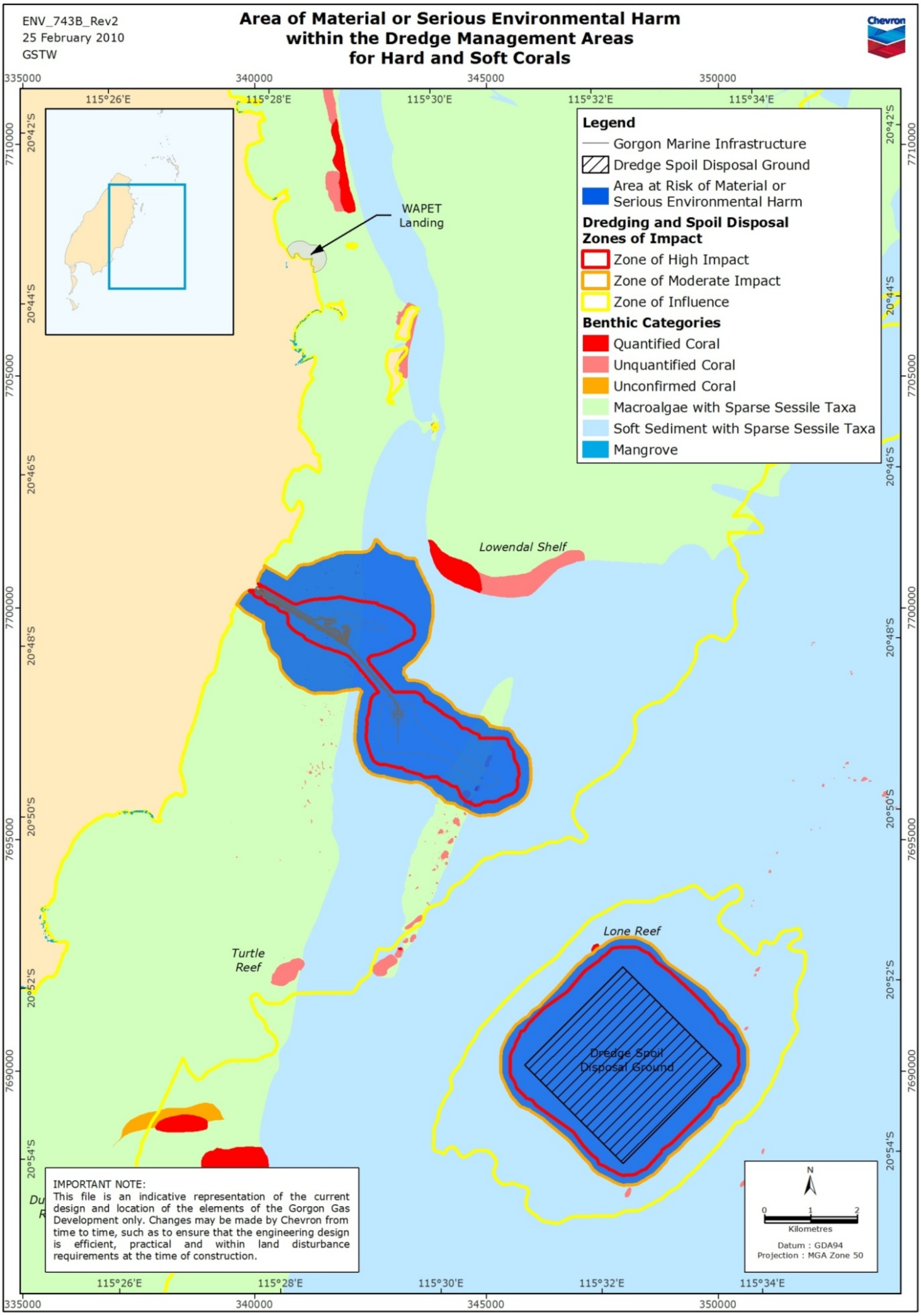


Figure 2-4 Area of Material or Serious Environmental Harm within the Dredge Management Areas for Hard and Soft Corals

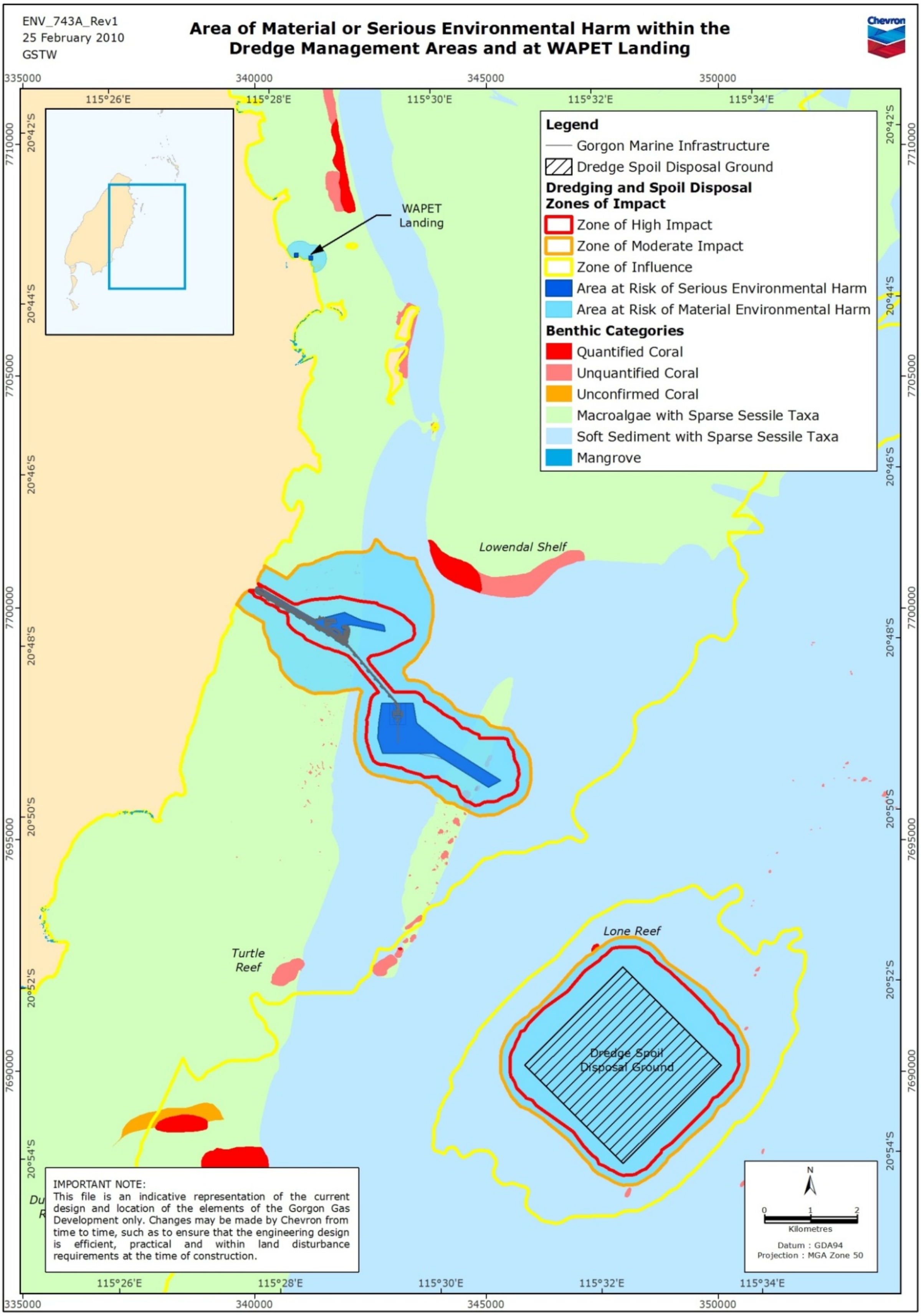


Figure 2-5 Area of Material or Serious Environmental Harm within the Dredge Management Areas and at WAPET Landing for Non-coral Benthic Macroinvertebrates, Macroalgae, Seagrass, and Demersal Fish

3.0 General Approach to Methods

3.1 Introduction

The Marine Baseline Program required under Condition 14 of Statement No. 800 and Condition 11 of EPBC Reference: 2003/1294 and 2008/4178, was initiated in November 2007. Results from that monitoring program are presented in the Coastal and Marine Baseline State and Environmental Impact Report (Chevron Australia 2012a). Note that revisions to the Marine Baseline Program data are used within this Post-Development Survey Year 2 report. Appendix 1 provides a summary and reasoning of changes to the Marine Baseline Program data. Chevron Australia are currently revising the Coastal and Marine Baseline State and Environment Impact Survey Report (Chevron Australia 2012a) to reflect these changes.

This Post-Development Survey Report Year 2 has been prepared to meet the requirements of Condition 24 of Statement No. 800 and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178. As stated under Condition 24.2 of Statement No. 800 and Condition 17.1 of EPBC Reference: 2003/1294 and 2008/4178, '*The purpose of the Post-Development Coastal and Marine State and Environmental Impact Surveys is to determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with predevelopment baseline marine environmental state*'. .As stated in the approved Scope of Works (RPS 2009 [amended 2012]), '*Condition 24 of Statement No. 800 and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178 requires post-construction monitoring to detect changes in ecological elements that may be attributable to dredging associated with the MOF and the LNG Jetty*.'

The changes assessed, as required under Condition 24.2 of Statement No. 800 and Condition 17.1 of EPBC Reference: 2003/1294 and 2008/4178 are therefore specifically those changes to ecological elements that may be attributable to dredging associated with the MOF and the LNG Jetty.

This is the second Post-Development Survey undertaken since completion of dredging and dredge spoil disposal activities. In the assessment of change in ecological elements between the Marine Baseline Program and Post-Development Surveys, the results from both Post-Development Survey Year 1 and Post-Development Survey Year 2 are included in the Report.

3.2 Sampling Methodology

As required under Condition 24 of Statement No. 800 and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178, this Post-Development Survey Report, Year 2 was undertaken in accordance with the approved Scope of Works (RPS 2009 [amended 2012]).

Based on the results and recommendations presented in the Post-Development Coast and Marine State and Environment Impact Survey Report Year 1: 2011–2012 (Chevron Australia 2012b), Chevron Australia recommended the removal of several ecological elements from the Post-Development Coast and Marine State and Environment Impact Survey Year 2. The recommendation to remove the ecological elements Seagrass and Macroalgae were subsequently approved by the Department of Environment and Conservation (DEC) on 21 November 2012 and conditionally approved by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) on 7 March 2013. Further advice was received by Chevron Australia from SEWPaC on 13 June 2013 and, at the time of preparing this Report, Chevron Australia were engaging in additional discussions with SEWPaC. The fieldwork for this survey report commenced in late November 2012 and was completed in early May 2013. Consultation with DEC and SEWPaC commenced prior to the commencement of the field component of the survey, and further consultation with SEWPaC continued in parallel with the field survey and the development of this report. As such, the ecological elements Seagrass and Macroalgae were not surveyed as part of Post-Development Survey Year 2 based on the outcome of these discussions with DEC and SEWPaC, and are not included in this Report for Year 2. The same correspondence also acknowledged that intertidal demersal fish were not a requirement under the Scope of Works, and therefore were also not required under Post-Development Survey Year 2.

In addition to the removal of elements, Chevron Australia proposed an alternate methodology to be applied to the assessment of coral recruitment if the timing of the Post-Development Survey was outside the predicted mass spawning coral periods. This alternate methodology was approved by DEC and SEWPaC in November 2012 and the alternate method for 'Recruitment Success' was employed during the Post-Development Survey Year 2 (see Section 4.6). A comparison of the methods used during the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2 are presented in Table 3-1.

3.3 Sampling Sites

The Marine Baseline Program was designed to include sites within the Dredge Management Areas, as well as Reference Sites outside these areas that are not at risk of Material or Serious Environmental Harm (Sections 2.2.2 and 2.2.3). Particular focus has been given to coral assemblages within the ZoHI, the ZoMI, and representative areas within the ZoI, as well as at Reference Sites and sites in Regionally Significant Areas.

The location of the Marine Facilities and information from the existing broad scale benthic habitat map of the Montebello/Barrow Islands area (Department of Environment and Conservation [DEC] 2007), aerial photographs, Laser Airborne Depth Sounder (LADS), Multi-Beam Sonar, and Side-Scan Sonar data (refer to Section 5.0 of Chevron Australia 2012a) were used to assist in the selection of survey sites for the other ecological elements (i.e. non-coral benthic macroinvertebrates, macroalgae, seagrass, mangroves, and demersal fish). For each ecological element, where practicable, sampling sites were selected in the ZoHI and the ZoMI, as well as at representative areas within the ZoI and at Reference Sites not at risk of Material or Serious Harm.

Reference Sites were established at varying distances from the ZoHI, ZoMI, and ZoI so that the Post-Development Surveys could test for differences between the predicted Impact Sites (ZoHI, ZoMI, and ZoI) and Reference Sites (RPS 2009 [amended 2012]). For ecological elements other than hard and soft corals, sites within the ZoI may be considered to be pseudo-Reference Sites[2] because turbidity and sedimentation are not expected to cause Material or Serious Environmental Harm at these sites (Chevron Australia 2012a). Note that these sites will not be included as Reference Sites in any analysis if there is evidence that they have been impacted by the generation of turbidity and sediment deposition from construction of, or dredging and dredge spoil disposal activities required for, the MOF, LNG Jetty, Dredge Spoil Disposal Ground, or the marine upgrade of the existing WAPET Landing.

Sampling sites for the Post-Development Survey Year 2 are listed in the individual sections for each ecological element. The Post-Development Survey sites were either the full suite or a subset of sites from the Marine Baseline Program, as per the requirements of the approved Scope of Works (RPS 2009 [amended 2012]).

[2] The term pseudo-Reference Site has been used in this Report to refer to those sites located within the ZoI that although not listed as Reference Sites in the Scope of Works (RPS 2009 [amended 2012]) or the Marine Baseline Program (Chevron Australia 2012a) can be considered in the same way as Reference Sites in the statistical analysis of specific ecological elements (i.e. non-coral benthic macroinvertebrates, macroalgae, and seagrass). For these ecological elements, these sites were not considered to be at risk of Material or Serious Environmental Harm (see Section 2.2.3) and data has shown they were not impacted by the dredging and dredge spoil disposal activities (see Chevron Australia 2012b). The use of pseudo-Reference Sites, enabling an MBACI-style comparison, meets the intent of the rationale of the Scope of Works (RPS 2009 [amended 2012]).

3.4 Sampling Frequency

The sampling frequency and temporal scope for each ecological element sampled during the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2 are summarised in Table 3-1.

During the Marine Baseline Program, sampling frequency was designed to account for predicted seasonal differences. For example, the seagrass and macroalgae surveys were conducted over summer and winter to capture seasonal differences, while water quality was measured continuously over a 12-month period to capture tidal, daily, and seasonal variations. Other ecological elements without predicted seasonal influences, such as surficial sediments, were sampled on different occasions during the Marine Baseline Program.

Condition 24.1 of Statement No. 800 requires the Post-Development Coastal and Marine State Surveys to be repeated at the same time of year (where practicable) (to Post-Development Survey Year 1). Post-Development Survey Year 1 was completed between 8 November 2011 and 11 February 2012. Post-Development Survey Year 2 was undertaken between 23 November 2012 and 7 May 2013. The timeframe for Post-Development Survey Year 2 was extended due to significant weather events that delayed the fieldwork, and a natural thermal bleaching event in late summer 2013 that increased the time taken to identify and tag new coral colonies.

Table 3-1 Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2 Sampling Frequency and Period*

Ecological Element	Survey Type/ Method	Marine Baseline Program		Post-Development Survey Year 1		Post-Development Survey Year 2	
		Frequency	Period	Frequency	Period	Frequency	Period
Hard and soft corals	Area of Coral Assemblages	Once (10 sites)	Nov 2009 to Dec 2009	Once (10 sites)	Nov 2011 to Dec 2011	Once (10 sites)	Dec 2012 to Mar 2013
	Dominant/ subdominant	Once (12 sites)	Oct 2008 to Jan 2009	Once (10 sites)	Nov 2011 to Feb 2012	Once (10 sites)	Dec 2012
	Size-class frequency	Once (10 sites)	Oct 2008 to Jan 2009	Once (10 sites)	Nov 2011 to Feb 2012	Once (10 sites)	Dec 2012
	Survival (transects and tagged colonies)	Approx. 6-monthly intervals (12 sites)	May 2008 to Nov 2009	Approx. 3-monthly intervals (12 sites)	Nov 2011 to Feb 2012	Once (12 sites)	Nov and Dec 2012 (tagged colonies Jan and Mar 2013)
	Coral growth	Approx. 6-monthly intervals (12 sites)	May 2008 to Nov 2009	Once (12 sites)	Nov 2011to Dec 2011	Once (12 sites)	Jan 2013 to Mar 2013
	Recruitment (tiles)	Every 8–12 weeks (11 sites)	Mar 2008 to Jul 2009	Once (11 sites)	Nov 2011 to Jan 2012	Tile method was replaced by a subset of size-class frequency data[3]	

Ecological Element	Survey Type/ Method	Marine Baseline Program		Post-Development Survey Year 1		Post-Development Survey Year 2	
		Frequency	Period	Frequency	Period	Frequency	Period
Non-coral benthic macroinvertebrates	Video transects	Surveyed in spring/ summer and winter at: 6 sites 20 sites 13 sites (2 new sites)	Nov 2008 Jan 2009 Jul 2009	Surveyed in summer at 19 sites	Dec 2011 to Jan 2012	Surveyed in autumn at 16 sites	April 2013
Macroalgae	Photoquadrats and biomass	Surveyed in spring/ summer and winter at: 8 sites 11 sites 12 sites (2 new sites)	Nov 2008 Jan 2009 Jul 2009	Surveyed in summer at 14 sites	Dec 2011 to Feb 2012	Not surveyed[1, 2]	
Seagrass	Photoquadrats and biomass	Surveyed in spring/ summer and winter at: 5 sites 14 sites 15 sites (2 new sites)	Nov 2008 Jan 2009 Jul 2009	Surveyed in summer at 16 sites	Dec 2011 to Feb 2012	Not surveyed[1, 2]	
Mangroves	Vegetation surveys	Surveyed at 8 sites in spring	Nov 2009	Surveyed at 8 sites in summer	Dec 2011	Surveyed at 8 sites in summer	Feb 2013
Demersal fish	Subtidal (Baited remote underwater stereo-video (stereo-BRUVs) systems)	38 sites 47 sites	Oct 2008 Mar 2009	43 sites	Nov 2011 and Feb 2012	43 sites	Nov and Dec 2012
	Intertidal	Once (3 sites)	Dec 2009	Once (3 sites)	Nov 2011	Not surveyed[1]	
Surficial sediments	Surface scrapes	185 sites	Oct 2008 to Apr 2009 (and some samples collected in 2004 and 2007)	99 sites	Dec 2011 to Jan 2012	93 sites	Dec 2012 to Apr 2013

Notes:

* *Only those scopes repeated during the Post-Development Surveys are included in this table. For the full listing of sampling frequency completed during the Marine Baseline Program, refer to Chevron Australia 2012a.*

1. *On 21 November 2012 the DEC, under authorisation from the Minister for Environment, approved the following changes to the ecological elements required under Post-Development Survey Year 2: removal of non-coral*

benthic macroinvertebrates (limestone pavement sites only), seagrass, and macroalgae. The same correspondence also acknowledges that intertidal demersal fish were not a requirement under the Scope of Works, and therefore was not required under Post-Development Survey Year 2.

2. *On 7 March 2013, SEWPaC, as a delegate for the Minister for Sustainability, Environment, Water, Population and Communities advised Chevron Australia that seagrass and macroalgae could be removed from the Post-Development Survey Year 2 and Year 3. The determination was conditional on Chevron Australia responding to a number of items, which were presented in a letter to SEWPaC on 5 April 2013.*
3. *Amendment 3 of the Scope of Works allows for an alternate methodology to be applied to the assessment of coral recruitment if the timing of the Post-Development Survey is outside the predicted mass spawning coral periods; an alternate method for 'Recruitment Success' was employed during the Post-Development Survey Year 2.*

3.5 Statistical Approach

3.5.1 Design

The Marine Baseline Program was designed (see RPS 2009 [amended 2012]) to provide a dataset against which to compare the data from the Post-Development Surveys. The basis of the design was to provide the potential for pre- and post-development data to be analysed using the Multiple Before–After, Control–Impact (MBACI) approach of 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. It was expected that the main focus of monitoring will be for 'press'-type impacts, where the dredging and dredge spoil disposal activities cause sustained changes in an ecological element. However, in some cases, transient changes such as 'pulse' type impacts may also be tested for (Underwood 1992).

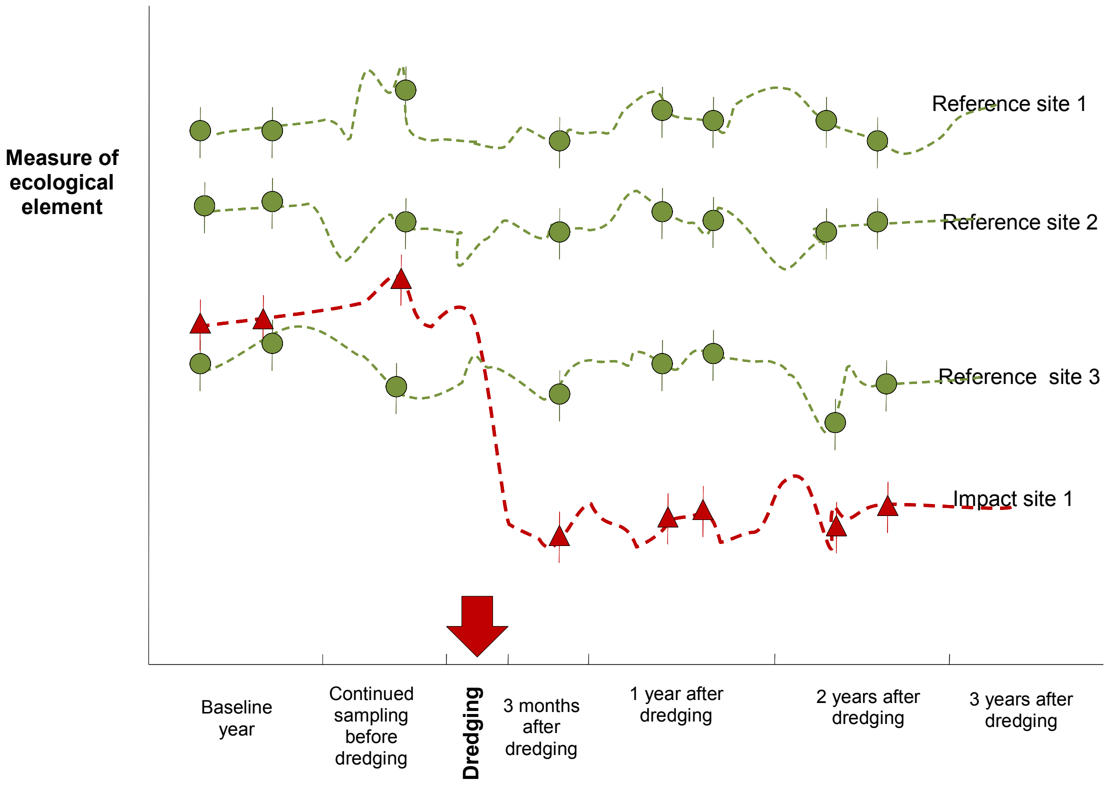


Figure 3-1 Overview of MBACI Sampling Designs – 'Press' Impact shows how Potential Changes will be Detected Before–After Dredging and Dredge Spoil Disposal Activities

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. This is not the case for the Marine Baseline Program and Post-Development Surveys, where a single potential impact area and a single control (hereafter termed reference) area were sampled. The single potential impact area encompasses sites at distances away from the activities of the dredging and dredge spoil disposal program. Within the potential impact area, sites are grouped by predicted levels of impact (zones) based on dredge plume modelling (ZoHI, ZoMI, and ZoI). The single reference area encompasses sites that are located outside the predicted ZoI, but that are not partitioned into an additional level of spatial hierarchy (e.g. multiple reference locations within which sites are nested).

This design allows for the detection of potential impacts by way of assessing whether the temporal trajectories of ‘impacted sites’ change more or less than that of the average of ‘Reference Sites’ (i.e. sites within the potential impact zones must change more/less from the Marine Baseline Program to the Post-Development Surveys, 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 step-wise approach was adopted for assessing potential environmental impacts. This approach addresses the most common form of statistical error in environmental impact assessment studies, Type II error (conclusion of no change when change has actually occurred; Schmitt and Osenberg 1996). Each step of the approach was designed to address potential issues with statistical power or high variance in the datasets, thereby reducing the chance of a Type II error. Flow charts were developed for each scope (see Sections 4.0 to 8.0), outlining the analyses, pooling, and partitioning steps particular to each dataset.

All statistical analyses, including post-hoc tests on significant interaction terms, were undertaken using PERMANOVA (non-parametric analysis of variance, Version 1.0.1, Primer-E Ltd.) (Anderson 2001a, 2001b). 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).

If the PERMANOVA analysis yielded a significant result ($p < 0.05$) for the Before v. After (BvA) × Zone or BvA × Impact v. Reference (IvR) interaction terms for any step of the step-wise approaches, a post-hoc, pair-wise comparison of the sample means was performed. Post-hoc tests focused primarily on evaluating changes from the Marine Baseline Program to the Post-Development Survey within each zone. If no changes were detected at any zone, further post-hoc tests examined differences among zones in an effort to determine the nature of the significant interaction.

3.5.2 Rationale

A Type II error (i.e. conclusion of no change when change has actually occurred) is the predominant form of statistical error in environmental impact assessment reporting due to insufficient spatial and temporal replication (Schmitt and Osenberg 1996). If the results of the primary analysis were non-significant for those terms that are potentially indicative of an impact, an *a priori* set of step-wise analyses was followed to improve the power of the test and thus reduce the chance of a Type II error. Steps to improve power may be achieved by:

- partitioning variation in the analysis
- pooling terms in the analysis.

Partitioning variation in an analysis was done by separating components of the dataset that potentially have different effects on an ecological element, thereby contributing to high sample variances (i.e. poor confidence in the sample mean). These components were then analysed separately (e.g. analysing sites associated with the dredging activities separately from sites associated with dredge spoil disposal activities).

Pooling terms in the analysis was done by combining terms in the test that have no interpretive value, but improve the power of tests of the terms of interest. Where pooling of terms was required, this occurred regardless of the p-value of the term in question. Pooling of terms when the p-value is >0.25 can increase the chance of Type I error (i.e. conclusion of change when actually no change has occurred) (Winer *et al*. 1991). If the pooled analysis failed to detect change despite the increased risk of a Type I error, then the interpretation of ‘no change’ was strengthened. If the pooled analysis detected change, a Type I error could not be ruled out, but at the very least the taxa and places of potential concern would be identified.

Each approach was successively applied in a step-wise process upon non-significance of terms that were potentially indicative of an impact (i.e. interaction terms). There were two motivations behind the step-wise approach: 1) to reduce Type II errors to allow the detection of change if change has actually occurred, and 2) to strengthen the reliability and interpretation of non-significant effects, which may otherwise have been weakened by the probability of a Type II error caused by low levels of replication in some datasets.

By adopting this step-wise approach, it is considered that sufficient effort was made in the statistical analyses to detect potential environmental changes.

The main hypothesis tested for each measure of an ecological element is that there is a change at impact zone(s) between before-and-after the dredging and dredge spoil disposal activities and Marine Facilities construction activities that is different to the changes occurring over the same time period within the reference area. Measures of recovery are accounted for in the statistical analyses with the inclusion of relevant data from Post-Development Survey Year 1.

3.6 Dredge Program Monitoring

Monitoring during the dredging and dredge spoil disposal program occurred in accordance with the Dredging and Spoil Disposal Management and Monitoring Plan (Chevron Australia 2011) between May 2010 and December 2011. Results from this monitoring program have previously been reported to the CDEEP[3]; and, given the requirement for ‘before-after’ analysis, are not discussed further in this Report.

[3] Note: The office of the EPA was also provided with access to these reports during the dredging and dredge spoil disposal program.

4.0 Hard and Soft Corals

4.1 Introduction

The marine habitats in the Pilbara Region support a variety of coral species that vary spatially, with clearer waters in offshore areas having higher coral density and diversity than high-turbidity nearshore areas (Gilmour *et al*. 2007, DEC 2007). A total of 229 species of coral from 57 hermatypic coral genera have been recorded in the Dampier Archipelago (Griffith 2004). Four coral genera dominated the coral assemblages: *Acropora* (especially plate *Acropora*), *Porites*, *Pavona*, and *Turbinaria* (Blakeway and Radford 2005). The fifth most abundant type of coral assemblage was a 'mixed' assemblage, consisting of *Turbinaria*, faviids, and other scleractinian corals.

As part of the Gorgon Gas Development Project, rapid visual assessment surveys in the Barrow Island region identified 196 species (48 genera) of hard coral and eight genera of soft coral (Chevron Australia 2012a), and highlighted that the most significant coral reefs around Barrow Island are located at Biggada Reef on the west coast, at Dugong Reef and Batman Reef off the south-east coast, and along the edge of the Lowendal Shelf on the east coast (Chevron Australia 2005, DEC 2007).

The most recent information on corals in this area was collected during the Marine Baseline Program (Chevron Australia 2012a) and the Post-Development Survey Year 1 (Chevron Australia 2012b), both of which form part of the basis of comparison for this report.

A thermal bleaching event was recorded in the Pilbara Region of Western Australia including off the east and south coasts of Barrow Island over the summer of 2010–2011, and approximately nine months prior to commencement of the Post-Development Survey Year 1. Towards the completion of this Post-Development Survey Report (Year 2) another thermal coral bleaching event was observed. Again, this event was reportedly region wide (National Oceanic and Atmospheric Administration [NOAA] 2013) and included the nearshore marine areas off Barrow Island. Both events may have contributed to some extent to changes in live tissue cover and, where relevant, each is further discussed below.

4.2 Scope

This Section is in two parts. The first part presents the results of the Post-Development Survey Year 2: 2012–2013 on Area of Coral Assemblages, coral size-class frequency distributions, dominant and subdominant corals, coral survival, and coral recruitment:

- within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence, associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal activities required for the MOF and LNG Jetty
- at Reference Sites not at risk of Material or Serious Environmental Harm due to the construction of the MOF, LNG Jetty, and the marine upgrade of the existing WAPET Landing.

The second part compares the Post-Development Surveys and the Marine Baseline Program to determine if changes have occurred as per Condition 24.2 of Statement No. 800 and Condition 17.2 of EPBC Reference: 2003/1294 and 2008/4178.

Note: As previously discussed (see Section 2.1.5), no specific results or comparisons are made for the area in the vicinity of the marine upgrade of the existing WAPET Landing.

For consistency with the Marine Baseline Program, 'hard corals' are considered to be the reef-building corals within the order Scleractinia. Corals were classified according to the online Integrated Taxonomic Information System (ITIS) (http://www.itis.gov), as recent taxonomic regrouping of some species and genera into new clades and families based on genetic analyses (Kerr 2005; Fukami *et al.* 2008) are only just being developed and are not yet commonly recognised.

'Soft corals' have no skeleton and are not considered reef-building organisms. For consistency with the Marine Baseline Program, 'soft corals' are those within the order Alcyonacea (soft corals) and suborder Alcyoniina ('true soft corals') (http://www.itis.gov). Identifying soft corals is generally difficult except for the suborder Alcyoniina and even then the species are difficult to distinguish (Dinesen 1983).

4.3 Area of Coral Assemblages

4.3.1 Methods

4.3.1.1 Site Locations

The Post-Development Survey Year 2 for the Area of Coral Assemblages was undertaken at ten sites; AHC, BAT, DUG, LNG3, LNG Jetty ZoHI, LNG Jetty ZoMI, Lone Reef, MOF ZoHI, MOF ZoMI, and SBS) (Figure 4-1). Two sites were in the Zone of High Impact (ZoHI), three were in the Zone of Moderate Impact (ZoMI), and five were Reference Sites or Regionally Significant Areas. Multiple transects were surveyed within each site, so there are no single coordinates that describe the site locations.

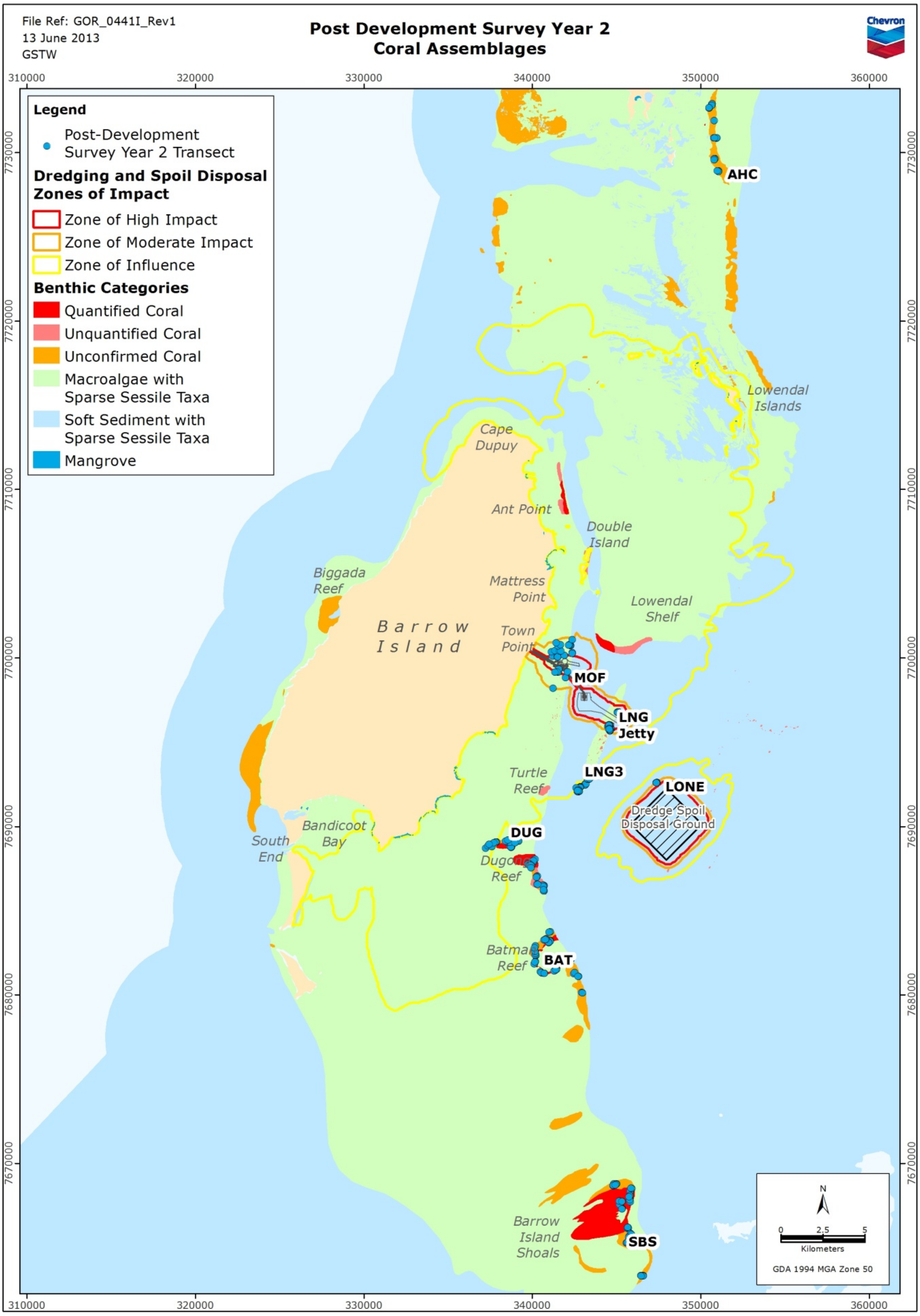


Figure 4-1 Post-Development Survey Year 2 Transects for the Area of Coral Assemblages

Note: LNG Jetty and MOF refer to two sites each, one within the ZoHI and one within the ZoMI.

4.3.1.2 Timing and Frequency of Sampling

Sites were surveyed in Post-Development Survey Year 2 between December 2012 and March 2013. Sites were surveyed in the Marine Baseline Program between November 2009 and December 2009 (Chevron Australia 2010a), and in Post-Development Survey Year 1 between November 2011 and December 2011 (Chevron Australia 2012b).

4.3.1.3 Survey Method

During Post-Development Survey Year 2, areas mapped as hard and soft coral were classified into the following strata based on the Area of Coral Assemblages Report (Chevron Australia 2010a) and as per the classification of strata during the Marine Baseline Program and Post-Development Survey Year 1. To ensure adequate geographic spread and coverage of different types of Coral Assemblage, and to potentially increase the precision of sampling, areas were stratified by different-sized features and coral communities. Areas around the Marine Facilities within the Zones of High and Moderate Impact were classified into six strata based on the size of features and distance offshore, whilst Reference Areas and Regionally Significant Areas were stratified by the different coral communities that were mapped in the Marine Baseline Program:

- Large Reefs
- Bombora 15–50 m diameter
- Bombora <15 m diameter.
- Unquantified Coral
- *Porites* Bombora (10–50% cover)
- *Porites* Bombora (51–75% cover)
- Mixed Coral Assemblage (10–50% cover)
- Mixed Coral Assemblage (51–75% cover)
- Mixed Coral Assemblage (10–50% cover), Mixed Phaeophyceae (25–75% cover)
- Unconfirmed Coral (defined as coral in the DEC (2007) habitat map but unconfirmed).

The basic field sampling units were five 0.5 × 0.5 m (i.e. 0.25 m^2) photoquadrats spaced at 1 m intervals along a transect (i.e. total transect length of 5 m) (Figure 4-2, Figure 4-3). Photoquadrats are a plan view photograph taken directly overhead of the substratum. Pre-survey calculations indicated that 20 to 25 transects within each of the ZoHI and ZoMI would provide relatively narrow confidence intervals for the overall calculations of coral assemblage and that there would be marginal increases in precision with additional transects (Chevron Australia 2010a). This density of transects was exceeded in both the Marine Baseline Program and Post-Development Survey Year 1 and Year 2.

Single transects were laid on the 15–50 m diameter bombora. On larger reef areas, multiple transects were laid radiating outwards from starting points at 5–20 m from the centre of the site. The starting points and directions of the transects were randomly selected prior to the survey to avoid any potential bias in the placement of transects in the field. Transects that would have extended beyond the stratum being sampled were rejected.

Each photoquadrat along a transect was treated as an independent measure of cover within the area determined by the starting point and direction of that transect (Figure 4-2). Thus, live cover of corals was averaged across the five photoquadrats per transect to obtain a measure of the average cover within each area. However, because that measure is based on a sample of cover across the area (and thus subject to sampling error), the upper 95% Confidence Interval (CI) estimate was used to determine the greatest coverage of coral that might be present in the area. This upper 95% CI estimate was then used to classify each area as Coral Assemblages (≥10% live coral cover) or not (Figure 4-3). Thus, a conservative approach was used to classify each sampled area; areas were classified as Coral Assemblages unless there was evidence that the average live cover of corals was almost certainly not 10% or greater.

During the Marine Baseline Program, some strata were not found, or were very uncommon in some areas and thus were not sampled (Chevron Australia 2010a). Bombora (<15 m diameter) strata were not sampled at any location, due to the difficulty in reliably sampling these small features (Chevron Australia 2010a). Additional strata not sampled included Bombora 15–50 m in diameter in the LNG Jetty area, the Large Reef stratum in the MOF area, *Porites* Bombora (51–75% cover) at AHC, and *Porites* Bombora (10–50% cover) at LNG3. These strata were also not surveyed during Post-Development Survey Year 1 and Post-Development Survey Year 2. The unsampled strata were small (0.06 to 0.57 ha), and as such not sampling them made little difference to the overall calculation of the Area of Coral Assemblage. However, as a conservative measure, unsampled strata in the ZoHI and ZoMI were assumed to have 100% coral cover in the Marine Baseline Program and 0% cover in Post-Development Survey Year 1 and Post-Development Survey Year 2. Strata not sampled in the Reference Sites were assigned the same coral proportion as the sampled strata within that site.

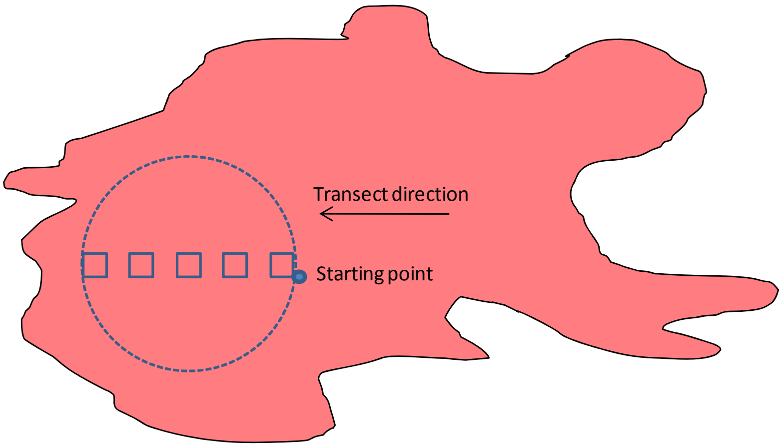


Figure 4-2 Five 0.5 m × 0.5 m Quadrats Located at One-metre Spacing along a Transect

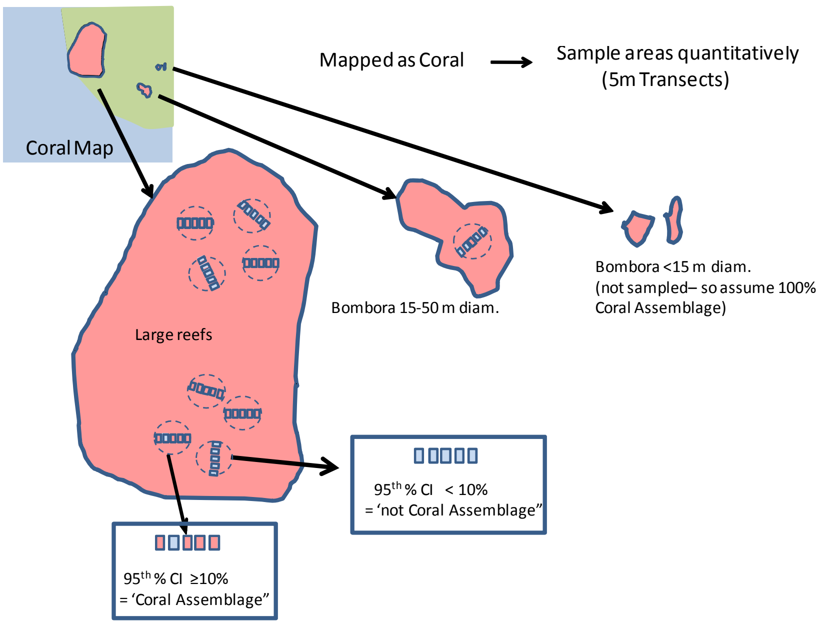


Figure 4-3 Diagrammatic Overview of the Calculation of the Area of Coral Assemblages

4.3.1.4 Treatment of Survey Data

The software program Coral Point Count with Excel extensions (CPCe; Kohler and Gill 2006) was used to analyse coral cover in the photoquadrat images. Analysis was undertaken by randomly distributing 30 points on each image and classifying the benthos under each point (see RPS 2009 [amended 2012] for more details).

4.3.1.5 Statistical Approach for Comparison to Baseline

The statistical approach was in accordance with RPS (2009, [amended 2012[), such that mean live coral cover and 95% CI were calculated for each transect (n=5). Transects were classified as Coral Assemblages if their upper 95% Confidence Limit (CL) was ≥10%. Transects were tabulated hierarchically by reef stratum, area, and zone, and the data were analysed to estimate the proportion and area of Coral Assemblages within each level in the hierarchy. Upper 95% CL were used in these estimations, as per the Scope of Works (RPS 2009, [amended 2012[). An identical method was applied in the Marine Baseline Program and Post-Development Survey Year 1 and Year 2, although the sampling locations differed as sites were randomly determined at each survey period. The number of transects was 217 in the Marine Baseline Program, 254 in Post-Development Survey Year 1, and 247 in Post-Development Survey Year 2.

4.3.2 Results of Post-Development Survey Year 2

The proportions and areas of Coral Assemblages in the Post-Development Survey Year 2 are presented in Table 4-1 and Table 4-2. The Post-Development Survey Year 2 areas of Coral Assemblages, and their associated 95% confidence limits in parentheses, were 3.10 ha (1.03 ha, 5.17 ha) in the ZoHI, 0.68 ha (0.00 ha[4], 1.86 ha) in the ZoMI, and 724.11 ha (468.09 ha, 980.13 ha) in the Reference Sites.

Table 4-1 Proportion and Area of each Coral Stratum Classified as Coral Assemblages within the Zones of High Impact and Zones of Moderate Impact for the Post-Development Survey Year 2

Zone/Stratum	Area (ha)[1]	# Transects Surveyed	Proportion of Coral Assemblages[2]	Area of Coral Assemblages (ha)[3]
Zones of High Impact				
MOF – Large Reefs	0.13	Not surveyed	Assume 0	0.00
MOF – Bombora 15–50 m diameter	0.52	16	0.00	0.00
MOF – Bombora <15 m diameter	0.31	Not surveyed	Assume 0	0.00
LNG Jetty – Large Reefs	7.58	22	0.41	3.10
LNG Jetty – Bombora 15–50 m diameter	0.06	Not surveyed	Assume 0	0.00
LNG Jetty – Bombora <15 m diameter	0.19	Not surveyed	Assume 0	0.00
Zone Total (95% confidence limits)	**8.79**	**38**		**3.10 (1.03, 5.17)**
Zones of Moderate Impact				
MOF – Large Reefs	0.30	Not surveyed	Assume 0	0.00
MOF – Bombora 15–50 m diameter	1.34	28	0.00	0.00
MOF – Bombora <15 m diameter	0.38	Not surveyed	Assume 0	0.00
LNG Jetty – Large Reefs	3.19	7	0.00	0.00

[4]Statistically the lower 95% confidence interval is -0.50; however, for ecological reasons this is presented as 0.00.

Zone/Stratum	Area (ha)[1]	# Transects Surveyed	Proportion of Coral Assemblages[2]	Area of Coral Assemblages (ha)[3]
LNG Jetty – Bombora 15–50 m diameter	-	No mapped features	-	-
LNG Jetty – Bombora <15 m diameter	-	No mapped features	-	-
Lone Reef (Dredge Spoil Disposal Ground)	0.68	9	1.00	0.68
Zone Total (95% confidence limits)	**5.89**	**44**		**0.68 (0.00, 1.86)[4]**

Notes:

1. *Area (ha) = areas previously mapped as coral (Chevron Australia 2010a)*
2. *Proportion of Coral Assemblages within Substratum = number of transects regarded as Coral Assemblages / total number of transects. Blank 'Zone Total' cells for 'Proportion Coral assemblages within substratum' are left blank intentionally*
3. *Area of Coral Assemblages = Area (ha) × Proportion of Coral Assemblages. Due to rounding, minor discrepancies in the decimal places in the 'Area Coral Assemblages (ha)' values may be evident*
4. *Statistically the lower 95% confidence interval is -0.50; however, for ecological reasons this is presented as 0.00.*

Table 4-2 Proportion and Area of each Coral Stratum Classified as Coral Assemblages within Reference Sites and Regionally Significant Areas for the Post-Development Survey Year 2

Site/Area	Stratum	Area (ha)[1]	# Transects Surveyed	Proportion Coral Assemblages[2]	Area of Coral Assemblages (ha)[3]
AHC	Unconfirmed Coral	244.99	17	0.00	0.00
	Porites Bombora (51–75% cover)	0.57	Not Surveyed	Assume as for Unconfirmed Coral stratum	0.00
Total (95% Confidence Limits)		**245.56**	**17**		**0.00 (-75.37, 75.37)**
BAT	*Porites* Bombora (10–50% cover)	20.20	5	0.40	8.08
	Mixed Coral Assemblage (10–50% cover)	39.74	18	0.28	11.04
	Mixed Coral Assemblage (51–75% cover)	0.50	5	1.00	0.50
	Unconfirmed Coral	262.05	18	0.56	145.58
Total (95% Confidence Limits)		**322.49**	**46**		**165.20 (97.17, 233.23)**
LNG3	Unquantified Coral	19.84	23	0.61	12.08
	Porites Bombora (10–50% cover)	0.43	Not surveyed	Assume as for Unquantified Coral stratum	0.26
Total (95% Confidence Limits)		**20.27**	**23**		**12.34 (6.56, 18.12)**
DUG	Unquantified Coral	51.37	9	0.11	5.71
	Mixed Coral Assemblage (10–50% cover)	35.16	8	1.00	35.16
	Mixed Coral Assemblage (51–75% cover)	96.03	9	0.78	74.69
	Unconfirmed Coral	88.18	29	0.17	15.20

Site/Area	Stratum	Area (ha)[1]	# Transects Surveyed	Proportion Coral Assemblages[2]	Area of Coral Assemblages (ha)[3]
Total (95% Confidence Limits)		**270.74**	**55**		**130.76 (80.53, 181.00)**
SBS	Mixed Coral Assemblage (10–50% cover)	32.10	6	0.83	26.75
	Mixed Coral Assemblage (10–50% cover) and Mixed Phaeophyceae (25–75% cover)	696.39	Not surveyed	Assume as for Unquantified Coral stratum	193.44
	Unconfirmed Coral	704.23	18	0.28	195.62
Total (95% Confidence Limits)		**1432.72**	**24**		**415.81 (4.54, 827.08)**
Zone Total (95% Confidence Limits)		**2291.78**	**165**		**724.11 (468.09, 980.13)**

Notes:

1. *Area (ha) = areas previously mapped as coral (Chevron Australia 2010a)*
2. *Proportion of Coral Assemblages within Substratum = number of transects regarded as Coral Assemblages / total number of transects. Blank 'Total' and 'Zone Total' cells for 'Proportion Coral assemblages within substratum' are left blank intentionally*
3. *Area of Coral Assemblages = Area (ha) × Proportion of Coral Assemblages. Due to rounding, minor discrepancies in the decimal places in the 'Area Coral Assemblages (ha)' values may be evident.*

4.3.3 Comparison between the Post-Development Survey Year 2 and the Marine Baseline Program Environmental State

4.3.3.1 Absolute Change in Coral Assemblages

The proportion of Coral Assemblages was lower in Post-Development Survey Year 2 than in the Marine Baseline Program in the ZoHI, the ZoMI, and the Reference Sites. The changes in the proportion of Coral Assemblages in these zones and the associated 95% confidence limits were -0.27 (-0.03, -0.50), -0.45 (-0.25, -0.65), and -0.30 (-0.19, -0.41) respectively (Table 4-3).

Table 4-3 Comparison of Proportions (and 95% CL) of Coral Assemblages in the Marine Baseline Program and the Post-Development Survey Year 2

Zone	Marine Baseline Program Proportion of Coral Assemblages	Post-Development Survey Year 2 Proportion of Coral Assemblages	Difference between Marine Baseline Program and Post-Development Survey Year 2
ZoHI	0.62 (0.45, 0.79)	0.35 (0.12, 0.59)	-0.27 (-0.03, -0.50)
ZoMI	0.56 (0.41, 0.71)	0.12 (-0.08, 0.32)	-0.45 (-0.25, -0.65)
Reference	0.62 (0.54, 0.70)	0.32 (0.20, 0.43)	-0.30 (-0.19, -0.41)

Notes: Due to rounding, the 'Difference between Marine Baseline Program and Post-Development Survey Year 2' value for the ZoMI is -0.45 and not -0.44 as would be suggested by the difference between 0.56 and 0.12.

These proportional changes were used to calculate the absolute change in the area of Coral Assemblages within each zone as specified in RPS (2009, amended 2012). The absolute change in the area of Coral Assemblages in the ZoHI was:

- Marine Baseline Program proportion Coral Assemblages = 0.62
- Post-Development Survey Year 2 proportion Coral Assemblages = 0.35

- Difference in proportions = 0.62 - 0.35 = 0.27
- 95% confidence interval for difference in proportion = ±0.24
- 95% confidence limits for change in the proportion of Coral Assemblages = 0.031, 0.501
- Multiplied by the area mapped within the ZoHI (8.79 ha) = 0.272, 4.403 ha.

Therefore, the upper 95% confidence limit for the absolute area of loss of Coral Assemblages in the ZoHI was 4.403 ha.

The absolute change in the area of Coral Assemblages in the ZoMI was:

- Marine Baseline Program proportion Coral Assemblages = 0.56
- Post-Development Survey Year 2 proportion Coral Assemblages = 0.12
- Difference in proportions = 0.56 - 0.12 = 0.45
- 95% confidence interval for difference in proportion = ±0.20
- 95% confidence limits for change in the proportion of Coral Assemblages = 0.246, 0.646
- Multiplied by the area mapped within the ZoHI (5.89 ha) = 1.449, 3.805 ha.

Therefore, the upper 95% confidence limit for the absolute area of loss of Coral Assemblages in the ZoMI was 3.805 ha.

Summing these two 95% confidence limit estimates gives a combined absolute area of change of Coral Assemblages in the ZoHI and ZoMI of 8.21 ha.

The absolute change in the area of Coral Assemblages in the Reference Sites was:

- Marine Baseline Program proportion Coral Assemblages = 0.62
- Post-Development Survey Year 2 proportion Coral Assemblages = 0.32
- Difference in proportions = 0.62 - 0.32 = 0.30
- 95% confidence interval for difference in proportion = ±0.11
- 95% confidence limits for change in the proportion of Coral Assemblages = 0.189, 0.412
- Multiplied by the area mapped within the ZoHI (2291.78 ha) = 433.146, 944.213 ha.

Therefore, the upper 95% confidence limit for the absolute area of change of Coral Assemblages in the Reference Sites was 944.21 ha.

4.3.3.2 Net Change in Coral Assemblages

The proportional changes were used to calculate the net change in the area of Coral Assemblages within each zone as specified in RPS (2009, amended 2012). The net change in the area of Coral Assemblages in the ZoHI was:

- Change in proportion of Coral Assemblages between the Marine Baseline Program and Post-Development Survey Year 2 for ZoHI = 0.27
- Change in proportion of Coral Assemblages between the Marine Baseline Program and Post-Development Survey Year 2 for Reference Sites = 0.30
- Difference in proportions = 0.30 - 0.27 = 0.03
- 95% confidence interval for difference in proportion = ±0.27
- 95% confidence limits for change in the proportion of Coral Assemblages = -0.240, 0.308
- Multiplied by the area mapped within the ZoHI (8.79 ha) = -2.109, 2.707 ha.

Therefore, the upper 95% CL for the net change in area of Coral Assemblages in the ZoHI was a loss of 2.707 ha.

The net change in the area of Coral Assemblages in the ZoMI was:

- Change in proportion of Coral Assemblages between the Marine Baseline Program and Post-Development Survey Year 2 for ZoMI = 0.45
- Change in proportion of Coral Assemblages between the Marine Baseline Program and Post-Development Survey Year 2 for Reference Sites = 0.30
- Difference in proportions = 0.30 - 0.45 = -0.15
- 95% confidence interval for difference in proportion = ±0.27
- 95% confidence limits for change in the proportion of Coral Assemblages = -0.419, 0.128
- Multiplied by the area mapped within the ZoHI (5.89 ha) = -2.468, 0.754 ha

Therefore, the upper 95% CL for the net change in area of Coral Assemblages in the ZoMI was a loss of 0.754 ha.

Summing these two upper 95% CL estimates gives a combined net Area of Loss of Coral Assemblages in the ZoHI and ZoMI of 3.46 ha.

4.3.4 Discussion

The estimated upper 95% confidence limit of the net area of loss of Coral Assemblages in the ZoHI and ZoMI was 3.46 ha and therefore did not exceed the permanent loss of Coral Assemblages limit of 8.47 ha (as per Condition 18.1ii.b of Statement No. 800).

As with Post-Development Survey Year 1 (Chevron Australia 2012b), negative changes were recorded in the ZoHI and ZoMI, and at most Reference Sites between the Marine Baseline Program and Post-Development Survey Year 2 (Table 4-4).

Within the Reference Sites, there was no obvious relationship between the reductions in the area of Coral Assemblages and their proximity to the ZoHI and ZoMI. Reference Site AHC showed the greatest loss in area of Coral Assemblages from the Marine Baseline Program to Post-Development Survey Year 2 despite being situated north of dredge and dredge spoil disposal activities (Table 4-4; Figure 4-1), and sites DUG and SBS situated south of dredge and dredge spoil disposal activities both showed ~50% reduction in area of Coral Assemblages from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-4; Figure 4-1). While the reason(s) for the reductions in the area of Coral Assemblages at sites AHC, DUG, and SBS is unknown, the random placement of transects in the Post-Development Surveys may have resulted in a larger number of quadrats placed over substrate that was ≤10% coral cover than in the Marine Baseline Program surveys, which would therefore not have been considered coral for the purposes of the calculations used (RPS 2009, amended 2012). Also, sites AHC and SBS had unsurveyed strata in the Post-Development Surveys and the values obtained are based on assumptions. That said, sites AHC, DUG, and SBS all contained live coral cover between~20% to ~60% in Post-Development Survey Year 2 (see Section 4.7). Reference Site BAT was the only site where the area of Coral Assemblages increased from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-4).

Table 4-4 Area of Coral Assemblages for Reference Sites for the Marine Baseline Program, Post-Development Survey Year 1 and Post-Development Survey Year 2

Site	Marine Baseline Program	Post-Development Survey Year 1	Post-Development Survey Year 2
Ah Chong (AHC)	138.13 ha	61.39 ha	0.00 ha
Batman Reef (BAT)	127.26 ha	136.56 ha	165.20 ha
Dugong Reef (DUG)	270.74 ha	184.55 ha	130.76 ha
LNG3 (LNG3)	14.19 ha	5.79 ha	12.34 ha
Southern Barrow Shoals (SBS)	862.49 ha	556.91 ha	415.81 ha

The distribution of loss among strata within the ZoHI and ZoMI was consistent, with all substrata (except Lone Reef [Dredge Spoil Disposal Ground] in the ZoMI) showing a reduction in the area of Coral Assemblages from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-5). The area of Coral Assemblages declined from Post-Development Survey Year 1 to Post-Development Survey Year 2 at one site (MOF Bombora 15–50 m diameter) but increased at another site (LNG Jetty – Large Reefs in the ZoHI) (Table 4-5). The total area of Coral Assemblages in the ZoHI increased from Post-Development Survey Year 1 to Post-Development Survey Year 2, whereas the total area of Coral Assemblages in the ZoMI declined from Post-Development Survey Year 1 to Post-Development Survey Year 2 (Table 4-5). However, as with the Reference Sites, a number of the strata were not surveyed in the Post-Development Surveys, and the values obtained were based on assumptions.

Table 4-5 Area of Coral Assemblages per Substratum for the ZoHI and ZoMI for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Stratum	Marine Baseline Program	Post-Development Survey Year 1	Post-Development Survey Year 2
ZoHI			
MOF – Large Reefs	0.13 ha	0.00 ha (assumed)	0.00 ha (assumed)
MOF – Bombora 15–50 m diameter	0.09 ha	0.07 ha	0.00 ha
MOF – Bombora <15 m diameter	0.31 ha	0.00 ha (assumed)	0.00 ha (assumed)
LNG Jetty – Large Reefs	4.66 ha	2.45 ha	3.10 ha
LNG Jetty – Bombora 15–50 m diameter	0.06 ha	0.00 ha (assumed)	0.00 ha (assumed)
LNG Jetty – Bombora <15 m diameter	0.19 ha	0.00 ha (assumed)	0.00 ha (assumed)
ZoHI Total	**5.44 ha**	**2.51 ha**	**3.10 ha**
ZoMI			
MOF – Large Reefs	0.30 ha	0.00 ha (assumed)	0.00 ha (assumed)
MOF – Bombora 15–50 m diameter	0.00 ha	0.08 ha	0.00 ha
MOF – Bombora <15 m diameter	0.38 ha	0.00 ha (assumed)	0.00 ha (assumed)
LNG Jetty – Large Reefs	1.95 ha	1.60 ha	0.00 ha
LNG Jetty – Bombora 15–50 m diameter	No mapped features	No mapped features	No mapped features

Stratum	Marine Baseline Program	Post-Development Survey Year 1	Post-Development Survey Year 2
LNG Jetty – Bombora <15 m diameter	No mapped features	No mapped features	No mapped features
Lone Reef (Dredge Spoil Disposal Ground)	0.68 ha	0.68 ha	0.68 ha
Zone Total	**3.31 ha**	**2.35 ha**	**0.68 ha**

Given the published information on the effect of dredging and dredge spoil disposal activities on corals (see Erftemeijer *et al*. 2012 for a review), it is likely that dredging and dredge spoil disposal activities may have contributed to some of the loss of area of Coral Assemblages in the ZoHI and ZoMI. However, loss of area of Coral Assemblages was also recorded at the Reference Sites during the Post-Development Surveys, suggesting that other factors besides the dredging and dredge spoil disposal activities may have contributed to the loss of area of Coral Assemblages in the ZoHI and ZoMI. Nonetheless, even when using the most conservative estimate (adopting the upper 95% CI value) the amount of loss of area of Coral Assemblages in the ZoHI and ZoMI in Post-Development Survey Year 2 was less than the approved permanent loss of Coral Assemblages limit of 8.47 ha (as per Condition 18.1ii.b of Statement No. 800).

4.4 Size-class Frequency

4.4.1 Methods

4.4.1.1 Site Locations

Ten sites were sampled during the Post-Development Survey Year 2 for size-class frequency (Table 4-6, Figure 4-4). One site was in the ZoHI, three were in the ZoMI, and six were Reference Sites and Regionally Significant Areas (hereafter referred to as Reference Sites).

The ZoI sites, ANT and LOW, were unsuitable for measures of size-class frequency due to presence of extensive *Acropora* thickets, which makes differentiation of individuals difficult.

Figure 4-4 Post-Development Survey Sites for Coral Size-class Frequency, Dominant and Subdominant Coral Taxa, and Coral Recruitment Success

Table 4-6 Post-Development Survey Sites for Size-class Frequency

Location	Site Name (Site Code)	Easting	Northing	Latitude	Longitude	Depth (m)
		(GDA94, MGA Zone 50)		(GDA94)		
Zone of High Impact	LNG0 (LNG0)	344796	7696108	20° 49.713' S	115° 30.507' E	9.00
Zones of Moderate Impact	MOF1 (MOF1)	342089	7698785	20° 48.249' S	115° 28.961' E	6.00
	LNG1 (LNG1)	344584	7695823	20° 49.867' S	115° 30.384' E	8.75
	Lone Reef (LONE)	347376	7692607	20° 51.624' S	115° 31.976' E	9.25
Reference Sites	Ah Chong (AHC)	350243	7731659	20° 30.472' S	115° 33.829' E	6.50
	Biggada Reef (BIG)	328237	7702674	20° 46.068' S	115° 21.001' E	1.50
	LNG3 (LNG3)	343157	7692657	20° 51.575' S	115° 29.544' E	6.50
Regionally Significant Areas	Dugong Reef (DUG)	340099	7687998	20° 54.085' S	115° 27.755' E	6.25
	Batman Reef (BAT)	340703	7681301	20° 57.717' S	115° 28.067' E	3.50
	Southern Barrow Shoals (SBS)	345599	7666195	21° 5.929' S	115° 30.810' E	4.75

4.4.1.2 Timing and Frequency of Sampling

Sites were surveyed in Post-Development Survey Year 2 in December 2012. Sites were surveyed in the Marine Baseline Program between October 2008 and January 2009 (Chevron Australia 2012a), and in Post-Development Survey Year 1 between November 2011 and January 2012 (Chevron Australia 2012b).

4.4.1.3 Survey Method

Hard coral colonies were measured along five randomly placed 10 m long belt transects. Corals were classified to genera where possible; otherwise, to family level (Table 4-7). The maximum linear dimension ('diameter') of colonies >10 cm was measured in a belt transect one metre wide on the right side of the transect, while colonies <10 cm were measured in a belt transect 25 cm wide on the left side of the transect (Smith *et al.* 2005) (Figure 4-5). Colonies were categorised into the following size-classes based on maximum colony diameter: 0.1–2.0 cm, 2.1–5.0 cm, 5.1–10.0 cm, 10.1–20 cm, 20.1–50.0 cm, 50.1–100.0 cm, 100.1–200.0 cm, 200.1–500.0 cm, and 500.1–1000.0 cm, which is consistent with other studies of coral size-class frequency distributions (e.g. van Woesik and Done 1997).

To avoid bias associated with boundary effects, if ≥50% of a colony was within the belt transect, it was included in the measurements; if <50% was within the belt transect it was excluded (Zvuloni *et al.* 2008). If a colony was divided by partial mortality into separate patches of living tissue but remained structurally intact as a single entity, it was considered to be one colony (Bak and Meesters 1998). In these cases, the longest linear dimension of the entire colony, including the separate patches, was measured. Examples of how maximum linear dimensions were measured for colonies with different morphologies are presented in Figure 4-6.

Genera were grouped into families for data analysis to be consistent with the Marine Baseline Program. Revised Marine Baseline Program data relevant to this Report is shown in Appendix 1.

Table 4-7 Classification System Used for Corals in Size-class Frequency

Family	Genera
Acroporidae	*Acropora, Astreopora, Montipora*
Agariciidae	*Pachyseris*, *Pavona*, *Agariciidae unknown*
Caryophylliidae*	*Euphyllia, Plerogyra*
Dendrophylliidae	*Tubastraea, Turbinaria*
Faviidae	*Barabattoia, Caulastrea, Cyphastrea, Diploastrea, Echinopora, Favia, Favites, Goniastrea, Leptastrea, Leptoria, Montastrea, Moseleya, Oulophyllia, Platygyra, Pavona, Faviidae unknown*
Fungiidae	*Fungia, Herpolitha, Podabacia, Fungiidae unknown*
Merulinidae	*Hydnophora, Merulina*
Milleporidae	*Millepora*
Mussidae	*Blastomussa, Lobophyllia, Symphyllia, Mussidae unknown*
Oculinidae	*Galaxea*
Pectiniidae	*Echinophyllia, Mycedium, Oxypora, Pectinia,* Pectiniidae unknown
Pocilloporidae	*Pocillopora, Seriatopora, Stylophora*
Poritidae	*Goniopora, Porites* (branching), *Porites* (massive)
Siderastreidae	*Coscinaraea, Psammocora*
Unidentified	Family Unknown/unidentified

*Note: * Euphyllia were included in the family Caryophylliidae to be consistent with the Marine Baseline Program (Euphyllia were previously classified as being in the subfamily Euphyllidae of the family Caryophylliidae; Euphyllidae has since been reclassified as a family).*

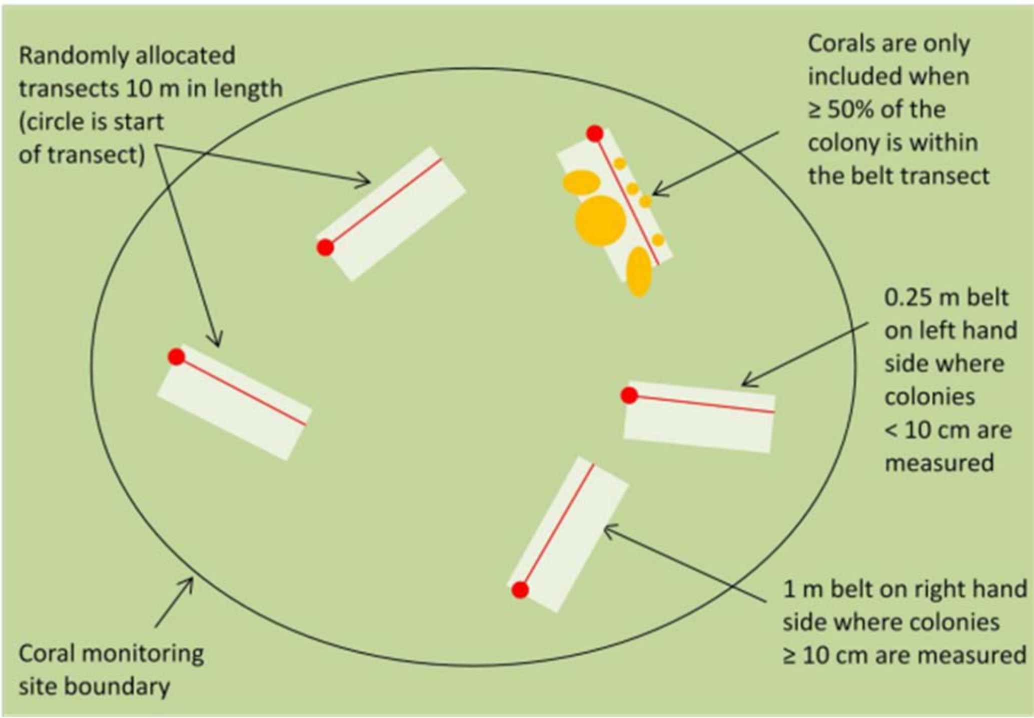


Figure 4-5 Schematic Representation of Transects used for Coral Size-class Frequency Monitoring

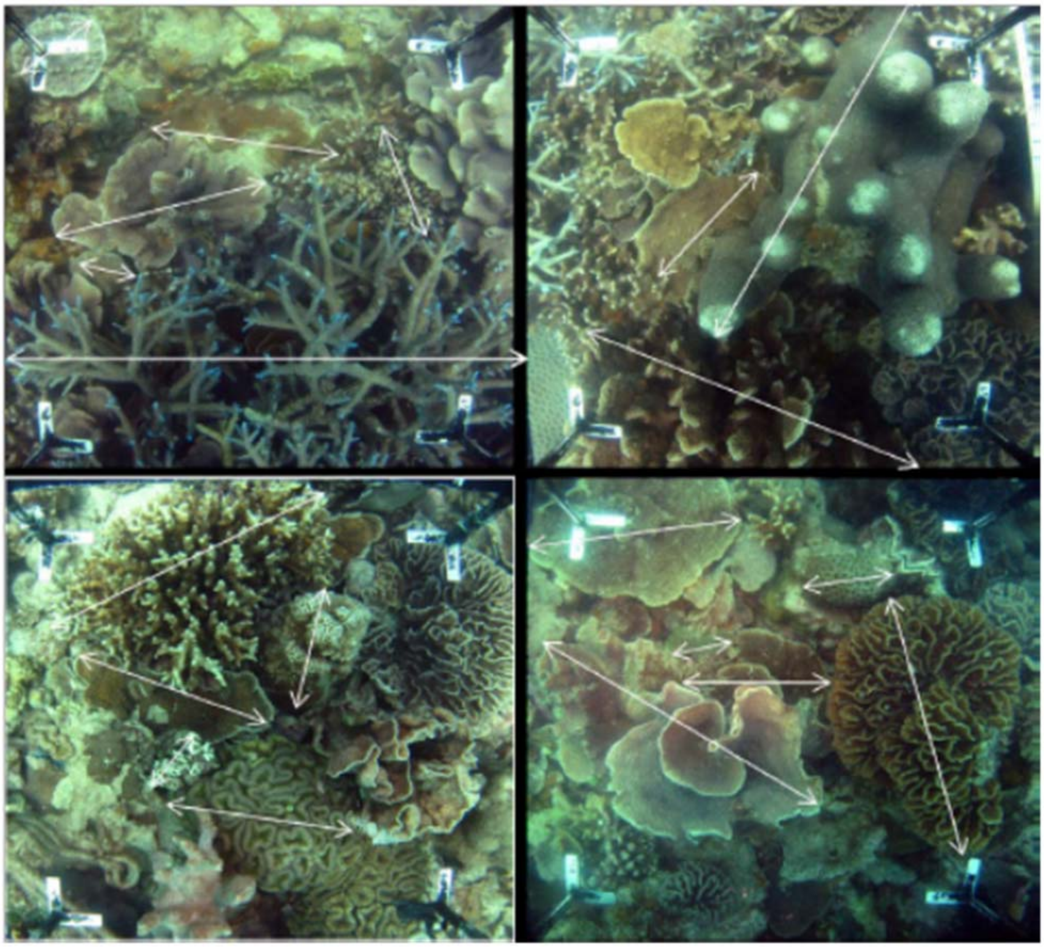


Figure 4-6 Examples of Measuring Maximum Linear Dimension of Hard Corals with Different Morphologies

4.4.1.4 Treatment of Survey Data

Coral colony size data were used to produce size-class frequency distribution plots for each of the sites (note, genera were grouped into families for data analysis). Several statistical measures were used to describe the size-class frequency distributions of the coral populations at each site (Table 4-8).

Table 4-8 Statistical Measures of Change in Coral Size-class Frequency

Resolution	Data Type	Statistical Measure	Population Structure Attribute
Site and family level	Count data	Mode	Represents most frequently occurring colony diameter at a site
		Skewness	Describes the shape of the distribution of the diameter of colonies at a site
Transect and genus/family level		Number of corals	Mean colony density at a site
		Mean number of juveniles ≤5 cm	Estimates the number of small (presumed newly recruited) colonies at a site
		Mean number of colonies >200 cm	Estimates the number of large (presumably older) colonies at a site
Transect and genus/family level	Size data	Arithmetic mean	Mean diameter of colonies at a site
		Standard deviation	Measure of variance in the diameter of colonies at a site

Resolution	Data Type	Statistical Measure	Population Structure Attribute
		Coefficient of variation	Describes variation in colony diameter (standardised by the mean diameter of colonies at a site) allowing a comparison of the relative variation in colony diameter among sites with different mean diameters

Mode was calculated as the size-class with the greatest number of colonies; skew was calculated on the raw data distributions. In general, if a distribution is symmetrical, skewness will be close to zero. A negative skew value indicates relatively few values in the lower size-classes of coral colonies (i.e. distribution skewed towards upper size-classes of coral colonies); and a positive skew value indicates relatively few values in the upper size-classes (i.e. distribution skewed towards lower size-classes of coral colonies).

4.4.1.5 Statistical Approach for Comparison against Baseline

Size-class frequency for the 12 coral families (Acroporidae, Agariciidae, Dendrophylliidae, Faviidae, Fungiidae, Merulinidae, Milleporidae, Mussidae, Oculinidae, Pectiniidae, Pocilloporidae, Poritidae) that had sufficient data to meet the criteria of a minimum of three Impact Sites and three Reference Sites were compared to assess whether distributions had changed from the Marine Baseline Program at Impact Sites and Reference Sites. The data for each of the 12 coral families were analysed separately. The families Caryophylliidae and Siderastreidae were excluded from the statistical analyses as they were rare, there was insufficient replication, and the sample sizes were extremely low. The family ‘Unidentified’ was also excluded from the statistical analyses based on biological grounds as it was unknown what corals were placed in this group, and therefore this grouping had the potential to contain colonies from different coral families.

A two-factor statistical design (Table 4-9; no step-wise approach adopted for size-class frequency analysis) was used to test whether the dredging and dredge spoil disposal activities affected the size-class distribution of corals. If the term of interest (i.e. the term that was potentially indicative of change associated with dredging and dredge spoil disposal activities) was significant, post-hoc tests combined with graphing were undertaken to determine the nature of the change.

Table 4-9 Statistical Treatment and Analyses used for Size-class Frequency

Size-class Frequency		
Pre-treatment of data	No test for coral families Caryophyllidae, Siderastreidae, and Unidentified	
	Only coral families Acroporidae, Agariciidae, Dendrophylliidae, Faviidae, Fungiidae, Merulinidae, Milleporidae, Mussidae, Oculinidae, Pectiniidae, Pocilloporidae, and Poritidae tested	
Sites used in statistical analyses	Marine Baseline Program	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
	Post-Development Survey Year 1 and Year 2	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
Step-wise approach	No step-wise approach adopted (insufficient factors)	

Size-class Frequency		
Main statistical design	Two-factor statistical design	Survey (fixed, orthogonal)
		Impact v. Reference [IvR] (fixed, orthogonal)
Term of interest	Survey × IvR	
Statistical program	PERMANOVA[1]	
Statistical tests	Size-class frequency distribution (multivariate; done separately on each family)	
Transformation	Log (X + 1)	
Distance measure	Bray-Curtis dissimilarity measure	
	Dummy variable (+1) added to samples where the resemblance matrix returned undefined values	

Notes:

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

4.4.2 Results of Post-Development Survey Year 2

In the Post-Development Survey Year 2, a total of 3170 colonies were counted, of which the highest number of colonies were recorded at the Reference Sites LNG3 (23% or 726 colonies) and DUG (17% or 531 colonies), and the lowest number of colonies were recorded at Reference Site BIG (5% or 154 colonies) and ZoMI site MOF1 (2% or 63 colonies) (Table 4-10). In general, the Acroporidae, Faviidae, and Poritidae were the dominant families across most sites and zones.

4.4.2.1 Size-Class Frequency of Hard Coral Taxa at Sites in the Zones of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

At LNG0 in the ZoHI, the coefficient of variation varied among families (Table 4-11), and the majority of the modes were in the smaller sizes classes (0.1–2.0 cm; 2.1–5.0 cm; 5.1–10.0 cm) (Table 4-12). The Agariciidae, Dendrophylliidae, Fungiidae, Milleporidae, and Poritidae were the only notable exceptions to this modal size trend but their sample sizes were all ≤3 colonies and therefore the mode should be interpreted with caution. The dominant and subdominant families (Dendrophylliidae, Faviidae, Poritidae) were all positively skewed (Table 4-13). The other less abundant families were also positively skewed, with the exception of the Agariciidae (-1.16) and Mussidae (-0.13) that were negatively skewed. The largest recorded coral colony in the ZoHI was a massive Porites (Poritidae) of 172 cm, and the smallest colony was a Fungia (Fungiidae) of 0.5 cm. The mean number of colonies per transect at the ZoHI site LNG0 was 43 and the mean size was 15.4 cm (Table 4-10).

In the ZoMI, the coefficient of variation varied among families within sites and also among sites within families (Table 4-11). The trend towards the smaller size-classes was not as evident in the ZoMI sites LNG1, LONE, and MOF1 (Table 4-12), whereby the Acroporidae, Agariciidae, Dendrophylliidae, Fungiidae, Merulinidae, Oculinidae, Pocilloporidae, and Poritidae at certain sites contained modal size-classes greater than the 5.1–10.0 cm size-class. However, the sample sizes for the Agariciidae, Fungiidae, Merulinidae, Milleporidae, and Oculinidae were all ≤5 colonies and therefore the mode should be interpreted with caution. The dominant and subdominant families (Acroporidae, Dendrophylliidae, Faviidae, Mussidae, Poritidae) were all positively skewed with the exception of the Dendrophylliidae at site MOF1, which was negatively skewed (-1.29) (Table 4-13). The other less abundant families were also positively skewed, except for the Pocilloporidae at site LNG1, which was negatively skewed (-1.29). The largest recorded coral colony in the ZoMI was a massive Porites (Poritidae) of 200 cm at site LONE, and the smallest colony was an unidentified Faviidae of 0.5 cm at site MOF1. The mean number of colonies per transect at ZoMI sites (LNG1, LONE and MOF1) was 62, 39, and 13 colonies respectively (Table 4-10). The mean size of colonies ranged between 10 cm (MOF1) and 29.9 cm (LONE) (Table 4-10).

4.4.2.2 Size-Class Frequency of Hard Coral Taxa at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction of the MOF or LNG Jetty

At the Reference Sites, the coefficient of variation varied among families within sites and among sites within families (Table 4-11). In general, the six Reference Sites contained coral populations with a predominance of larger size-classes compared to the ZoHI and ZoMI (Table 4-12). The most common modal size-classes in the Reference Sites were 10.1–20.0 cm and 20.1–50.0 cm (Table 4-12). All families across the six sites were positively skewed, with only three instances of negative skewness recorded at site AHC for the Merulinidae (-0.08) and the Oculinidae (-0.45), and at site BAT for the Pocilloporidae (-1.10) (Table 4-13). The largest recorded coral colony at the Reference Sites was an *Echinopora* (Faviidae) of 217 cm at site BIG, and the smallest colony was an unidentified Faviidae (Faviidae) of 0.3 cm at site LNG3. The mean number of colonies at Reference Sites and Regionally Significant Areas ranged from 31 (at BIG) to 145 (at LNG3) (Table 4-10). Corals larger than 200 cm were recorded at Reference Sites BAT and BIG (one individual each) (Table 4-10).

4.4.3 Comparison between the Post-Development Surveys and Marine Baseline Environmental State

4.4.3.1 Statistical Comparison

The size-class frequency distributions of 12 coral families showed no significant differences between Impact Sites (ZoHI and ZoMI) and Reference Sites.

4.4.3.2 Descriptive Comparison

4.4.3.2.1 Size-class Frequency of Coral Families

Based on the limited replication and the difference in abundance of coral families at the different sites, the small sample sizes of many of the frequent, infrequent, and rare families may not necessarily reflect the true nature of the population at each site. As such, while size-class frequency distributions are presented for 12 coral families (Figure 4-7 to Figure 4-18), the interpretations are restricted to the dominant and subdominant families due to their larger sample sizes.

At site LNG0 in the ZoHI, there were no major shifts in the size-class frequency distributions of the Acroporidae (Figure 4-7), Dendrophylliidae (Figure 4-9), Faviidae (Figure 4-10), and Poritidae (Figure 4-18) between the Marine Baseline Program and Post-Development Survey Year 1 and Year 2. However, there was an appearance of <2 cm juvenile colonies in Post-Development Survey Year 2 for the Dendrophylliidae (Figure 4-9). The Faviidae (Figure 4-10) showed a loss of colonies in the 10–50 cm range in Post-Development Survey Year 2 when compared to the Marine Baseline Program and Post-Development Survey Year 1. No major shifts in the modal size-classes for most families from the Marine Baseline Program to Post-Development Survey Year 2 were recorded at site LNG0.

In the ZoMI, there were no major shifts in the size-class frequency distributions of the Acroporidae (Figure 4-7), Dendrophylliidae (Figure 4-9), Faviidae (Figure 4-10), and Poritidae (Figure 4-18) between the Marine Baseline Program and Post-Development Survey Year 1 and Year 2. However, there was an appearance of <5 cm colonies in Post-Development Survey Year 2 for the Acroporidae (Figure 4-7) and the Faviidae (Figure 4-10). Both the Faviidae (Figure 4-10) and the Poritidae (Figure 4-18) at site MOF1 showed a decrease in the proportion of colonies >50 cm in Post-Development Survey Year 2 when compared to the Marine Baseline Program. Besides a reduction to smaller modes for the Dendrophylliidae (MOF1) and Faviidae (LONE, MOF1), there were no major shifts in the modal size-classes for most families from the Marine Baseline Program to Post-Development Survey Year 2 in the ZoMI.

At the Reference Sites, there were no major shifts in the size-class frequency distributions of any of the coral families (Figure 4-7 to Figure 4-18). However, there was an appearance of <5 cm colonies in Post-Development Survey Year 2 for the Acroporidae (Figure 4-7) and the

Faviidae (Figure 4-10). Although there was some variability in modal size-classes across families and sites in the Reference Sites, there were no major shifts in the modal size-classes from the Marine Baseline Program to Post-Development Survey Year 2 at Reference Sites.

Table 4-10 Coral Colonies Surveyed in each Site for Size-class Frequency

Zone	Site	# Colonies Sampled	Mean # Colonies per Transect	Total # Colonies <5 cm	% of Total # of Colonies <5 cm	Total # Colonies >200 cm	% of Total # of Colonies >200 cm	Mean size of Colonies (cm)
Marine Baseline Program								
ZoHI	LNG0	285	57	76	27	1	<1	23
ZoMI	LNG1	269	53.8	31	12	3	1	30.7
	LONE	223	55.8	28	13	4	2	42.7
	MOF1	315	63	8	3	7	3	32.1
Reference	AHC	464	92.8	56	12	2	<1	20.5
	BAT	360	72	17	5	1	<1	31.9
	BIG	133	26.6	10	8	1	1	42.2
	DUG	449	89.8	45	10	5	1	35.7
	LNG3	338	67.6	82	24	2	1	16
	SBS	349	69.8	17	5	1	<1	24.8
Post-Development Survey Year 1								
ZoHI	LNG0	245	49	61	25	0	0	19.8
ZoMI	LNG1	427	85.4	200	47	0	0	10.9
	LONE	624	124.8	237	38	0	0	12.1
	MOF1	103	20.6	25	24	0	0	12.3
Reference	AHC	544	108.8	134	25	0	0	16.3
	BAT	547	109.4	62	11	0	0	28.2
	BIG	171	34.2	10	6	0	0	29.8
	DUG	595	119	20	3	5	1	32.5
	LNG3	914	182.8	262	29	0	0	10.1
	SBS	384	76.8	58	15	1	<1	23.7
Post-Development Survey Year 2								
ZoHI	LNG0	214	42.8	91	43	0	0	15.4
ZoMI	LNG1	310	62	135	44	0	0	12.6
	LONE	192	38.4	30	16	0	0	29.9
	MOF1	63	12.6	29	46	0	0	10.0
Reference	AHC	326	65.2	100	31	0	0	19.9
	BAT	347	69.4	67	19	1	<1	23.9
	BIG	154	30.8	16	10	1	<1	27.4
	DUG	531	106.2	75	14	0	0	24.7
	LNG3	726	145.2	261	36	0	0	10.4
	SBS	307	61.4	83	27	0	0	19.1

Table 4-11 Coefficient of Variation of Coral Families per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Family	Survey	Zone/Site									
		ZoHI	ZoMI			Reference					
		LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Acroporidae	MBP	1.07	0.83	1.35	0.82	0.66	0.58	0.67	0.82	0.77	0.65
	PDS1	0.51	0.58	0.96	0.68	1.12	0.94	–	1.10	0.75	0.87
	PDS2	1.10	1.38	1.06	1.03	1.11	1.04	0.71	0.87	1.24	0.77
Agariciidae	MBP	–	0.52	1.26	1.42	0.02	–	–	0.89	0.59	–
	PDS1	0.53	1.16	–	–	–	–	0.15	0.80	1.02	–
	PDS2	0.64	–	0.87	–	–	0.77	–	0.68	0.47	0.65
Dendrophylliidae	MBP	0.76	1.01	0.61	0.58	0.30	0.89	–	0.64	0.37	0.63
	PDS1	0.70	0.94	0.81	–	0.81	0.31	–	0.33	0.53	0.95
	PDS2	0.91	0.93	0.78	0.48	1.02	0.75	0.71	0.60	0.52	1.25
Faviidae	MBP	0.81	0.91	0.67	1.43	0.55	0.76	0.87	1.15	0.63	0.90
	PDS1	0.69	0.79	0.84	0.95	0.71	0.67	0.99	1.10	0.64	0.89
	PDS2	0.71	0.80	0.69	0.93	1.16	0.84	0.96	1.13	0.72	1.04
Fungiidae	MBP	0.45	1.08	–	1.11	0.56	0.58	0.13	1.25	1.08	0.02
	PDS1	–	0.54	–	–	0.39	0.87	–	0.89	0.66	–
	PDS2	0.92	–	0.45	–	1.37	1.53	0.57	0.93	0.85	–
Merulinidae	MBP	1.36	1.01	0.88	0.53	0.62	0.52	1.12	0.98	0.36	0.43
	PDS1	–	–	0.63	0.02	0.48	0.82	1.09	0.83	0.68	0.29
	PDS2	–	0.35	1.02	–	0.56	0.97	0.84	0.59	1.28	–
Milleporidae	MBP	1.10	–	0.52	–	–	0.37	–	–	–	0.99
	PDS1	0.42	–	1.07	–	–	0.38	–	0.27	–	0.50
	PDS2	1.15	–	–	–	–	0.71	–	–	–	–
Mussidae	MBP	0.82	0.96	0.55	0.77	1.02	0.62	–	0.69	0.47	0.22
	PDS1	0.76	1.34	1.26	–	0.94	0.60	0.82	0.64	0.66	0.69
	PDS2	0.31	1.04	0.54	1.04	1.17	0.38	–	0.72	0.90	0.88
Oculinidae	MBP	–	–	0.75	0.47	0.63	0.67	–	2.09	–	–
	PDS1	1.53	0.61	0.69	–	0.79	0.46	–	0.85	0.51	0.39
	PDS2	–	0.39	0.63	0.84	0.50	1.27	–	1.08	0.67	0.57
Pectiniidae	MBP	1.26	1.00	10.7	0.56	1.00	0.50	0.77	0.77	0.76	–
	PDS1	0.76	0.70	0.85	0.74	0.83	0.81	0.72	0.82	0.65	0.03
	PDS2	0.60	0.45	1.02	–	0.84	1.00	–	0.80	0.73	–
Pocilloporidae	MBP	–	0.51	0.52	–	0.58	0.63	0.74	0.53	0.95	0.42
	PDS1	0.79	–	1.15	–	0.62	0.59	0.42	0.17	0.42	0.51
	PDS2	–	0.23	0.80	–	0.59	0.67	–	0.97	1.15	0.71
Poritidae	MBP	1.14	1.31	1.02	1.23	1.25	0.86	0.64	1.68	2.70	1.22
	PDS1	0.89	0.96	1.18	0.73	0.97	0.67	0.86	1.04	1.00	1.38
	PDS2	0.96	0.88	0.77	0.80	0.82	0.84	0.84	0.94	0.61	1.13

Table 4-12 Modal Size-class (cm) for Coral Families at each Site

Family	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Marine Baseline Program										
Acroporidae	2.1–5.0	2.1–5.0	5.1–10.0	20.1–50.0	10.1–20.0	20.1–50.0	10.1–20.0	20.1–50.0	2.1–5.0 5.1–10.0	20.1–50.0
Agariciidae	20.1–50.0	20.1–50.0	2.1–5.0 10.1–20.0 50.1–100.0	20.1–50.0	20.1–50.0	100.1–200.0	–	20.1–50.0	5.1–10.0 10.1–20.0	20.1–50.0
Dendrophylliidae	5.1–10.0	5.1–10.0	10.1–20.0	5.1–10.0 10.1–20.0	10.1–20.0 20.1–50.0	2.1–5.0 5.1–10.0 10.1–20.0 20.1–50.0	–	5.1–10.0 10.1–20.0	10.1–20.0	10.1–20.0
Faviidae	2.1–5.0	2.1–5.0	10.1–20.0	10.1–20.0	10.1–20.0	20.1–50.0	20.1–50.0	10.1–20.0	5.1–10.0	10.1–20.0
Fungiidae	10.1–20.0 20.1–50.0	5.1–10.0	–	5.1–10.0	10.1–20.0	10.1–20.0	5.1–10.0 10.1–20.0	2.1–5.0	0.0–2.0	20.1–50.0
Merulinidae	0.0–2.0 100.1–200.0	5.1–10.0 50.1–100.0 100.1–200.0	10.1–20.0	10.1–20.0 20.1–50.0	2.1–5.0	50.1–100.0	20.1–50.0	20.1–50.0	50.1–100.0	20.1–50.0
Milleporidae	20.1–50.0	100.1–200.0	20.1–50.0	–	50.1–100.0	20.1–50.0	–	–	–	10.1–20.0
Mussidae	2.1–5.0	2.1–5.0 5.1–10.0	5.1–10.0 10.1–20.0	10.1–20.0	2.1–5.0	20.1–50.0	20.1–50.0	20.1–50.0	5.1–10.0	10.1–20.0
Oculinidae	2.1–5.0	–	2.1–5.0 10.1–20.0	10.1–20.0	10.1–20.0	20.1–50.0	–	20.1–50.0	–	20.1–50.0
Pectiniidae	2.1–5.0 10.1–20.0 50.1–100.0	10.1–20.0	5.1–10.0	20.1–50.0	10.1–20.0	20.1–50.0	50.1–100.0	20.1–50.0	5.1–10.0	20.1–50.0
Pocilloporidae	10.1–20.0	10.1–20.0	50.1–100.0	10.1–20.0	20.1–50.0	5.1–10.0 20.1–50.0	20.1–50.0	10.1–20.0 20.1–50.0 50.1–100.0	2.1–5.0 10.1–20.0 20.1–50.0	10.1–20.0
Poritidae	20.1–50.0	20.1–50.0	50.1–100.0	20.1–50.0	20.1–50.0	20.1–50.0	10.1–20.0	20.1–50.0	2.1–5.0	20.1–50.0

Family	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Post-Development Survey Year 1										
Acroporidae	2.1–5.0	2.1–5.0	2.1–5.0	10.1–20.0	5.1–10.0	2.1–5.0 20.1–50.0	10.1–20.0	20.1–50.0	2.1–5.0	20.1–50.0
Agariciidae	10.1–20.0	2.1–5.0 5.1–10.0 20.1–50.0	–	–	10.1–20.0	–	10.1–20.0	20.1–50.0	5.1–10.0	20.1–50.0
Dendrophylliidae	10.1–20.0	5.1–10.0 10.1–20.0	2.1–5.0	10.1–20.0	10.1–20.0 20.1–50.0	20.1–50.0	–	10.1–20.0	10.1–20.0	2.1–5.0 20.1–50.0
Faviidae	2.1–5.0	2.1–5.0	2.1–5.0	10.1–20.0	10.1–20.0	10.1–20.0	20.1–50.0	10.1–20.0	2.1–5.0	10.1–20.0
Fungiidae	–	2.1–5.0	0.0–2.0	10.1–20.0	2.1–5.0	10.1–20.0	–	10.1–20.0	2.1–5.0 5.1–10.0	–
Merulinidae	2.1–5.0	2.1–5.0	2.1–5.0	20.1–50.0	10.1–20.0	50.1–100.0	20.1–50.0	20.1–50.0	2.1–5.0	10.1–20.0
Milleporidae	20.1–50.0 50.1–100.0	–	20.1–50.0 100.1–200.0	20.1–50.0	–	20.1–50.0	–	50.1–100.0	–	20.1–50.0
Mussidae	2.1–5.0	2.1–5.0	0.0–2.0 2.1–5.0	0.0–2.0	10.1–20.0	10.1–20.0	50.1–100.0	10.1–20.0	2.1–5.0	20.1–50.0
Oculinidae	0.0–2.0	0.0–2.0 2.1–5.0	10.1–20.0	–	10.1–20.0	20.1–50.0	–	20.1–50.0	5.1–10.0	10.1–20.0
Pectiniidae	0.0–2.0 2.1–5.0	2.1–5.0	0.0–2.0 10.1–20.0	10.1–20.0	2.1–5.0	20.1–50.0	20.1–50.0 50.1–100.0	20.1–50.0	5.1–10.0	10.1–20.0
Pocilloporidae	5.1–10.0 20.1–50.0	2.1–5.0	0.0–2.0 20.1–50.0	–	20.1–50.0	20.1–50.0	20.1–50.0	20.1–50.0	10.1–20.0	20.1–50.0
Poritidae	20.1–50.0	10.1–20.0 20.1–50.0	20.1–50.0	10.1–20.0	20.1–50.0	20.1–50.0	10.1–20.0	20.1–50.0	10.1–20.0	10.1–20.0

Family	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Post-Development Survey Year 2										
Acroporidae	2.1–5.0	2.1–5.0	5.1–10.0 10.1–20.0	20.1–50.0	2.1–5.0 5.1–10.0	20.1–50.0	2.1–5.0 10.1–20.0 20.1–50.0	20.1–50.0	2.1–5.0	20.1–50.0
Agariciidae	20.1–50.0	0.0–2.0	5.1–10.0 20.1–50.0	–	–	20.1–50.0	–	20.1–50.0	5.1–10.0	2.1–5.0 5.1–10.0
Dendrophylliidae	5.1–10.0 10.1–20.0 20.1–50.0	2.1–5.0	10.1–20.0	0.0–2.0	5.1–10.0	20.1–50.0	10.1–20.0 20.1–50.0	10.1–20.0	10.1–20.0	2.1–5.0
Faviidae	2.1–5.0	2.1–5.0	2.1–5.0 5.1–10.0	0.0–2.0	2.1–5.0	10.1–20.0	20.1–50.0	10.1–20.0	2.1–5.0	10.1–20.0
Fungiidae	20.1–50.0	0.0–2.0	10.1–20.0	5.1–10.0	0.0–2.0 50.1–100.0	0.0–2.0	2.1–5.0	10.1–20.0	0.0–2.0	0.0–2.0
Merulinidae	2.1–5.0	2.1–5.0 5.1–10.0	5.1–10.0	20.1–50.0	10.1–20.0	50.1–100.0	10.1–20.0 50.1–100.0 100.1–200.0	20.1–50.0	10.1–20.0	0.0–2.0
Milleporidae	10.1–20.0 100.1–200.0	–	–	20.1–50.0	–	20.1–50.0	–	10.1–20.0	2.1–5.0	100.1–200.0
Mussidae	2.1–5.0	2.1–5.0	2.1–5.0	0.0–2.0 10.1–20.0	2.1–5.0	20.1–50.0	50.1–100.0	20.1–50.0	2.1–5.0	20.1–50.0
Oculinidae	–	5.1–10.0 10.1–20.0	5.1–10.0 10.1–20.0 20.1–50.0	2.1–5.0 10.1–20.0	10.1–20.0	10.1–20.0 200.1–500.0	–	10.1–20.0	10.1–20.0	10.1–20.0
Pectiniidae	5.1–10.0 10.1–20.0	5.1–10.0	10.1–20.0	2.1–5.0	10.1–20.0 20.1–50.0	20.1–50.0	–	20.1–50.0	5.1–10.0	10.1–20.0
Pocilloporidae	5.1–10.0	20.1–50.0	5.1–10.0 10.1–20.0 20.1–50.0	–	20.1–50.0	20.1–50.0	10.1–20.0	2.1–5.0 20.1–50.0	0.0–2.0 10.1–20.0	20.1–50.0
Poritidae	20.1–50.0	10.1–20.0	20.1–50.0	10.1–20.0	20.1–50.0	20.1–50.0	10.1–20.0	20.1–50.0	20.1–50.0	2.1–5.0

Notes: – = not present

Table 4-13 Skew for Coral Colony Families at each Site

Family	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Marine Baseline Program										
Acroporidae	2.12	1.48	2.24	2.31	1.00	0.87	-1.54	1.84	0.78	1.75
Agariciidae	–	1.15	1.61	2.61	–	–	–	1.67	–	–
Dendrophylliidae	2.26	2.24	1.20	1.26	–	1.70	–	1.46	-0.18	1.97
Faviidae	1.56	3.03	0.50	2.72	0.81	1.75	1.71	4.09	1.43	5.14
Fungiidae	–	1.99	–	2.33	-1.73	0.39	–	2.40	1.20	–
Merulinidae	–	0.88	1.45	1.03	0.75	1.04	1.48	2.30	-	-1.72
Milleporidae	2.32	–	1.69	–	–	1.94	–	–	–	2.03
Mussidae	1.87	1.75	–	2.00	1.61	0.41	–	0.39	0.45	0.00
Oculinidae	–	–	0.00	0.55	1.18	0.00	–	4.23	–	–
Pectiniidae	1.61	2.22	2.18	1.00	2.70	0.53	0.52	1.35	1.48	–
Pocilloporidae	–	0.85	-0.58	–	0.20	0.62	-0.06	0.00	1.22	0.19
Poritidae	3.82	4.53	3.14	1.98	3.75	3.39	0.62	3.07	6.79	2.37
Post-Development Survey Year 1										
Acroporidae	-0.27	1.48	2.33	1.46	3.79	0.88	–	3.15	1.33	2.35
Agariciidae	2.30	1.62	–	–	–	–	0.21	2.35	2.61	–
Dendrophylliidae	0.82	4.09	2.13	–	2.10	0.63	–	0.83	0.79	0.97
Faviidae	1.15	1.78	2.34	1.88	1.35	2.56	2.25	6.62	1.10	2.05
Fungiidae	–	1.81	–	–	1.60	0.60	–	0.79	1.86	–
Merulinidae	–	–	0.72	–	0.33	1.31	1.95	1.51	1.53	1.69
Milleporidae	-0.54	–	1.05	–	–	-0.45	–	1.55	–	0.54
Mussidae	2.46	3.17	4.31	–	2.56	1.71	-0.51	1.42	1.11	1.05
Oculinidae	1.73	0.35	1.62	–	2.19	-0.02	–	3.16	0.47	1.36
Pectiniidae	1.16	1.38	0.00	1.20	0.37	2.20	–	1.60	1.31	0.00
Pocilloporidae	–	–	1.20	–	-0.32	0.03	0.25	1.06	-0.80	-0.58
Poritidae	1.83	1.84	2.17	2.50	1.99	0.98	1.24	3.38	3.58	2.99
Post-Development Survey Year 2										
Acroporidae	1.93	2.56	2.06	1.67	2.04	3.66	0.18	1.49	2.67	1.14
Agariciidae	-1.16	–	1.46	–	–	1.75	–	1.58	1.07	–
Dendrophylliidae	1.30	1.46	1.75	-1.29	1.93	2.45	1.37	0.62	1.65	1.69
Faviidae	3.39	2.17	0.88	0.80	6.75	1.32	3.54	3.11	1.08	2.05
Fungiidae	0.37	–	0.11	–	–	2.86	2.20	1.44	1.11	–
Merulinidae	–	–	2.02	–	-0.08	0.71	0.58	0.00	2.85	-
Milleporidae	–	–	–	–	–	0.89	–	–	–	–
Mussidae	-0.13	2.64	1.30	0.61	2.19	0.06	–	2.34	1.86	0.49

Family	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Oculinidae	–	–	0.35	–	-0.45	–	–	2.01	0.61	0.04
Pectiniidae	0.41	0.33	1.96	–	0.90	1.97	–	1.64	2.45	–
Pocilloporidae	–	-1.29	1.36	–	0.84	-1.10	–	0.61	1.98	0.62
Poritidae	2.77	1.30	1.52	0.32	2.14	2.52	2.42	2.16	1.19	1.53

Notes: – = not present

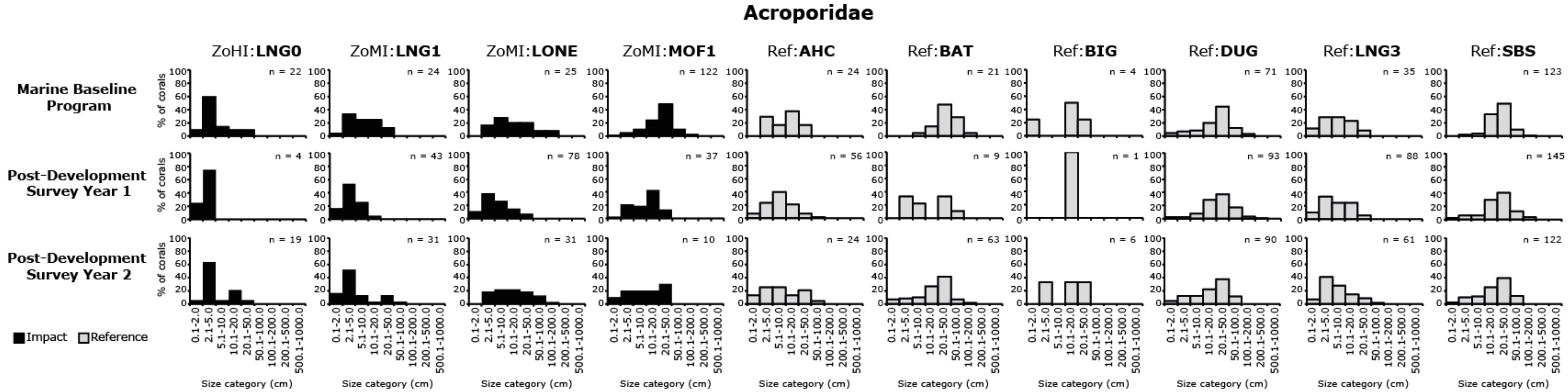


Figure 4-7 Size-class Frequency Distribution for the Family Acroporidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

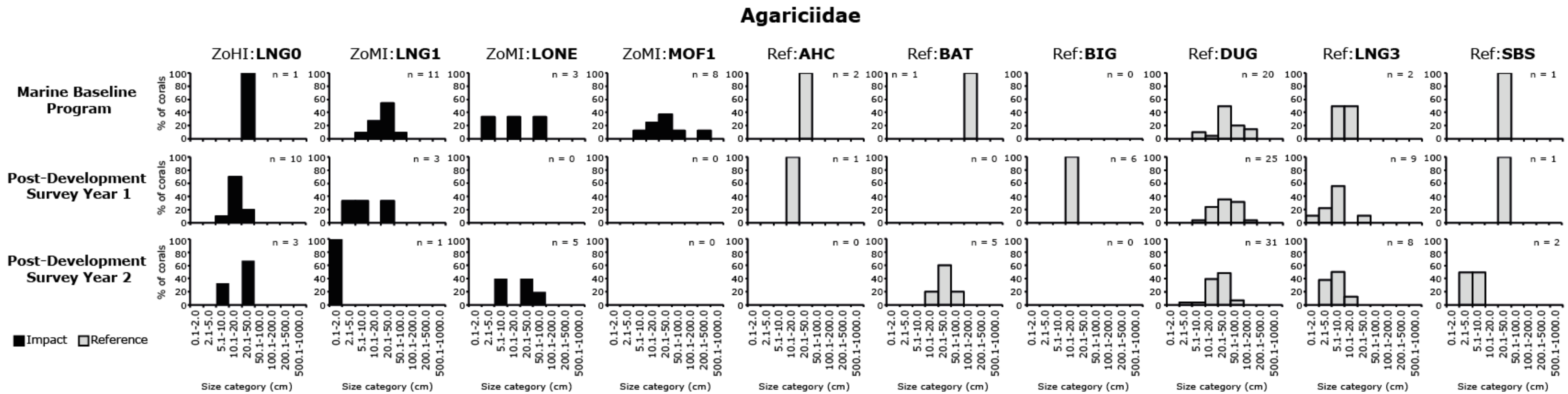


Figure 4-8 Size-class Frequency Distribution for the Family Agariciidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

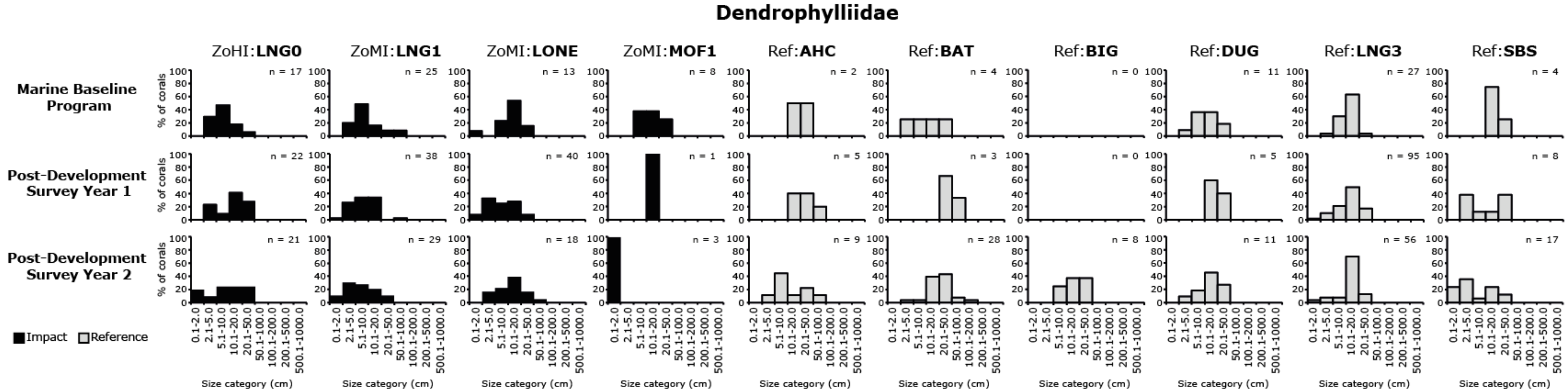


Figure 4-9 Size-class Frequency Distribution for the Family Dendrophylliidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

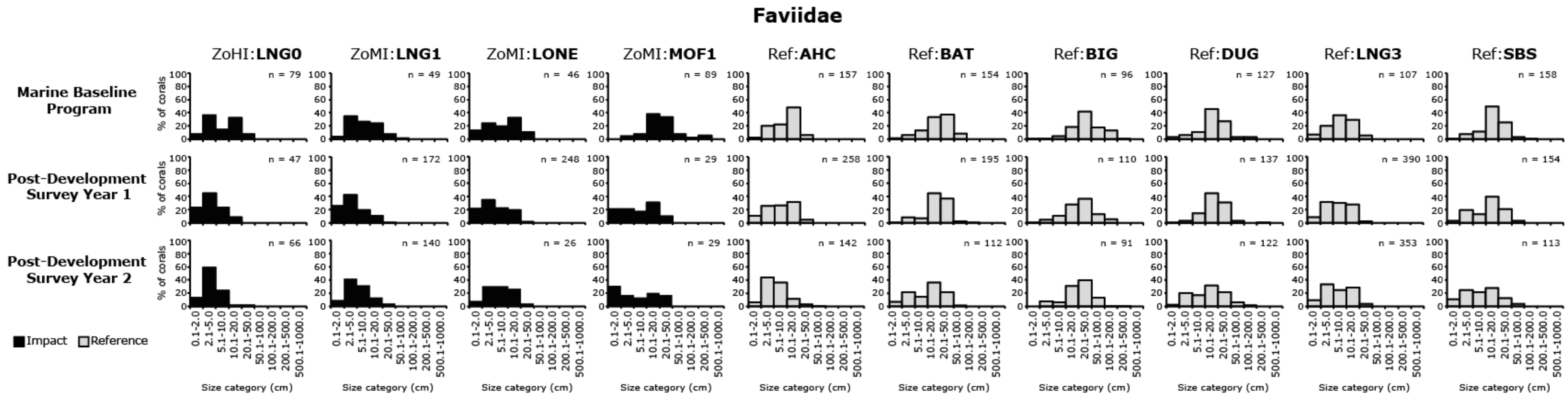


Figure 4-10 Size-class Frequency Distribution for the Family Faviidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

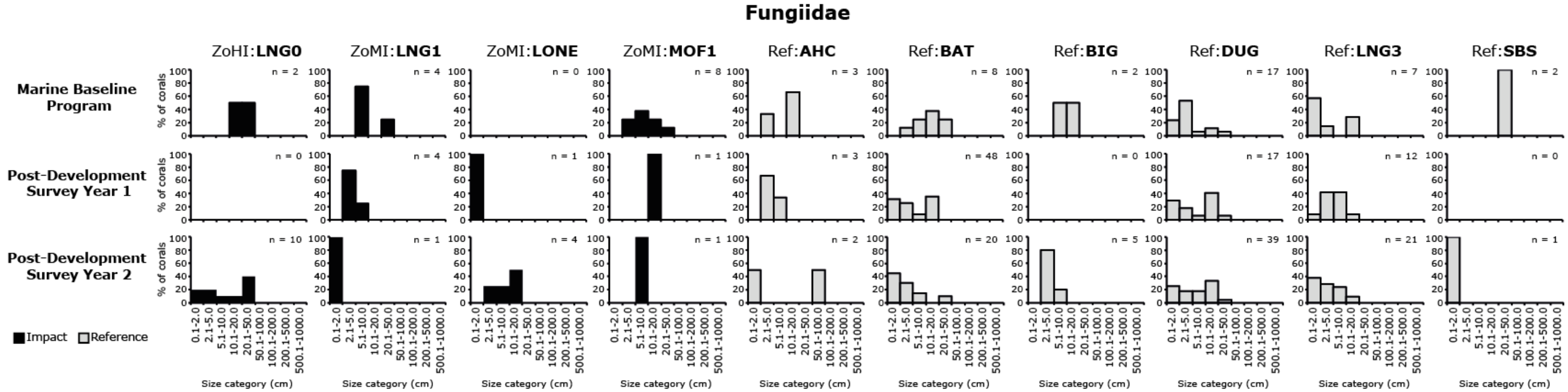


Figure 4-11 Size-class Frequency Distribution for the Family Fungiidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

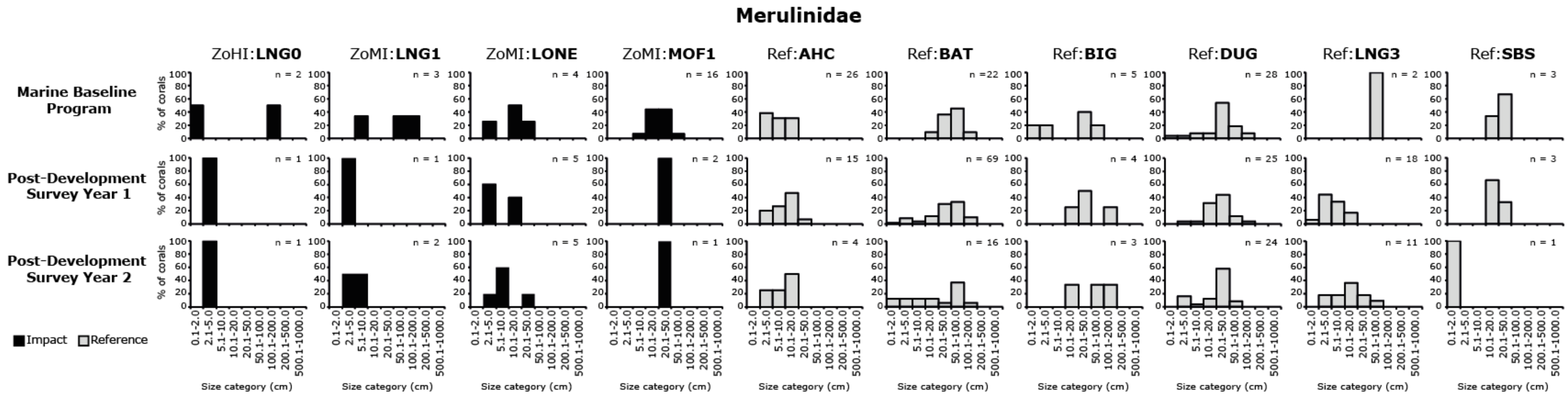


Figure 4-12 Size-class Frequency Distribution for the Family Merulinidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

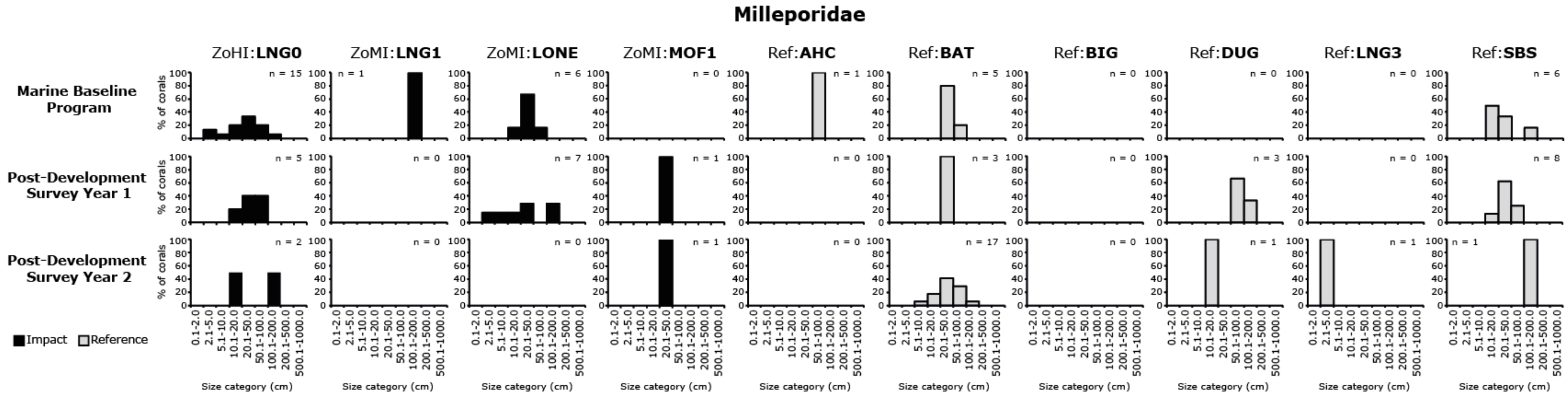


Figure 4-13 Size-class Frequency Distribution for the Family Milleporidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

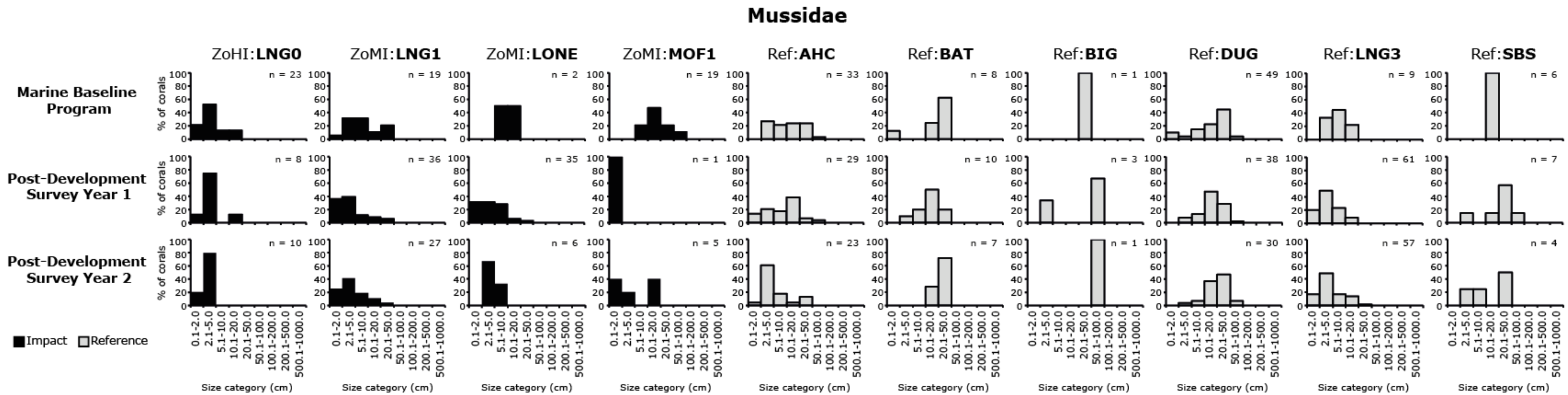


Figure 4-14 Size-class Frequency Distribution for the Family Mussidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

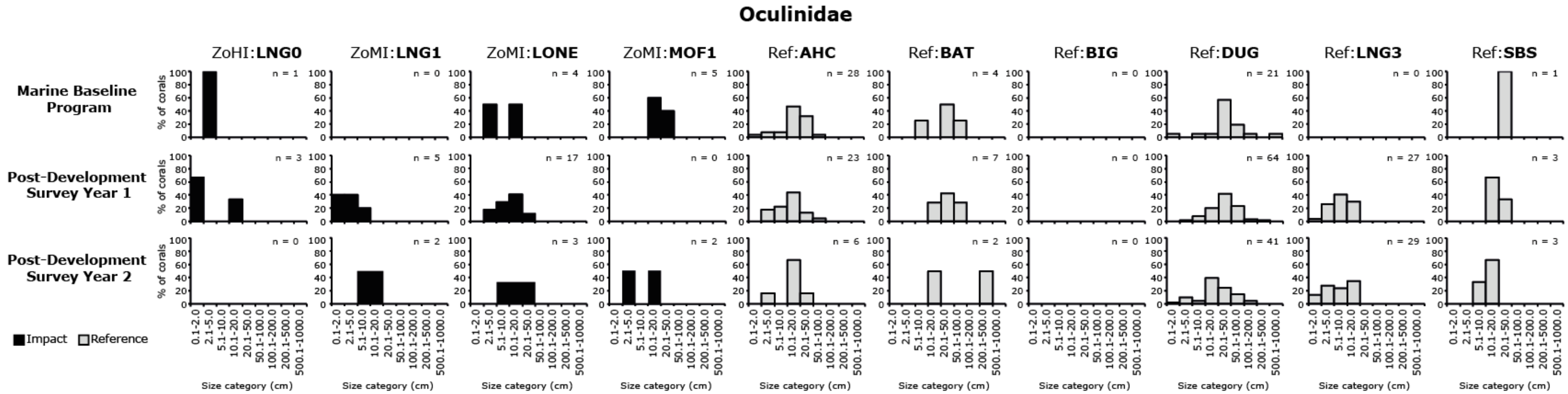


Figure 4-15 Size-class Frequency Distribution for the Family Oculinidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

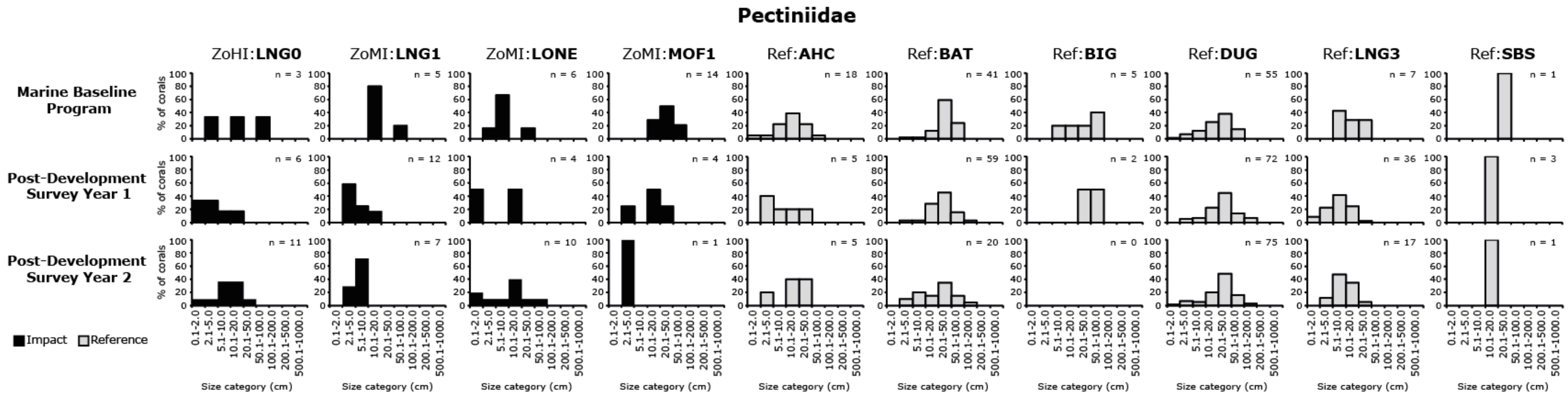


Figure 4-16 Size-class Frequency Distribution for the Family Pectiniidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

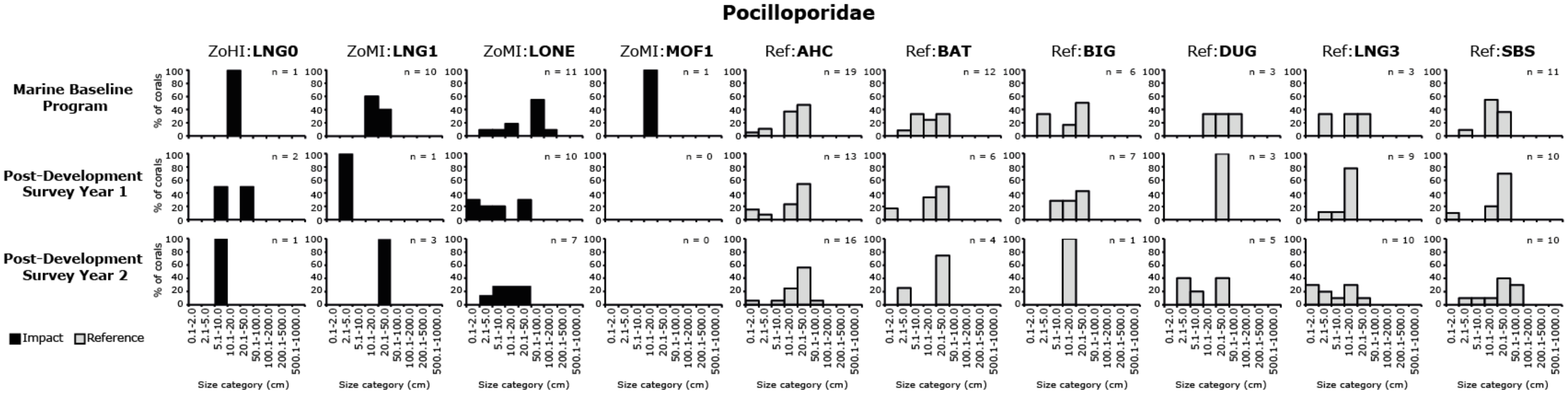


Figure 4-17 Size-class Frequency Distribution for the Family Pocilloporidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

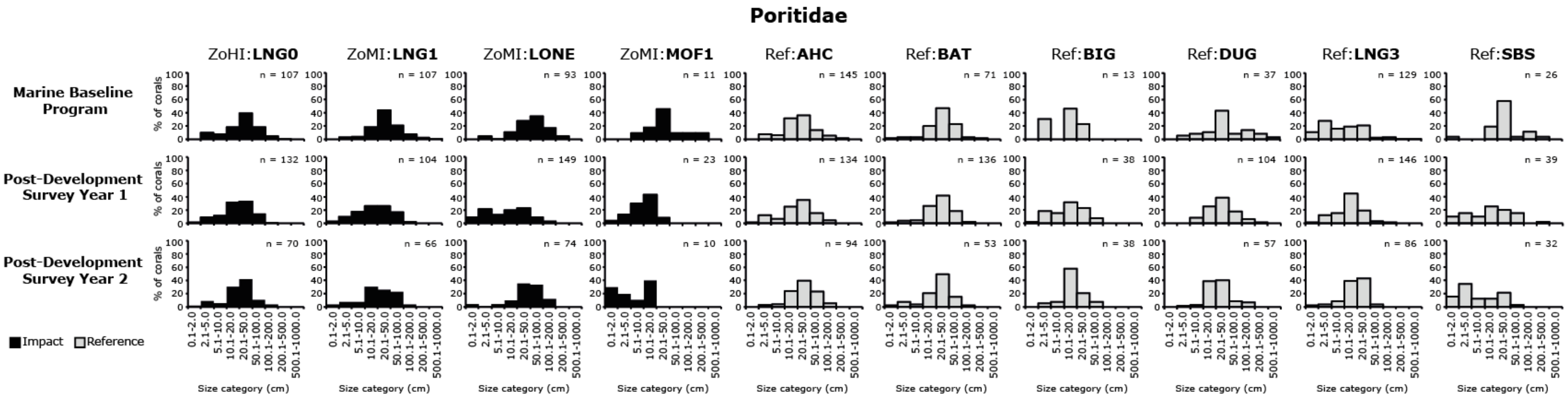


Figure 4-18 Size-class Frequency Distribution for the Family Poritidae per Site and Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

4.4.3.2.2 Colony Size

There was some variability in mean colony size between coral families, but in general, the majority of the families fell within the 10–30 cm size range (Figure 4-19). In most cases, the mean colony size at the Reference Sites was higher than the Impact Sites across the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2 (Figure 4-19). The mean colony size at the Impact Sites decreased from the Marine Baseline Program to Post-Development Survey Year 1 in all 12 families. With the exception of the Agariciidae, Milleporidae, Oculinidae, and Poritidae, which had colony sizes in Post-Development Survey Year 2 similar or greater to the Marine Baseline Program, in all other cases the mean colony size in Post-Development Survey Year 2 remained fairly consistent with Post-Development Survey Year 1 levels (which were below the Marine Baseline Program values). At the Reference Sites, the mean colony size remained stable, with the exception of the Agariciidae and Oculinidae, which showed a strong decrease from the Marine Baseline Program to Post-Development Survey Year 1 and Year 2 (Figure 4-19).

4.4.3.2.3 Skewness

Skewness varied among coral families, but in all cases (except the Pocilloporidae in Post-Development Survey Year 1) the size distributions were positively skewed, indicating a predominance of coral colonies in the small to medium size-classes (Figure 4-19; Table 4-13). The average skewness was 1.81 (Marine Baseline Program), 1.66 (Post-Development Survey Year 1), and 1.13 (Post-Development Survey Year 2) for the Impact Sites, and 1.38 (Marine Baseline Program), 1.44 (Post-Development Survey Year 1), and 1.58 (Post-Development Survey Year 2) for the Reference Sites.

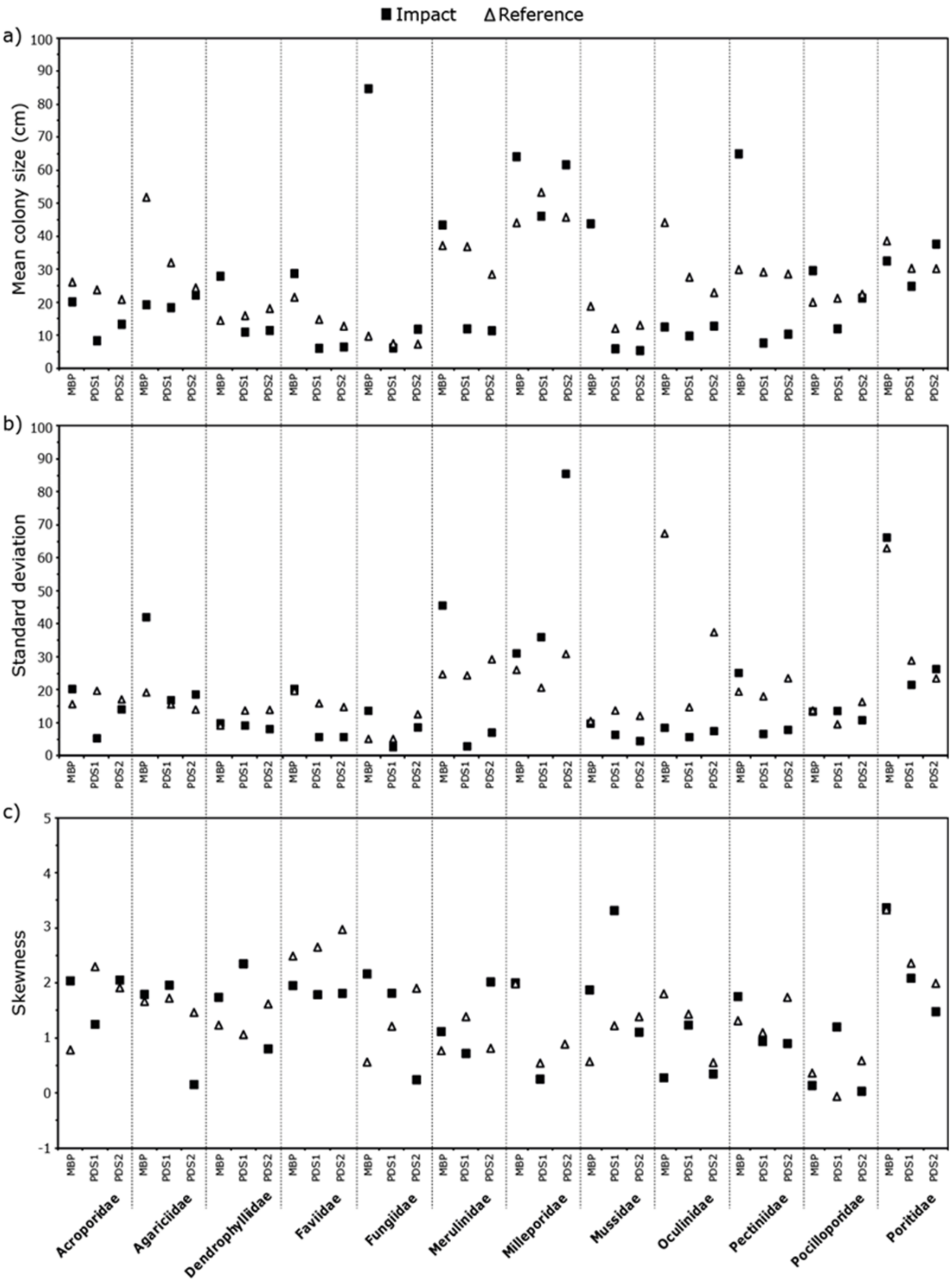


Figure 4-19 Mean Colony Size, Mean Standard Deviation, and Mean Skewness of Coral Families for Impact and Reference Sites for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Notes: a) Mean colony size (cm); b) Mean standard deviation; c) Mean skewness
Impact = sites LNG0, LNG1, LONE, MOF1; Reference = sites AHC, BAT, BIG, DUG, LNG3, SBS

4.4.4 Discussion

Corals are slow-growing organisms characterised by high longevity, and surveys over long periods are necessary to observe their dynamics and understand the mechanisms of change in their populations (Hughes and Jackson 1985, Babcock 1991). However, long-term data are often lacking for most coral communities, and size-class frequency distributions provide valuable clues to the underlying dynamics of growth, survival, and recruitment (Meesters *et al.* 2001). Colony size is an important characteristic in corals because life-history processes (e.g. reproduction and mortality) are strongly related to size (Meesters *et al.* 2001). As these processes are affected by the environment, size-class frequency distributions of coral populations provide information on their responses to environmental conditions. In general, there were no major shifts in the size-class frequency distributions of the 12 coral families from the Marine Baseline Program to Post-Development Survey Year 2, and no significant differences were recorded between Impact Sites (ZoHI and ZoMI) and Reference Sites from the Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2.

The mode represents the most frequently occurring colony size and is indicative of coral mortality processes, with larger colonies more prone to partial mortality and smaller colonies more prone to total mortality as a response to stress (Bak and Meesters 1998). Despite the loss of Faviidae colonies in the 10–50 cm range in the ZoHI , Faviidae and Poritidae colonies >50 cm in the ZoMI, and a reduction in the mode at certain Reference Sites for the Acroporidae, Dendrophylliidae, and the Faviidae, the modes did not show any major changes from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-12). Interestingly, there was an increase in <5 cm colonies in Post-Development Survey Year 1 and Post-Development Survey Year 2 across most sites and zones, suggesting some level of recruitment success both during and after the dredging and dredge spoil disposal activities. This is important because the influx of small colonies is often limited in degraded environments (Meesters *et al.* 2001), and turbidity and sedimentation are known to affect the reproductive success and the settlement and survival of coral larvae (Gilmour 1999, Babcock and Smith 2000), with reports of near-zero settlement rates on sediment-covered surfaces (Fabricius 2005).

The assessment of size-class frequencies in 13 Caribbean coral species across control and degraded reef areas revealed that parameters such as colony size, standard deviation, and skewness reflect a general response to reef condition (Meesters *et al.* 2001). Meesters *et al.* (2001) found that over all 13 species there was no general pattern evident in mean colony size between control and degraded reef areas. This finding is mirrored in the present study where the mean colony size did not show any striking patterns between the Impact Sites and the Reference Sites across the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2 (Figure 4-19). However, the standard deviation in the Acroporidae, Dendrophylliidae, Faviidae, Merulinidae, Mussidae, and Pectiniidae did show reductions in the Impact Sites from Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2 compared to the Reference Sites (Figure 4-19). Meesters *et al.* (2001) reported similar small differences in standard deviation between control and degraded reef areas, whereby the standard deviation in the degraded area was smaller in 70% of the species compared to the control reef areas, suggesting that colony size varies less in degraded areas due to lower recruitment and mortality of larger colonies (Meesters *et al.* 2001). There was evidence of recruitment success in Post-Development Survey Year 1 and Post-Development Survey Year 2, and the lower standard deviations in the Acroporidae, Faviidae, Merulinidae, Mussidae, and Pectiniidae are probably related to the reduction of the larger size-classes after the Marine Baseline Program. The reduction of the larger colonies is possibly due to mortality of adult colonies as a response to sediment stress associated with the dredging and dredge spoil disposal activities or bleaching mortality associated with the 2010–2011 summer coral bleaching (Moore *et al.* 2012) as the genera within these families have been reported to have higher susceptibility to turbidity and sediment stress and thermal stress (Marshall and Baird 2000, Gilmour *et al.* 2007).

Meesters *et al.* (2001) state that skewness represents the most sensitive indicator of change, and that size-class frequency distributions in degraded reef areas generally tend to show increased negative skewness; once again implying that there is less recruitment to the populations and that the populations are aging without replenishment (Bak and Meesters 1998). This was not the case in the present study where, with the exception of the Pocilloporidae at the Reference Sites in Post-Development Survey Year 1, the size-class frequency distributions were all positively skewed suggesting no major changes as a result of the dredging and dredge spoil disposal activities (Figure 4-19).

There is limited evidence to suggest a major change in the size-class frequency distributions of corals from the Marine Baseline Program to Post-Development Survey Year 2 due to dredging and dredge spoil disposal activities. There were no significant differences and no major shifts in the size-class frequency distributions, skewness was positive, and there was successful recruitment (see Section 4.6) both during and after the dredging and dredge spoil disposal activities. In addition, the most abundant and dominant coral families (Acroporidae, Faviidae and Poritidae) did not show any major change associated with the dredging and dredge spoil disposal activities and they showed successful recruitment during Post-Development Survey Year 1 and Post-Development Survey Year 2 (see Section 4.6), the importance of which should not be overlooked as these coral families represent the groups that provide the biggest input in terms of population maintenance and recovery following a disturbance.

4.5 Dominant and Subdominant Taxa

4.5.1 Methods

4.5.1.1 Site Locations

Ten sites were sampled during Post-Development Survey Year 2 for dominant and subdominant coral taxa (Table 4-14, Figure 4-4). One site was in the ZoHI, three were in the ZoMI, and six were Reference Sites and Regionally Significant Areas (hereafter referred to as Reference Sites).

The ZoI sites, ANT and LOW, were unsuitable for measures of size-class frequency[5] due to the presence of *Acropora* thickets, which in turn resulted in these sites being unsuitable for dominant and subdominant coral taxa analyses.

Table 4-14 Post-Development Survey Sites for Dominant and Subdominant Coral Taxa

Location	Site Name (Site Code)	Easting	Northing	Latitude	Longitude	Depth (m)
		(GDA94, MGA Zone 50)		(GDA94)		
Zones of High Impact	LNG0 (LNG0)	344796	7696108	20° 49.713' S	115° 30.507' E	9.00
Zones of Moderate Impact	MOF1 (MOF1)	342089	7698785	20° 48.249' S	115° 28.961' E	6.00
	LNG1 (LNG 1)	344584	7695823	20° 49.867' S	115° 30.384' E	8.75
	Lone Reef (LONE)	347376	7692607	20° 51.624' S	115° 31.976' E	9.25
Reference Sites	Ah Chong (AHC)	350243	7731659	20° 30.472' S	115° 33.829' E	6.50
	Biggada Reef	328237	7702674	20° 46.068' S	115° 21.001' E	1.50

[5] Refer to Section 4.5.1.3; dominant and subdominant coral taxa has been determined using information from the size-class frequency data.

Location	Site Name (Site Code)	Easting	Northing	Latitude	Longitude	Depth (m)
		(GDA94, MGA Zone 50)		(GDA94)		
	(BIG)					
	LNG3 (LNG3)	343157	7692657	20° 51.575' S	115° 29.544' E	6.50
Regionally Significant Areas	Dugong Reef (DUG)	340099	7687998	20° 54.085' S	115° 27.755' E	6.25
	Batman Reef (BAT)	340703	7681301	20° 57.717' S	115° 28.067' E	3.50
	Southern Barrow Shoals (SBS)	345599	7666195	21° 5.929' S	115° 30.810' E	4.75

4.5.1.2 Timing and Frequency of Sampling

The dominant and subdominant coral Post-Development Survey Year 2 sites were surveyed in December 2012. Sites were surveyed in the Marine Baseline Program between October 2008 and January 2009 (Chevron Australia 2012a), and in Post-Development Survey Year 1 between November 2011 and January 2012 (Chevron Australia 2012b).

4.5.1.3 Survey Method

Data on dominant and subdominant coral taxa were obtained from size-class frequency surveys (see Section 4.4 for size-class frequency survey method) (Scope of Works (RPS 2009 [amended 2012])). Soft corals were not part of the size-class frequency surveys and consequently, they were not included in the assessment of dominant and subdominant taxa for the Post-Development Survey Year 2.

Note: Data from the Marine Baseline Program were re-analysed due to the change of method (from Rapid Visual Assessment[6] in the Marine Baseline Program to the use of size-class frequency data in Post-Development Survey Year 1 and Post-Development Survey Year 2) to derive measures of dominant and subdominant coral taxa. A comparison of results from the Marine Baseline Program and the re-analysed data are presented in Appendix 1.

The mean percentage cover of the coral families used in the measures of dominance and subdominance were calculated based on the methods outlined in Section 4.7. The mean percentage cover data was used as a tool to support the dominant and subdominant data, because not all coral families are of equal size. Numerically abundant coral families with small colony sizes may not contribute much to overall coral cover, and vice versa for coral families with large colony sizes.

4.5.1.4 Treatment of Survey Data

The relative abundance of each genus was estimated for each site using a five-point scale (Table 4-15). The definition of dominant and subdominant species in Schedule 2 of Statement No. 800 and Schedule 2 of EPBC Reference: 2003/1294 and 2008/4178, specifically refers to the relative percentage cover, expressed as the proportion of total cover, of individual species; thus the size of colonies was also taken into account in the surveys for measures of dominance and subdominance. In the case of colonies estimated to be >100 cm in maximum linear dimension, each additional metre of the colony was counted as one additional colony (e.g. a large *Porites* colony of up to 450 cm was counted as five colonies; Table 4-16). Coral taxa lists and estimated relative abundance were compiled for each site. Genera or families with an abundance score of 5 or 4 were regarded as dominant and subdominant respectively.

[6] Rapid Visual Assessment (RVA) was undertaken using snorkel surveys at a number of the monitoring sites during the Marine Baseline Program. Due to changes in Chevron Australia's Diving Standards, repeating RVA using snorkel surveys during the Post-Development Surveys was not an option.

Assessments of relative abundance and dominance were undertaken at a site (not individual transect) scale.

Table 4-15 Relative Abundance Scale for Corals used in Assessment of Dominance and Subdominance

Abundance Scale	Number of Colonies	Abundance Term
5	51+	Most Common
4	21–50	Common
3	6–20	Frequent
2	3–5	Infrequent
1	1–2	Rare

Table 4-16 Adjustment to Colony Number for Measures of Dominance

Size (cm)	Add to existing count	Total colonies (for dominance)
0–99	0	1
100–199	1	2
200–299	2	3
300–399	3	4
400–499	4	5
500–599	5	6
600–699	6	7
700–799	7	8
800–899	8	9

4.5.2 Results of Post-Development Survey Year 2

The Acroporidae, Faviidae, and Poritidae were the dominant families across most sites and zones, followed by the Dendrophylliidae and Mussidae. The Caryophylliidae, Milleporidae, and Siderastreidae were the families that were least common across most sites and zones. Within the dominant families, the genera *Acropora* (Acroporidae), *Cyphastrea* (Faviidae), *Favia* (Faviidae), *Favites* (Faviidae), *Lobophyllia* (Mussidae), *Montipora* (Acroporidae), *Porites* (Poritidae), and *Turbinaria* (Dendrophylliidae) were the most representative genera (Table 4-17).

The number of coral families did not vary much between sites. Reference Sites DUG and LNG3 contained the greatest number of families, and ZoMI site MOF1 and Reference Site BIG contained the lowest number of families (Table 4-17).

4.5.2.1 Dominant and Subdominant Coral Taxa at sites in the Zones of High Impact and Zones of Moderate Impact associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

At site LNG0 in the ZoHI, the Faviidae and Poritidae were the dominant coral families, and the Dendrophylliidae were subdominant (Table 4-17). At the genus level, massive *Porites* (Poritidae) were dominant, and *Favia* (Faviidae) and *Turbinaria* (Dendrophylliidae) were subdominant (Table 4-17).

Sites within the ZoMI varied in their composition of dominant and subdominant coral families, with site LNG1 having the highest and site MOF1 the lowest representation of dominant and subdominant families. Dominant families in the ZoMI were the Poritidae (LNG1, LONE) and the Faviidae (LNG1). Subdominant families in the ZoMI were the Acroporidae (LNG1, LONE), the Dendrophylliidae (LNG1), the Faviidae (LONE, MOF1), and the Mussidae (LNG1) (Table 4-17). At the genus level, massive *Porites* (Poritidae) were dominant at sites LNG1 and LONE, and *Cyphastrea* (Faviidae), *Favia* (Faviidae), *Favites* (Faviidae), *Lobophyllia* (Mussidae), *Montipora* (Acroporidae), and branching *Porites* (Poritidae) were subdominant across sites LNG1, LONE, and MOF1 (Table 4-17).

4.5.2.2 Dominant and Subdominant Coral Taxa at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction of the MOF or LNG Jetty

Reference Sites varied in their composition of dominant and subdominant coral families, with sites DUG and LNG3 having the highest representation of dominant and subdominant families. Most Reference Sites were dominated by Acroporidae, Faviidae, and Poritidae (Table 4-17). At the genus level, dominant and subdominant taxa varied among sites, but included *Cyphastrea* (Faviidae), *Favia* (Faviidae), *Favites* (Faviidae), *Lobophyllia* (Mussidae), *Montipora* (Acroporidae), branching *Porites* (Poritidae), and massive *Porites* (Poritidae) (Table 4-17).

Table 4-17 Post-Development Survey Year 2 Dominant and Subdominant Coral Taxa by Family and Genus

Coral taxa	Zone/site									
	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Acropora	2	2	3	2	3		2	3	**4**	**4**
Astreopora		1			1	1			1	4
Montipora	3	**4**	**4**	3	3	**5**	1	**5**	**4**	**5**
Acroporidae	3	**4**	**4**	3	**4**	**5**	3	**5**	**5**	**5**
Pachyseris			1			1		3	3	
Pavona	2	1	2			2		3	1	1
Agariciidae	2	1	2			2		**4**	3	1
Euphyllia								1		
Plerogyra		1						1		
Caryophylliidae		1						2		
Turbinaria	**4**	**4**	3	2	3	**4**	3	3	**5**	3
Dendrophylliidae	**4**	**4**	3	2	3	**4**	3	3	**5**	3
Barabattoia									2	
Caulastrea		1				1		2	2	3
Cyphastrea	3	**4**	2	2	**4**	**4**	**4**	**4**	**5**	3
Echinopora		1			1	3	3	3	1	1
Favia	**4**	**4**	3	1	**4**	**4**	2	3	**5**	3
Faviidae unidentified	2	2		2	2	2		2		1
Favites	3	**4**	2	3	**4**	**4**	3	**4**	**5**	**4**

Coral taxa	Zone/site									
	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Goniastrea	1	3	2	2	3	3	**4**	3	**4**	3
Leptastrea		1	1	1	1				3	
Leptoria		1	1	1			1			
Montastrea	1	1			2	1		1	**4**	1
Moseleya								1	1	1
Oulophyllia									1	
Platygyra	3	3	2	1	3	3	1	3	**4**	3
Faviidae	**5**	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**
Fungia	2	1	2		1	3	2	**4**	3	1
Fungiidae unidentified								2	1	
Herpolitha	2					1		1	1	
Podabacia			1	1	1	1		2	2	
Fungiidae	3	1	2	1	1	3	2	**4**	**4**	1
Hydnophora		1	1			3	2	3	2	
Merulina	1	1	2	1	2	3	1	3	3	1
Merulinidae	1	1	2	1	2	3	2	**4**	3	1
Millepora	2			1		3		1	1	1
Milleporidae	2			1		3		1	1	1
Blastomussa									1	
Lobophyllia	3	**4**	3	2	**4**	3	1	**4**	**5**	2
Mussidae unidentified		1								
Symphyllia		1							1	
Mussidae	3	**4**	3	2	**4**	3	1	**4**	**5**	2
Galaxea		1	2	1	3	2		**4**	**4**	2
Oculinidae		1	2	1	3	2		**4**	**4**	2
Echinophyllia								3		
Mycedium		1	1		1	1		2	2	
Oxypora	2	2	2	1	1	3		3	3	
Pectinia	3	1	2		1	3		**4**	3	1
Pectiniidae unidentified	1	1				1		1		
Pectiniidae	3	3	3	1	2	**4**		**5**	3	1
Pocillopora		1	3		1	1	1	2	3	1
Seriatopora	1	1			3	1		1	1	3
Stylophora									1	1
Pocilloporidae	1	2	3		3	2	1	2	3	3
Goniopora	1	3			1	2		3	2	
Porites (branching)	2		**4**		**4**	**4**	3	**4**	3	2
Porites (massive)	**5**	**5**	**5**	3	**5**	3	**4**	**4**	**5**	**4**

Coral taxa	Zone/site									
	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Poritidae	**5**	**5**	**5**	3	**5**	**5**	**4**	**5**	**5**	**4**
Coscinaraea			1		1		1	1	3	
Psammocora			1							
Siderastreidae			2		1		1	1	3	
Unidentified genus									1	
Unidentified family									1	
Total colonies	214	310	192	63	326	347	154	531	726	307
Total genera	22	32	25	18	26	30	17	36	38	25
Total families	11	11	12	10	11	12	9	14	13	12

Notes: Bold font in 'Coral taxa' = Coral Family; Bold font in Site columns = Dominant (5) and Subdominant (4) coral taxa; Blank cell = not recorded; Euphyllidae were added to the Caryophylliidae to enable comparison with the Marine Baseline Program as it was previously classified as a subfamily of the Caryophylliidae (see Veron 2000)

4.5.3 Comparison between the Post-Development Surveys and Marine Baseline Program Environmental State

In general, the Acroporidae, Faviidae, and Poritidae were the dominant families across most sites and zones, while the Caryophylliidae and Siderastreidae were rare across most sites and zones (Table 4-18).

In the ZoHI, differences were detected in the coral family abundances between the Marine Baseline Program and Post-Development Survey Year 2. At site LNG0 there was a reduction in coral families from 13 in the Marine Baseline Program to 11 in Post-Development Survey Year 2 (Figure 4-20). The Faviidae and Poritidae remained dominant from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-18). There was a reduction in the Acroporidae from subdominant in the Marine Baseline Program to frequent in Post-Development Survey Year 2, but this is an increase in abundance from Post-Development Survey Year 1 where the Acroporidae were infrequent (Table 4-18). In terms of the less abundant families, there was an increase in abundance in the Fungiidae and Pectiniidae from rare/infrequent to frequent and the Dendrophylliidae became subdominant from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-18).

While the number of coral families in the ZoMI remained stable from the Marine Baseline Program to Post-Development Survey Year 2 (Figure 4-20), differences were detected in the coral family abundances (most notably at site MOF1). With the exception of the Acroporidae at site MOF1 for Post-Development Survey Year 2 (which decreased from dominant to frequent), the Acroporidae, Faviidae, and Poritidae remained dominant/subdominant from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-18). The Mussidae increased in abundance from the Marine Baseline Program to Post-Development Survey Year 2 at site LNG1 (subdominant) and site LONE (frequent), but reduced in abundance to infrequent at site MOF1 (which was up from rare in Post-Development Survey Year 1) (Table 4-18). The Dendrophylliidae remained subdominant at LNG1 in Post-Development Survey Year 2, but declined from the Marine Baseline Program at site MOF1 (infrequent) (Table 4-18).

The number of coral families in the Reference Sites either remained stable or increased from the Marine Baseline Program to Post-Development Survey Year 2, with the exception of site AHC that declined from 12 to 11 families (Figure 4-20). In contrast to the ZoHI and ZoMI, most of the differences detected in the Reference Sites were positive; the dominance scores either remained stable or increased from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-18). Exceptions to this trend were at site AHC for the Merulinidae and Oculinidae, which were subdominant in the Marine Baseline Program but infrequent and frequent, respectively, in Post-Development Survey Year 2, and for the Merulinidae at site BAT, which was also subdominant in the Marine Baseline Program but frequent in Post-Development Survey Year 2 (Table 4-18).

Table 4-18 Dominant and Subdominant Coral Taxa by Family for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Family	Survey	Zone/Site									
		ZoHI	ZoMI			Reference					
		LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Acroporidae	MBP	**4**	**4**	**4**	**5**	**4**	**4**	2	**5**	**4**	**5**
	PDS1	2	**4**	**5**	**4**	**5**	3	1	**5**	**5**	**5**
	PDS2	3	**4**	**4**	3	**4**	**5**	3	**5**	**5**	**5**
Agariciidae	MBP	1	3	2	3	1	1		**4**	1	1
	PDS1	3	2			1		3	**4**	3	1
	PDS2	2	1	2			2		**4**	3	1
Caryophylliidae	MBP		1						1		
	PDS1	1							1	1	
	PDS2								2		
Dendrophylliidae	MBP	3	**4**	3	3	1	2		3	**4**	2
	PDS1	**4**	**4**	**4**	1	2	2		2	**5**	3
	PDS2	**4**	**4**	3	2	3	**4**	3	3	**5**	3
Faviidae	MBP	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
	PDS1	**4**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**5**
	PDS2	**5**	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**
Fungiidae	MBP	1	2		3	2	3	1	3	3	1
	PDS1		2	1	1	2	**4**		3	3	
	PDS2	3	1	2	1	1	3	2	**4**	**4**	1
Merulinidae	MBP	2	2	2	3	**4**	**4**	2	**4**	1	2
	PDS1	1	1	2	1	3	**5**	2	**4**	3	2
	PDS2	1	1	2	1	2	3	2	**4**	3	1
Milleporidae	MBP	3	2	3		1	2				3
	PDS1	2		3	1		2		2		3
	PDS2	2			1		3		1	1	1
Mussidae	MBP	**4**	3	1	3	**4**	3	1	**4**	3	3
	PDS1	3	**4**	**4**	1	**4**	3	2	**4**	**5**	3
	PDS2	3	**4**	3	2	**4**	3	1	**4**	**5**	2
Oculinidae	MBP	1		2	2	**4**	2		**4**		1
	PDS1	2	2	3		**4**	3		**5**	**4**	2
	PDS2		1	2	1	3	2		**4**	**4**	2

Family	Survey	Zone/Site									
		ZoHI	ZoMI			Reference					
		LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Pectiniidae	MBP	2	2	3	3	3	**4**	2	**5**	3	1
	PDS1	3	3	2	2	2	**5**	1	**5**	**4**	2
	PDS2	3	3	3	1	2	**4**		**5**	3	1
Pocilloporidae	MBP	1	3	3	1	3	3	3	2	2	3
	PDS1	1	1	3		3	3	3	2	3	3
	PDS2	1	2	3		3	2	1	2	3	3
Poritidae	MBP	**5**	**5**	**5**	3	**5**	**5**	3	**5**	**5**	**4**
	PDS1	**5**	**5**	**5**	**4**	**5**	**5**	**4**	**5**	**5**	**4**
	PDS2	**5**	**5**	**5**	3	**5**	**5**	**4**	**5**	**5**	**4**
Siderastreidae	MBP	1						1			
	PDS1		1	4					2	1	
	PDS			2		1		1	1	3	

Notes: Bold font in Site columns = Dominant (5) and Subdominant (4) coral taxa; Blank cells= not recorded
Euphyllidae were added to the Caryophylliidae to enable comparison with the Marine Baseline Program as it was previously classified as a subfamily of the Caryophylliidae (see Veron 2000)

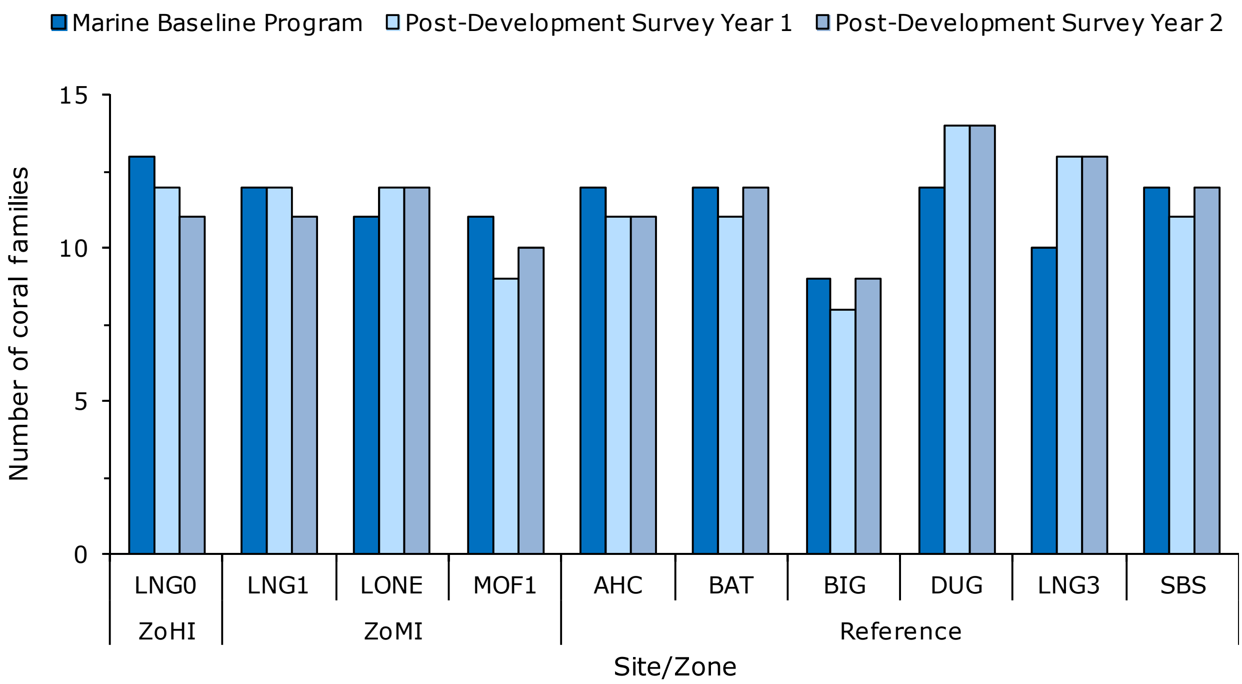


Figure 4-20 Total Number of Families of Hard Corals Recorded during the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

4.5.4 Discussion

The Acroporidae, Faviidae, and Poritidae were the dominant families across most sites and zones (Table 4-18). In general, the number of coral families did not show any major changes from the Marine Baseline Program to Post-Development Survey Year 2 (Figure 4-20); however, the Reference Sites contained a greater selection of dominant/subdominant families compared to the Impact Sites (Table 4-18). The Reference Sites included a greater number of sites compared to the Impact Sites, which possibly accounts for the greater number of dominant/subdominant families. Also, the trend in dominant/subdominant families is based on what was present at the sites during the Marine Baseline Program, where certain Impact Sites (e.g. LNG0) contained fewer dominant/subdominant families (Table 4-18). Moreover, *Turbinaria* is a genus that is known to be dominant in shallow turbid (low-light) environments (Veron 2000), and the greater abundance of *Turbinaria* (Dendrophylliidae) within the ZoHI and ZoMI sites relative to the majority of Reference Sites in the Marine Baseline Program suggest lower light conditions in the Impact Sites prior to dredging and dredge spoil disposal activities. Due to the attenuation of light with depth, the deeper depths of the Impact Sites (mean 8.3 m) compared to the Reference Sites (mean 4.8 m) further indicate more favourable coral growth conditions (Kleypas *et al.* 1999) in the shallower Reference Sites, which is reflected in their different community compositions (Chevron Australia 2012a).

The Acroporidae, Faviidae, and Poritidae remained dominant/subdominant from the Marine Baseline Program to Post-Development Survey Year 2 in the Reference Sites (Table 4-18). Within the ZoHI, the Faviidae and Poritidae remained dominant, but there was a reduction in percentage cover of the Poritidae from the Marine Baseline Program to Post-Development Survey Year 1 (Table 4-18). On the other hand, the dominance score of the Acroporidae increased from Post-Development Survey Year 1 to Post-Development Survey Year 2, but still represented a reduction in the dominance score from the Marine Baseline Program (Table 4-18). A similar trend was evident in the ZoMI where the Acroporidae, Faviidae, and Poritidae largely remained dominant/subdominant from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-18), but the dominance score of the Acroporidae and Faviidae declined at site MOF1. Within the ZoHI and ZoMI, changes in dominance scores were recorded for the Agariciidae, Dendrophylliidae, Merulinidae, and Mussidae, but there was no common trend, with some sites increasing while other sites declined for the same coral family.

Corals can withstand a certain level of turbidity and sediment (Rogers 1990), but the main issues arising from turbidity and sedimentation derived from dredging and dredge spoil disposal activities relate to shading caused by decreases in ambient light and sediment cover on the coral colony surface (Erftemeijer *et al.* 2012). While there were no major changes in the dominance of corals from the Marine Baseline Program to Post-Development Survey Year 2 (Table 4-18), the turbidity and sediment stress associated with the dredging and dredge spoil disposal activities cannot be disregarded when investigating the minor reductions present in the ZoHI and ZoMI and at certain Reference Sites. Recent reviews (Gilmour *et al.* 2007, Erftemeijer *et al.* 2012) of the published literature on the sensitivity of corals to turbidity and sedimentation have revealed that different coral taxa show different susceptibilities to elevated turbidity and sedimentation (conditions often associated with dredging and dredge spoil disposal activities). In general, plating and encrusting growth forms (including plating and corymbose *Acropora* and *Montipora* (Acroporidae), Agariciidae, Pectinidae) have the highest susceptibility, followed by medium susceptibility of massive corals (including massive *Porites* (Poritidae), Faviidae), with branching corals (including branching *Acropora* (Acroporidae), branching *Porites* (Poritidae)) showing the lowest susceptibility (Gilmour *et al.* 2007).

The majority of taxa within the Acroporidae (*Acropora*, *Montipora*) had plating, encrusting, and corymbose growth forms in the survey sites in this study (sites ANT and LOW the exceptions), and massive *Porites* (Poritidae) were common in the ZoHI and ZoMI sites during the Marine Baseline Program (Chevron Australia 2012a). The reductions of these taxa within the ZoHI and ZoMI after dredging and dredge spoil disposal activities largely follow the published coral susceptibility levels, in that the reductions are evident within high and medium susceptibility taxa. That said, extensive coral bleaching was recorded at Barrow Island (~50% bleaching) in the 2010–2011 summer (Moore *et al.* 2012) as part of a 'marine heat wave' off Western Australia (Pearce *et al.* 2011). The susceptibility of coral taxa to thermal stress that results in coral bleaching bears similarities to the susceptibility of corals to turbidity and sedimentation

(Marshall and Baird 2000, Gilmour *et al.* 2007), and bleaching associated mortality may also have contributed to the reduction in dominance scores. However, the reductions in dominance scores were not unanimous across all sites for all coral families (Table 4-18), suggesting that the possible response to the dredging and dredge spoil disposal activities and/or coral bleaching was not uniform.

There is limited evidence to suggest a major change in the dominance of corals from the Marine Baseline Program to Post-Development Survey Year 2 due to dredging and dredge spoil disposal activities. However, the influence of the dredging and dredge spoil disposal activities cannot be totally disregarded given that minor reductions in dominance scores in certain coral families were recorded in the ZoHI and ZoMI but not in the Reference Sites.

4.6 Recruitment Success

4.6.1 Methods

Coral mass spawning at Barrow Island generally occurs in autumn (February to March) with some secondary spawning in spring (October to November) (Rosser and Gilmour 2008, Styan and Rosser 2012, Rosser 2013). The Post-Development Survey Year 2 field data collection was undertaken over summer and did not fully coincide with the predicted coral spawning. As such, the coral recruitment tile method laid out in the Scope of Works (RPS 2009 [amended 2012]) and used in the Marine Baseline Program and Post-Development Survey Year 1 was not appropriate for Post-Development Survey Year 2. Rather, a subset of the coral size-class frequency data was used to assess coral recruitment success (RPS 2009 [amended 2012]). Studies have shown that the patterns established at settlement may be substantially modified by post-settlement processes such as differential growth and survival (e.g. Smith 1992; Dunstan and Johnson 1998); however, for the purposes of this approach, it is assumed that all coral taxa have the same growth rates, that growth rates are the same at both Impact and Reference Sites, and that growth rates were the same before and after dredging. Data are presented for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2.

Based on the size at settlement and current estimates of coral growth, corals are broadly regarded as juvenile (<5 cm) until they reach sexual maturity, which may occur from 5 to 10 cm in size depending on the species (Smith *et al.* 2005, Penin *et al.* 2007).

4.6.1.1 Site Locations

Ten sites were sampled in Post-Development Survey Year 2 for recruitment success (Table 4-19; Figure 4-4). One site was in the ZoHI, three were in the ZoMI, and six were Reference Sites and Regionally Significant Areas (hereafter referred to as Reference Sites). The ZoI sites, ANT and LOW, were unsuitable for measures of size-class frequency due to the presence of *Acropora* thickets, which in turn resulted in these sites being unsuitable for recruitment success analyses.

Table 4-19 Post-Development Survey Year 2 Survey Sites for Coral Recruitment Success

Location	Site Code	Site Coordinates (GDA94, UTM50)				Depth (m)
		Easting	Northing	Latitude	Longitude	
ZoHI	LNG0 (LNG0)	344796	7696108	20°49.713'S	115°30.507'E	9.00
ZoMI	LNG1 (LNG1)	344584	7695823	20°49.867'S	115°30.384'E	8.75
	Lone Reef (LONE)	347376	7692607	20°51.624'S	115°31.976'E	9.25

Location	Site Code	Site Coordinates (GDA94, UTM50)				Depth (m)
		Easting	Northing	Latitude	Longitude	
	MOF1 (MOF1)	342089	7698785	20°48.249'S	115°28.961'E	6.00
Ref	Ah Chong (AHC)	350243	7731659	20°30.472'S	115°33.829'E	6.50
	Batman Reef (BAT)	340703	7681301	20°57.717'S	115°28.067'E	3.50
	Biggada Reef (BIG)	328237	7702674	20°46.068'S	115°21.001'E	1.50
	Dugong Reef (DUG)	340099	7687998	20°54.085'S	115°27.755'E	6.25
	LNG3 (LNG3)	343157	7692657	20°51.575'S	115°29.544'E	6.50
ZoHI ZoMI	Southern Barrow Shoals (SBS)	345599	7666195	21°5.929'S	115°30.810'E	4.75
	LNG0 (LNG0)	344796	7696108	20°49.713'S	115°30.507'E	9.00
	LNG1 (LNG1)	344584	7695823	20°49.867'S	115°30.384'E	8.75

Notes: AHC, BIG, LNG3 = Regionally Significant Areas; DUG, BAT, LOW = Reference Sites

4.6.1.2 Timing and Frequency of Sampling

Sites were surveyed in Post-Development Survey Year 2 between November 2012 and December 2012. Sites were surveyed in the Marine Baseline Program between October 2008 and January 2009 (Chevron Australia 2012a), and in Post-Development Survey Year 1 between November 2011 and January 2012 (Chevron Australia 2012b).

4.6.1.3 Survey Method

Data on coral recruitment success were obtained from size-class frequency surveys (refer to Section 4.4.1.3 for size-class frequency survey method). Soft corals were not part of the size-class frequency surveys and as a result they were not included in the assessment of coral recruitment success.

4.6.1.4 Treatment of Survey Data

To be consistent with the Marine Baseline Program, the genera were grouped into coral families (Table 4-7). Colonies were categorised into the following size-classes based on maximum colony diameter: 0.1–2.0 cm, 2.1–5.0 cm, 5.1–10.0 cm, 10.1–20 cm, 20.1–50.0 cm, 50.1–100.0 cm, 100.1–200.0 cm, 200.1–500.0 cm, and 500.1–1000.0 cm, which is consistent with other studies of size-class frequency distributions (van Woesik and Done 1997).

The size-classes used to assess recruitment success were 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm (colonies ≤10 cm) to reflect the broad categorisation of van Moorsel (1988), whereby it was assumed that:

- corals 0.1–2.0 cm were recruited within the past year
- corals 2.1–5.0 cm were recruited more than 1 year ago
- corals 5.1–10.0 cm were recruited more than 2 years ago.

It is acknowledged that brooding and broadcasting coral species have different dispersal capabilities, vary in growth rates, and potentially recruit at different times. However, using the size-class approach it is assumed that all coral taxa have the same growth rates, that growth rates are the same at both Impact and Reference Sites, that growth rates were the same before and after dredging, and that brooders and broadcasters all recruit during the same time window.

Corals will only recruit on certain substrata such as coralline algae, dead coral, and rock (Heyward and Negri 1999), with the amount of substrate available for coral recruitment varying among sites and/or over time. The amount of suitable substrate for coral recruitment was therefore obtained from the random transect data (Section 4.7). The substrate available for coral recruitment was calculated as the sum of the percentage cover of Coralline Algae (CA) and Pavement/Rock/Rubble (PAV) (= PAV/CA). Given the broad categorisation of the estimation of the age of the three size-classes, it was necessary to standardise the colony numbers by the substrate available for recruitment during the year that a particular size-class recruited. As such, not all possible combinations were available for statistical analyses based on the unavailability of substrate information from time periods where no data was available.

4.6.2 Statistical Approach for Comparison Against Baseline

As detailed in Section 4.7.1.5, a step-wise approach was adopted for assessing potential environmental change. A combination of a two-factor and a four-factor statistical design (Table 4-20; flow chart: Figure 4-21) was used to test whether the dredging and dredge spoil disposal activities affected the number of coral colonies ≤10 cm. If the term(s) of interest (i.e. the terms that were potentially indicative of change associated with dredging and dredge spoil disposal activities) was significant in Step 1 of Figure 4-21, post-hoc, pair-wise tests combined with graphing were undertaken to determine the nature of the change. Regardless of whether the term of interest in Step 1 was significant, the next step in Figure 4-21 was followed. If both the terms of interest were non-significant in Step 2 of Figure 4-21, then only the results of Step 1 were used. If the terms of interest were significant in Step 2 of Figure 4-21, then the next step was followed. If the term of interest was significant in Step 3 of Figure 4-21, post-hoc, pair-wise tests combined with graphing were undertaken to determine the nature of the change.

Table 4-20 Statistical Treatment and Analyses used for Recruitment Success

Recruitment Success		
Pre-treatment of data	For the multivariate analysis on total count data where coral families were variables, the families Caryophyllidae, Siderastreidae, and Unidentified corals were removed from the dataset as there was insufficient replication	
Sites used in statistical analyses	Marine Baseline Program	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
	Post-Development Survey Year 1	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
	Post-Development Survey Year 2	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
Step-wise approach	Step-wise approach adopted (see flow chart: Figure 4-21)	
Main statistical design	Total counts Two-factor statistical design	Survey (fixed, orthogonal)
		Impact v. Reference [IvR] (fixed, orthogonal)
	Substrate availability Four-factor statistical design	Survey (fixed, orthogonal)
		Impact v. Reference [IvR] (fixed, orthogonal)
		Zone (fixed, nested within IvR)
		Site (random, nested within Zone)
Term(s) of interest	Total counts Two-factor statistical design	Survey × IvR
	Substrate availability	Survey × Site

Recruitment Success		
	Four-factor statistical design	Site
Statistical program	PERMANOVA	
Statistical tests	Total counts	Size-class as variables (multivariate)
		Coral families as variables (multivariate)
		Substrate availability (univariate)
	Standardised total counts	Separate test for each size-class (univariate)
Transformation	None	
Distance measure	Univariate: Euclidean distance	
	Multivariate: Bray-Curtis dissimilarity measure	

Notes: PERMANOVA (non-parametric analysis of variance, Version 1.0.1, Primer E Ltd) (Anderson 2001a, 2001b)

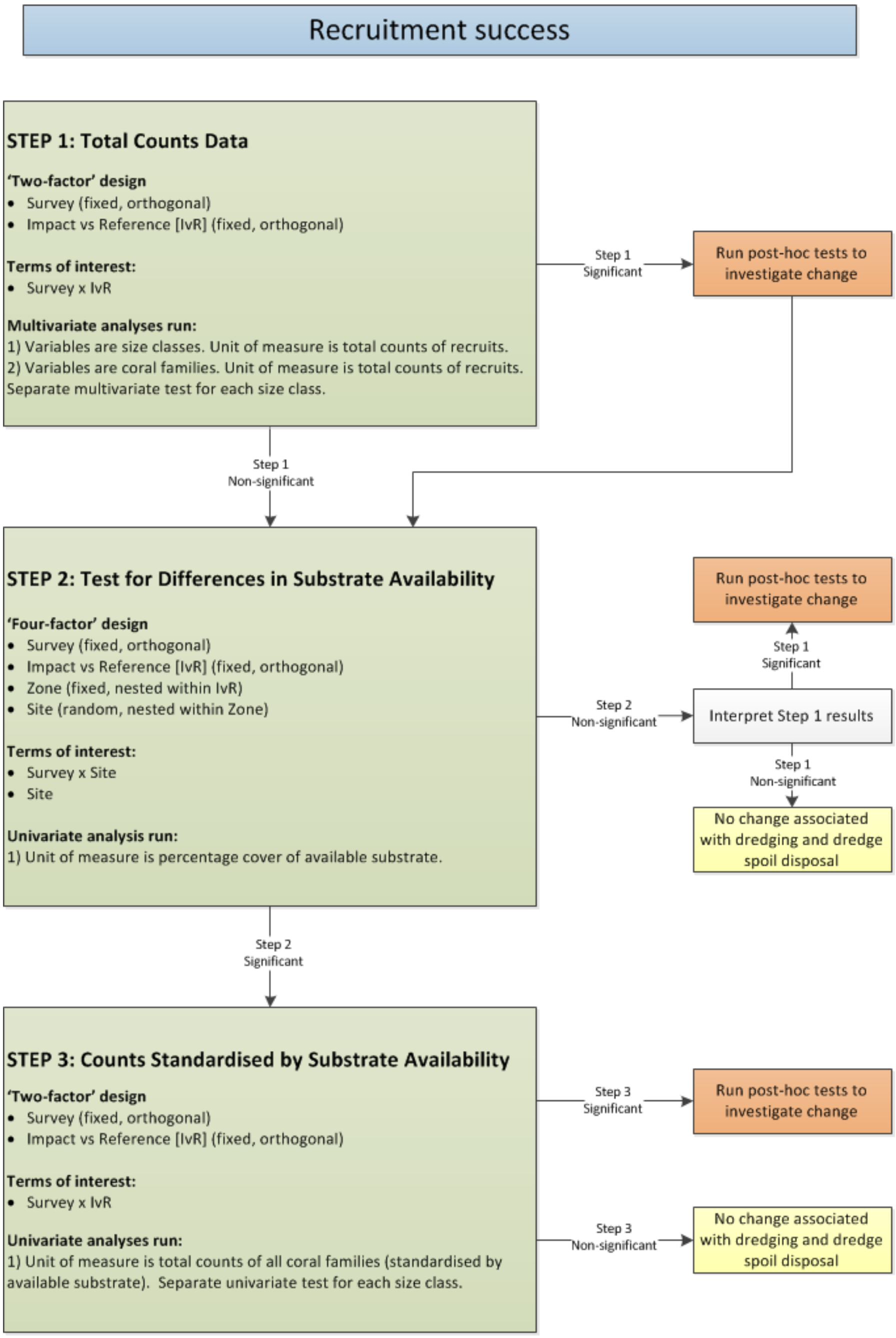


Figure 4-21 Statistical Designs and Step-wise Approach for Assessment of Change in Coral Recruitment Success

4.6.3 Results of Post-Development Survey Year 2

4.6.3.1 Recruitment Success of Hard Corals at Sites in the Zone of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment from Dredging and Dredge Spoil Disposal

At site LNG0 in the ZoHI, 124 colonies were ≤10 cm (Figure 4-22), which represents 58% of the sample coral population (Figure 4-22). Size-class 2.1–5.0 cm contained the largest number of colonies, followed by size-classes 5.1–10.0 cm and 0.1–2.0 cm, respectively (Figure 4-23).

Sites within the ZoMI varied in the number of colonies ≤10 cm, with site LNG1 having the highest number (n=209) and site MOF1 (n=38) the lowest number of colonies ≤10 cm (Figure 4-22). Site LNG1 (67%) and site MOF1 (62%) had a similar proportion of the sample population made up of colonies ≤10 cm, which was almost double that of site LONE (36%) (Figure 4-22). The size composition of the colonies ≤10 cm also varied across the ZoMI sites (Figure 4-23).

4.6.3.2 Recruitment Success of Hard Corals at Reference Sites Not at Risk of Material or Serious Environmental Harm Due to Construction of the MOF or LNG Jetty

Reference Sites varied in the number of colonies ≤10 cm, with site LNG3 having the highest number (n=425) and site BIG the lowest number (n=28) of colonies ≤10 cm (Figure 4-22). The other four sites (AHC, BAT, DUG, SBS) had similar number of colonies ≤10 cm (mean = 135 ± 14 cm) (Figure 4-22). The proportion of the population made up of colonies ≤10 cm followed a similar pattern, with site LNG3 having the highest (59%) and site BIG the lowest (18%) contribution (Figure 4-22). The size composition of the colonies ≤10 cm was fairly uniform across the Reference Sites, with size-class 2.1–5.0 cm the most abundant, followed by size-classes 5.1–10.0 cm and 0.1–2.0 cm, respectively (Figure 4-23).

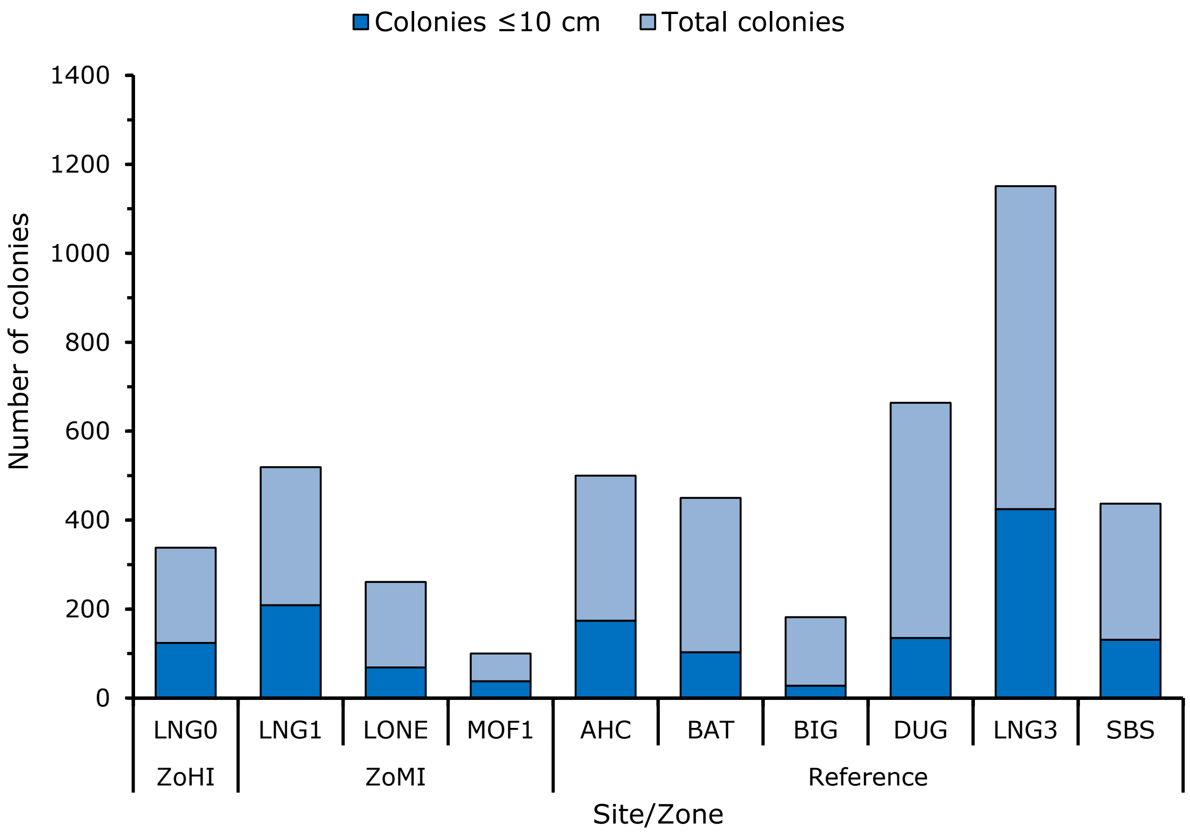


Figure 4-22 Number of Total Coral Colonies ≤10 cm recorded during Post-Development Survey Year 2

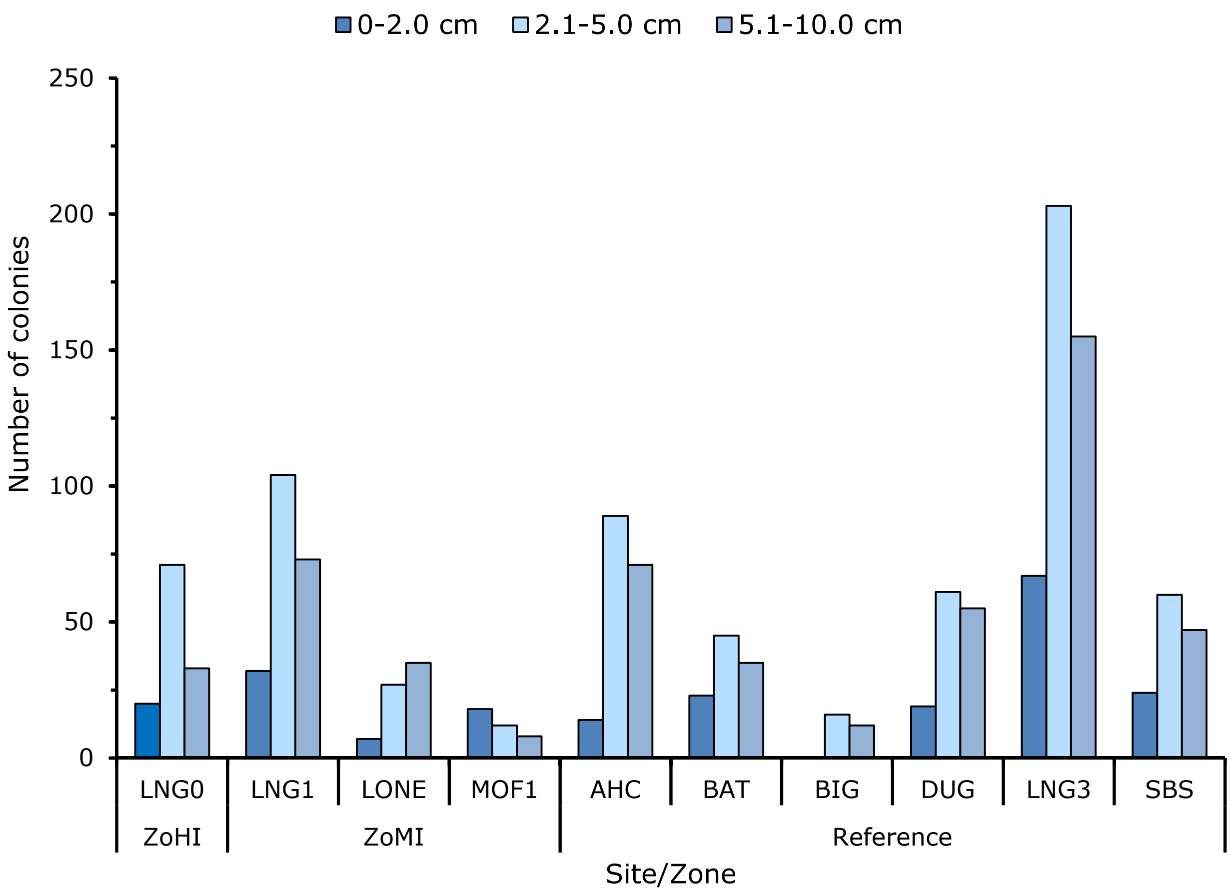


Figure 4-23 Total Number of Coral Colonies per Size-class recorded during Post-Development Survey Year 2

4.6.4 Comparison between the Post-Development Surveys and Marine Baseline Program

The number of coral colonies ≤10 cm was 936 colonies in the Marine Baseline Program, 2036 colonies in Post-Development Survey Year 1, and 1436 colonies in Post-Development Survey Year 2. The Acroporidae, Dendrophylliidae, Faviidae, Mussidae, and Poritidae were the most abundant families across most sites and zones for colonies ≤10 cm.

The total number of colonies ≤10 cm and the number of coral colonies in the size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm showed no significant differences between Impact Sites (ZoHI and ZoMI) and Reference Sites from the Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2. However, in all three size-classes at the Impact Sites (ZoMI and ZoHI) there was an increase in colony numbers from the Marine Baseline Program to Post-Development Survey Year 1, and a subsequent decline in colony numbers in Post-Development Survey Year 2 (Figure 4-24). At the Reference Sites, there was an increase in colony numbers from the Marine Baseline Program to Post-Development Survey Year 1, but the Post-Development Survey Year 2 colony numbers remained similar to Post-Development Survey Year 1 values for the size-classes 0.1–2.0 cm and 2.1-5.0 cm (Figure 4-24). There was a slight reduction in colony numbers in Post-Development Survey Year 2 in the Reference Sites for the size-class 5.1–10.0 cm (Figure 4-24).

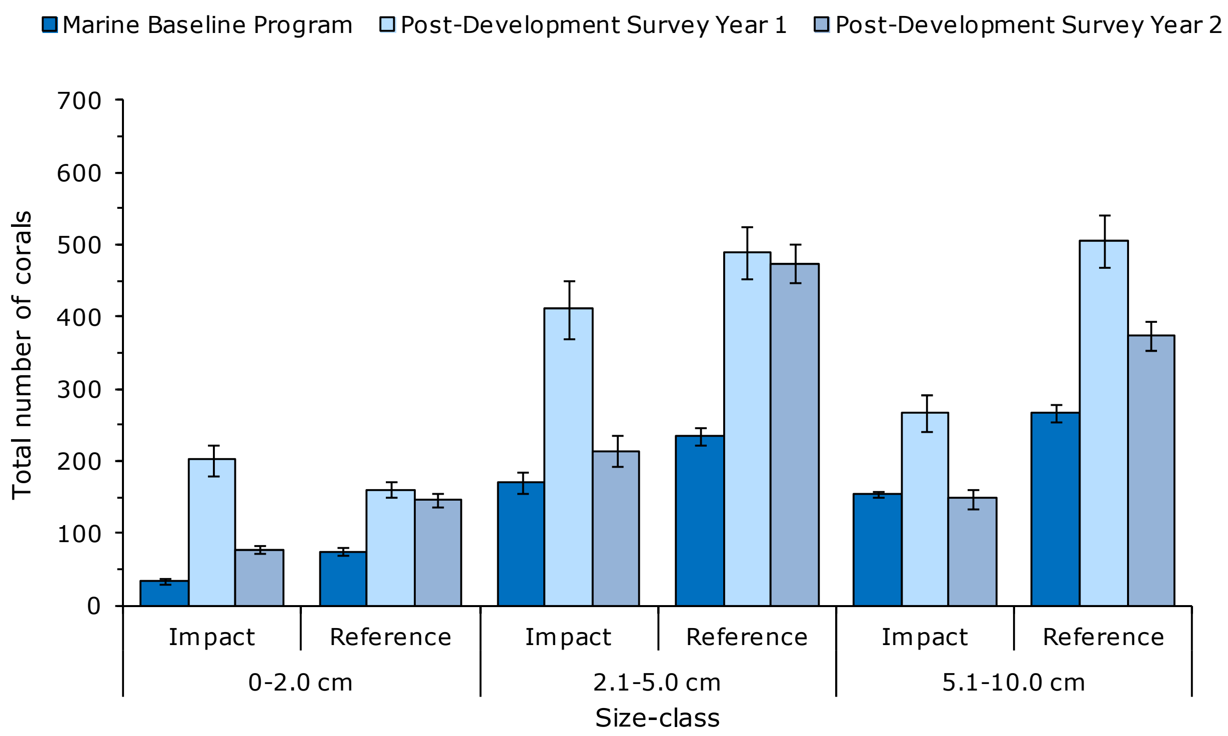


Figure 4-24 Total (±SE) Colony Numbers for the Size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm at Impact and Reference Sites for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Notes: Impact = sites LNG0, LNG1, LONE, MOF1; Reference = sites AHC, BAT, BIG, DUG, LNG3, SBS

The number of colonies of each coral family in each size-class showed no significant differences between Impact Sites and Reference Sites from the Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2. At the Impact Sites the coral family composition of the colonies ≤10 cm varied from the family composition of the colonies >10 cm, but a similar pattern was evident across all three survey periods (Figure 4-25). In general, the colonies ≤10 cm at the Impact Sites were predominantly of the Faviidae, whereas the colonies >10 cm were predominantly of the Poritidae (Figure 4-25). The colonies ≤10 cm and the colonies >10 cm had a similar family composition at the Reference Sites, whereby the Faviidae, Poritidae, and Acroporidae occurred in the highest abundances across all three survey periods (Figure 4-25).

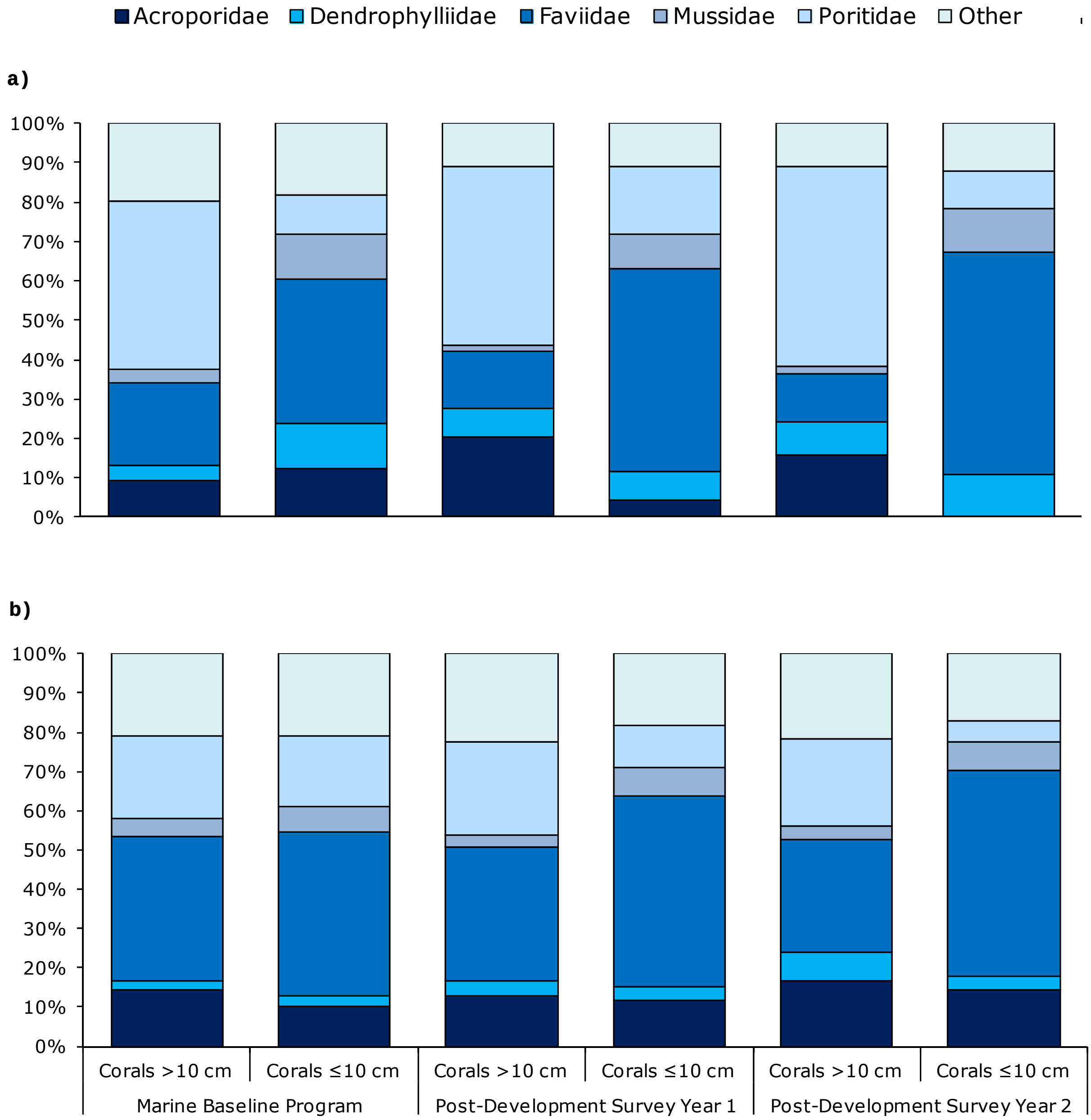


Figure 4-25 Relative Abundance of Different Size-classes of Dominant Coral Families at Impact and Reference Sites for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Notes: a) Impact Sites = LNG0, LNG1, LONE, MOF1; b) Reference Sites = AHC, BAT, BIG, DUG, LNG3, SBS

Other = Agariciidae, Caryophyllidae, Fungiidae, Merulinidae, Milleporidae, Mussidae, Oculinidae, Pectiniidae, Pocilloporidae, Siderastreidae, Unidentified

Corals >10 cm = size-classes 10.1–20 cm, 20.1–50.0 cm, 50.1–100.0 cm, 100.1–200.0 cm, 200.1–500.0 cm, and 500.1–1000.0 cm

The number of coral colonies that were standardised by the available recruitment substrate (PAV/CA) in the size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm showed no significant differences between Impact Sites (ZoHI and ZoMI) and Reference Sites where suitable tests were available. There appeared to be no clear relationship between the number of colonies ≤10 cm and the live coral cover, sediment cover, and PAV/CA cover (Figure 4-26). The live coral cover declined with a subsequent increase in the amount of sediment post the Marine Baseline Program at the Impact Sites, whereas live coral cover, sediment, and PAV/CA remained fairly stable at the Reference Sites across the three survey periods (Figure 4-26).

Despite the differences in benthic cover, at both the Impact Sites and Reference Sites the number of colonies ≤10 cm increased from the Marine Baseline Program to Post-Development Survey Year 1, and then declined in Post-Development Survey Year 2 (Figure 4-26).

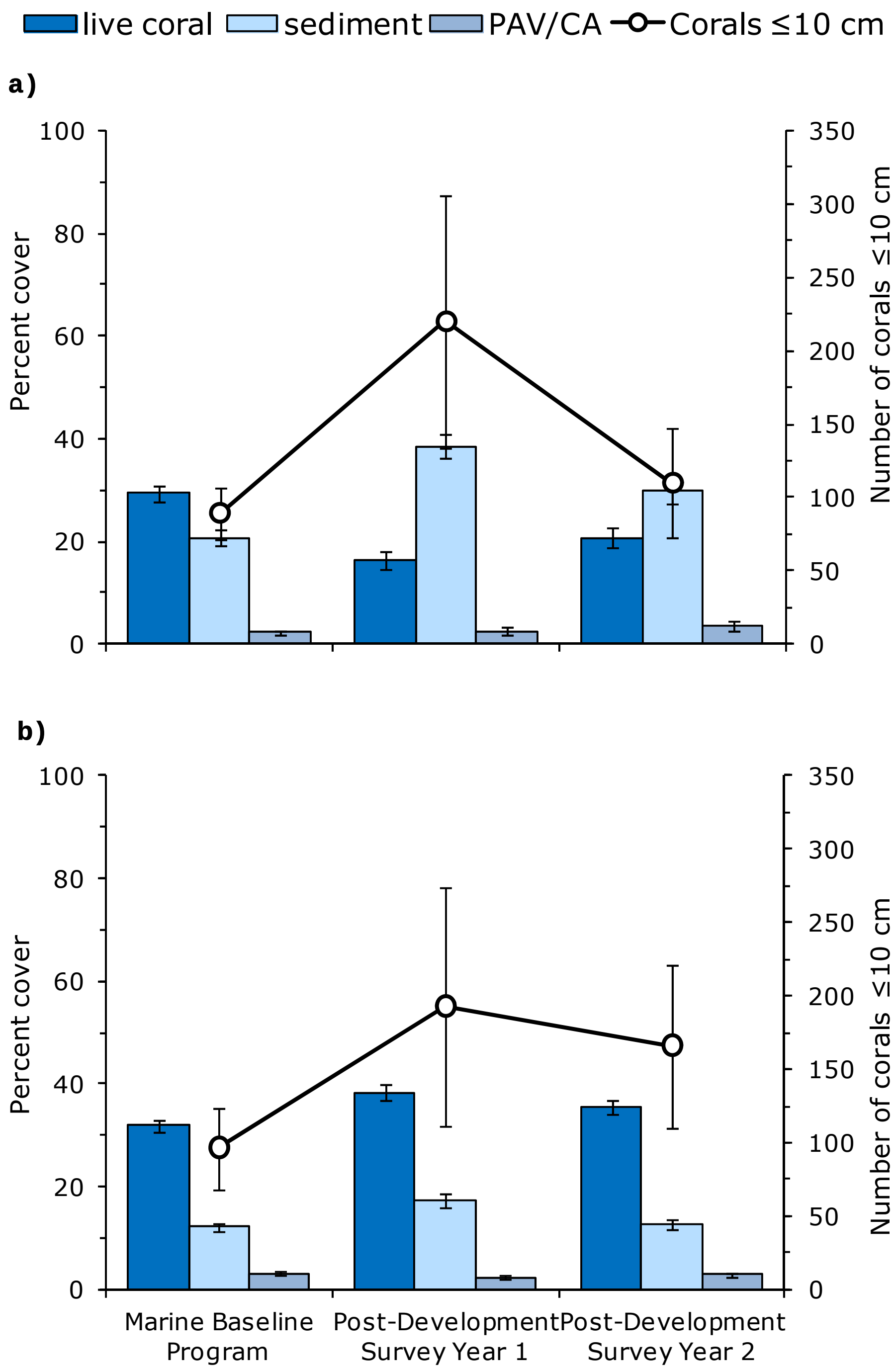


Figure 4-26 Mean (±SE) Percentage Cover of Live Coral, sediment, PAV/CA, and the mean (±SE) of the number of corals ≤10 cm

Notes: a) Impact Sites = LNG0, LNG1, LONE, MOF1; b) Reference Sites = AHC, BAT, BIG, DUG, LNG3, SBS
Refer to Section 4.7 for percentage cover results

4.6.5 Discussion

Measuring recruitment patterns of marine organisms is of fundamental importance for understanding the mechanisms that regulate their populations (Underwood and Fairweather 1989). In corals, the early life-history stages are often more susceptible than adults to environmental perturbations such as eutrophication (Ward and Harrison 1997) and sedimentation (Gilmour 1999), and measuring changes in patterns of settlement and recruitment can provide an early warning of potential damage to reefs or impacts on their resilience after disturbance (Babcock *et al.* 2003).

Numerous studies have shown that settlement rates of corals on artificial settlement tiles are highly variable in space and time (e.g. Wallace 1985, Connell *et al.* 1997, Hughes *et al.* 1999), and that the patterns established at settlement may be substantially modified by post-settlement processes such as differential growth and survival (e.g. Smith 1992, Dunstan and Johnson 1998). Therefore, settlement patterns often bear little resemblance to patterns of adult coral abundance (Edmunds 2000), which may be related to the high mortality of recently settled corals within the first month's post-settlement (Babcock and Mundy 1996, Wilson and Harrison 2005). Given that mortality rates often decline with increasing size of coral colonies, the distribution of juvenile corals (recruitment success) have been suggested to offer a better predictor of the distribution, abundance, and composition of coral populations (Trapon *et al.* 2013).

Based on the assumption that there was no change due to the dredging and dredge spoil disposal activities at the Reference Sites, and that turbidity and sedimentation have been shown to affect the settlement and survival of coral larvae (Gilmour 1999, Babcock and Smith 2000), it may be expected that recruitment success would be negatively affected at the Impact Sites following the dredging and dredge spoil disposal activities (May 2010 to September 2011). Using the assumptions outlined in Section 4.6.1.4 and the broad categorisation of van Moorsel (1988), where corals 0.1–2.0 cm were recruited within the past year, corals 2.1–5.0 cm were recruited more than one year ago, and corals 5.1–10.0 cm were recruited more than two years ago, coupled with a conservative assessment for Impact Sites, the following recruitment scenarios exist (Table 4-21).

Table 4-21 Predicted Recruitment Success Scenarios for Size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm for Post-Development Survey Year 1 and Post-Development Survey Year 2 Based on Known Relationships from the Literature and the Timing of Dredging and Dredge Spoil Activities Relative to Recruitment and Growth of Corals

Size-class	Estimated Recruitment Time	Potential Impact
Post-Development Survey Year 1		
0.1–2.0 cm	During the dredging and dredge spoil disposal	Reduction in recruitment success
2.1–5.0 cm	At the start of the dredging and dredge spoil disposal	Reduction in recruitment success
5.1–10.0 cm	Prior to the dredging and dredge spoil disposal	Potential reduction in recruitment success
Post-Development Survey Year 2		
0.1–2.0 cm	After the dredging and dredge spoil disposal	No reduction in recruitment success
2.1–5.0 cm	During the dredging and dredge spoil disposal	Reduction in recruitment success
5.1–10.0 cm	At the start of the dredging and dredge spoil disposal	Reduction in recruitment success

Successful recruitment was recorded at all sites and zones across all three survey periods but the numbers in the 0.1–2.0 cm size-class are possibly an underestimation due to the difficulty of finding and identifying small colonies in situ (Miller *et al.* 2000). No significant differences between Impact Sites (ZoHI and ZoMI) and Reference Sites from the Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2 were detected in the total number of colonies ≤10 cm and in the size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm (Figure 4-24), which does not follow the predicted scenarios (Table 4-21). Higher numbers of colonies in all three size-classes were recorded in Post-Development Survey Year 1 than in the Marine Baseline Program and Post-Development Survey Year 2, despite it being the sample period immediately following the dredging and dredge spoil disposal activities. However, large differences in the numbers of colonies in the three size-classes were recorded among survey periods, sites, and zones (Figure 4-23), highlighting that the recruitment success of colonies ≤10 cm was consistent with previous studies on recruitment patterns (e.g. Wallace 1985, Connell *et al*. 1997, Hughes *et al.* 1999) in that success was highly variable in both space and time. Although a defined impact change due to the dredging and dredge spoil disposal activities was not evident in the recruitment success data, the non-significant result should be interpreted with caution because the increased variance from the small sample sizes as a result of the grouping of sites into Impact and Reference may have masked the detection of change due to the dredging and dredge spoil disposal activities.

A similar non-significant result between Impact Sites and Reference Sites from the Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2 was evident for the coral family numbers in each size-class. However, once again the non-significant result should be interpreted with caution because there was great variability in the coral family composition at the site level in both the Impact and Reference Sitess, and the grouping of sites into Impact and Reference increases variance and presents a misleading picture and oversimplification of the family composition results. The Impact Sites did show a slightly different pattern to the Reference Sites in that the colonies ≤10 cm had a slightly different composition to the colonies >10 cm, whereas Reference Sites showed no real differences (Figure 4-25). Nevertheless, the Acroporidae, Dendrophylliidae, Faviidae, Mussidae, and Poritidae were the most abundant families across most sites and zones (Figure 4-25), which may be a function of their dominance at the sites (Table 4-18), and that they represent some of the families where juveniles can be reliably distinguished in situ (Babcock *et al.* 2003).

No significant differences were detected in the number of colonies in the size-classes 0.1–2.0 cm, 2.1–5.0 cm, and 5.1–10.0 cm when their numbers were standardised for available recruitment substrate (PAV/CA). There was also no clear relationship between the number of colonies ≤10 cm and the live coral cover, sediment cover, and PAV/CA cover (Figure 4-26). The live coral cover declined with an increase in the amount of sediment after the Marine Baseline Program at the Impact Sites, whereas live coral cover, sediment, and PAV/CA remained fairly stable at the Reference Sites across the three survey periods. Despite the differences in benthic cover at both the Impact Sites and Reference Sites, the number of colonies ≤10 cm increased from the Marine Baseline Program to Post-Development Survey Year 1, and then declined in Post-Development Survey Year 2.

Caution should be applied when interpreting the results of recruitment success because the classification used was general, and therefore taxon-specific differences in settlement, growth, and survival of coral larvae are not fully accounted for in the results. Rather, general patterns based on the assumptions outlined in Section 4.6.1.4 are presented that provide an overview of the results. Nevertheless, there is evidence of successful recruitment at both Impact Sites and Reference Sites in Post-Development Survey Year 1 and Post-Development Survey Year 2. This is an important result because turbidity and sedimentation (Gilmour 1999, Babcock and Smith 2000) and thermal stress (Szmant and Gassman 1990) have been shown to affect reproductive success and the settlement and survival of coral larvae, with reports of near-zero settlement rates on sediment-covered surfaces (Fabricius 2005). Both the Impact Sites and southern Reference Sites were affected by coral bleaching in January 2011 to March 2011

(Moore *et al.* 2012), and the Impact Sites were exposed to turbidity and sedimentation during the dredging and dredge spoil disposal activities from May 2010 to September 2011. However, there was successful establishment and growth of juvenile corals during and after dredging and coral bleaching, which is important given that successful recruitment plays a critical role in the population maintenance and recovery following a disturbance, and the subsequent resilience of coral populations.

4.7 Survival

4.7.1 Methods

4.7.1.1 Site Locations

Twelve sites were sampled during the Post-Development Survey Year 2 for live coral cover (Table 4-22, Figure 4-27). One site was in the ZoHI, three were in the ZoMI, two within the ZoI, and six were Reference Sites and Regionally Significant Areas (hereafter referred to as Reference Sites).

Table 4-22 Post-Development Survey Year 2 Sites for Live Coral Cover

Location	Site Name (Site Code)	Easting	Northing	Latitude	Longitude	Depth (m)
		(GDA94, MGA Zone 50)		(GDA94)		
Zones of High Impact	LNG0 (LNG0)	344796	7696108	20° 49.713’ S	115° 30.507’ E	9.00
Zones of Moderate Impact	MOF1 (MOF1)	342089	7698785	20° 48.249’ S	115° 28.961’ E	6.00
	LNG1 (LNG 1)	344584	7695823	20° 49.867’ S	115° 30.384’ E	8.75
	Lone Reef (LONE)	347376	7692607	20° 51.624’ S	115° 31.976’ E	9.25
Zones of Influence	Ant Point Reef (ANT)	342065	7708657	20° 42.898' S	115° 29.001' E	4.00
	Lowendal Shelf (LOW)	344504	7700689	20° 47.229’ S	115° 30.363’ E	3.00
Reference Sites	Ah Chong (AHC)	350243	7731659	20° 30.472’ S	115° 33.829’ E	6.50
	Biggada Reef (BIG)	328237	7702674	20° 46.068’ S	115° 21.001’ E	1.50
	LNG3 (LNG3)	343157	7692657	20° 51.575’ S	115° 29.544’ E	6.50
Regionally Significant Areas	Dugong Reef (DUG)	340099	7687998	20° 54.085’ S	115° 27.755’ E	6.25
	Batman Reef (BAT)	340703	7681301	20° 57.717’ S	115° 28.067’ E	3.50
	Southern Barrow Shoals (SBS)	345599	7666195	21° 5.929’ S	115° 30.810’ E	4.75

Figure 4-27 Post-Development Survey sites for Live Coral Cover and Growth

4.7.1.1.1 Random Transects

All 12 sites were sampled in Post-Development Survey Year 2 for live coral cover from random transects.

4.7.1.1.2 Fixed Transects

Four sites were sampled in Post-Development Survey Year 2 for the daily rate of change in percentage live coral cover (coral survival) from fixed transects: ANT and LOW in the ZoI; BAT and DUG were Reference Sites.

4.7.1.1.3 Tagged colonies

All 12 sites were sampled in Post-Development Survey Year 2 for coral survival from tagged colonies.

4.7.1.2 Timing and Frequency of Sampling

Sites surveyed for both live coral cover (random transects) and coral survival (fixed transects) were surveyed in Post-Development Survey Year 2 between November 2012 and December 2012. Sites for coral survival (tagged colonies) were sampled in Post-Development Survey Year 2 between January 2013 and March 2013. Sites were surveyed in the Marine Baseline Program between May 2008 and November 2009 (Chevron Australia 2012a), and in Post-Development Survey Year 1 between November 2011 and February 2012 (Chevron Australia 2012b). Summer data from the Marine Baseline Program were compared with the Post-Development Surveys that were also sampled in summer.

4.7.1.3 Survey Method

4.7.1.3.1 Random Transects

Random transects were surveyed at all 12 coral monitoring sites to calculate percentage cover of live coral (hard and soft). At each coral monitoring site, five 20 m long transects were set out and a 1 m^2 quadrat was photographed every two metres along each transect, giving a total of 11 quadrats per transect (Plate 4-1). All photographs were taken with a digital camera fixed in a frame mounted to the quadrat to maintain a consistent distance and orientation above the seabed. Photoquadrats in the Post-Development Surveys were 1 m^2 quadrats comprised of four subquadrats of 0.25 m^2. In the Marine Baseline Program, the photoquadrats were 1 m^2, with the exception of site BIG, where four subquadrats of 0.25 m^2 were used due to the shallow water depths.

The location of the random transects was determined prior to field mobilisation to prevent potential sampler bias associated with transect placement in the field. Transects were overlaid onto habitat maps to ensure they were within areas mapped as coral assemblages (Chevron Australia 2012a). If they were not within mapped coral assemblages, new random transects were generated until they met the criteria.

4.7.1.3.2 Fixed Transects

Fixed transects were surveyed at four coral monitoring sites (ANT, BAT, DUG, and LOW) to calculate the temporal change in live coral cover (hard and soft), expressed as the daily rate of change. In the Post-Development Survey Year 2, fixed transects were surveyed in November 2012 and compared to fixed transects surveyed in Post-Development Survey Year 1 in November 2011. Fixed transects were established using ropes, star pickets, and reinforced steel bars. The original position of the fixed transects were generated randomly, as for the random transects. The same criteria set for random transects were applied to the location of fixed transects, and hence the first fixed transects are both fixed and random at the same time. Photoquadrats were established as for the random transects.

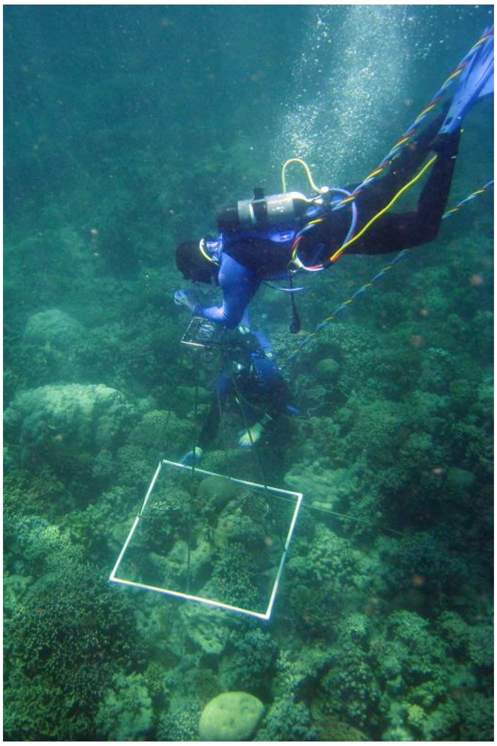


Plate 4-1 Diver Photographing a 1 m^2 Photoquadrat during the Marine Baseline Program

4.7.1.3.3 Tagged Colonies

Non-branching hard coral colonies were haphazardly chosen and tagged at each of the 12 coral monitoring sites during Post-Development Survey Year 1. All tagged colonies were identified to genus (with the exception of the Faviidae that were identified to family) during Post-Development Survey Year 1 (Time 0). The taxonomic assignment, and the number of colonies tagged and photographed at each site at Time 0 is outlined in Table 4-27. During Post-Development Survey Year 2 (Time 1), every effort was made to locate all the Time 0 tagged colonies. However, due to tag loss and missing colonies, the number of tagged colonies at Time 1 was less than at Time 0. At both Time 0 and Time 1, the tagged colonies were photographed from above while maintaining a consistent distance and orientation.

During the Marine Baseline Program, the same tagged colony photographic method was used, with the exception of sites BAT, DUG, and LOW where fixed photoquadrats were used to monitor coral survival of non-branching coral colonies (Chevron Australia 2012a). Revised Marine Baseline Program data relevant to measures of live coral cover and survival are shown in Appendix 1.

4.7.1.4 Treatment of Survey Data

4.7.1.4.1 Random Transects

Live coral cover in the photoquadrat images was analysed using Coral Point Count with Excel extensions (CPCe) software (Kohler and Gill 2006). Thirty random points were overlain on each 1 m^2 quadrat image in the Marine Baseline Program, whereas eight random points were overlain on each 0.25 m^2 image in the Post-Development Surveys (giving a total of 32 random points per 1 m^2). Each point was visually classified by trained observers into a benthic cover category (Table 4-23). The Marine Baseline Program identified different coral categories than the Post-Development Surveys. In order to analyse the data, the coral categories were matched between the two surveys as described in Chevron Australia (2012b); the categories used in the analyses are listed in Table 4-23. Estimates of the percentage cover of these benthic categories were calculated.

Analyses of percentage live coral cover included all hard and soft coral categories (Table 4-23). Soft corals were included in analyses of live coral cover but were very rarely recorded. Bleached coral was not included for Marine Baseline Program or Post-Development Survey Year 1 data as it could not be determined from images whether individual bleached corals were alive. As such, Post-Development Survey Year 2 images were treated in the same way as the Marine Baseline Program for bleached corals.

Table 4-23 Benthic Cover Categories used in CPCe Analysis of Coral Survival and Categories included in Calculations of Percentage Live Coral Cover

Major Category	Minor Category	Included in Live Coral Calculation
Hard Corals	Acroporidae	Yes
	Agariciidae	Yes
	Caryophyllidae	Yes
	Dendrophylliidae	Yes
	Faviidae	Yes
	Fungiidae	Yes
	Merulinidae	Yes
	Milleporidae	Yes
	Mussidae	Yes
	Oculinidae	Yes
	Pectiniidae	Yes
	Pocilloporidae	Yes
	Porites	Yes
	Siderastreidae	Yes
	Unidentified Coral	Yes
Soft Corals	Alcyonacea	Yes
Bleached Coral	Bleached Coral	No
Non-coral Invertebrates	Sessile Invertebrates	No
Flora	Coralline Algae	No
	Macroalgae	No
	Seagrass	No
	Turf Algae	No
Abiotic substrate	Pavement/Rock/Rubble	No
	Sand/Sediment	No

Notes: Live Coral = Hard Corals + Soft Corals

4.7.1.4.2 Fixed transects

Fixed transects were analysed in the same way as the random transects (above) using CPCe software (Kohler and Gill 2006) and the same coral categories (Table 4-23). For analyses of coral cover at fixed transects, the daily rate of change in percentage live coral cover was calculated as percentage live coral cover at a final time period (Time 1) minus percentage cover at the starting time (Time 0), divided by the number of days between the two time periods.

4.7.1.4.3 Tagged Colonies

Survival was measured as the change in the proportion of live coral tissue (partial mortality) on individually tagged non-branching colonies. For estimates of partial mortality, images were analysed using CPCe software (Kohler and Gill 2006). A bounding box was drawn around an individual colony and 60 random points were overlain within the bounding box. Each point was visually classified by trained observers into either Live coral, Bleached coral, Dead coral, Sediment, Unknown, and Off coral. The Unknown and Off coral points were excluded from the analyses, and only Live coral, Bleached coral, Dead coral, and Sediment were included in the calculations; i.e. if six points fell Off coral (off the colony), then the percentage calculations would be based on 54 points (60 minus 6). As such, the estimation of the percentage of live tissue was calculated as the *(number of points: Live Coral) / (number of points: Live coral + Bleached coral + Dead coral + Sediment)*100*. Estimates of colony survival for Post-Development Survey Year 2 were calculated as the percentage of live tissue at the final time period (Time 1) minus the percentage of live tissue at the starting time (Time 0), divided by the number of days between the two time periods. The daily rate was converted to an annual rate. The Marine Baseline Program contained three sampling time periods, and the estimates of colony survival for the Marine Baseline Program were calculated as above but for all possible time spans (i.e. Time 2–Time 0; Time 1–Time 0; Time 2–Time 1).

4.7.1.5 Statistical Approach for Comparison against Baseline

The approach required in the Scope of Works (RPS 2009, amended 2012) was a Multiple-Before-After-Control-Impact (MBACI) approach, which is one of the most robust statistical designs for detecting changes caused by anthropogenic disturbances (Keough and Mapstone 1995). For the Post-Development Survey analyses, a single potential impact area was compared against a single reference area, each with multiple monitoring sites. Within that potential impact area, sites were grouped by predicted levels of impact (zones: ZoHI, ZoMI, ZoI). The objective was to assess whether significant environmental change that could be associated with dredging and dredge spoil disposal activities had occurred between the Marine Baseline Program and the Post-Development Surveys. A step-wise approach, as used in the Post-Development Survey Year 1 report (Chevron Australia 2012b), was adopted for assessing potential environmental change.

4.7.1.5.1 Random Transects

A five-factor statistical design (Table 4-24; flow chart: Figure 4-28) was used to test whether the dredging and dredge spoil disposal activities affected the percentage cover of live coral and the percentage of benthic cover. If the terms of interest (i.e. those terms that are potentially indicative of change associated with dredging and dredge spoil disposal activities) were non-significant, the next step in the flow chart was followed. If the terms of interest were significant at any stage in the flow chart, post-hoc, pair-wise tests combined with graphing were undertaken to determine the nature of the change.

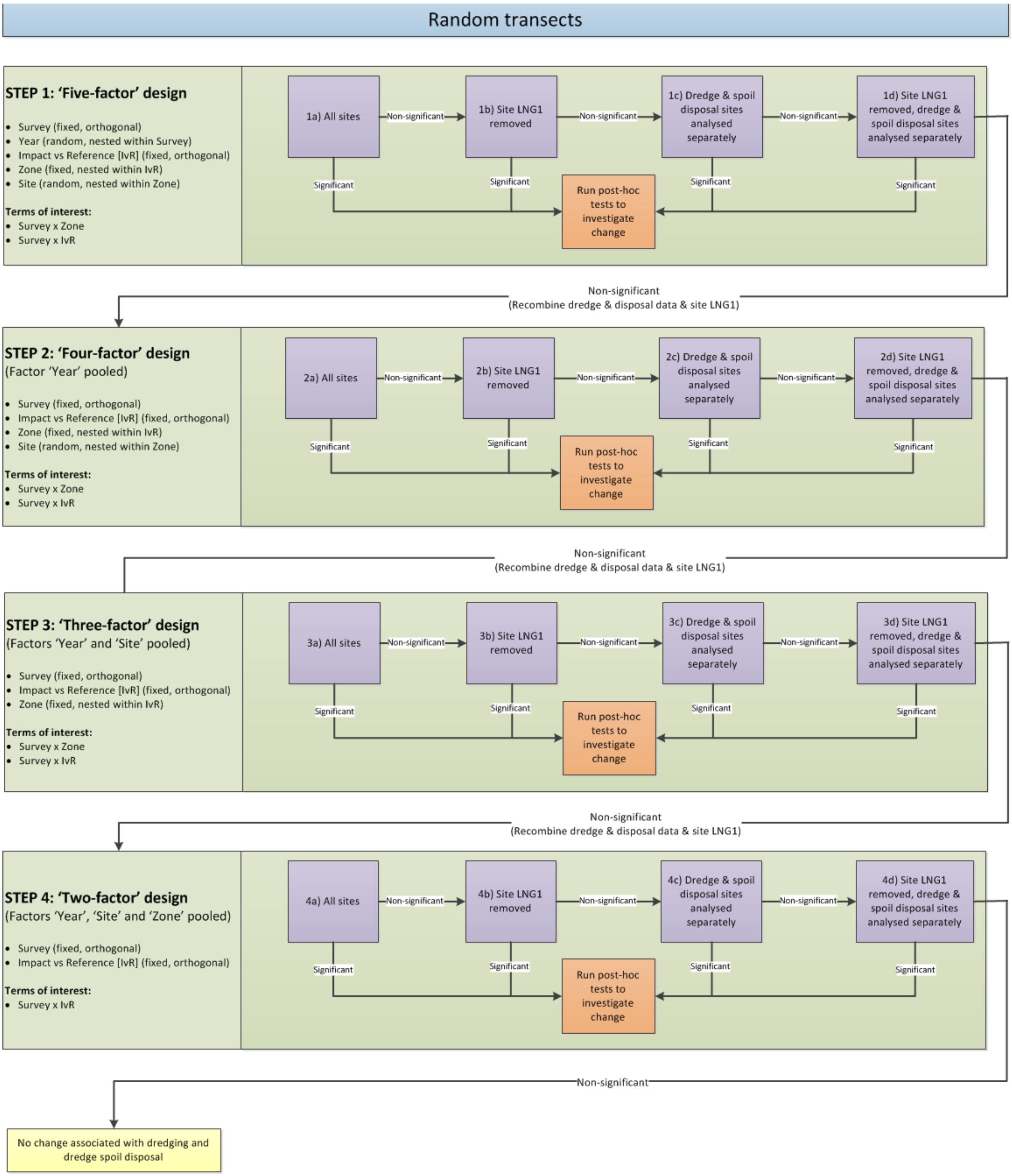


Figure 4-28 Statistical Designs and Step-wise Approach for Assessment of Change in Percentage Cover at Random Transects

Table 4-24 Statistical Treatment and Analyses used for Random Transects

Random Transects		
Pre-treatment of data	Site ANT removed from all analyses[1]	
	Summer only data used in Marine Baseline Program	
Sites used in statistical analyses	Marine Baseline Program	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		ZoI: LOW
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
	Post-Development Survey Year 1	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		ZoI: LOW
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
	Post-Development Survey Year 2	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		ZoI: LOW
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
Step-wise approach	Step-wise approach adopted (see flow chart: Figure 4-28)	
Main statistical design	Five-factor statistical design	Survey (fixed, orthogonal)
		Year (random, nested within Survey)
		Impact v. Reference [IvR] (fixed, orthogonal)
		Zone (fixed, nested within IvR)
		Site (random, nested within Zone)
Terms of interest	Survey × Zone	
	Survey × IvR	
Statistical program	PERMANOVA	
Statistical tests	Percentage live coral cover (univariate)	
	Benthic cover (multivariate) (PERMANOVA)	
	MDS with vector overlay and similarity contours (PRIMER)	
Transformation	Univariate: square-root arcsine transformed	
	Multivariate: fourth-root transformed	
Distance measure	Univariate: Euclidean distance	
	Multivariate: Bray-Curtis dissimilarity measure	

Notes:

1. *Coral cover at site ANT declined due to natural processes that were not related to the dredging and dredge spoil activities (Chevron Australia 2010b). Due to the natural loss of coral cover it was no longer possible to detect further declines in coral cover that might have been attributable to dredging or dredge spoil disposal activities.*

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

4.7.1.5.2 Fixed Transects

A three-factor statistical design (Table 4-25; flow chart: Figure 4-29) was used to test whether the dredging and dredge spoil disposal activities affected the percentage cover of live coral. If the term of interest (i.e. the term that is potentially indicative of change associated with dredging and dredge spoil disposal activities) was non-significant, the next step in the flow chart was followed. If the term of interest was significant at any stage in the flow chart, post-hoc, pair-wise tests combined with graphing were undertaken to determine the nature of the change.

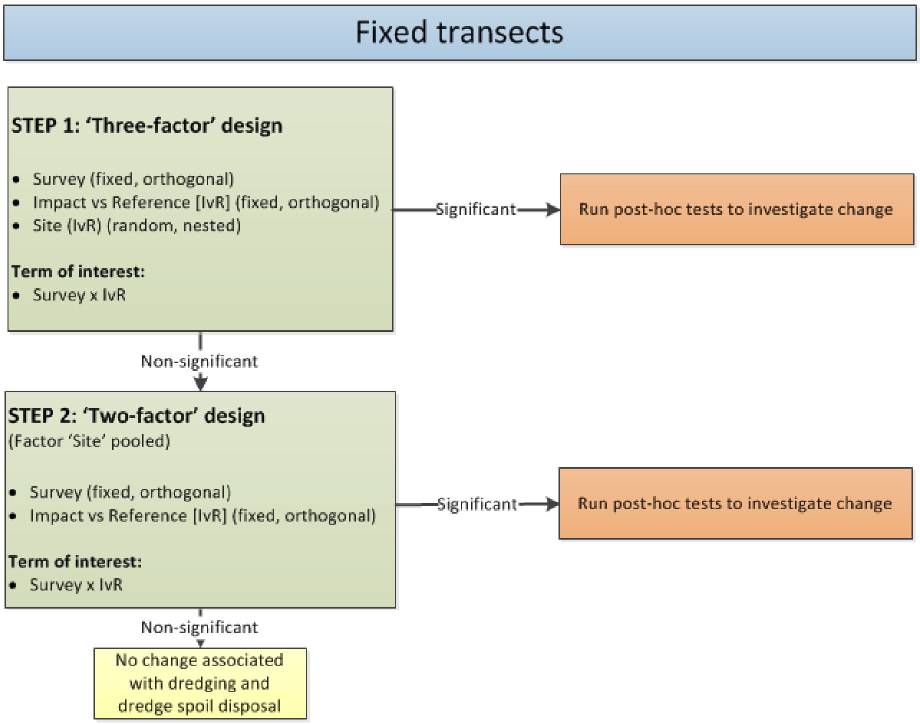


Figure 4-29 Statistical Designs and Step-wise Approach for Assessment of Change in Daily Rate of Change at Fixed Transects

Table 4-25 Statistical Treatment and Analyses used for Fixed Transects

Fixed Transects		
Pre-treatment of data	Site ANT removed from all analyses[1]	
	Quadrats that only had data available for one time period of the Marine Baseline Program or the Post-Development Surveys were excluded from statistical analyses, as it was not possible to calculate rates of change	
Sites used in statistical analyses	Marine Baseline Program	ZoI: LOW
		Reference: BAT, DUG
	Post-Development Survey Year 1	ZoI: LOW
		Reference: BAT, DUG
	Post-Development Survey Year 2	ZoI: LOW
		Reference: BAT, DUG
Step-wise approach	Step-wise approach adopted (see flow chart: Figure 4-29)	
Main statistical design	Three-factor statistical design	Survey (fixed, orthogonal)
		Impact v. Reference [IvR] (fixed, orthogonal)

Fixed Transects		
		Site (random, nested within IvR)
Terms of interest	Survey × IvR	
Statistical program	PERMANOVA	
Statistical tests	Daily rate of change in live coral cover (univariate)	
Transformation	None	
Distance measure	Euclidean distance	

Notes:

1. *Coral cover at site ANT declined due to natural processes that were not related to the dredging and dredge spoil activity (Chevron Australia 2010b). Due to the natural loss of coral cover it was no longer possible to detect further declines in coral cover that might have been attributable to dredging or dredge spoil disposal activities.*

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

4.7.1.5.3 Tagged Colonies

Statistical analyses comparing Impact Sites and Reference Sites were undertaken on the Acroporidae and Mussidae. For the Mussidae a three-factor statistical design (Table 4-26; flow chart: Figure 4-30), and for the Acroporidae a four-factor statistical design (Table 4-26; flow chart: Figure 4-31) was used to test whether the dredging and dredge spoil disposal activities affected the live coral tissue. If the term(s) of interest (i.e. those terms that are potentially indicative of change associated with dredging and dredge spoil disposal activities) were non-significant, the next step in the flow chart was followed. If the term(s) of interest were significant at any stage in the flow chart, post-hoc, pair-wise tests combined with graphing were undertaken to determine the nature of the change.

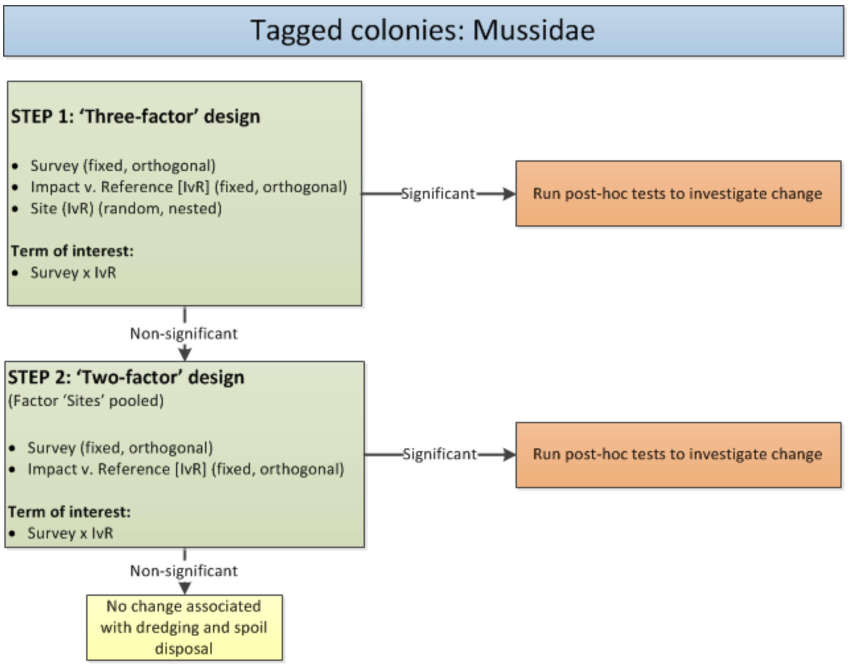


Figure 4-30 Statistical Designs and Step-wise Approach for Assessment of Change in Coral Survival for the Mussidae

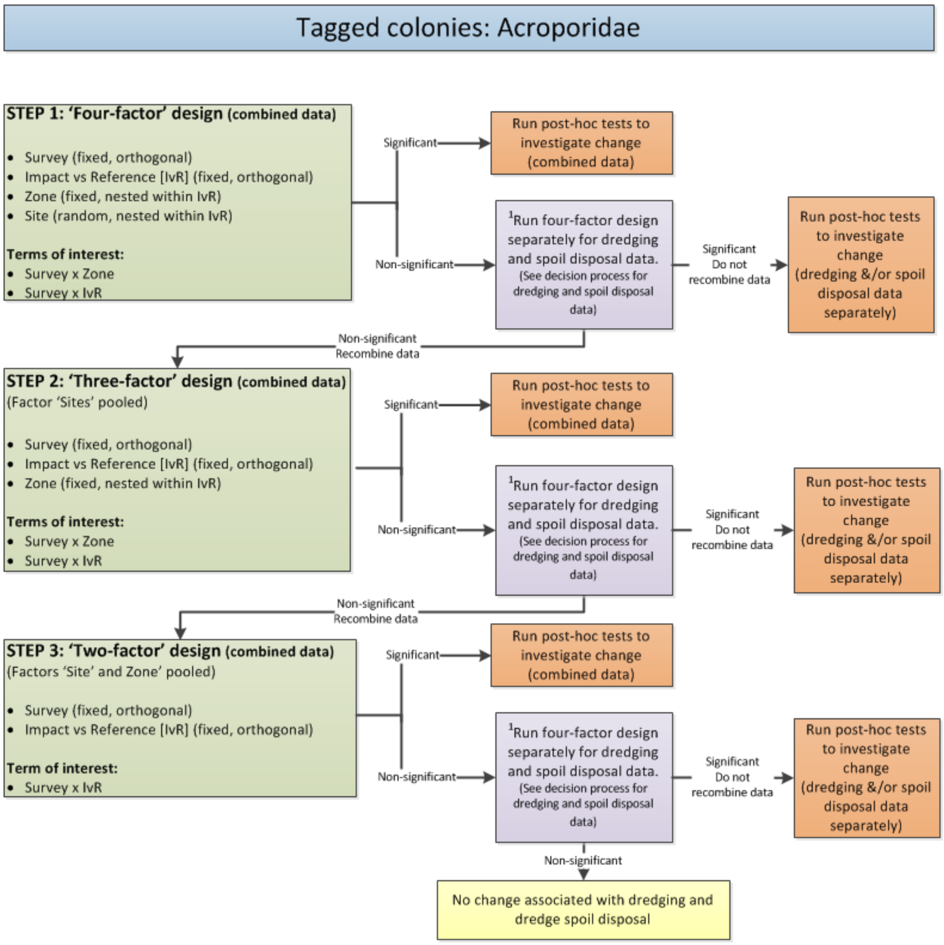


Figure 4-31 Statistical Designs and Step-wise Approach for Assessment of Change in Coral Survival for the Acroporidae

Table 4-26 Statistical Treatment and Analyses used for Tagged Colonies

Tagged Colonies		
Pre-treatment of data	No test for coral families Faviidae and Pectiniidae (insufficient data)	
	Statistical analyses undertaken separately on Acroporidae and Mussidae due to reported differences in growth rates and susceptibility to disturbance among coral families	
	Colonies that were only sampled during one time period of the Marine Baseline Program or the Post-Development Surveys were excluded from statistical analyses, as it was not possible to calculate rates of change	
	Assessment of whether rates measured over six months in the Marine Baseline Program could be used to compare against rates measured over one year in the Post-Development Surveys, for each site	
	Site comparison test done to determine whether additional sites should be retained or removed if an uneven number of sites was sampled between the Marine Baseline Program and the Post-Development Surveys	
Sites used in statistical analyses	Mussidae	
	Marine Baseline Program	ZoMI: LNG1, MOF1
		Reference: AHC, LNG3
	Post-Development Survey Year 1	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1

Tagged Colonies		
		ZoI: ANT
		Reference: AHC, BAT, DUG, LNG3
	Post-Development Survey Year 2	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		ZoI: ANT
		Reference: AHC, BAT, DUG, LNG3
	Acroporidae	
	Marine Baseline Program	ZoHI: LNG0
		ZoMI: LNG1, LONE, MOF1
		ZoI: ANT, LOW
		Reference: AHC, BIG, DUG, LNG3, SBS
	Post-Development Survey Year 1	ZoMI: LNG1, LONE, MOF1
		ZoI: ANT, LOW
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
	Post-Development Survey Year 2	ZoMI: LNG1, LONE, MOF1
		ZoI: ANT, LOW
		Reference: AHC, BAT, BIG, DUG, LNG3, SBS
Step-wise approach	Step-wise approach adopted (see flow charts: Figure 4-30; Figure 4-31)	
Main statistical design	Mussidae	
	Three-factor statistical design	Survey (fixed, orthogonal)
		Impact v. Reference [IvR] (fixed, orthogonal)
		Site (random, nested within IvR)
	Acroporidae	
	Four-factor statistical design	Survey (fixed, orthogonal)
		Impact v. Reference [IvR] (fixed, orthogonal)
		Zone (fixed, nested within IvR)
		Site (random, nested within IvR)
Terms of interest	Mussidae	Survey × IvR
	Acroporidae	Survey × Zone
		Survey × IvR
Statistical program	PERMANOVA	
Statistical tests	Survival of tagged colonies	
Transformation	None	
Distance measure	Euclidean distance	

Notes:

A three-factor design was used for the Mussidae because they were not sampled in the ZoHI and the ZoI. The Acroporidae were sampled in all zones and a four-factor design could therefore be used that included the factor 'Zone'

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

4.7.2 Results of Post-Development Survey Year 2

4.7.2.1 Percentage Live Coral Cover (Random Transects)

4.7.2.1.1 Percentage Live Coral Cover at Sites in the Zones of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

Live coral cover in the ZoHI was 21.5% but was only represented by one site (LNG0). Coral cover in the ZoMI ranged from 1.8% at site MOF1 to 50.2% at site LONE (Figure 4-32).

4.7.2.1.2 Percentage Live Coral Cover at Representative Areas in the Zones of Influence Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

Live coral cover in the ZoI ranged from 1.5% at site ANT to 59.2% at site LOW (Figure 4-32). The percentage live coral cover at LOW was the highest recorded in Post-Development Survey Year 2.

4.7.2.1.3 Percentage Live Coral Cover at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction of the MOF or LNG Jetty

Coral cover at Reference Sites ranged from 15.5% at site LNG3 to 58.4% at site DUG (Figure 4-32). The percentage live coral cover at site DUG was the second highest recorded in Post-Development Survey Year 2.

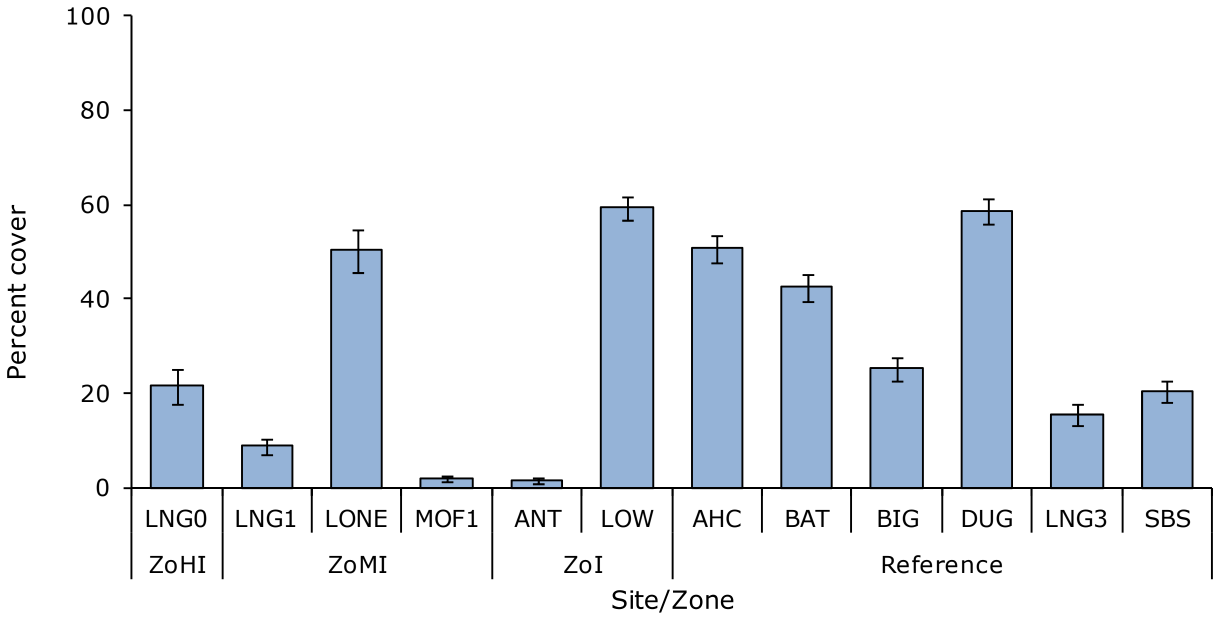


Figure 4-32 Percentage Live Coral Cover (mean ± SE) at each Site

4.7.2.2 Temporal Changes in Live Coral Cover from Fixed Transects

The rate of change of percentage live coral cover was positive at sites LOW (ZoI), BAT (Reference), and DUG (Reference), with site LOW having the highest daily rate of positive change (Figure 4-33). Site ANT in the ZoI was the only site that showed a negative daily rate of change (Figure 4-33).

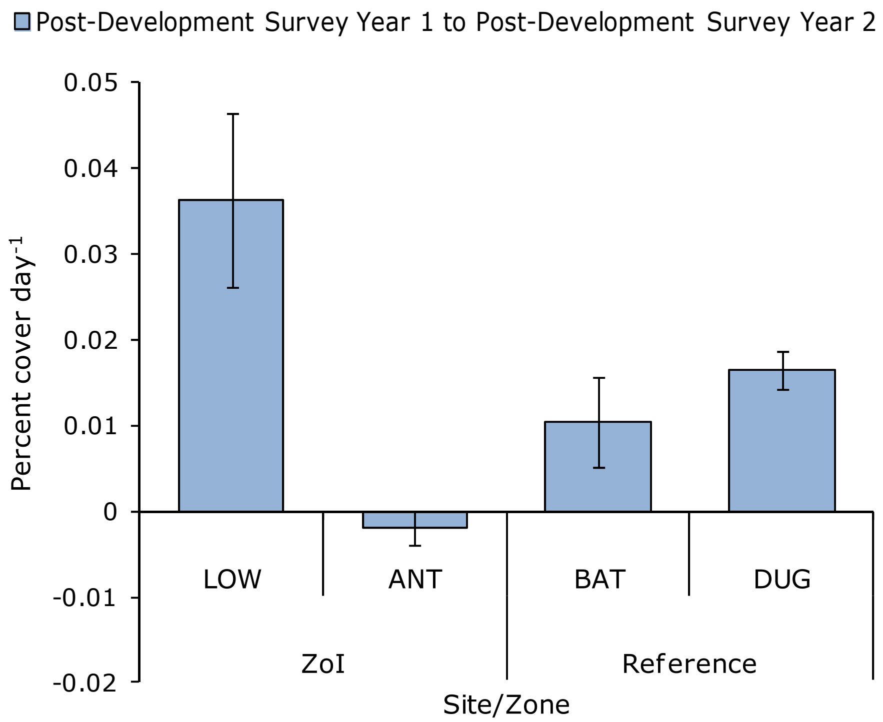


Figure 4-33 Temporal Change in Live Coral Cover (mean ± SE) from Fixed Transects at each Site

4.7.2.3 Temporal Changes in Live Coral Tissue from Tagged Colonies

The percentage live coral tissue from tagged colonies showed minimal to no 'rate of change' from Time 0 (Post-Development Survey Year 1) to Time 1 (Post-Development Survey Year 2) for *Acropora* (Acroporidae) at site LNG1 (ZoMI) and site SBS (Reference), for *Lobophyllia* (Mussidae) at site AHC (Reference), and for *Pectinia* (Pectiniidae) at site BAT (Reference) (Table 4-28). All other coral taxa and site combinations showed a slight reduction of live coral tissue from Time 0 to Time 1 (Table 4-28). Site MOF1 (ZoMI) and site ANT (ZoI) showed the largest reduction for both *Acropora* (Acroporidae) and *Lobophyllia* (Mussidae) (Table 4-28).

Table 4-27 Non-branching Coral Colony Number and Identification of Tagged Colonies at Time 0 and Time 1

Location	Site Code	Number of Colonies and Identification of Tagged Colonies	
		Time 0	Time 1
ZoHI	LNG0	2 × *Acropora* (Acroporidae) 5 × *Lobophyllia* (Mussidae)	3 × *Lobophyllia* (Mussidae)
ZoMI	LNG1	6 × *Acropora* (Acroporidae) 16 × *Lobophyllia* (Mussidae)	5 × *Acropora* (Acroporidae) 13 × *Lobophyllia* (Mussidae)
	LONE	19 × *Acropora* (Acroporidae) 11 × *Lobophyllia* (Mussidae)	19 × *Acropora* (Acroporidae) 10 × *Lobophyllia* (Mussidae)
	MOF1	11 × *Acropora* (Acroporidae) 10 × *Lobophyllia* (Mussidae)	9 × *Acropora* (Acroporidae) 10 × *Lobophyllia* (Mussidae)
ZoI	ANT	16 × *Acropora* (Acroporidae) 8 × *Lobophyllia* (Mussidae)	13 × *Acropora* (Acroporidae) 8 × *Lobophyllia* (Mussidae)

Location	Site Code	Number of Colonies and Identification of Tagged Colonies	
		Time 0	Time 1
	LOW	10 × *Acropora* (Acroporidae) 14 × *Montipora* (Acroporidae)	9 × *Acropora* (Acroporidae) 14 × *Montipora* (Acroporidae)
Ref	AHC	10 × *Acropora* (Acroporidae) 11 × *Lobophyllia* (Mussidae)	10 × *Acropora* (Acroporidae) 9 × *Lobophyllia* (Mussidae)
	BAT	7 × *Acropora* (Acroporidae) 10 × *Lobophyllia* (Mussidae) 12 × *Pectinia* (Pectiniidae) 13 × Faviidae	7 × *Acropora* (Acroporidae) 10 × *Lobophyllia* (Mussidae) 10 × *Pectinia* (Pectiniidae) 12 × Faviidae
	BIG	19 × *Acropora* (Acroporidae) 17 × Faviidae	13 × *Acropora* (Acroporidae) 14 × Faviidae
	DUG	12 × *Acropora* (Acroporidae) 11 × *Montipora* (Acroporidae) 15 × *Lobophyllia* (Mussidae) 12 × *Pectinia* (Pectiniidae)	11 × *Acropora* (Acroporidae) 7 × *Montipora* (Acroporidae) 14 × *Lobophyllia* (Mussidae) 12 × *Pectinia* (Pectiniidae)
	LNG3	12 × *Acropora* (Acroporidae) 12 × *Lobophyllia* (Mussidae)	11 × *Acropora* (Acroporidae) 11 × *Lobophyllia* (Mussidae)
	SBS	15 × *Acropora* (Acroporidae) 16 × *Montipora* (Acroporidae)	14 × *Acropora* (Acroporidae) 13 × *Montipora* (Acroporidae)

Notes: See Chevron Australia (2012a) for more detail on the decision process for which colonies were tagged

Table 4-28 Change in Percentage Live Coral Tissue (mm per year) for Tagged Colonies in Post-Development Surveys

Zone	Site	Acroporidae				Mussidae		Pectiniidae		Faviidae	
		Acropora		*Montipora*		*Lobophyllia*		*Pectinia*			
		n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)
ZoHI	LNG0					3	-2.42 (±2.60)				
ZoMI	LNG1	5	0.00 (±0.00)			13	-39.17 (±9.35)				
	LONE	19	-7.50 (±4.60)			10	-27.27 (±12.14)				
	MOF1	9	-75.42 (±1.85)			10	-77.16 (±0.22)				
ZoI	ANT	13	-83.90 (±0.78)			8	-67.60 (±6.32)				
	LOW	9	-10.16 (±10.16)	14	-8.47 (±6.41)						
Ref	AHC	10	-18.37 (±10.82)			9	-0.59 (±0.42)				
	BAT	7	-26.37 (±15.04)			10	-19.05 (±11.28)	12	-1.46 (±1.95)	12	-28.79 (±9.35)
	BIG	13	-11.71 (±7.04)							14	-4.43 (±2.08)
	DUG	11	-15.41 (±9.97)	7	-4.02 (±1.92)	14	-5.82 (±2.87)	12	-6.05 (±7.03)		

Zone	Site	Acroporidae				Mussidae		Pectiniidae		Faviidae	
		Acropora		*Montipora*		*Lobophyllia*		*Pectinia*			
		n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)
	LNG3	11	-23.94 (±10.35)			11	-32.10 (±11.27)				
	SBS	14	-1.78 (±1.54)	13	-10.19 (±5.97)						

Notes: Blank cells = not surveyed.

4.7.3 Comparison between the Post-Development Surveys and Marine Baseline Environmental State

4.7.3.1 Percentage Live Coral Cover (Random Transects)

The five-factor statistical design was significant after the three-factor analysis when the full dataset was used. Both the Survey × Zone and Survey × IvR interaction terms were significant (Table 4-29). Given that the factor 'Zone' is nested within the factor 'IvR', the Survey × IvR interaction term groups all potential Impact zones to compare with the Reference Sites, and therefore can only be meaningfully interpreted if the Survey × Zone interaction is non-significant. Therefore, interpretations are restricted to the post-hoc tests on the Survey × Zone interaction term (Table 4-30), which revealed significant differences at all four zones. However, caution should be used when dealing with the ZoHI and ZoI as both zones only consisted of a single site (LNG0 and LOW respectively).

At the ZoHI, there was no significant difference in the percentage live coral cover between the Marine Baseline Program (27.5%) and Post-Development Survey Year 2 (21.5%) (Figure 4-34). In contrast, a significant decline in percentage live coral cover from the Marine Baseline Program (27.5%) to Post-Development Survey Year 1 (15.6%) was detected, the percentage live coral cover increased (non-significantly) from Post-Development Survey Year 1 (15.6%) to Post-Development Survey Year 2 (21.5%) (Figure 4-34). At the ZoMI, the percentage live coral cover declined significantly from the Marine Baseline Program (29.9%) to Post-Development Survey Year 2 (20.4%) (Figure 4-34). There was also a significant decline in the percentage live coral cover from the Marine Baseline Program (29.9%) to Post-Development Survey Year 1 (16.6%) (Figure 4-34). However, as with the ZoHI, the percentage live coral cover increased (non-significantly) from Post-Development Survey Year 1 (16.6%) to Post-Development Survey Year 2 (20.4%) in the ZoMI (Figure 4-34). At the ZoI, there was no significant difference in the percentage live coral cover between the Marine Baseline Program (49.4%) and Post-Development Survey Year 2 (59.2%) (Figure 4-34); however, the percentage live coral cover did increase significantly from Post-Development Survey Year 1 (50.6%) to Post-Development Survey Year 2 (59.2%) (Figure 4-34). The percentage live coral cover at the Reference Sites increased significantly from the Marine Baseline Program (32.0%) to Post-Development Survey Year 2 (35.4%). The percentage live coral cover in Post-Development Survey Year 1 (38.3%) was also significantly higher than the Marine Baseline Program (32.0%) (Table 4-29, Figure 4-34). However, the percentage live coral cover in Post-Development Survey Year 2 (35.4%) was marginally lower (non-significantly) than in Post-Development Survey Year 1 (38.3%) at the Reference Sites (Figure 4-34).

Table 4-29 Summary Results for Live Coral Cover

Source	df	SS	MS	Pseudo-F	P-value
Survey	2	0.10523	5.2613E^{-2}	0.40678	0.662
IvR	1	1.6268	1.6268	12.578	0.0005
Zone(IvR)	2	23.986	11.993	92.726	0.0001
Survey × IvR	2	2.8835	1.4418	11.147	**0.0001**
Survey × Zone(IvR)	4	1.3899	0.34748	2.6866	**0.0251**
Res	2182	282.22	0.12934		
Total	2193	318.36			

Notes: Bold font in P-value column = significant difference for term of interest

Table 4-30 Post-hoc Tests for Live Coral Cover (Survey × Zone)

Zone	df	t	P-value
ZoHI			
Marine Baseline Program, Post-Development Survey Year 1	153	2.12	**0.0361**
Marine Baseline Program, Post-Development Survey Year 2	153	0.9832	0.3311
Post-Development Survey Year 1, Post-Development Survey Year 2	108	0.9994	0.3197
ZoMI			
Marine Baseline Program, Post-Development Survey Year 1	478	5.0388	**0.0001**
Marine Baseline Program, Post-Development Survey Year 2	476	3.4154	**0.0007**
Post-Development Survey Year 1, Post-Development Survey Yea 2	326	1.3565	0.1840
ZoI			
Marine Baseline Program, Post-Development Survey Year 1	102	6.2778E^{-2}	0.9497
Marine Baseline Program, Post-Development Survey Year 2	102	1.7752	0.0753
Post-Development Survey Year 1, Post-Development Survey Year 2	108	2.1966	**0.0282**
Reference			
Marine Baseline Program, Post-Development Survey Year 1	850	3.5327	**0.0008**
Marine Baseline Program, Post-Development Survey Year 2	850	2.2442	**0.0263**
Post-Development Survey Year 1, Post-Development Survey Year 2	658	1.3177	0.1898

Notes: Bold font in P-value column = significant difference for term of interest

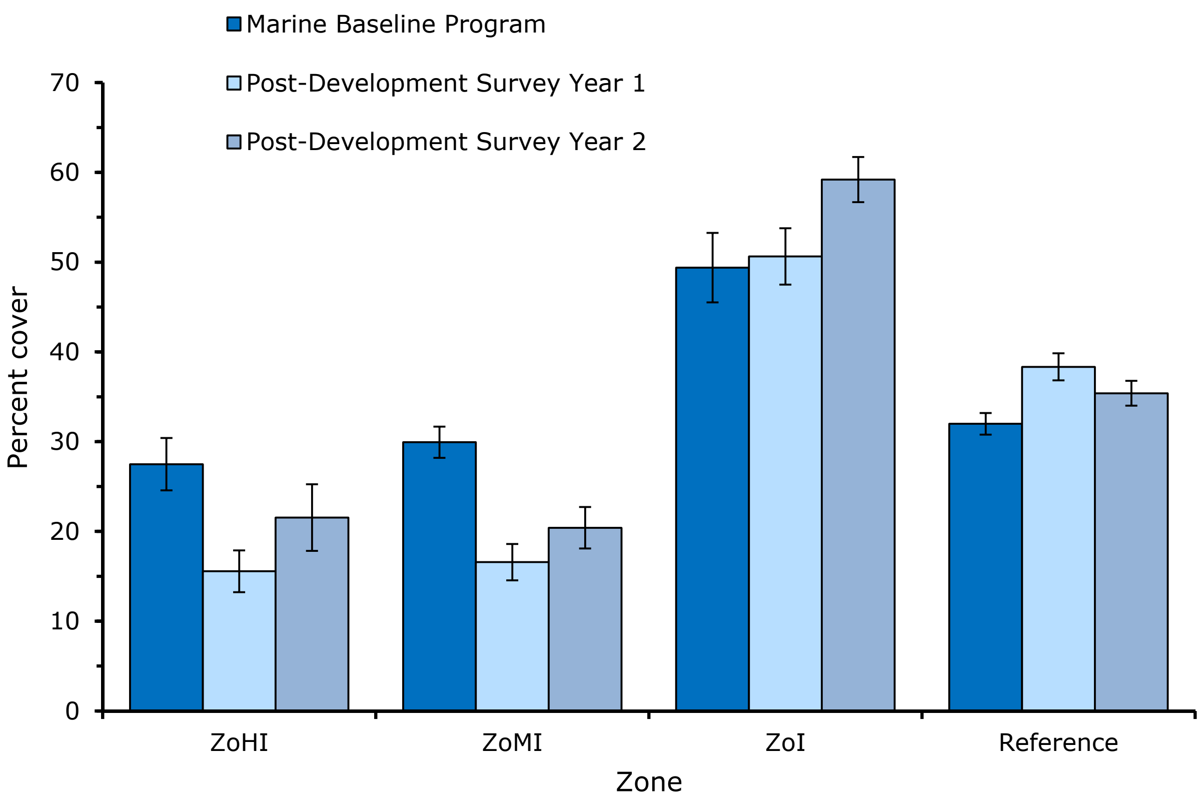


Figure 4-34 Change in Live Coral Cover (mean ±SE) Recorded within each Zone for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Notes: a) ZoHI; b) ZoMI; c) ZoI; d) Reference

4.7.3.2 Temporal Changes in Live Coral Cover from Fixed Transects

There were no significant differences in the temporal change in live coral cover from the Marine Baseline Program to Post-Development Survey Year 2 within the ZoI and Reference Sites (Figure 4-35), as indicated by a non-significant Survey × IvR interaction term at either step of the flow chart (Figure 4-30; Table 4-31). Note that the rate of change in live coral cover assumes a constant rate over the measured time period, which is improbable due to the dynamic nature of coral communities and how different corals respond to changes in environmental conditions (Gilmour *et al.* 2007).

Table 4-31 Summary Results for Temporal Changes in Live Coral Cover

Source	df	SS	MS	Pseudo-F	P-value
Survey	1	$5.9167E^{-4}$	$5.9167E^{-4}$	3.4586	0.0739
IvR	1	$3.1723E^{-3}$	$3.1723E^{-3}$	18.544	0.0003
Survey × IvR	1	$2.6215E^{-7}$	$2.6215E^{-7}$	$1.5324E^{-3}$	0.9713
Res	24	$4.1057E^{-3}$	$1.7107E^{-4}$		
Total	27	$8.2105E^{-3}$			

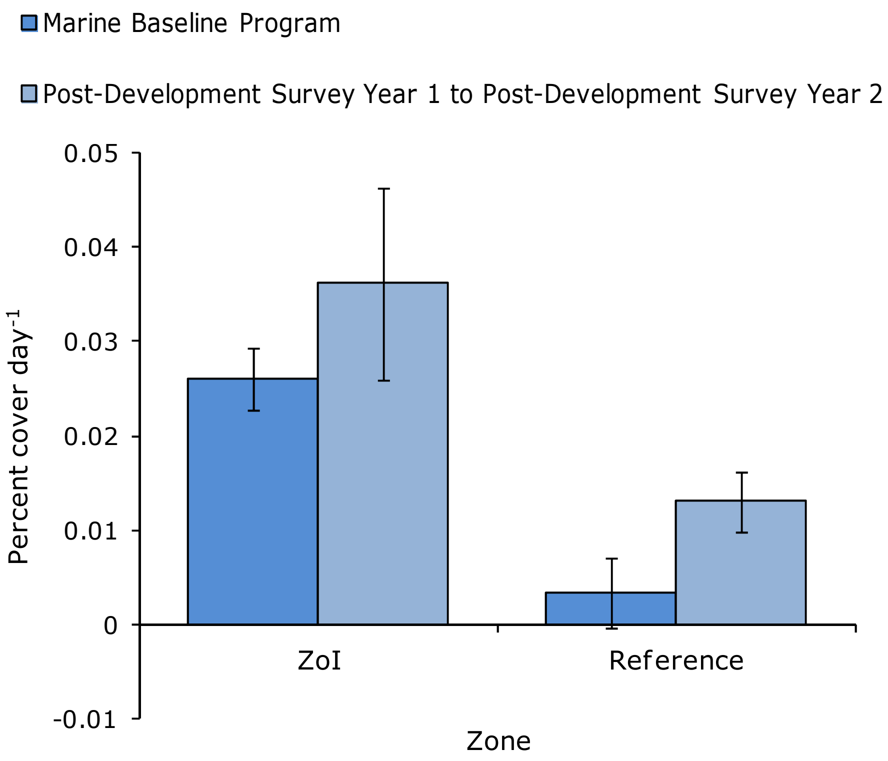


Figure 4-35 Temporal Change in Live Coral Cover (±SE) from Fixed Transects per Site for the Marine Baseline Program and Post-Development Surveys

4.7.3.3 Temporal Changes in Live Coral Tissue from Tagged Colonies

For the Mussidae, the Survey × IvR interaction term was significant (Table 4-32) after the two-factor analysis (Step 2 of Figure 4-30) when the full dataset was used. The post-hoc tests revealed a significant difference at the Impact Sites between the Marine Baseline Program and Post-Development Survey Year 2 (Table 4-32). However, based on the low degrees of freedom (df=1) (Table 4-32), the estimate of variance is likely to be poor. The rate of change of live coral tissue (shrinkage) in Post-Development Survey Year 2 was greater at the Impact Sites than at the Reference Sites (Figure 4-36).

Table 4-32 Summary Results for Temporal Changes in Live Coral Tissue for the Mussidae

Source	df	SS	MS	Pseudo-F	P-value
Survey	1	0.12926	0.12926	22.199	0.0001
IvR	1	4.7245E-2	4.7245E-2	8.1138	0.0069
Survey × IvR	1	3.9536E-2	3.9536E-2	6.7899	**0.0102**
Res	111	0.64632	5.8227E-3		
Total	114	0.96022			

Notes: Bold font in P-value column = significant difference for term of interest

Table 4-33 Post-hoc Tests for Temporal Changes in Live Coral Tissue for the Mussidae (Survey × IvR)

Zone	df	t	P-value
Impact			
Marine Baseline Program, Post-Development Survey Year 2	56	4.766	**0.0001**
Reference			
Marine Baseline Program, Post-Development Survey Year 2	55	0.6593	0.0962

Notes: Bold font in P-value column = significant difference for term of interest

For the Acroporidae, the four-factor statistical design was significant after the three-factor analysis (Step 2 of Figure 4-31) when the full dataset was used. The Survey × IvR interaction term was significant (Table 4-34), whereby the post-hoc tests revealed a significant difference at the Impact Sites between the Marine Baseline Program and Post-Development Survey Year 2 (Table 4-35). Although the decline in the rate of change of live coral tissue in Post-Development Survey Year 2 was greater in the Impact Sites (Figure 4-36), these results should be interpreted with caution because the estimate of variance is likely to be poor due to the low level of replication (Table 4-34).

Table 4-34 Summary Results for Temporal Changes in Live Coral Tissue for the Acroporidae

Source	df	SS	MS	Pseudo-F	P-value
Survey	1	0.1751	0.1751	28.962	0.0001
IvR	1	$5.3314E^{-2}$	$5.3314E^{-2}$	8.8185	0.0046
Zone(IvR)	2	$4.8781E^{-3}$	$2.4391E^{-3}$	0.40344	0.6736
Survey × IvR	1	$8.0981E^{-2}$	$8.0981E^{-2}$	13.395	**0.0003**
Survey × Zone(IVR)	1	$9.1607E^{-3}$	$9.1607E^{-3}$	1.5152	0.2191
Res	266	1.6082	$6.0457E^{-3}$		
Total	272	1.9126			

Notes: Bold font in P-value column = significant difference for term of interest

Table 4-35 Post-hoc Tests for Temporal Changes in Live Coral Tissue for the Acroporidae (Survey × IvR)

Zone	df	t	P-value
Impact			
Marine Baseline Program, Post-Development Survey Year 2	118	5.0057	**0.0001**
Reference			
Marine Baseline Program, Post-Development Survey Year 2	148	1.6149	0.1135

Notes: Bold font in P-value column = significant difference for term of interest

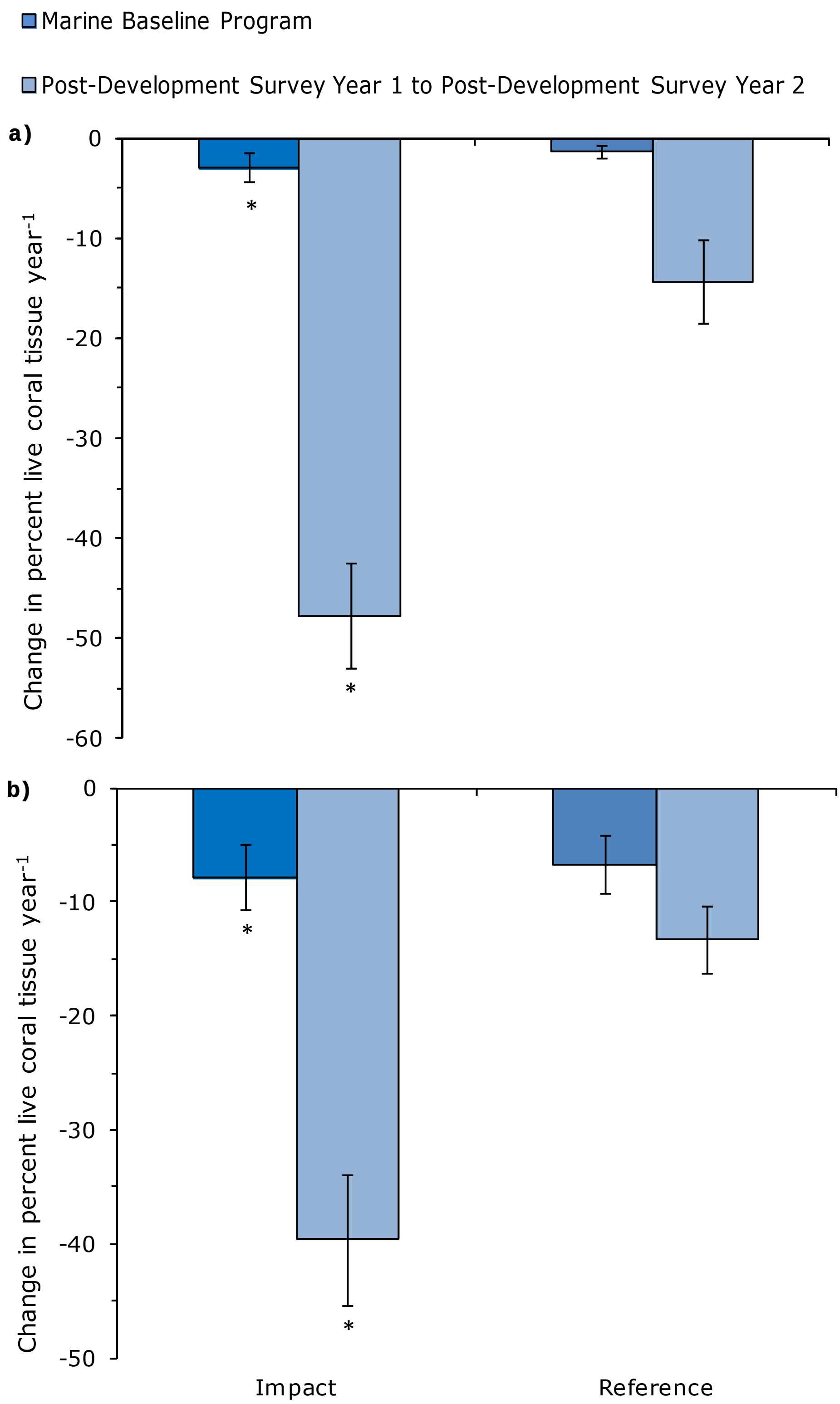


Figure 4-36 Temporal Change in Live Coral Tissue (±SE) from Tagged Colonies per Site for the Marine Baseline Program and Post-Development Surveys

Notes: a) Mussidae; b) Acroporidae

*Significant differences at Survey × IvR: * = Marine Baseline Program, Post-Development Survey Year 2*

4.7.4 Discussion

4.7.4.1 Percentage Live Coral Cover

Coral reefs are dynamic systems that are increasingly subjected to disturbance events operating on a range of spatial and temporal scales. For example, the reefs around Barrow Island were affected by coral bleaching in the 2010–2011 summer as part of a 'marine heat wave' off Western Australia (Pearce *et al.* 2011), which resulted in ~8.6% loss of live coral cover on the reefs around Barrow Island (Moore *et al.* 2012). In the present study, significant declines in live coral cover were recorded in the ZoMI from the Marine Baseline Program to Post-Development Survey Year 2. During the same period, a significant increase in live coral cover was recorded in the Reference Sites. Declines in live coral cover between the Marine Baseline Program and Post-Development Survey Year 1 at sites within the ZoHI and the ZoMI were likely associated with dredging and dredge spoil disposal activities, given that there was no significant decline at the Reference Sites. However, the coral bleaching event around Barrow Island may have had a minor contribution to the loss of live coral cover in the ZoHI and ZoMI. Note that the ZoHI and the ZoI were each represented by a single site only (LNG0 and LOW respectively) and therefore caution should be used when extrapolating patterns at these sites to the entire zone. LOW was also located north of dredging and dredge spoil disposal activities and therefore the ZoI does not have any representative site south of this area. .

A certain amount of loss of live coral cover was expected in the ZoHI and ZoMI and approved in the Ministerial Conditions, which was reflected in the data of the present study where there was a significant reduction in live coral cover in the ZoMI and a non-significant decline in live coral cover in the ZoHI from the Marine Baseline Program to Post-Development Survey Year 2. The loss in live coral cover in the ZoHI and ZoMI from the Marine Baseline Program to the Post-Development Survey Year 1 suggests that the loss of live coral cover is likely due to the dredging and dredge spoil disposal activities. There were positive signs of a level of recovery in the ZoHI and ZoMI, in that the live coral cover increased in Post-Development Survey Year 2, following significant declines in live coral cover from the Marine Baseline Program to Post-Development Survey Year 1. However, a recovery of live coral cover does not necessarily imply that the coral assemblage has recovered in other characteristics, such as its species composition and diversity, colony size structure, growth, and rates of reproduction (Connell 1997), which are assessed in other sections of this Report.

4.7.4.2 Rate of Change in Live Coral Cover

There was no significant difference in the rate of change in live coral cover measured from the fixed transects between the ZoI and the Reference Sites, and neither of these zones differed from before to after the dredging and dredge spoil disposal activities. While significant differences were recorded in the rate of change in live coral tissue from tagged colonies, these results should be interpreted with caution due to the low replication. However, the major trend across the two coral genera sampled was a reduction in the rate of change in live coral tissue during the Post-Development Surveys at Impact and Reference Sites. The rate of change in live coral tissue declined at Impact sites after the Marine Baseline Program, which may be partly attributable to the dredging and dredge spoil disposal activities. However, when the colonies were sampled at Time 1 during Post-Development Survey Year 2, the reefs around Barrow Island had experienced water temperatures above seasonal averages (NOAA 2013) that resulted in coral bleaching on the reefs around Barrow Island (Oceanica Consulting, personal communication). Therefore, it is possible that the partial or total mortality associated with the 2012–2013 summer coral bleaching event may have partly contributed to the recorded declines in rate of change live coral tissue.

4.8 Growth

4.8.1 Methods

4.8.1.1 Site Locations

Twelve sites were sampled in Post-Development Survey Year 2 for coral growth (Figure 4-27;Table 4-36). One site was in the ZoHI, three were in the ZoMI, two within the ZoI, and six were Reference Sites and Regionally Significant Areas (hereafter referred to as Reference Sites).

4.8.1.1.1 Branching corals

Four sites were sampled in Post-Development Survey Year 2 for branching coral growth from tagged colonies: LOW in the ZoI; AHC, BAT, and SBS were Reference Sites. Sufficient numbers of branching corals were not present at ZoHI and ZoMI sites.

4.8.1.1.2 Non-branching corals

All 12 sites were sampled in Post-Development Survey Year 2 for non-branching coral growth from tagged colonies: LNG0 in the ZoHI; LNG1, LONE, and MOF1 in the ZoMI; ANT and LOW in the ZoI; AHC, BAT, BIG, DUG, LNG3, and SBS were Reference Sites.

Table 4-36 Post-Development Survey Year 2 Survey Sites for Coral Growth

Location	Site Name (Site Code)	Easting	Northing	Latitude	Longitude	Depth (m)
		(GDA94, MGA Zone 50)		(GDA94)		
Zones of High Impact	LNG0 (LNG0)	344796	7696108	20° 49.713' S	115° 30.507' E	9.00
Zones of Moderate Impact	MOF1 (MOF1)	342089	7698785	20° 48.249' S	115° 28.961' E	6.00
	LNG1 (LNG1)	344584	7695823	20° 49.867' S	115° 30.384' E	8.75
	Lone Reef (LONE)	347376	7692607	20° 51.624' S	115° 31.976' E	9.25
Zones of Influence	Ant Point Reef (ANT)	342065	7708657	20° 42.898'S	115°29.001'E	4.00
	Lowendal Shelf (LOW)	344504	7700689	20° 47.229'S	115°30.363'E	3.00
Reference Sites	Ah Chong (AHC)	350243	7731659	20° 30.472' S	115° 33.829' E	6.50
	Biggada Reef (BIG)	328237	7702674	20° 46.068' S	115° 21.001' E	1.50
	LNG3 (LNG3)	343157	7692657	20° 51.575' S	115° 29.544' E	6.50
Regionally Significant Areas	Dugong Reef (DUG)	340099	7687998	20° 54.085' S	115° 27.755' E	6.25
	Batman Reef (BAT)	340703	7681301	20° 57.717' S	115° 28.067' E	3.50
	Southern Barrow Shoals (SBS)	345599	7666195	21° 5.929' S	115° 30.810' E	4.75

4.8.1.2 Timing and Frequency of Sampling

Sites were initially surveyed for Time 0 in Post-Development Survey Year 1 between November 2011 and December 2011, and subsequently surveyed for Time 1 in Post-Development Survey Year 2 between January 2013 and March 2013 for both branching and non-branching corals. In the Marine Baseline Program, sites for branching corals were initially surveyed for Time 0 between September 2008 and October 2008, and subsequently surveyed for Time 1 between March 2009 and April 2009, and Time 2 between September 2009 and November 2009 (Chevron Australia 2012a). Sites for non-branching corals were initially surveyed for Time 0 between May 2008 and January 2009, and subsequently surveyed for Time 1 between

November 2008 and August 2009, and Time 2 between May 2009 and November 2009 in the Marine Baseline Program (Chevron Australia 2012a).

4.8.1.3 Survey Method

4.8.1.3.1 Branching corals

At sites AHC, BAT, LOW, and SBS, up to 12 haphazardly selected branching hard coral colonies were tagged during Post-Development Survey Year 1. All tagged colonies were identified to genus and one to five individual branches per colony were tagged with coloured cable ties. The maximum linear length from the cable tie to the branch tip was measured during Post-Development Survey Year 1 (Time 0). The taxonomic assignment and the number of colonies tagged at each site at Time 0 is outlined in Table 4-37. During Post-Development Survey Year 2 (Time 1), every effort was made to locate and measure the branch lengths of all the Time 0 tagged colonies using the same methods. However, due to tag and cable tie loss and missing colonies, the number of tagged colonies measured at Time 1 was less than at Time 0.

During the Marine Baseline Program, the same four sites and the same tagged colony method was used, with the exception of the inclusion of site ANT as an additional site. Site ANT was not included during Post-Development Surveys because insufficient branching colonies could be found due to the dramatic loss of coral cover prior to the dredging and dredge spoil disposal activities.

Table 4-37 Branching Coral Colony Number and Identification of Tagged Colonies at Time 0

Location	Site Code	Number and Identification of Tagged Colonies at Time 0
Zone of Influence	LOW	10 × *Acropora* (Acroporidae)
Reference Sites	AHC	10 × *Porites* (Poritidae)
	BAT	11 × *Porites* (Poritidae)
	SBS	12 × *Acropora* (Acroporidae)

4.8.1.3.2 Non-branching Corals

At each of the 12 sites, non-branching hard coral colonies were haphazardly chosen and tagged during Post-Development Survey Year 1. All tagged colonies were identified to genus (with the exception of the Faviidae, which were identified to family) and photographed from above with the inclusion of a scale-bar during Post-Development Survey Year 1 (Time 0). The same tagged colonies that were used for non-branching Survival data were used for non-branching Growth data, and Table 4-27 outlines the taxonomic assignment and the number of colonies tagged and photographed at each site at Time 0. During Post-Development Survey Year 2 (Time 1), every effort was made to locate and photograph all the Time 0 tagged colonies using the same methods. However, due to tag loss and missing colonies, the number of tagged colonies photographed at Time 1 was less than at Time 0.

During the Marine Baseline Program, the same tagged colony photographic method was used, with the exception of sites BAT, DUG, and LOW where no growth measurements were possible due to the lack of a suitable scale-bar in the fixed photoquadrats. The scale-bar was placed on the photographic frame that was attached to the camera rather than on the colony. As such, the scale remained constant with the placement of the camera rather than with the location of the tagged coral colony. Consequently, no growth data exist for the Marine Baseline Program for sites BAT, DUG, and LOW.

Revised Marine Baseline Program data relevant to measures of coral growth are shown in Appendix 1

4.8.1.4 Treatment of Survey Data

4.8.1.4.1 Branching Corals

Growth rates were calculated as the branch length measurement at the final time period (Time 1) minus the branch length measurement at the starting time (Time 0), divided by the number of days between the two time periods (English *et al.* 1997). The daily rate was then converted to a monthly rate.

4.8.1.4.2 Non-branching Corals

Growth was measured as the increase/decrease in area of individual tagged colonies (English *et al.* 1997). The images with the scale-bars were analysed using CPCe software (Kohler and Gill 2006), where the colony perimeter was traced and the area within the traced margins calculated. Estimates of colony growth rates for Post-Development Survey Year 2 were calculated as the coral colony area at the final time period (Time 1) minus the coral colony area at the starting time (Time 0), divided by the number of days between the two time periods. The daily rate was then converted to a monthly rate. The Marine Baseline Program contained three sampling time periods, and the estimates of colony growth for the Marine Baseline Program were calculated as above but for all possible time spans (i.e. Time 2–Time 0; Time 1–Time 0; Time 2–Time 1).

4.8.1.5 Statistical Approach for Comparison Against Baseline

4.8.1.5.1 Branching Corals

A two-factor statistical design (Table 4-38) was used to test whether the dredging and dredge spoil disposal activities affected the linear growth of branching corals. If the term of interest (i.e. the term that was potentially indicative of change associated with dredging and dredge spoil disposal activities) was significant, post-hoc tests combined with graphing were undertaken to determine the nature of the change.

Table 4-38 Statistical Treatment and Analyses used for Branching Coral Growth

Branching Coral Growth		
Pre-treatment of data	Growth rates only measured at two ZoI sites (ANT and LOW) and three Reference Sites (AHC, BAT, SBS)	
	Site ANT was excluded as insufficient colonies were found during Post-Development Survey Year 1	
	Comparisons among *Acropora* colonies only as not enough data to run a separate test on *Porites* colonies and *Porites* growth rates not comparable with *Acropora*[1]	
	Site AHC removed from all analyses as *Porites* colonies were not measured at this site during the Post-Development Survey 1	
	Site BAT, in the Marine Baseline Program, was excluded from all analyses as only six months of data were collected and no assessment could be done to determine whether this six month data was comparable to one year data collected at the site	
	Assessment of whether rates measured over six months in the Marine Baseline Program could be used to compare against rates measured over one year in the Post-Development Surveys, for each site	
Sites used in statistical analyses	Marine Baseline Program	ZoI: LOW
		Reference: SBS
	Post-Development Survey Year 1	ZoI: LOW
		Reference: SBS

Branching Coral Growth		
	Post-Development Survey Year 2	ZoI: LOW
		Reference: SBS
Step-wise approach	No step-wise approach adopted (insufficient factors)	
Main statistical design	Two-factor statistical design	Survey (fixed, orthogonal)
		Site (fixed, orthogonal)
Terms of interest	Survey × Site	
Statistical program	PERMANOVA	
Statistical tests	Growth of branching corals (univariate)	
Transformation	None	
Distance measure	Euclidean	

Notes:

1. *Harriott (1999), Dullo (2005)*

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

4.8.1.5.2 Non-branching Corals

Statistical analyses were undertaken on the Acroporidae and Mussidae. There was insufficient data for coral families Faviidae and Pectiniidae. For the Mussidae a three-factor statistical design (Table 4-39; flow chart: Figure 4-30), and for the Acroporidae a four-factor statistical design (Table 4-39; flow chart: Figure 4-31) was used to test whether the dredging and dredge spoil disposal activities affected the growth rates. If the term(s) of interest (i.e. those terms that were potentially indicative of change associated with dredging and dredge spoil disposal activities) were non-significant, the next step in the flow chart was followed. If the term(s) of interest were significant at any stage in the flow chart, post-hoc, pair-wise tests combined with graphing were undertaken to determine the nature of the change.

Table 4-39 Statistical Treatment and Analyses used for Non-branching Coral Growth

Tagged Colonies	
Pre-treatment of data	No test for coral families Faviidae and Pectiniidae (insufficient data)
	Statistical analyses undertaken separately on Acroporidae and Mussidae due to reported differences in growth rates and susceptibility to disturbance among coral families
	Colonies that were only sampled during one time period of the Marine Baseline Program or the Post-Development Surveys were excluded from statistical analyses, as it was not possible to calculate rates of change
	Assessment of whether rates measured over six months in the Marine Baseline Program could be used to compare against rates measured over one year in the Post-Development Surveys, for each site
	Site comparison test done to determine whether additional sites should be retained or removed if an uneven number of sites was sampled between the Marine Baseline Program and the Post-Development Surveys

<table>
<tr><th colspan="3">Tagged Colonies</th></tr>
<tr><td rowspan="22">Sites used in statistical analyses</td><td colspan="2">Mussidae</td></tr>
<tr><td rowspan="2">Marine Baseline Program</td><td>ZoMI: LNG1, MOF1</td></tr>
<tr><td>Reference: AHC, LNG3</td></tr>
<tr><td rowspan="4">Post-Development Survey Year 1</td><td>ZoHI: LNG0</td></tr>
<tr><td>ZoMI: LNG1, LONE, MOF1</td></tr>
<tr><td>ZoI: ANT</td></tr>
<tr><td>Reference: AHC, BAT, DUG, LNG3</td></tr>
<tr><td rowspan="4">Post-Development Survey Year 2</td><td>ZoHI: LNG0</td></tr>
<tr><td>ZoMI: LNG1, LONE, MOF1</td></tr>
<tr><td>ZoI: ANT</td></tr>
<tr><td>Reference: AHC, BAT, DUG, LNG3</td></tr>
<tr><td colspan="2">Acroporidae</td></tr>
<tr><td rowspan="4">Marine Baseline Program</td><td>ZoHI: LNG0</td></tr>
<tr><td>ZoMI: LNG1, LONE, MOF1</td></tr>
<tr><td>ZoI: ANT</td></tr>
<tr><td>Reference: AHC, BIG, LNG3, SBS</td></tr>
<tr><td rowspan="3">Post-Development Survey Year 1</td><td>ZoMI: LNG1, LONE</td></tr>
<tr><td>ZoI: ANT</td></tr>
<tr><td>Reference: AHC, BAT, BIG, DUG, LNG3, SBS</td></tr>
<tr><td rowspan="3">Post-Development Survey Year 2</td><td>ZoMI: LNG1, LONE</td></tr>
<tr><td>ZoI: ANT</td></tr>
<tr><td>Reference: AHC, BAT, BIG, DUG, LNG3, SBS</td></tr>
<tr><td>Step-wise approach</td><td colspan="2">Step-wise approach adopted (see flow charts: Figure 4-30; Figure 4-31)</td></tr>
<tr><td rowspan="9">Main statistical design</td><td colspan="2">Mussidae</td></tr>
<tr><td rowspan="3">Three-factor statistical design</td><td>Survey (fixed, orthogonal)</td></tr>
<tr><td>Impact v. Reference [IvR] (fixed, orthogonal)</td></tr>
<tr><td>Site (random, nested within IvR)</td></tr>
<tr><td colspan="2">Acroporidae</td></tr>
<tr><td rowspan="4">Four-factor statistical design</td><td>Survey (fixed, orthogonal)</td></tr>
<tr><td>Impact v. Reference [IvR] (fixed, orthogonal)</td></tr>
<tr><td>Zone (fixed, nested within IvR)</td></tr>
<tr><td>Site (random, nested within IvR)</td></tr>
<tr><td rowspan="3">Terms of interest</td><td>Mussidae</td><td>Survey (fixed, orthogonal)</td></tr>
<tr><td rowspan="2">Acroporidae</td><td>Survey × Zone</td></tr>
<tr><td>Survey × IvR</td></tr>
<tr><td>Statistical program</td><td colspan="2">PERMANOVA</td></tr>
<tr><td>Statistical tests</td><td colspan="2">Growth of branching corals (univariate)</td></tr>
<tr><td>Transformation</td><td colspan="2">None</td></tr>
<tr><td>Distance measure</td><td colspan="2">Euclidean distance</td></tr>
</table>

Notes: A three-factor design was used for the Mussidae because they were not sampled in the ZoHI and the ZoI. The Acroporidae were sampled in all zones and therefore a four-factor design could be used that included the factor 'Zone'

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

4.8.2 Results of Post-Development Survey Year 2

4.8.2.1 Coral Colony Growth at Sites in the Zone of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment from Dredging and Dredge Spoil Disposal

4.8.2.1.1 Branching Corals

No branching corals were sampled in the ZoHI and ZoMI due to insufficient numbers of branching corals available (Table 4-40). This is the same approach as that taken during the Marine Baseline Program.

4.8.2.1.2 Non-branching Corals

At site LNG0 in the ZoHI, *Lobophyllia* (Mussidae) showed a reduction in colony size (-16.35 ± 14.75 cm month^{-1}) from Time 0 (Post-Development Survey Year 1) to Time 1 (Post-Development Survey Year 2) (Table 4-41). In the ZoMI, *Acropora* (Acroporidae) at site LNG1 (11.20 ± 2.18 cm month^{-1}) and site LONE (2.00 ± 8.83 cm month^{-1}) showed positive growth rates from Time 0 to Time 1 (Table 4-41). The growth rate of *Lobophyllia* (Mussidae) at site MOF1 (1.54 ± 1.13 cm month^{-1}) was positive but at site LNG1 (-13.70 ± 5.93 cm month^{-1}) and site LONE (-4.18 ± 1.94 cm month^{-1}) the growth rates from Time 0 to Time 1 were negative (Table 4-41).

4.8.2.2 Coral Colony Growth at Representative Areas in the Zones of Influence Associated with the Generation of Turbidity and Sediment from Dredging and Dredge Spoil Disposal

4.8.2.2.1 Branching Corals

At site LOW in the ZoI, *Acropora* (Acroporidae) showed a positive growth rate (4.95 ± 0.60 mm month^{-1}) from Time 0 to Time 1 (Table 4-40).

4.8.2.2.2 Non-branching Corals

At the ZoI, the *Acropora* (Acroporidae) showed a positive growth rate from Time 0 to Time 1 at site ANT (8.16 ± 5.70 cm^2 month^{-1}) and site LOW (43.72 ± 5.06 cm^2 month^{-1}) (Table 4-41). The growth rate from Time 0 to Time 1 of *Montipora* (Acroporidae) at site LOW was positive (28.53 ± 4.88 cm^2 month^{-1}), as was the growth rate from Time 0 to Time 1 of *Lobophyllia* (Mussidae) at site ANT (6.72 ± 5.90 cm^2 month^{-1}) (Table 4-41).

4.8.2.3 Coral Colony Growth at Reference Sites not at Risk of Material or Serious Environmental Harm due to Construction of the MOF or LNG jetty

4.8.2.3.1 Branching Corals

At the Reference Sites, *Acropora* (Acroporidae) at site SBS (2.61 ± 0.57 mm month^{-1}), and *Porites* (Poritidae) at site AHC (1.56 ± 0.17 mm month^{-1}) and site BAT (1.61 ± 0.22 mm month^{-1}) showed positive growth rates from Time 0 to Time 1 (Table 4-40).

4.8.2.3.2 Non-branching Corals

At the Reference Sites, *Acropora* (Acroporidae) showed positive growth rates from Time 0 to Time 1 at all sites except site BAT (-2.55 ± 4.64 cm^2 month^{-1}) (Table 4-41). Both *Montipora* (Acroporidae) and *Pectinia* (Pectiniidae) showed positive growth rates from Time 0 to Time 1 at the sites where they were sampled (Table 4-41). Reductions in colony size from Time 0 to Time 1 were recorded in *Lobophyllia* (Mussidae) at all four sites, as well as in the Faviidae at site BAT (-6.02 ± 4.01 cm^2 month^{-1}) and site BIG (-0.98 ± 0.81 cm^2 month^{-1}) (Table 4-41).

Table 4-40 Monthly Growth Rates (mm $month^{-1}$) of Branching Corals from Post-Development Survey Year 2

Zone	Site	Acroporidae		Poritidae	
		Acropora		*Porites*	
		n	Mean (±SE)	n	Mean (±SE)
ZoI	LOW	7	4.95 (±0.60)		
Ref	AHC			10	1.56 (±0.17)
	BAT			11	1.61 (±0.22)
	SBS	7	2.61 (±0.57)		

Notes: n = number of colonies. Blank cell= not surveyed.

Table 4-41 Monthly Growth Rates (cm^2 $month^{-1}$) of Non-branching Corals from Post-Development Survey Year 2

Zone	Site	Acroporidae				Mussidae		Pectiniidae		Faviidae	
		Acropora		*Montipora*		*Lobophyllia*		*Pectinia*			
		n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)	n	Mean (±SE)
ZoHI	LNG0					3	-16.35 (±14.75)				
ZoMI	LNG1	5	11.20 (±2.18)			8	-13.70 (±5.93)				
	LONE	19	2.00 (±8.83)			7	-4.18 (±1.94)				
	MOF1					10	1.54 (±1.13)				
ZoI	ANT	9	8.16 (±5.70)			6	6.72 (±5.90)				
	LOW	8	43.72 (±5.06)	13	28.53 (±4.88)						
Ref	AHC	8	22.64 (±6.36)			9	-0.48 (±1.02)				
	BAT	6	-2.55 (±4.64)			9	-4.21 (±4.16)	12	1.79 (±2.59)	12	-6.02 (±4.01)
	BIG	12	9.97 (±5.57)							14	-0.98 (±0.81)
	DUG	9	22.29 (±6.95)	7	8.30 (±7.38)	14	-0.98 (±1.36)	11	1.65 (±4.80)		
	LNG3	8	34.19 (±18.12)			8	-2.87 (±1.53)				
	SBS	14	38.07 (±11.92)	13	14.86 (±12.90)						

Notes: n = number of colonies. Blank cell= not surveyed.

4.8.3 Comparison between the Post-Development Surveys and Marine Baseline Program

4.8.3.1.1 Branching Corals

For the Acroporidae, the two-factor statistical design was non-significant for the Survey × Site interaction term (Table 4-42). However, the results should be interpreted with caution because the estimate of variance is likely to be very poor due to the low degrees of freedom (df=1) (Table 4-42). As with the Marine Baseline Program, the growth rate at site LOW (ZoI) remained higher than the growth rate at site SBS (Reference) (Figure 4-37).

Table 4-42 Summary Results for Branching Coral Growth for the Acroporidae

Source	df	SS	MS	Pseudo-F	P-value
Survey	1	$2.6072E^{-3}$	$2.6072E^{-3}$	0.57377	0.4489
Site	1	$2.2829E^{-2}$	$2.2829E^{-2}$	5.024	0.0305
Survey × Site	1	$3.4028E^{-3}$	$3.4028E^{-3}$	0.74886	0.3893
Res	26	0.11814	$4.5439E^{-3}$		
Total	29	0.14668			

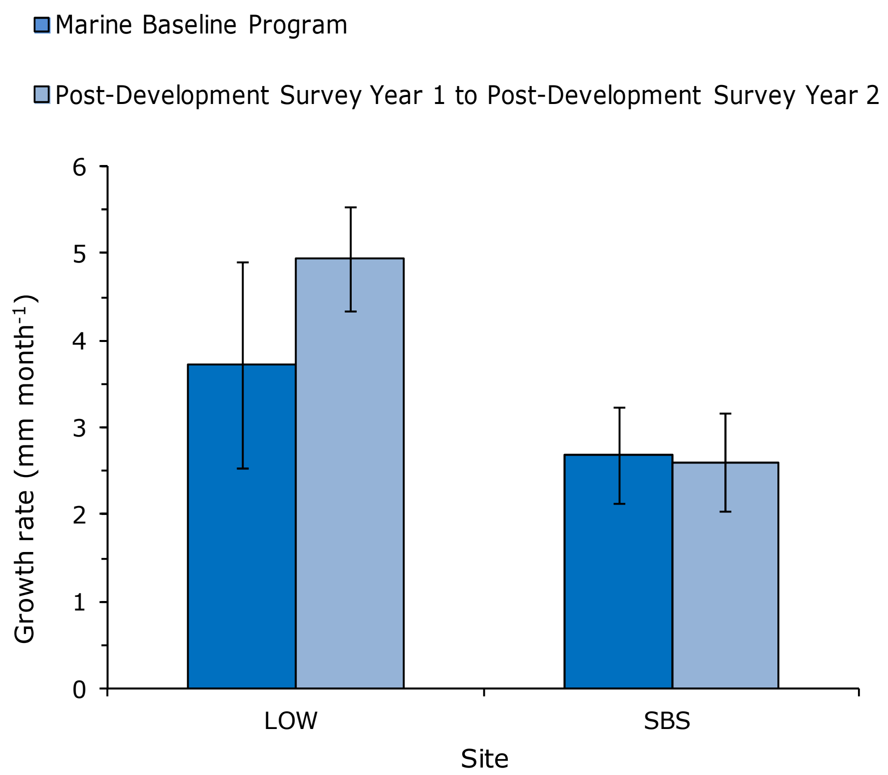


Figure 4-37 Branching Coral Growth (mm month^{-1}) (±SE) for the Marine Baseline Program and Post-Development Surveys

4.8.3.1.2 Non-branching Corals

For the Mussidae, the three-factor statistical design was non-significant after the two-factor analysis (Step 2 of Figure 4-30) when the full dataset was used (Table 4-43). However, the results should be interpreted with caution because the estimate of variance is likely to be very poor due to the low degrees of freedom (df=1) (Table 4-43).

Table 4-43 Summary Results of Non-branching Coral Growth for the Mussidae

Source	df	SS	MS	Pseudo-F	P-value
Survey	1	0.34566	0.34566	3.6764	0.0536
IvR	1	$1.1227E^{-2}$	$1.1227E^{-2}$	0.1194	0.7267
Survey × IvR	1	$3.5996E^{-2}$	$3.5996E^{-2}$	0.38284	0.5423
Res	102	9.5903	$9.4022E^{-2}$		
Total	105	9.9956			

For the Acroporidae, the Survey × IvR interaction term was significant (Table 4-44), and the post-hoc tests revealed a significant difference at the Reference Sites between the Marine Baseline Program and Post-Development Survey Year 2 (Table 4-45). However, based on the low degrees of freedom (df=1) (Table 4-44), the estimate of variance is likely to be poor. The growth rates in Post-Development Survey Year 2 were higher in the Reference Sites compared to the Impact Sites (Figure 4-38).

Table 4-44 Summary Results for Non-branching Coral Growth for the Acroporidae

Source	df	SS	MS	Pseudo-F	P-value
Survey	1	3.8202	3.8202	13.284	0.0246
IvR	1	0.24384	0.24384	0.22402	0.6636
Zone(IvR)	2	$5.7865E^{-2}$	$2.8932E^{-2}$	$2.4816E^{-2}$	0.9521
Survey × IvR	1	2.6196	2.6196	9.1088	**0.0421**
Site(Zone(IvR)	7	8.996	1.2851	1.7599	0.1096
Survey × Zone(IvR)	1	$2.1772E^{-3}$	$2.1772E^{-3}$	$7.1843E^{-3}$	0.9309
Survey × Site(Zone(IvR)	4	1.0402	0.26006	0.35612	0.8316
Res	200	146.05	0.73024		
Total	217	168.03			

Notes: Bold font in P-value column = significant difference for term of interest

Table 4-45 Post-hoc Tests for Non-branching Coral Growth for the Acroporidae (Survey × IvR)

Zone	df	t	P-value
Impact			
Marine Baseline Program, Post-Development Survey Year 2	1	0.88974	0.534
Reference			
Marine Baseline Program, Post-Development Survey Year 2	4.65	5.0262	**0.022**

Notes: Bold font in P-value column = significant difference for term of interest

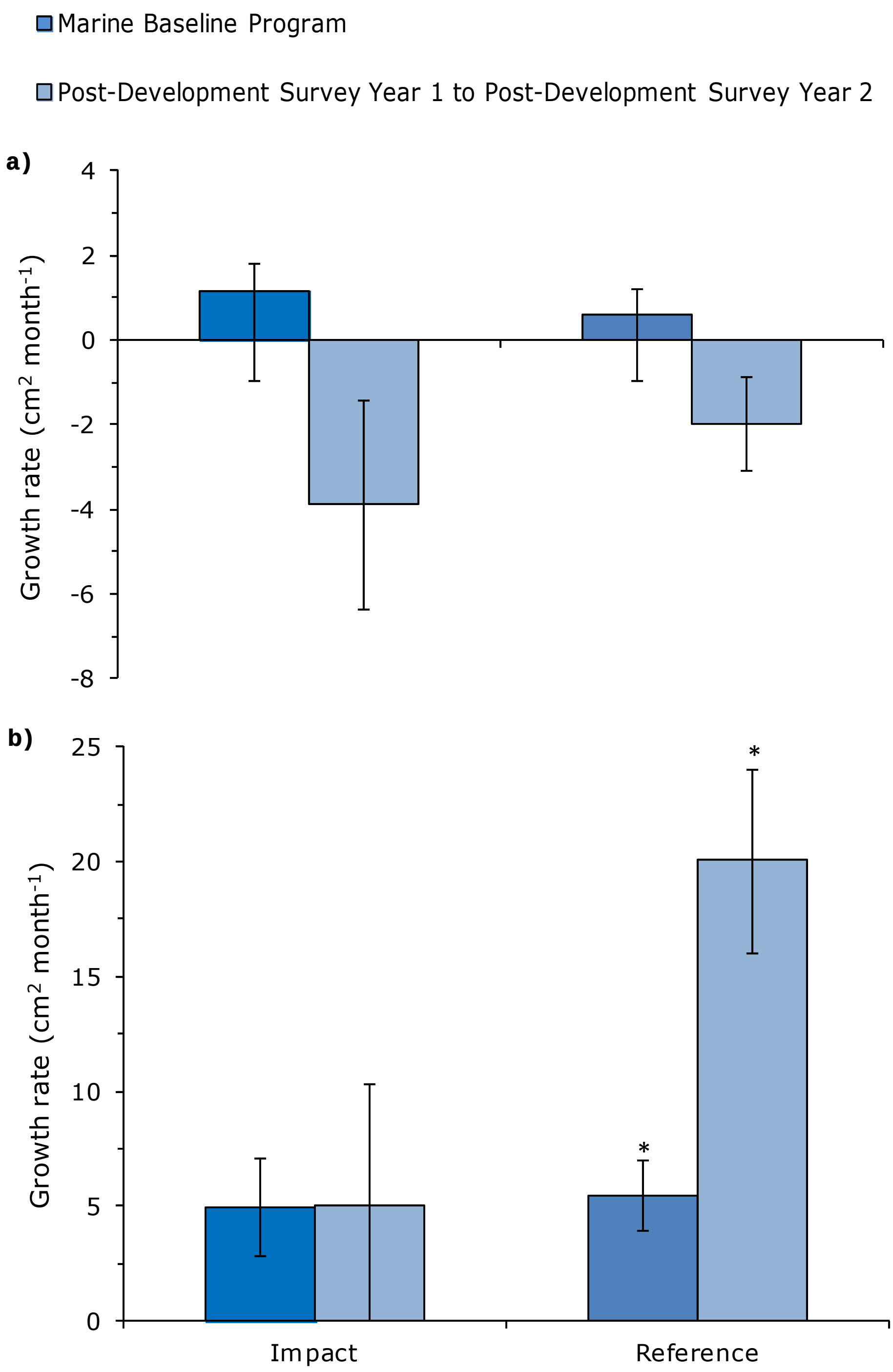


Figure 4-38 Non-branching Coral Growth (cm^2 $month^{-1}$) (±SE) for the Marine Baseline Program and Post-Development Surveys

Notes: a) Mussidae; b) Acroporidae
*Significant differences at Survey × IvR: * = Marine Baseline Program, Post-Development Survey Year 2*

4.8.4 Discussion

Coral growth varies seasonally (Guzman and Cortes 1989; Bak *et al.* 2009) and generally falls into two major groups: rapidly growing corals belonging to the Acroporidae and Pocilloporidae and slower growing corals with have a more massive appearance (Dullo 2005). This classification is largely supported by the present study, where *Acropora* and *Montipora* (Acroporidae) showed higher daily growth rates in Post-Development Survey Year 2 compared to the Mussidae and Faviidae, which have a massive morphology. The growth rates in the Acroporidae are also known to be greater than in the Poritidae (Harriott 1999; Dullo 2005) and this is reflected in the reported higher growth rates of the branching *Acropora* (Acroporidae) compared to the branching *Porites* (Poritidae).

Coral growth rates are influenced by both the physical and chemical properties of the marine environment (Buddemeier and Kinzie 1976), and they are frequently used as reef health indicators in environmental assessments of coral reefs, where the expectation is that the physiological stress associated with an impact/disturbance should lead to decreased growth rates (Eakin *et al.* 1993; Guzman *et al.* 1994). For example, corals subject to high sedimentation (common in dredging activities) typically show a decline in growth rates that is largely attributable to reduced light penetration into the water column (Hudson 1981; Rogers 1990).

The branching *Acropora* (Acroporidae) did not show any significant differences or reduced growth rates from the Marine Baseline Program to Post-Development Survey Year 2. The growth rates were higher at site LOW in the ZoI than at site SBS (Reference) suggesting site variability, but the limited number of sites studied limits the interpretative value of this reported difference in growth rates. No sites were sampled in the ZoHI and ZoMI for branching corals, which limits the assessment on the potential effects of the dredging and dredge spoil disposal activities on branching coral growth.

In terms of the non-branching corals, the growth rates of the Acroporidae at the Impact Sites remained stable from the Marine Baseline Program to Post-Development Survey Year 2, while there was a significant increase in the growth rates in the Reference Sites during Post-Development Survey Year 2 compared to the Marine Baseline Program. No significant differences were recorded between the Marine Baseline Program and Post-Development Survey Year 2 for the Mussidae. Despite the statistical significance reported for the Acroporidae, the results should be interpreted with caution as there is known site-level variability in growth rates, which, coupled with the limited replication, would have resulted in a poor estimate of the variance. The statistical analyses were also done at the family level, where different species (and genera and growth morphologies in the case of the Acroporidae) were grouped together, which does not reflect the true life-history characteristics of the individual species.

All methods followed the Scope of Works (RPS 2009, [amended 2012[), under which individual coral colonies were not sampled for growth rate from the Marine Baseline Program through the dredging campaign and into the Post-Development Surveys. Rather, coral growth rates were assessed prior to the dredging and dredge spoil disposal activities in the Marine Baseline Program and healthy colonies were retagged in Post-Development Survey Year 1 and their growth rate recorded in Post-Development Survey Year 2 (after the dredging and dredge spoil disposal activities). While the Post-Development Survey Year 2 growth rates represent an important spatial and temporal estimate of coral growth rates on the reefs around Barrow Island, the sedimentation and turbidity had largely dissipated before the Post-Development Survey Year 1 field campaign, and therefore the Post-Development Survey Year 2 growth rates do not necessarily reflect the dredging and dredge spoil disposal activities.

Significant differences were detected at the Reference Sites for the non-branching Acroporidae between the Marine Baseline Program and Post-Development Surveys, but the limitations of the sample design and the statistical analyses mean that the influence of the dredging and dredge spoil disposal activities on the growth rates cannot be fully assessed.

4.9 Summary

As part of the Gorgon Gas Development, Post-Development Surveys were required to 'determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with pre-development baseline marine environmental state' (Condition 24.2 of Statement No. 800). Based on the reported effects of dredging activities on corals, a certain amount of loss of live coral cover in the ZoHI and ZoMI was approved in the Ministerial Conditions, which was reflected in the data of the present study. The estimated upper 95% confidence limit of the net area of loss of Coral Assemblages in the ZoHI and ZoMI during Post-Development Survey Year 2 was 3.46 ha, which is likely to be attributable to the dredging and dredge spoil disposal activities. The net loss value of 3.46 ha is less than the permanent loss of Coral Assemblages limit of 8.47 ha (Condition 18.1ii.b of Statement No. 800) and therefore is within compliance limits.

The estimated upper 95% confidence limit of the net area of loss of Coral Assemblages in the ZoHI and ZoMI was greater in Post-Development Survey Year 2 (3.46 ha) compared to Post-Development Survey Year 1 (3.26 ha). While this indicates an additional change in Coral Assemblages from Post-Development Survey Year 1 to Post-Development Survey Year 2, the Coral Assemblage values are based on the upper 95% confidence limit and therefore represent the 'worst-case' (overestimation) estimates of change. Moreover, certain strata were not surveyed during the Post-Development Surveys (as per the approved Scope of Work (RPS 2009 [amended 1012]) and the Coastal and Marine Baseline State and Environmental Impact Report Supplement: Area of Coral Assemblages (Chevron Australia 2010a)); the zero values used for these strata were based on assumptions and therefore may not fully represent the actual change present. The reefs around Barrow Island were affected by coral bleaching in the 2010–2011 summer that resulted in ~8.6% loss of live coral cover (Moore *et al.* 2012) and a small proportion of the decline in Coral Assemblage in the ZoHI and ZoMI is likely attributable to coral bleaching associated mortality. That said, the data collected from the random transects from the same site locations showed an increase in live coral cover from Post-Development Survey Year 1 to Post-Development Survey Year 2 in the ZoHI and ZoMI. The live coral cover in the ZoHI increased from 15.5% to 21.5%, and the live coral cover in the ZoMI increased from 16.6% to 20.4%. During the same period, the live coral cover in the Reference Sites declined from 38.3% (Post-Development Survey Year 1) to 35.4% (Post-Development Survey Year 2).

The discrepancy between the Area of Coral Assemblages results and the percentage live coral cover results is likely driven by the method used to calculate Coral Assemblage. According to the Scope of Works (RPS 2009, [amended 2012]), Coral Assemblage is classified as any transect with ≥10% coral cover. For example, 11% live coral cover is considered the same as 70% live coral cover. As such, the estimation of the live coral cover in the Area of Coral Assemblages calculations differs from the random survival transects method, which uses the actual percentage cover.

As such, there were signs of recovery in the ZoHI and ZoMI in that the live coral cover increased from Post-Development Survey Year 1 to Post-Development Survey Year 2. The Acroporidae, Faviidae, and Poritidae were the dominant families across most sites and zones, a pattern that is consistent with that observed at other Indo–Pacific locations (van Woesik and Done 1997; Veron 2000). Although there were some minor reductions in the dominance scores and percentage cover in these coral families (with known susceptibility to turbidity and sedimentation; Gilmour *et al.* 2007; Erftemeijer *et al.* 2012), the community compositions were not adversely affected by the dredging and dredge spoil disposal activities. No major changes in the size-class frequency distributions of corals were detected from the Marine Baseline Program to the Post-Development Surveys and there was also evidence of the successful establishment of coral colonies ≤10 cm in both the ZoHI and ZoMI during Post-Development Survey Year 1 and Post-Development Survey Year 2. This is particularly important in the context of this study because turbidity and sedimentation have been shown to affect reproductive success and settlement rates (Gilmour 1999; Babcock and Smith 2000; Fabricius 2005) and the presence of colonies ≤10 cm from the dominant coral families are likely to represent an important input in terms of population maintenance and recovery following the dredging and dredge spoil disposal activities. The results show that the increase in coral cover is a combination of both successful recruitment and growth and survival of existing (pre-disturbance) colonies, both of which have been shown to be important in the recovery of the oceanic Western Australian Scott Reef following the catastrophic 1998 bleaching event (Gilmour *et al.* 2013).

The major conclusions from the Post-Development Survey Year 2 for hard and soft corals can be summarised as:

- The upper 95% confidence limit estimate of the net loss of Coral Assemblage in the ZoHI and ZoMI during Post-Development Survey Year 2 was 3.46 ha and, therefore, did not exceed the permanent loss of Coral Assemblages limit of 8.47 ha (Condition 18.1ii.b of Statement No. 800).
- Signs of recovery from potential impacts associated with dredging and dredge spoil disposal activities are evident in that the Post-Development Survey Year 2 live coral cover in the ZoHI and ZoMI has increased from Post-Development Survey Year 1.
- The results do not indicate a major change in the dominance of corals from the Marine Baseline Program to Post-Development Survey Year 2 due to dredging and dredge spoil disposal activities.
- The results do not indicate a major change in the size-class frequency distributions of corals from the Marine Baseline Program to Post-Development Survey Year 2 due to dredging and dredge spoil disposal activities.
- The results do not indicate a major change in the growth rates of branching Acroporidae and non-branching Acroporidae and Mussidae from the Marine Baseline Program to Post-Development Survey Year 2 due to dredging and dredge spoil disposal activities.
- The results do not indicate a major change in the number coral colonies ≤10 cm from the Marine Baseline Program to Post-Development Survey Year 2 due to dredging and dredge spoil disposal activities.
- There is evidence of establishment and survival of coral colonies ≤10 cm (recruitment success) at the ZoHI and ZoMI in Post-Development Survey Year 2.

The results of the present study are encouraging because not only has the live coral cover increased in the ZoHI and ZoMI since Post-Development Survey Year 1, but there have been no dramatic shifts in community and colony structure based on the size-class frequency data, the colony survivors post-dredging are surviving and growing, and there are positive signs of successful recruitment at all sites. Resilience refers to the ability of a system to maintain key functions and processes in the face of stresses or pressures by either resisting or adapting to change (Nyström and Folke 2001), and the reefs around Barrow Island are showing positive signs of ecological resilience. However, the recovery trajectory of reefs in the ZoHI and ZoMI during Post-Development Survey Year 3 may be negatively affected by any coral mortality associated with the 2012–2013 summer coral bleaching event due to the above average summer sea temperatures around Barrow Island (NOAA 2013).

5.0 Non-coral Benthic Macroinvertebrates

5.1 Introduction

The knowledge of the benthic macroinvertebrate assemblages in the Montebello/Barrow Islands 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; 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; DEC 2007). Deeper limestone reef areas in the region may support benthic macroinvertebrate communities that contain diverse assemblages of tubular, digitate, laminar, branching, globose, and encrusting sponges; hydroids; gorgonians (sea fans); soft corals (sea whips); colonial and solitary ascidians; bryozoans and small scleractinian corals (such as *Turbinaria* spp.) (Chevron Australia 2005).

The habitats on the east and west coasts of Barrow Island support different benthic macroinvertebrate assemblages; e.g. of the 316 species of molluscs recorded from Barrow Island, less than one-third occur on both coasts (Chevron Australia 2005). The muddier habitats on the east coast support a greater proportion of bivalve species, whilst the west coast supports a greater proportion of coral reef gastropod species (Chevron Australia 2005).

Surveys undertaken on the eastern side of Barrow Island during the Marine Baseline Program complement these original observations. Results of the Marine Baseline Program, which were based on metrics of abundance, revealed a diverse fauna, with communities on the east coast of Barrow Island dominated by hard coral communities, sponges, sea whips, colonial ascidians, and *Turbinaria* spp. Subdominant benthic macroinvertebrates included numerous sponge morphs (digitate, branching, cup, and fan), other soft corals, crinoids, hydroids, sea cucumbers, sea stars, gastropods, sea pens, gorgonians, sea urchins, and tubular and barrel sponges.

Benthic macroinvertebrates were generally sparsely distributed and relatively homogenous across broad areas of similar substratum. Distinct assemblages were observed on the different substrate types (sand or soft sediment and limestone pavement) (Chevron Australia 2012a). Benthic macroinvertebrates often occurred with macroalgae, and the only areas where benthic macroinvertebrates were the most common or abundant benthic biota were in the deeper (>10 m) sand habitats, even though they were generally in lower abundances there than on limestone pavements.

5.2 Scope

This Section is in two parts. The first presents the dominant species and describes the non-coral benthic macroinvertebrates recorded during the Post-Development Survey Year 2: 2012–2013:

- within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence, associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal activities required for the MOF and LNG Jetty
- at Reference Sites not at risk of Material or Serious Environmental Harm due to the construction of the MOF and LNG Jetty.

The second part compares the Post-Development Surveys and the Marine Baseline Program to determine if changes have occurred as per Condition 24.2 of Statement No. 800 and Condition 17.2 of EPBC Reference: 2003/1294 and 2008/4178.

As previously discussed (Section 2.1.5), no specific results or comparisons are made for the area in the vicinity of the marine upgrade of the existing WAPET Landing.

Non-coral 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 habitats 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 corals *Turbinaria* spp. are also common in these habitats and have been included as a benthic macroinvertebrate category as, from a habitat perspective, corals in this genus are more like other benthic macroinvertebrates (i.e. solitary with a low profile and low benthic cover) than the hard corals discussed in Section 4.0.

5.3 Methods

5.3.1 Site Locations

Twenty-eight non-coral benthic macroinvertebrate sampling locations were established as part of the Marine Baseline Program (Chevron Australia 2012a). As per the requirements in the approved Scope of Works (RPS 2009, amended 2012), a subset of these sites was sampled as part of the Post-Development Survey Year 2 (Table 5-1, Figure 5-1). Three sites were in the Zone of High Impact (ZoHI), one was in the Zone of Moderate Impact (ZoMI), five were in the Zone of Influence South (ZoI Sth), four were in the Zone of Influence North (ZoI Nth), and three were Reference Sites. A reduced number of sites were surveyed in Post-Development Survey Year 2 compared to Post-Development Survey Year 1 due to operational constraints and access associated with construction activities.

Table 5-1 Post-Development Survey Year 2 Sites for Non-coral Benthic Macroinvertebrates

Location	Site code	Site Coordinates (GDA94, UTM50)				Substrate
		Easting	Northing	Latitude	Longitude	
ZoHI	DS1	348019	7691926	20°51.996'S	115°32.343'E	Soft sediment
	LNGI2	344879	7696121	20°49.707'S	115°30.555'E	Limestone
	TP6	342238	7699286	20°47.978'S	115°29.050'E	Soft sediment
ZoMI	TP2	342235	7700923	20°47.091'S	115°29.057'E	Soft sediment
ZoI Sth	DSS1	347316	7687119	20°54.598'S	115°31.913'E	Soft sediment
	LNGR1	344321	7694295	20°50.694'S	115°30.224'E	Soft sediment
	LNGR3	343604	7694856	20°50.386'S	115°29.813'E	Limestone
	TP9	341069	7695737	20°49.895'S	115°28.357'E	Soft sediment
	TP10	337827	7694122	20°50.754'S	115°26.478'E	Limestone
ZoI Nth	LC1	344931	7700025	20°47.591'S	115°30.606'E	Soft sediment
	LC4	344832	7698996	20°48.148'S	115°30.543'E	Soft sediment
	LNGR2	345444	7697787	20°48.807'S	115°30.890'E	Soft sediment
	TP1	342332	7701483	20°46.788'S	115°29.116'E	Soft sediment
Ref	DSR3	353494	7695109	20°50.297'S	115°35.516'E	Soft sediment
	DSR5	346075	7694125	20°50.794'S	115°31.234'E	Soft sediment
	DSR6	350774	7693683	20°51.057'S	115°33.941'E	Limestone

Notes: Reference Site DSR6 was classified as coral/limestone in Post-Development Survey Year 1

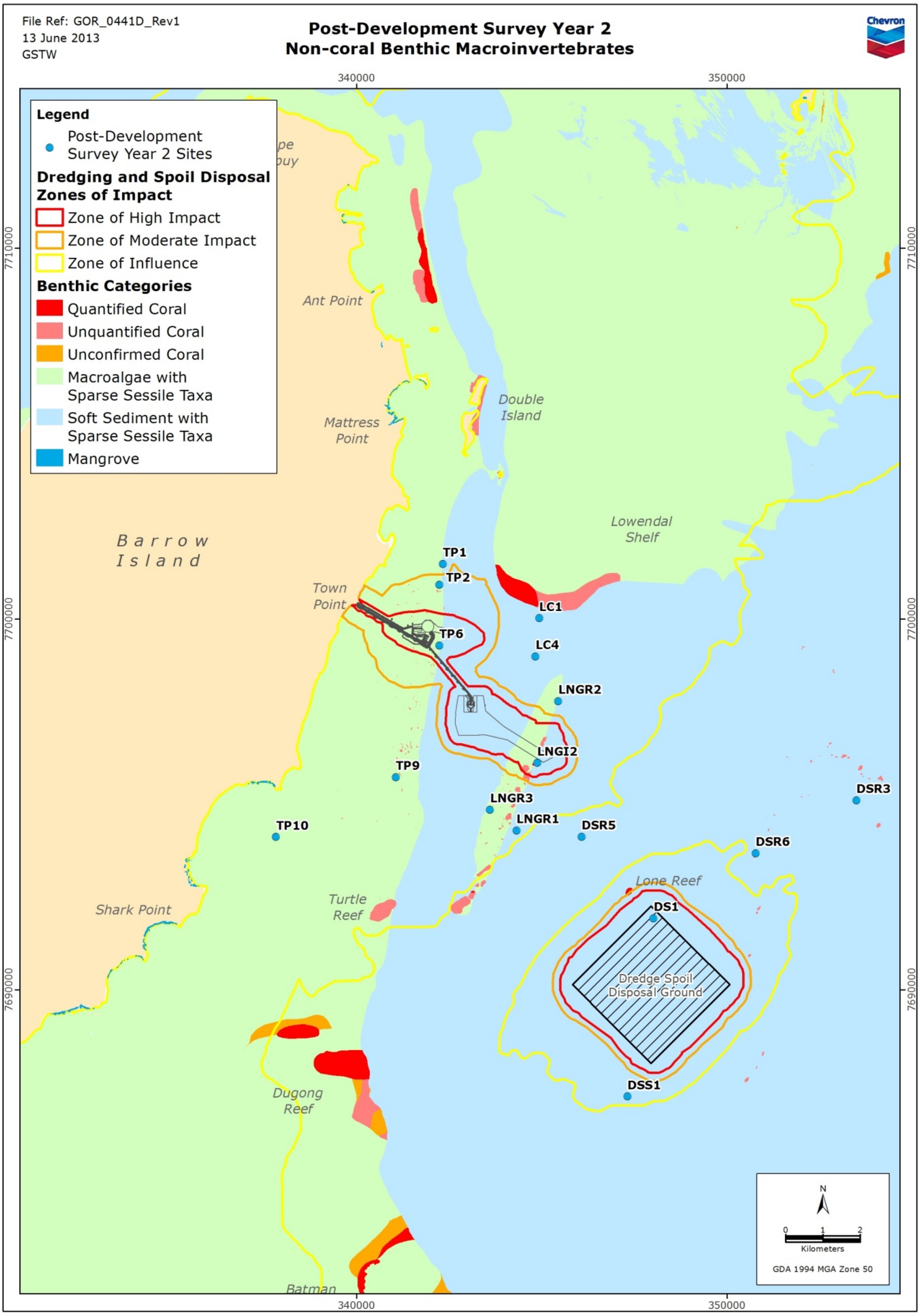


Figure 5-1 Post-Development Survey Year 2 Sites for Non-coral Benthic Macroinvertebrates

5.3.2 Timing and Frequency of Sampling

The benthic macroinvertebrate Post-Development Survey Year 2 was undertaken in April 2013.

5.3.3 Survey Method

At each site, three 30 m long and 0.5 m wide belt transects were filmed using a diver-operated high-definition video camera in a waterproof housing, with the lens maintained at a fixed distance of 50 cm from the substratum (RPS 2009, amended 2012). Each transect covered an area of approximately 15 m^2. The first transect was orientated parallel to the anchor line and the two others at 90° to the first. The coordinates of the start point of each transect was recorded using Global Positioning System (GPS) and the transect bearing was noted.

The dominant benthic macroinvertebrates along each transect were photographed with a digital camera in a waterproof housing. Representative voucher specimens were collected, preserved (in 70% ethanol) and catalogued.

5.3.4 Treatment of Survey Data

Video footage was analysed using the TransectMeasure software program (SeaGIS 2013). 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, as specimens smaller than this were difficult to classify accurately. Counts were averaged to determine the abundance of taxonomic groups per transect.

For the purpose of this Post-Development Survey Year 2 Report, dominant and subdominant taxonomic groups of benthic macroinvertebrates were determined based on average abundance across sites. Taxonomic groups were defined as dominant or subdominant based on these criteria:

- Dominant − the top ten most abundant taxonomic groups
- Subdominant − taxonomic groups not in the top ten most abundant groups.

The naming categories applied to benthic macroinvertebrates followed in Post-Development Survey Year 1 (Chevron Australia 2012b). The Marine Baseline Program transects were reclassified in Post-Development Survey Year 1 so that the Marine Baseline Program and Post-Development Survey Year 1 transects were analysed with consistent categories (Table 5-2). Two taxonomic groups (Bivalves and Zoanthids) were present in the Post-Development Survey Year 2 that were not present in the Marine Baseline Program and Post-Development Survey Year 1 surveys. Therefore, Bivalves and Zoanthids were added as additional categories in Post-Development Survey Year 2 (Table 5-2).

Each transect was assigned a substrate classification (soft sediment, limestone, or coral) based on the dominant substrate observed in the video footage. Classification was based on the percentage cover of observed substrate, with transects defined by the substrate representing greater than 50% of the total cover. For example, transects that were classified as 10% coral, 10% limestone, and 80% soft sediment, were classified as soft sediment. The Marine Baseline Program transects were reclassified in Post-Development Survey Year 1, which resulted in new substrate classifications for the Marine Baseline Program as outlined in the Post-Development Survey Year 1 (Chevron Australia 2012b) and Appendix 1. Revised Marine Baseline Program data relevant to non-coral macroinvertebrates is shown in Appendix 1.

Table 5-2 Naming Categories Applied to Benthic Macroinvertebrates Identified in the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Benthic Macroinvertebrate Category	Categories used in the Marine Baseline Program	Additional Categories included in Post-Development Survey Year 1	Additional Categories included in Post-Development Survey Year 2
Ascidians (colonial)		X	
Ascidians (solitary)		X	
Bivalves			X
Crinoids	X		
Gastropods		X	
Gorgonians	X		
Hydroids	X		
Nudibranchs		X	
'Other' hard corals		X	
'Other' soft corals		X	
Sea cucumbers		X	
Sea pens		X	
Sea stars		X	
Sea urchins		X	
Sea whips	X		
Sponges (barrel)	X		
Sponges (branching)	X		
Sponges (cup)	X		
Sponges (digitate)	X		
Sponges (fan)	X		
Sponges (globular)	X		
Sponges (tubular)	X		
Sponges (variable)	X		
Turbinaria spp.	X		
Zoanthids			X
Unidentified	X		

Note: 'Other' hard coral includes all hard corals except those individually listed (e.g. Turbinaria spp.*). 'Other' soft corals include all soft corals except those individually listed (e.g. Gorgonians, Sea whips, Sea pens). Bivalves and Zoanthids were not present in the Marine Baseline Program and Post-Development Survey Year 1 but were present in Post-Development Survey Year 2, resulting in these two categories being added in Post-Development Survey Year 2*

5.3.5 Statistical Approach for Comparison against Baseline

The approach required in the Scope of Works (RPS 2009, [amended 2012]) was a Multiple-Before-After-Control-Impact (MBACI) approach, which is one of the most robust statistical designs for detecting changes caused by anthropogenic disturbances (Keough and Mapstone 1995). For the Post-Development Survey analyses, a single potential impact area was compared against a single reference area, each with multiple monitoring sites. Within that potential impact area, sites were grouped by predicted levels of impact (zones: ZoHI, ZoMI, ZoI Sth, ZoI Nth). The objective was to assess whether significant environmental change that could be associated with dredging and dredge spoil disposal activities had occurred between the Marine Baseline Program and the Post-Development Surveys.

Sites were grouped into soft sediment substrate (hereafter referred to as soft sediment) and limestone substrate (hereafter referred to as limestone) datasets according to the substrate present during the Marine Baseline Program. As part of the step-wise approach to assess potential changes in the benthic macroinvertebrate community structure, separate analyses were conducted on the full (soft sediment and limestone) dataset, the soft sediment dataset, and the limestone dataset. Within the context of performing statistical analyses for these datasets, two step-wise approaches were followed:

- Reference Sites present (used for the soft sediment and limestone dataset, and the soft sediment dataset) (Figure 5-2).
- Reference Sites absent (used for the limestone dataset) (Figure 5-3).

The limestone dataset only contained a single Reference Site (DSR6). The substrate at site DSR6 changed from limestone in the Marine Baseline Program to coral in Post-Development Survey Year 1 to limestone in Post-Development Survey Year 2. The change from limestone to coral was considered unlikely to have resulted from the dredging and dredge spoil disposal activities, but rather due to the random placement of transects between surveys. The change in benthic substrate is an artefact of the method design rather than a result of the dredging and dredge spoil disposal activities. As benthic invertebrate assemblages are known to differ among substrates (Pante *et al.* 2006), the inclusion of site DSR6 could result in a change in benthic macroinvertebrate community structure that was entirely due to the change in substrate rather than the dredging and dredge spoil disposal activities, thereby resulting in a Type I or Type I error. As such, site DSR6 was excluded from statistical analyses, resulting in no Reference Sites available for the limestone dataset (i.e. Reference Sites absent).

Where Reference Sites were present, a four-factor statistical design, and where Reference Sites were absent, a three-factor statistical design was used to test whether the dredging and dredge spoil disposal activities affected the abundance of benthic macroinvertebrates (Figure 5-2, Figure 5-3). If the term(s) of interest (i.e. those terms that are potentially indicative of change associated with dredging and dredge spoil disposal activities) were non-significant, the next step in the analysis process was followed. If the term(s) of interest were significant at any stage in analysis process, post-hoc, pair-wise tests combined with a non-metric multidimensional scaling (nMDS) plot with vector overlays was undertaken. The vector overlays enabled the top ten taxonomic groups that had the strongest correlations with the patterns in the multivariate data to be determined. The top ten taxonomic groups identified by the vector overlays were further explored with univariate tests and graphing to investigate the direction of change.

Given the possibility that the separate activities of dredging and dredge spoil disposal could have affected the benthic macroinvertebrate community structure in different ways, the inclusion of the two activities into one analysis could have increased estimates of variation within potential impact zones, leading to a Type II error. As such, if the term(s) of interest remained non-significant after the last step of the analysis process when all the data were used (as above), the analyses were re-run using a separate dredging dataset, and a separate dredge spoil disposal dataset. Once again, if the term(s) of interest were significant at any stage in the analysis process, post-hoc, pair-wise tests combined with graphing and univariate test were undertaken to investigate the nature of the change.

Table 5-3 Statistical Treatment and Analyses used for Non-coral Benthic Macroinvertebrates

<table>
<tr><th colspan="3">Belt Transects</th></tr>
<tr><td rowspan="5">Pre-treatment of data</td><td colspan="2">ZoI separated into ZoI North and ZoI South</td></tr>
<tr><td colspan="2">Sites and transects classified according to substrate visible during Marine Baseline Program footage</td></tr>
<tr><td colspan="2">Site DSR6 removed from all analyses[1]</td></tr>
<tr><td colspan="2">Site TP10, Marine Baseline Program limestone data set, Transect 3 was removed from all analyses[2]</td></tr>
<tr><td colspan="2">Site comparison test done to determine whether additional sites should be retained or removed if an uneven number of sites was sampled between the Marine Baseline Program and the Post-Development Surveys</td></tr>
<tr><td rowspan="15">Sites used in statistical analyses</td><td rowspan="5">Marine Baseline Program</td><td>ZoHI: DS1, DS2, LNGI1, LNGI2, TP6, TPCI1, TPCI2</td></tr>
<tr><td>ZoMI: TP2</td></tr>
<tr><td>ZoI Sth: DSS1, LNGR1, LNGR3, TP9, TP10, TPC1, TPC3</td></tr>
<tr><td>ZoI Nth: LC1, LC2, LC3, LC4, LNGR2, NEBWI2, TP1</td></tr>
<tr><td>Reference: DGI0, DSR3, DSR5</td></tr>
<tr><td rowspan="5">Post-Development Survey Year 1</td><td>ZoHI: DS1, LNGI2, TP6</td></tr>
<tr><td>ZoMI: TP2</td></tr>
<tr><td>ZoI Sth: DSS1, LNGR1, LNGR3, TP9, TP10, TPC1, TPC3</td></tr>
<tr><td>ZoI Nth: LC1, LC4, LNGR2, TP1</td></tr>
<tr><td>Reference: DGI0, DSR3, DSR5</td></tr>
<tr><td rowspan="5">Post-Development Survey Year 2</td><td>ZoHI: DS1, LNGI2, TP6</td></tr>
<tr><td>ZoMI: TP2</td></tr>
<tr><td>ZoI Sth: DSS1, LNGR1, LNGR3, TP9, TP10</td></tr>
<tr><td>ZoI Nth: LC1, LC4, LNGR2, TP1</td></tr>
<tr><td>Reference: DSR3, DSR5</td></tr>
<tr><td>Step-wise approach</td><td colspan="2">Step-wise approach adopted</td></tr>
<tr><td rowspan="9">Main statistical design</td><td colspan="2">Reference Sites present</td></tr>
<tr><td rowspan="4">Four-factor statistical design</td><td>Survey (fixed, orthogonal)</td></tr>
<tr><td>Impact v. Reference [IvR] (fixed, orthogonal)</td></tr>
<tr><td>Zone (fixed, nested within IvR)</td></tr>
<tr><td>Site (random, nested within Zone)</td></tr>
<tr><td colspan="2">Reference Sites absent</td></tr>
<tr><td rowspan="3">Three-factor statistical design</td><td>Survey (fixed, orthogonal)</td></tr>
<tr><td>Zone (fixed, orthogonal)</td></tr>
<tr><td>Site (random, nested within Zone)</td></tr>
<tr><td rowspan="2">Term of interest</td><td colspan="2">Survey × Zone</td></tr>
<tr><td colspan="2">Survey × IvR</td></tr>
<tr><td>Statistical program</td><td colspan="2">PERMANOVA</td></tr>
<tr><td rowspan="2">Statistical tests</td><td colspan="2">Benthic macroinvertebrate community structure (multivariate) (PERMANOVA)</td></tr>
<tr><td colspan="2">nMDS with vector overlay (PRIMER)</td></tr>
</table>

Belt Transects	
	Benthic macroinvertebrate abundance of individual taxa (univariate)
Transformation	Univariate: square-root transformed
	Multivariate: fourth-root transformed
Distance measure	Univariate: Euclidean distance
	Multivariate: Bray-Curtis dissimilarity

Notes:

1. *See Section 5.3.5 for the rationale behind the exclusion of site DSR6*
2. *For statistical purposes, transects were used as replicates, resulting in n=3 replicates per site. The exception was site TP10 during the Marine Baseline Program, where two transects were classified as limestone and one was classified as soft sediment. In this case, only transects classified as limestone were included in the analysis, reducing the sample size to n=2. All transects sampled at TP10 during Post-Development Survey Year 1 and Post-Development Survey Year 2 (n=3 for each survey) were included in the analyses.*

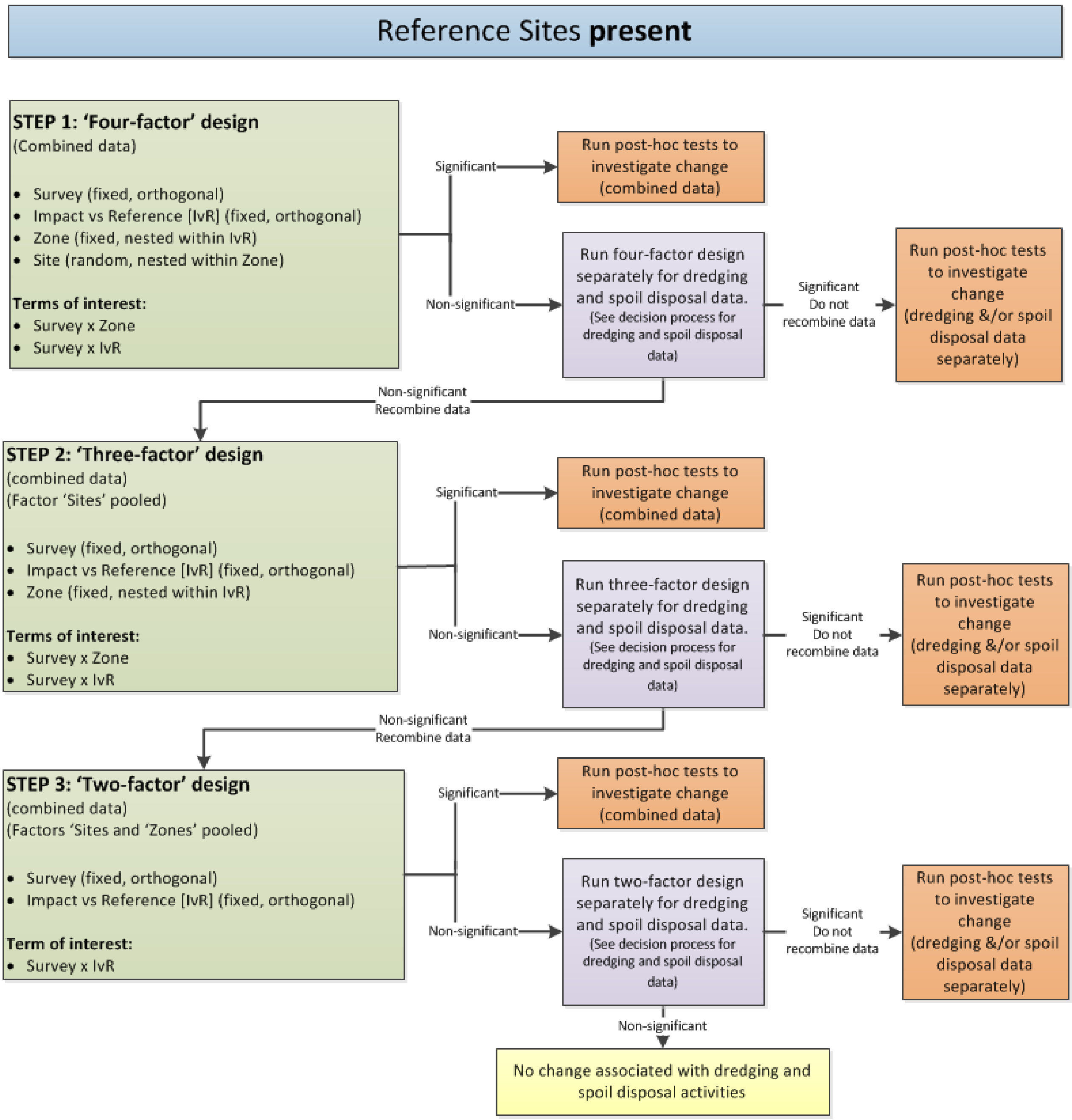


Figure 5-2 Statistical Designs and Step-wise Approach for Assessment of Change in Benthic Macroinvertebrates for Datasets that included Reference Sites

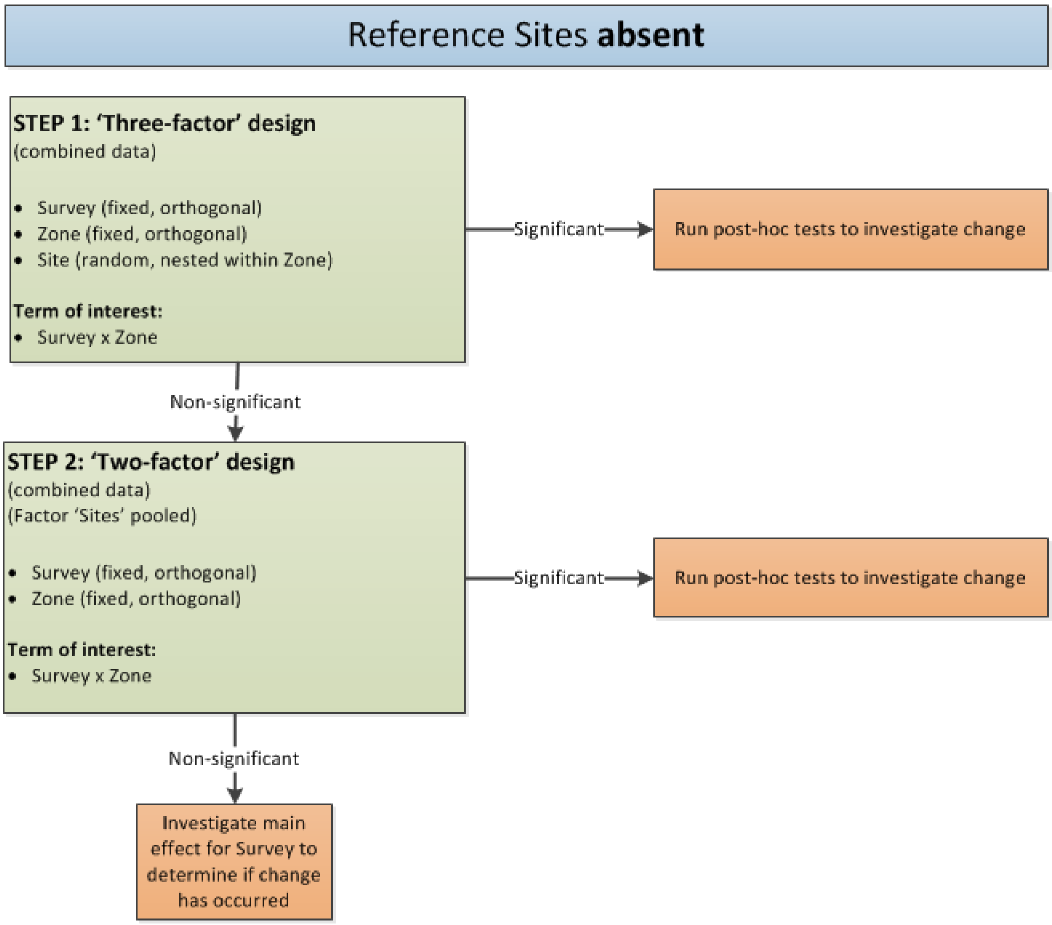


Figure 5-3 Statistical Designs and Step-wise Approach for Assessment of Change in Benthic Macroinvertebrates for Datasets that did not include Reference Sites

5.4 Results of Post-Development Survey Year 2

Forty-eight transects were undertaken across 16 sites during Post-Development Survey Year 2. Thirty-six transects were surveyed over soft sediment and 12 transects were surveyed over limestone, with no transects surveyed over coral substrate (Table 5-1). Twenty-four (including the unidentified) taxonomic groups were recorded, with only the Gastropods and Sea pens absent in Post-Development Survey Year 2 surveys. Two new taxonomic groups (Bivalves and Zoanthids) were added in Post-Development Survey Year 2 (Table 5-2).

5.4.1 Distribution of Benthic Macroinvertebrates in Barrow Island Waters

There did not appear to be any clear observed difference in benthic macroinvertebrate community structure between substrates; however, substrate-specific differences were difficult to quantify, with very few transects undertaken exclusively in the same substrate, with most including a mixture of limestone, coral, and soft sediment. Even small patches of limestone (or other hard substrate) in an otherwise soft sediment transect tended to skew the observations, affecting both measures of taxonomic group richness and abundance. Note that while there is no observed difference in macroinvertebrate groups between substrates, dominant groups were separated into substrate type for statistical analysis (see statistical approach in Section 5.3.5 and statistical results in Section 5.5.2).

Fifteen taxonomic groups were recorded on limestone (Table 5-4), and 23 were recorded on soft sediment (Table 5-5). The number of taxonomic groups was variable across sites on both limestone and soft sediment, with limestone ranging from three to 12 taxonomic groups (Table 5-4) and soft sediment ranging from three to 18 taxonomic groups (Table 5-5). The highest number of taxonomic groups was recorded at the ZoI Sth site DSS1 (18), and the lowest number were recorded at the Reference Sites DSR3 (3) and DSR6 (3) (Table 5-4; Table 5-5).

Table 5-4 Mean Abundance (SE) of Benthic Macroinvertebrate Taxonomic Groups Observed per Transect on Limestone Substrates during the Post-Development Survey Year 2

Taxonomic group	Zone/site			
	ZoHI	ZoI Sth		Reference
	LNGI2	LNGR3	TP10	DSR6
Ascidians (colonial)	**–**	**1.67 (0.96)**	**2.67 (1.54)**	**–**
Ascidians (solitary)	–	–	–	–
Bivalves	–	–	–	–
Crinoids	–	0.67 (0.38)	–	–
Gastropods	–	–	–	–
Gorgonians	–	–	–	–
Hydroids	–	–	–	–
Nudibranchs	–	–	–	–
'Other' hard corals	**1.67 (0.96)**	**14.00 (8.08)**	**6.33 (3.66)**	**4.00 (2.31)**
'Other' soft corals	**0.67 (0.38)**	**8.33 (4.81)**	**3.67 (2.12)**	**–**
Sea cucumbers	**–**	**1.33 (0.77)**	**1.67 (0.96)**	**–**
Sea pens	–	–	–	–
Sea stars	–	–	–	–
Sea urchins	–	–	–	–
Sea whips	**–**	**8.00 (4.62)**	**1.33 (0.77)**	**–**
Sponges (barrel)	–	–	0.67 (0.38)	–
Sponges (branching)	**–**	**–**	**3.67 (2.12)**	**–**
Sponges (cup)	**–**	**1.33 (0.77)**	**0.67 (0.38)**	**–**
Sponges (digitate)	**–**	**1.67 (0.96)**	**1.00 (0.58)**	**–**
Sponges (fan)	–	0.33 (0.19)	–	0.33 (0.19)
Sponges (globular)	–	–	–	–
Sponges (tubular)	–	–	0.33 (0.19)	–
Sponges (variable)	**0.67 (0.38)**	**3.33 (1.92)**	**10.33 (5.97)**	**3.33 (1.92)**
***Turbinaria* spp.**	**–**	**3.00 (1.73)**	**1.00 (0.58)**	
Zoanthids	–	–	–	–
Unidentified	0.33 (0.19)	1.00 (0.58)	–	–
Total number of taxonomic groups	**4**	**12**	**12**	**3**

Notes: Bold font (except for last row of table) indicates the top ten most abundant taxonomic groups, based on average across sites. '–'= the taxonomic group was not recorded at that site.

Table 5-5 Mean Abundance (SE) of Benthic Macroinvertebrate Taxonomic Groups Observed per Transect on Soft Sediment Substrates during the Post-Development Survey Year 2

Taxonomic group	Zone/Site											
	ZoHI		ZoMI	ZoI Sth			ZoI Nth				Reference	
	DS1	TP6	TP2	DSS1	LNGR1	TP9	LC1	LC4	LNGR2	TP1	DSR3	DSR5
Ascidians (colonial)	**6.33 (3.66)**	**0.67 (0.38)**	**10.67 (6.16)**	**6.00 (3.46)**	**–**	**0.67 (0.38)**	**–**	**0.33 (0.19)**	**–**	**1.00 (0.58)**	**–**	**0.33 (0.19)**
Ascidians (solitary)	–	–	–	0.33 (0.00)	–	–	–	–	–	–	–	–
Bivalves	–	–	–	–	–	2.00 (1.15)	1.33 (0.77)	–	–	–	–	–
Crinoids	2.00 (1.15)	–	1.00 (0.58)	0.67 (0.38)	–	–	0.33 (0.19)	0.67 (0.38)	–	–	0.33 (0.19)	–
Gastropods	–	–	–	–	–	–	–	–	–	–	–	–
Gorgonians	0.67 (0.38)	–	0.33 (0.19)	–	–	–	–	–	0.33 (0.19)	–	–	–
Hydroids	**2.33 (1.35)**	**0.33 (0.19)**	**1.33 (0.77)**	**1.67 (0.96)**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Nudibranchs	–	–	–	–	0.33 (0.19)	–	–	-	–	–	–	–
'Other' hard corals	**13.33 (7.70)**	**2.33 (1.35)**	**7.00 (4.04)**	**20.33 (11.74)**	**0.33 (0.19)**	**18.00 (10.39)**	**–**	**3.33 (1.92)**	**5.67 (3.27)**	**10.67 (6.16)**	**–**	**2.67 (1.54)**
'Other' soft corals	**3.00 (1.73)**	**–**	**1.67 (0.96)**	**2.00 (1.15)**	**–**	**–**	**–**	**0.67 (0.38)**	**3.00 (1.73)**	**0.67 (0.38)**	**–**	**1.00 (0.58)**
Sea cucumbers	–	0.33 (0.19)	–	1.33 (0.77)	–	–	–	–	0.33 (0.19)	0.33 (0.19)	0.33 (0.19)	–
Sea pens	–	–	–	–	–	–	–	–	–	–	–	–
Sea stars	–	–	–	–	0.33 (0.19)	–	–	–	–	–	–	–
Sea urchins	–	–	–	–	0.33 (0.19)	–	–	–	–	–	–	–
Sea whips	**11.00 (6.35)**	**5.33 (3.08)**	**1.33 (0.77)**	**6.33 (3.66)**	**0.33 (0.19)**	**–**	**–**	**9.00 (5.20)**	**7.33 (4.23)**	**1.67 (0.96)**	**6.67 (3.85)**	**0.33 (0.19)**
Sponges (barrel)	–	–	–	–	–	–	–	–	–	–	–	–
Sponges (branching)	**2.00 (1.15)**	**0.33 (0.19)**	**0.33 (0.19)**	**7.67 (4.43)**	**1.00 (0.58)**	**0.33 (0.19)**	**–**	**0.33 (0.19)**	**2.00 (1.15)**	**1.33 (0.77)**	**–**	**–**
Sponges (cup)	**1.33 (0.77)**	**–**	**–**	**3.33 (1.92)**	**–**	**–**	**0.33 (0.19)**	**0.33 (0.19)**	**0.67 (0.38)**	**0.33 (0.19)**	**–**	**–**
Sponges (digitate)	0.33 (0.19)	–	0.33 (0.19)	0.33 (0.19)	–	–	–	–	0.33 (0.19)	0.33 (0.19)	–	–
Sponges (fan)	**2.33 (1.35)**	**1.67 (0.96)**	**2.33 (1.35)**	**6.00 (3.46)**	**–**	**–**	**–**	**0.33 (0.19)**	**–**	**1.33 (0.77)**	**–**	**–**
Sponges (globular)	0.33 (0.19)	–	–	0.67 (0.38)	0.33 (0.19)	–	–	0.33 (0.19)	–	–	–	–
Sponges (tubular)	–	–	–	0.67 (0.38)	–	–	–	–	–	–	–	–
Sponges (variable)	**9.33 (5.39)**	**6.33 (3.66)**	**5.33 (3.08)**	**11.00 (6.35)**	**–**	**4.00 (2.31)**	**0.33 (0.19)**	**3.00 (1.73)**	**1.33 (0.77)**	**2.67 (1.54)**	**–**	**–**
***Turbinaria* spp.**	**4.33 (2.50)**	**–**	**0.33 (0.19)**	**1.33 (0.77)**	**0.33 (0.19)**	**–**	**–**	**0.67 (0.38)**	**2.33 (1.35)**	**–**	**–**	**0.33 (0.19)**
Zoanthids	–	–	0.33 (0.19)	2.00 (1.15)	–	–	–	–	–	–	–	–
Unidentified	–	0.33 (0.19)	0.33 (0.19)	0.33 (0.19)	–	–	–	0.33 (0.19)	–	–	–	–
Total number of	**14**	**9**	**14**	**18**	**8**	**5**	**4**	**12**	**10**	**10**	**3**	**5**

Taxonomic group	Zone/Site											
	ZoHI		ZoMI	ZoI Sth			ZoI Nth				Reference	
	DS1	TP6	TP2	DSS1	LNGR1	TP9	LC1	LC4	LNGR2	TP1	DSR3	DSR5
taxonomic groups												

Note: Bold font (except for last row of table) indicates the top ten most abundant taxonomic groups, based on average across sites. '–'= the taxonomic group was not recorded at that site.

5.4.2 Dominant and Subdominant Benthic Macroinvertebrates

The majority of the dominant taxonomic groups were recorded in both limestone (Table 5-4) and soft sediment (Table 5-5). Eight of the dominant taxonomic groups (Ascidians (colonial), 'Other' hard corals, 'Other' soft corals, Sea whips, Sponges (branching), Sponges (cup), Sponges (variable), *Turbinaria* spp.) were shared across the two substrate types. The only minor differences were Sea cucumbers and Sponges (digitate) that were dominant on limestone (Table 5-4), whereas Hydroids and Sponges (fan) were dominant on soft sediment (Table 5-5). Subdominant benthic macroinvertebrates on limestone included Crinoids, Sponges (barrel), Sponges (fan), and Sponges (tubular) (Table 5-4). Subdominant benthic macroinvertebrates on soft sediment included Ascidians (solitary), Bivalves, Crinoids, Gorgonians, Nudibranchs, Sea cucumbers, Sea stars, Sea urchins, Sponges (digitate), Sponges (globular), Sponges (tubular), and Zoanthids (Table 5-5).

5.4.3 Description of Benthic Macroinvertebrate Assemblages within the Zones of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

5.4.3.1 Limestone

At site LNGI2 in the ZoHI, 'Other' hard corals were the most common taxonomic group, followed by 'Other' soft corals and Sponges (variable) (Table 5-4). No limestone sites were present in the ZoMI (Table 5-4).

5.4.3.2 Soft Sediment

At sites DS1 and TP6 in the ZoHI, 'Other' hard corals, Sea whips, and Sponges (variable) were the most common taxonomic groups (Table 5-5). Other common taxonomic groups at site DS1 in the Dredge Spoil Disposal Ground included *Turbinaria* spp. and Ascidians (colonial) (Table 5-5). Within the ZoMI, Ascidians (colonial), 'Other' hard corals, and Sponges (variable) were common at site TP2 (Table 5-5).

5.4.4 Description of Benthic Macroinvertebrate Assemblages at Representative Areas of the Zones of Influence Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

5.4.4.1 Limestone

Within the ZoI Sth, the most common taxonomic groups showed minor differences between site LNGR3 and site TP10. At site LNGR3, 'Other' hard corals, 'Other' soft corals, and Sea whips were the most common taxonomic groups, followed by Sponges (variable) and *Turbinaria* spp. (Table 5-4). At site TP10, the most common taxonomic groups were Sponges (variable) and 'Other' hard corals, followed by 'Other' soft corals and Sponges (branching) (Table 5-4). No sites were present in the ZoI Nth (Table 5-4).

5.4.4.2 Soft Sediment

Within the ZoI Sth, the number of taxonomic groups was 18 at site DSS1, eight at site LNGR1, and five at site TP9 (Table 5-5). 'Other' hard corals and Sponges (variable) were the most common taxonomic groups at site TP9, whereas none of the eight taxonomic groups present at site LNGR1 occurred in great numbers (Table 5-5). Site DSS1 had the greatest number of taxonomic groups, with 'Other' hard corals, Sponges (variable), Sponges (branching), Sea whips, Ascidians (colonial), and Sponges (fan) being the common taxonomic groups at this site (Table 5-5).

The number of taxonomic groups was similar (10–12) at sites in the ZoI Nth, with the exception of site LC1 that had four taxonomic groups (Table 5-5). In general, Sea whips, 'Other' hard corals, and Sponges (variable) were the most common taxonomic groups across the sites LC4, LNGR2, and TP1 (Table 5-5). In comparison, none of the four taxonomic groups at site LC1 were common (Table 5-5).

5.4.5 Description of Benthic Macroinvertebrate Assemblages at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction of the MOF and LNG Jetty

5.4.5.1 Limestone

Reference Site DSR6 contained three taxonomic groups, of which 'Other' hard corals and Sponges (variable) were the most common taxonomic groups (Table 5-4).

5.4.5.2 Soft Sediment

Within the Reference Sites, site DSR3 had three taxonomic groups and site DSR5 had five taxonomic groups (Table 5-5). The common taxonomic groups differed between these two sites, with Sea whips being the most common taxonomic group at site DSR3, whereas 'Other' hard corals and 'Other' soft corals were the most common taxonomic groups at site DSR5 (Table 5-5).

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

5.5.1 Descriptive Comparison

All benthic macroinvertebrate taxonomic groups recorded during the Marine Baseline Program were also recorded during Post-Development Survey Year 2 (with the exception of the Gastropods and Sea pens), with the Bivalves and Zoanthids added as additional taxonomic groups in Post-Development Survey Year 2.

For soft sediment (representing the majority of sites), the dominant taxonomic groups comprised cnidarians (Gorgonians, Hydroids, 'Other' hard corals, 'Other' soft corals, Sea whips, *Turbinaria* spp.), poriferans (Sponges (barrel), Sponges (branching), Sponges (fan), Sponges (tubular), Sponges (variable)), echinoderms (Crinoids, Sea cucumbers, Sea urchins), and a chordate (Ascidians (colonial)). The dominant taxonomic groups did not vary from the Marine Baseline Program to the Post-Development Surveys (Table 5-6). Within the ZoHI and ZoMI, the dominant taxonomic groups in Post-Development Survey Year 2 were very similar in community composition to the Marine Baseline Program, where 90% (ZoHI) and 80% (ZoMI) of the dominant taxonomic groups were shared (Table 5-6). A similar pattern was present in the ZoI Sth, with the major change in Post-Development Survey Year 2 being the presence of the new taxonomic groups (Bivalves and Zoanthids) that were not recorded in the Marine Baseline Program and Post-Development Survey Year 1 (Table 5-6). Ascidians (colonial), Sponges (cup), and Sponges (fan) became dominant in the Post-Development Survey Year 2 in the ZoI Nth compared to the Marine Baseline Program (Table 5-6). The Reference Sites had fewer dominant taxonomic groups compared to the Marine Baseline Program and the Post-Development Survey Year 1 (Table 5-6), which could represent natural variability or that fewer

Reference Sites were sampled in the soft sediment in Post-Development Survey Year 2 (two sites compared to four and three sites in the Marine Baseline Program and Post-Development Survey Year 1 respectively).

Table 5-6 Dominant Taxonomic Groups per Zone in the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Zone	Marine Baseline Program	Post-Development Survey Year 1	Post-Development Survey Year 2
ZoHI	Ascidians (colonial)	**Ascidians (colonial)**	**Ascidians (colonial)**
	Gorgonians	Crinoids	Crinoids
	Hydroids	**Hydroids**	**Hydroids**
	'Other' hard corals	**'Other' hard corals**	**'Other' hard corals**
	'Other' soft corals	**Sea whips**	**'Other' soft corals**
	Sea whips	Sponges (digitate)	**Sea whips**
	Sponges (branching)	**Sponges (fan)**	**Sponges (branching)**
	Sponges (fan)	**Sponges (variable)**	**Sponges (fan)**
	Sponges (variable)	**Turbinaria spp.**	**Sponges (variable)**
	Turbinaria spp.	**Unidentified**	**Turbinaria spp.**
ZoMI	Ascidians (colonial)	**Ascidians (colonial)**	**Ascidians (colonial)**
	Crinoids	Hydroids	**Crinoids**
	'Other' hard corals	**'Other' hard corals**	Hydroids
	'Other' soft corals	Sea cucumbers	**'Other' hard corals**
	Sea whips	**Sea whips**	**'Other' soft corals**
	Sponges (branching)	**Sponges (branching)**	**Sea whips**
	Sponges (fan)	**Sponges (fan)**	Sponges (digitate)
	Sponges (tubular)	**Sponges (variable)**	**Sponges (fan)**
	Sponges (variable)	***Turbinaria* spp.**	**Sponges (variable)**
	Turbinaria spp.	Unidentified	***Turbinaria* spp.**
ZoI Sth	Ascidians (colonial)	**Ascidians (colonial)**	**Ascidians (colonial)**
	Hydroids	**'Other' hard corals**	Bivalves
	'Other' hard corals	**'Other' soft corals**	**'Other' hard corals**
	'Other' soft corals	**Sea whips**	**'Other' soft corals**
	Sea whips	**Sponges (branching)**	**Sea whips**
	Sponges (barrel)	Sponges (digitate)	**Sponges (branching)**
	Sponges (branching)	**Sponges (fan)**	Sponges (cup)
	Sponges (fan)	**Sponges (variable)**	**Sponges (fan)**
	Sponges (variable)	***Turbinaria* spp.**	**Sponges (variable)**
	Turbinaria spp.	Unidentified	Zoanthids
ZoI Nth	Crinoids	Ascidians (colonial)	Ascidians (colonial)
	Gorgonians	**Crinoids**	Bivalves
	'Other' hard corals	**'Other' hard corals**	**'Other' hard corals**
	'Other' soft corals	**Sea whips**	**'Other' soft corals**
	Sea urchins	**Sponges (branching)**	**Sea whips**
	Sea whips	Sponges (cup)	**Sponges (branching)**

Zone	Marine Baseline Program	Post-Development Survey Year 1	Post-Development Survey Year 2
	Sponges (branching)	Sponges (fan)	Sponges (cup)
	Sponges (variable)	**Sponges (variable)**	Sponges (fan)
	Turbinaria spp.	***Turbinaria* spp.**	**Sponges (variable)**
	Unidentified	**Unidentified**	***Turbinaria* spp.**
Reference	Crinoids	Ascidians (colonial)	Ascidians (colonial)
	'Other' hard corals	Ascidians (solitary)	**Crinoids**
	Sea cucumbers	**Crinoids**	**'Other' hard corals**
	Sea urchins	**'Other' hard corals**	'Other' soft corals
	Sea whips	'Other' soft corals	**Sea cucumbers**
	Sponges (branching)	**Sea whips**	**Sea whips**
	Sponges (fan)	**Sponges (branching)**	***Turbinaria* spp.**
	Sponges (variable)	**Sponges (variable)**	
	Turbinaria spp.	***Turbinaria* spp.**	
	Unidentified	**Unidentified**	

Note: Taxonomic groups listed alphabetically; 'Dominant' refers to the top ten most abundant taxonomic groups based on average across sites in each zone; Bold font indicates dominant taxonomic groups that are shared with the Marine Baseline Program results; Bivalves and Zoanthids were added as categories in Post-Development Survey Year 2; The blank cells for Reference Sites in the Post-Development Survey Year 2 are because only seven taxonomic categories were present.

5.5.2 Statistical Comparison

5.5.2.1 Soft Sediment

The four-factor statistical design was non-significant after the three-factor analysis when the full dataset was used. When the data were partitioned into separate dredging and dredge spoil disposal datasets, the dredging dataset remained non-significant for the Survey × IvR term of interest after the two-factor analysis.

The dredge spoil disposal dataset was significant ($p<0.05$) for the Survey × IvR term of interest after the three-factor analysis (Table 5-7). Post-hoc tests on the Survey × IvR interaction term revealed significant differences at the Impact Sites between the Marine Baseline Program and Post-Development Survey Year 1 ($t=1.97$, $p<0.01$) and Post-Development Survey Year 2 ($t=1.73$, $p<0.01$) (Table 5-8).

Table 5-7 Summary Results for the Assessment of Change in Benthic Macroinvertebrates in Soft Sediment; Dredge Spoil Disposal Dataset

Source	df	SS	MS	Pseudo-F	P-value
Survey	2	7080.3	3540.1	1.9743	0.0182
IvR	1	11298	11298	6.3004	0.0001
Zone(IvR)	1	2063.2	2063.2	1.1506	0.342
Survey × IvR	2	7051	3525.5	1.9661	**0.0264**
Survey × Zone(IvR)	2	983.4	491.7	0.27421	0.9861
Res	36	64553	1793.1		
Total	44	92751			

Note: Bold font in P value column = significant difference for term of interest

Table 5-8 Post-hoc Tests for the Assessment of Change in Benthic Macroinvertebrates in Soft Sediment; Dredge Spoil Disposal Dataset (Survey × IvR)

Zone	df	t	P-value
Impact			
Marine Baseline Program, Post-Development Survey Year 1	11	1.9699	**0.0039**
Marine Baseline Program, Post-Development Survey Year 2	11	1.7287	**0.0077**
Post-Development Survey Year 1, Post-Development Survey Year 2	8	0.9242	0.5114
Reference			
Marine Baseline Program, Post-Development Survey Year 1	16	1.3121	0.0752
Marine Baseline Program, Post-Development Survey Year 2	13	1.5543	0.0555
Post-Development Survey Year 1, Post-Development Survey Year 2	13	1.4088	0.0833

Note: Bold font in P value column = significant difference for term of interest

In general, there was an increase in abundance in the top ten taxonomic groups from the Marine Baseline Program to Post-Development Survey Year 2 at the Dredge Spoil Disposal Impact Sites (Figure 5-4). At the Impact Sites, Ascidians (colonial), 'Other' hard corals, Sea whips, Sponges (fan), and Sponges (variable) were the most abundant taxonomic groups in Post-Development Survey Year 1 and Post-Development Survey Year 2, whereas only Sea whips were abundant in Post-Development Survey Year 2, and 'Other' hard corals and Ascidians (colonial) were abundant in Post-Development Survey Year 1 at the Reference Sites (Figure 5-4). The abundance of Ascidians (colonial) and 'Other' hard corals increased significantly from the Marine Baseline Program to Post-Development Survey Year 2 at the Impact Sites (Figure 5-4). In both cases, the abundance increased from Post-Development Survey Year 1 to Post-Development Survey Year 2 (Figure 5-4). No Sponges (variable) were recorded at the Reference Sites in Post-Development Survey Year 2, resulting in a significant difference in the abundance of Sponges (variable) from the Marine Baseline Program to Post-Development Survey Year 2 (Figure 5-4). The abundance of 'Other' hard corals increased significantly from the Marine Baseline Program to Post-Development Survey Year 1 at the Reference Sites, and then declined significantly to the Marine Baseline Program values during Post-Development Survey Year 2 (Figure 5-4).

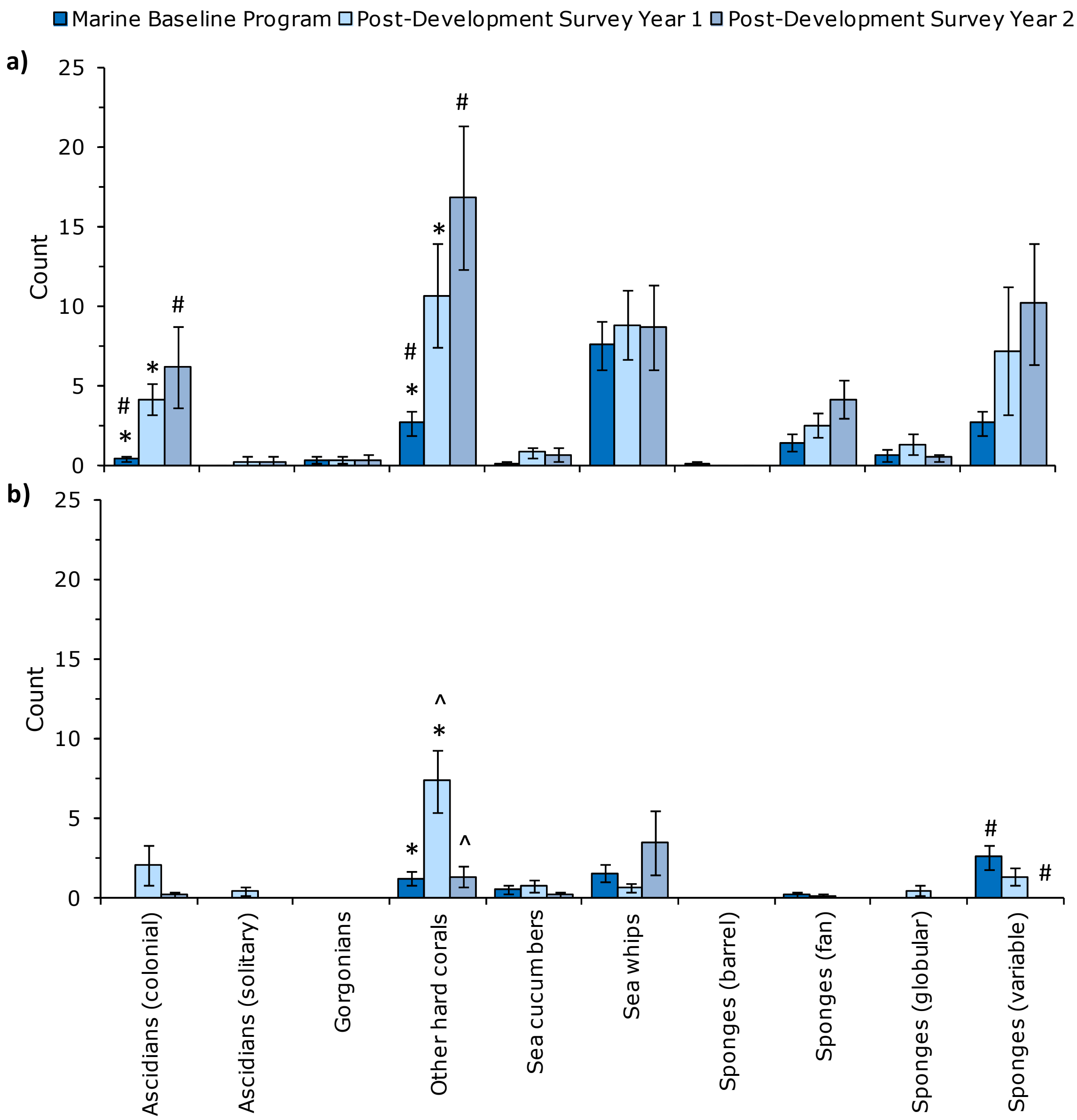


Figure 5-4 Mean Abundance of the Top Ten Benthic Macroinvertebrate Taxonomic Groups (± SE) Observed on Soft Sediment Substrates (dredge spoil disposal dataset) within a) Impact Sites and b) Reference Sites during the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Notes: a) Impact Sites; b) Reference Sites

*Significant differences at Survey × IvR: * = Marine Baseline Program, Post-Development Survey Year 1; # = Marine Baseline Program, Post-Development Survey Year 2; ^ = Post-Development Survey Year 1, Post-Development Survey Year 2.*

5.5.2.2 Limestone Pavement

The three-factor statistical design was significant (p<0.05) for the Survey × Zone term of interest after the two-factor analysis when the dredging dataset was used (Table 5-9). Post-hoc tests on the Survey × Zone interaction term revealed significant differences in the ZoHI between the Marine Baseline Program and Post–Development Survey Year 2 (t=1.42, p<0.05) (Table 5-10). There was no dredge spoil disposal dataset for limestone pavement.

Table 5-9 Summary Results for the Assessment of Change in Benthic Macroinvertebrates in Limestone; Dredging Dataset

Source	df	SS	MS	Pseudo-F	P-value
Survey	2	5998.5	2999.3	1.9969	0.0128
Zone	2	14871	7435.5	4.9505	0.0001
Survey × Zone	2	6034.6	3017.3	2.0089	**0.0113**
Res	25	37550	1502		
Total	31	62295			

Note: Bold font in P value column = significant difference for term of interest

Table 5-10 Post-hoc Tests for the Assessment of Change in Benthic Macroinvertebrates in Limestone; Dredging Dataset (Survey × Zone)

Zone	df	t	P-value
ZoHI			
Marine Baseline Program, Post-Development Survey Year 1	7	1.5785	0.0698
Marine Baseline Program, Post-Development Survey Year 2	7	1.4237	**0.0467**
Post-Development Survey Year 1, Post-Development Survey Year 2	4	0.69152	0.8972
ZoI South			
Marine Baseline Program, Post-Development Survey Year 1	9	1.3969	0.0665
Marine Baseline Program, Post-Development Survey Year 2	9	1.2374	0.1937
Post-Development Survey Year 1, Post-Development Survey Year 2	10	1.3432	0.0796

Note: Bold font in P value column = significant difference for term of interest

At the ZoI Sth, all ten taxonomic groups were abundant across all surveys, whereas in the ZoHI only 'Other' hard corals, and Sponges (variable) were abundant taxonomic groups across all surveys (Figure 5-5). In the ZoHI, no Sea cucumbers, Sea whips, Sponges (cup), Sponges (digitate), Sponges (fan), and *Turbinaria* spp. were recorded in the Post-Development Survey Year 1 and Post-Development Survey Year 2, but the reduction in abundance between the Marine Baseline Program and Post-Development Survey Year 2 was only significant for Sea cucumbers, with three individuals recorded in the Marine Baseline Program and no individuals recorded during Post-Development Survey Year 2 (Figure 5-5). In addition, there appeared to be a trend (although statistically non-significant) of a decline in the abundances of 'Other' hard corals and Sponges (variable) from the Marine Baseline Program to Post-Development Survey Year 2 (Figure 5-5). In the ZoI Sth, there was a significant increase in the abundance of 'Other' hard corals from the Marine Baseline Program to Post-Development Survey Year 1 (Figure 5-5). The abundance of 'Other' hard corals declined from Post-Development Survey Year 1 to Post-Development Survey Year 2, but the values were still higher than the Marine Baseline Program (Figure 5-5). A similar (although statistically non-significant) pattern to 'Other' hard corals was present in the Sea whips, Sponges (variable), and *Turbinaria* spp., whereas 'Other' soft corals only increased in abundance in Post-Development Survey Year 2 (Figure 5-5).

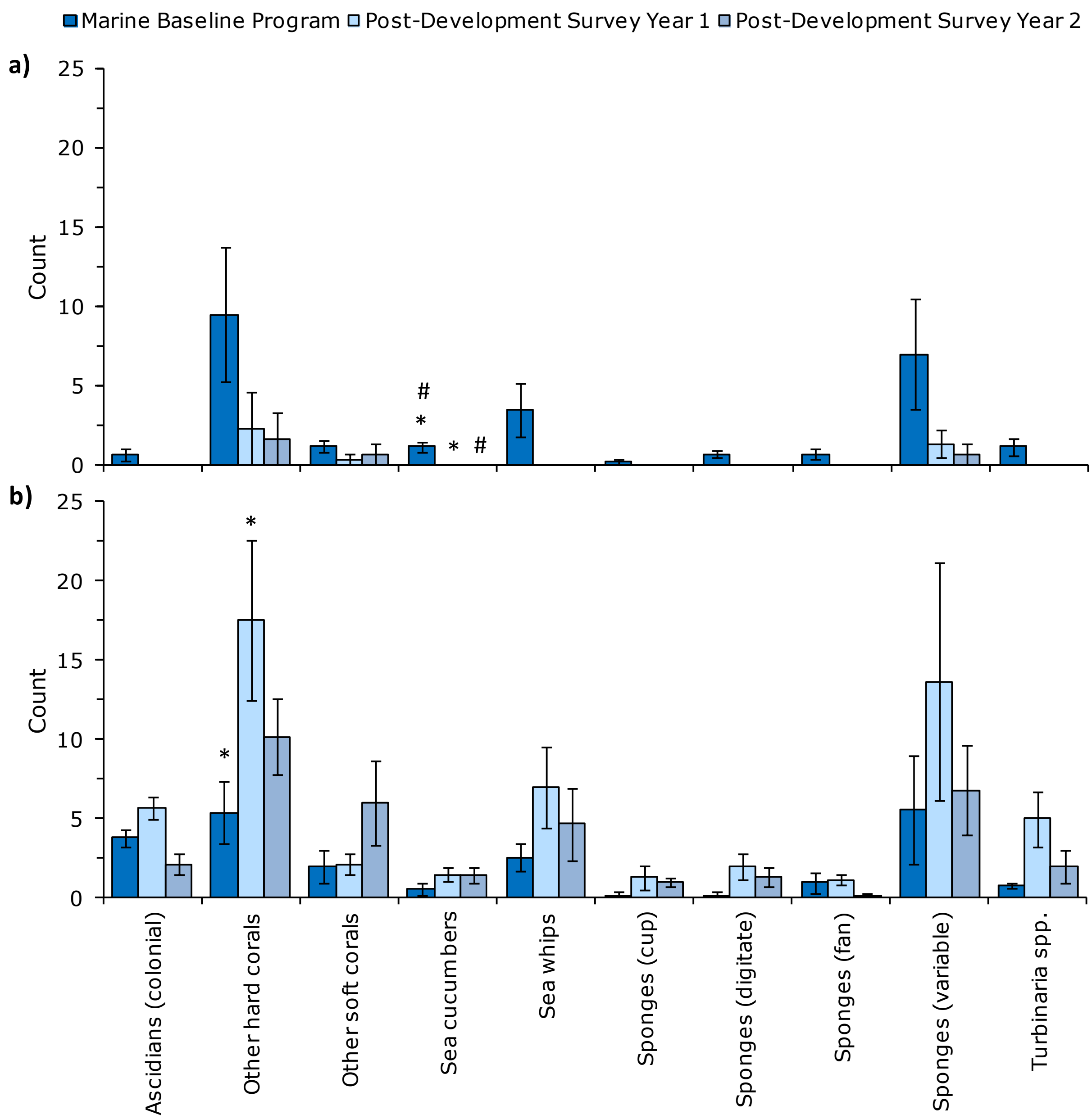


Figure 5-5 Mean Abundance of the Top Ten Benthic Macroinvertebrate Taxonomic Groups (± SE) Observed on Limestone (dredging data) within a) Zones of High Impact and b) Zones of Influence (South) during the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

*Notes: Significant differences at Survey × Zone: * = Marine Baseline Program, Post-Development Survey Year 1; # = Marine Baseline Program, Post-Development Survey Year 2*

5.6 Discussion

Caution should be used in interpreting the results of the benthic macroinvertebrate analyses due to caveats associated with the statistical design. A step-wise process was used, with each step progressively increasing the power of the test. This was undertaken to reduce the likelihood of Type II error, which is the most common statistical error in environmental impact assessments (Schmitt and Osenberg 1996). In adopting this step-wise approach, the probability of making a Type I error was intentionally increased. This was viewed as an acceptable risk, given the motivation to reduce the chance of Type II error, and in doing so, maximise the sensitivity of the test to detect environmental change. By adopting this step-wise approach, significant effort was made to detect potential environmental changes.

Benthic macroinvertebrates are potentially vulnerable to changing environmental conditions because they are often sessile, slow moving, or infaunal, and are therefore restricted in their ability to directly escape unfavourable conditions (Przeslawski *et al.* 2008). This is particularly pertinent when dealing with dredging activities that usually involve the physical removal of substrate and associated biota from the seabed and burial due to the deposition of the material (Newell *et al.* 1998). Dredging activities not only disturb sediments at the dredging and dredge spoil disposal sites, reducing visibility and smothering benthic organisms (Bak 1978), but also affect surrounding areas through vectors such as turbid plumes, sedimentation, and re-suspension (Erftemeijer *et al.* 2012).

In general, hard corals (including 'Other' hard corals, *Turbinaria* spp.) and soft corals (including 'Other' soft corals, Gorgonians, Sea whips), poriferans (Sponges (branching), Sponges (cup), Sponges (digitate), Sponges (fan), Sponges (variable)), and Ascidians (colonial) were the dominant taxa recorded in Post-Development Survey Year 2. Echinoderms (Crinoids, Sea cucumbers) were also dominant at certain sites. The substrates recorded at the 16 sites in Post-Development Survey Year 2 were the same as the substrates recorded in the Marine Baseline Program, where 12 sites were soft sediment and four sites were limestone. There were no clear observed differences in the dominant taxonomic groups between limestone and soft sediment, despite a higher number of taxonomic groups recorded on soft sediment. No significant difference in the benthic macroinvertebrate community structure was evident between the Marine Baseline Program and Post-Development Surveys when the soft sediment dredging dataset was used. However, the factors 'Survey' and 'IvR' (not terms of interest) were significant, suggesting that natural temporal variation was greater than any potential change associated with the dredging and dredge spoil disposal activities.

The soft sediment dredge spoil disposal dataset showed a significant difference at the Impact Sites between the Marine Baseline Program and Post-Development Survey Year 1 and Post-Development Survey Year 2. The abundance of Ascidians (colonial) and 'Other' hard corals increased significantly from the Marine Baseline Program to Post-Development Survey Year 2 at the Impact Sites, following a similar pattern to the significant increase in Post-Development Survey Year 1 from the Marine Baseline Program. The abundance of Sponges (fan) and Sponges (variable) at the Impact Sites also increased (non-significantly) from the Marine Baseline Program to Post-Development Survey Year 2 and Post-Development Survey Year 1. On the other hand, 'Other' hard corals in Post-Development Survey Year 2 at the Reference Sites were not significantly different from the Marine Baseline Program, but represented a significant decline from Post-Development Survey Year 1. No Sponges (variable) were recorded in Post-Development Survey Year 2 at the Reference Sites, resulting in a significant decline in abundance from the Marine Baseline Program to Post-Development Survey Year 2.

Sponges, ascidians, and corals have been reported to be adversely affected by turbidity and sedimentation (commonly associated with dredging and dredge spoil disposal activities) (Bakus 1968; Erftemeijer *et al.* 2012), but at the Impact Sites, the abundance of 'Other' hard corals and Ascidians (colonial) increased significantly after the Marine Baseline Program. While decreases in abundance in recently used spoil grounds have been reported in several studies (Hall 1994; Roberts *et al.* 1998), other studies have found no detriment or increases in abundances in some components of the benthic macroinvertebrate community following the disposal of dredged material (van Dolah *et al.* 1984; Harvey *et al.* 1998). In these cases, a decrease in the abundance of some taxa was offset by a major increase of more opportunistic taxa, most likely due to an increase in food supplied by the newly deposited material (Wilber and Clarke 1998). Moreover, rapid rates of recolonisation (one week to three months) of benthic macroinvertebrate communities inside dredge spoil grounds have been reported in previous studies after disturbance by dredge spoil disposal activities (Jones 1986; McCauley *et al.* 1977; Cruz-Motta and Collins 2004). As such, while change was evident at the Impact Sites in the soft sediment dredge spoil disposal dataset, in all cases the changes have resulted in an increased abundance of many of the taxonomic groups that were present at the Impact Sites in the Marine Baseline Program.

Limestone substrate was not recorded in the Dredge Spoil Disposal Ground but the limestone dredging dataset showed a significant difference in the ZoHI between the Marine Baseline Program and Post-Development Survey Year 2. Within the ZoHI, no Sea cucumbers were recorded in Post-Development Survey Year 2 and Post-Development Survey Year 1. As such, the only significant difference in the univariate tests was a decline in the abundance of Sea cucumbers from the Marine Baseline Program to Post-Development Survey Year 2 and Post-Development Survey Year 1. 'Other' hard corals and Sponges (variable) declined (non-significantly) in abundance after the Marine Baseline Program, and no Ascidians (colonial), Sea cucumbers, Sea whips, Sponges (cup), Sponges (digitate), Sponges (fan), and *Turbinaria* spp. were recorded in Post-Development Survey Year 2 and Post-Development Survey Year 1. In the ZoI Sth, all taxonomic groups (except Ascidians (colonial) and Sponges (fan)) increased in abundance in Post-Development Survey Year 2 compared to the Marine Baseline Program, and a significant increase in abundance from the Marine Baseline Program to Post-Development Survey Year 1 was recorded for 'Other' hard corals. The Ascidians (colonial) and Sponges (fan) declined (non-significantly) in abundance from the Marine Baseline Program to Post-Development Survey Year 2 in the ZoI Sth.

While both the ZoHI and ZoI Sth were considered to be 'influenced' by the dredging and dredge spoil disposal activities, the degree of influence between the two zones differed. Within the ZoHI there was a predicted loss of benthic habitat, whereas in the ZoI Sth there was a predicted change in water quality but no alteration of the benthic habitat. While no Reference Sites were included in the statistical analyses, the significant change in the ZoHI between the Marine Baseline Program and Post-Development Survey Year 2 and the lack of a significant change in the ZoI Sth, suggests that the observed changes in the benthic macroinvertebrate community structure for the limestone dredging dataset were potentially due to the dredging activities. However, the significant change within the ZoHI appears to be largely driven by a reduction in the number of Sea cucumbers in the Post-Development Surveys (no individuals recorded) from the Marine Baseline Program (three individuals recorded).

The assessment of change in benthic macroinvertebrate assemblages between the Marine Baseline Program and the Post-Development Surveys for the limestone substrate was based on a comparison of the ZoHI and the ZoI Sth, both of which were potential impact zones and considered to be influenced by the dredging and dredge spoil disposal activities. As the results are based on pseudo Reference Sites, it is not possible to determine with certainty whether the observed changes to benthic macroinvertebrate assemblages for the limestone substrate habitat were due to natural variation, or to dredging and dredge spoil disposal activities.

As such, there is evidence to suggest that the dredging and dredge spoil disposal activities caused changes in the benthic macroinvertebrate communities at the Impact Sites for the soft sediment dredge spoil disposal dataset, and in the ZoHI for the limestone dredging dataset.

6.0 Mangroves

6.1 Introduction

Six species of mangrove are found in the Montebello/Barrow Islands region, including the Grey Mangrove (*Avicennia marina*), Ribbed-fruit Orange Mangrove (*Bruguiera exaristata)*, Yellow-leaf Spurred Mangrove (*Ceriops tagal*), Red Mangrove (*Rhizophora stylosa*), Club Mangrove (*Aegialitis annulata*), and the River Mangrove (*Aegiceras corniculatum*) (DEC 2007). The majority of mangrove forests in the area occur in the Montebello Islands (DEC 2007).

The Grey Mangrove (*Avicennia marina*) is the only species found around Barrow Island. *A. marina* grows as a narrow fringe in the sheltered embayments on the southern and eastern coasts from Bandicoot Bay to Shark Point, with small communities further north at Mattress Point, Ant Point, and Square Bay. In the Barrow Island region, flowering often occurs between December and January, while propagules mature mostly in March (Duke 2006). The pneumatophores of *A. marina* are often tall and slender and can reach heights of 30 cm. It grows in both soft sediments and on rock, as well as where sediment accumulates in the intertidal zone (Kellogg Joint Venture Gorgon 2008).

There are no stands of *A. marina* in the immediate vicinity of the Gorgon Gas Development facilities; the closest stands are located at the Donald River mouth, approximately 5 km north of Town Point (Chevron Australia 2005, 2008). There are no mangroves within the Zones of High Impact (ZoHI) and Zones of Moderate Impact (ZoMI) on the east coast of Barrow Island, i.e. there is no mangrove cover relevant to the construction of the MOF or LNG Jetty. Similarly, there are no mangroves within the area at risk of Material or Serious Environmental Harm due to the construction of the MOF or LNG Jetty.

During the Marine Baseline Program, natural spatial variability was observed from both quantitative (light infiltration, pneumatophore density, leaf pathology) and qualitative (visual health score) assessments of mangrove communities on the east coast of Barrow Island, with variability generally observed at the quadrat, tree, transect, and site scales. This indicates that there is a naturally high spatial variability in mangrove condition on Barrow Island. This variability was observed across sites in the Zone of Influence (ZoI) and at Reference Sites.

6.2 Scope

This Section is in two parts. The first part presents the dominant species and describes the characteristics of mangroves recorded during the Post-Development Survey Year 2: 2012–2013:

- within representative areas in the Zones of Influence, associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal activities required for the MOF and LNG Jetty
- at Reference Sites not at risk of Material or Serious Environmental Harm due to the construction of the MOF and LNG Jetty.

The second part compares the Post-Development Surveys and the Marine Baseline Program survey to determine if changes have occurred as per Condition 24.2 of Statement No. 800 and Condition 17.2 of EPBC Reference: 2003/1294 and 2008/4178.

As previously discussed (Section 2.1.5), no specific results or comparisons are made for the area in the vicinity of the marine upgrade of the existing WAPET Landing.

6.3 Methods

6.3.1 Site Locations

Eight mangrove survey sites were established during the Marine Baseline Program along the eastern and southern coasts of Barrow Island—at Square Bay, Mattress Bay, Perentie II Bay, Stokes Bay, Bandicoot Bay, and Pelican Island (Table 6-1 and Figure 6-1). Six of these sites were located within the ZoI (Mattress Bay North and South, Perentie II North and South, Square Bay, and Stokes Bay), and two Reference Sites (Bandicoot Bay and Pelican Island) were located outside the ZoI. The same eight survey sites were used during Post-Development Survey Year 2.

Table 6-1 Post-Development Survey Sites for Mangroves

Location	Site Name (Code)	Easting	Northing	Latitude	Longitude
		(UTM50, GDA94)		(GDA94)	
Zone of Influence	Square Bay (SQ)	339638	7710880	20° 41.681' S	115° 27.615' E
	Mattress Bay North (MTN)	340986	7706145	20° 44.254' S	115° 28.366' E
	Mattress Bay South (MTS)	341167	7705389	20° 44.665' S	115° 28.466' E
	Perentie II Bay North (P2N)	335121	7691780	20° 52.009' S	115° 24.906' E
	Perentie II Bay South (P2S)	334290	7691118	20° 52.363' S	115° 24.423' E
	Stokes Bay (ST)	332713	7689488	20° 53.238' S	115° 23.504' E
Reference Sites	Bandicoot Bay (BB)	326314	7691064	20° 52.348' S	115° 19.823' E
	Pelican Island (PI)	326624	7691053	20° 52.356' S	115° 20.002' E

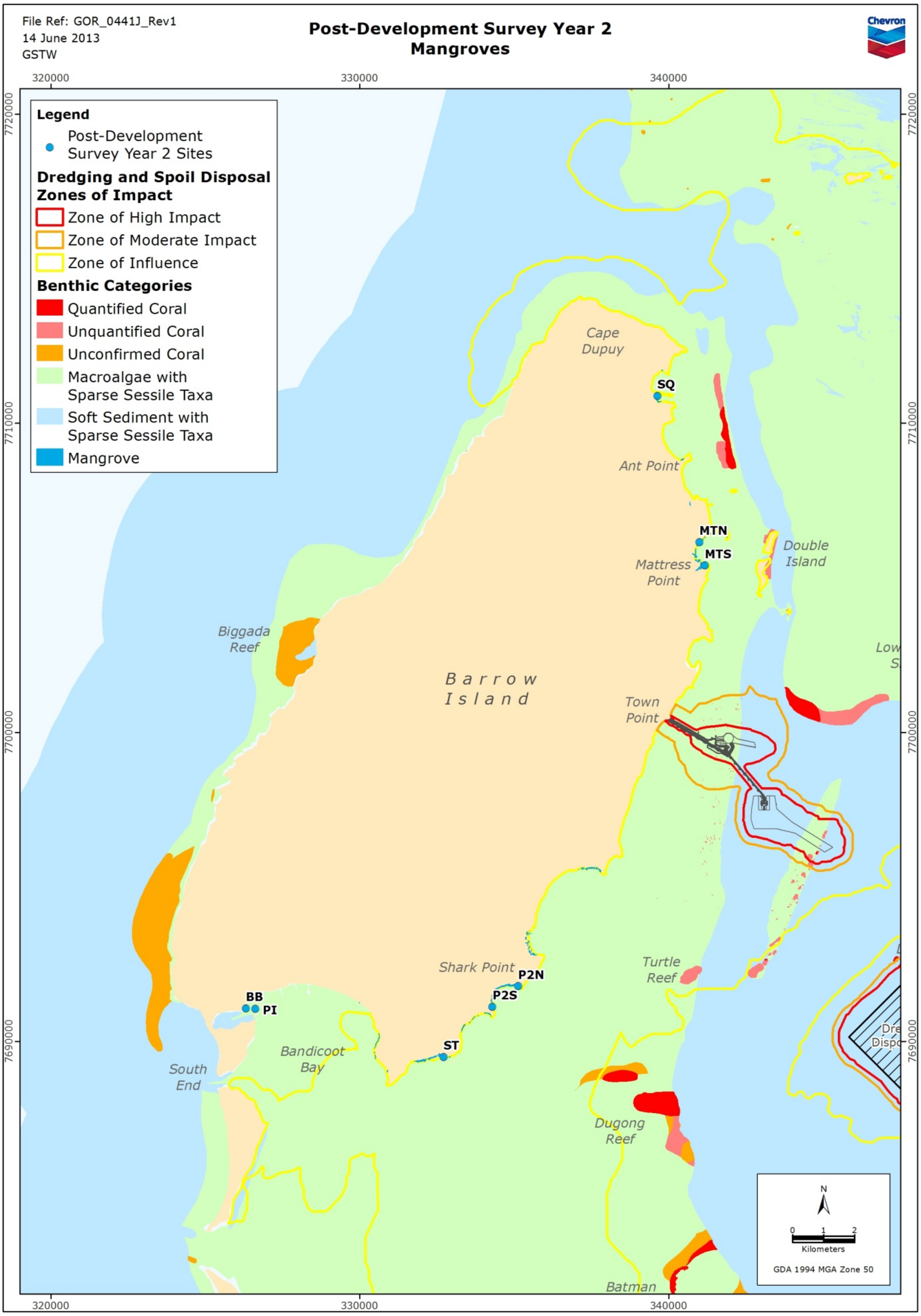


Figure 6-1 Post-Development Survey Year 2 Sites for Mangroves

6.3.2 Timing and Frequency of Sampling

The Post-Development mangrove survey was undertaken between 18 and 23 February 2013.

6.3.3 Survey Method

6.3.3.1 General Site Assessment

During the Marine Baseline Program survey, at each site three permanent one-metre wide belt transects were installed perpendicular to the shoreline and intersecting the mangrove community; the same transects were surveyed during Post-Development Survey Year 2.

The following attributes were recorded along each transect:

- species composition
- total canopy cover (m) – length of mangrove canopy intercepting the transect
- presence/absence of seedlings
- total number of (adult) trees

6.3.3.2 Canopy Density

Five mangrove trees were randomly selected at each site and a digital light illuminance meter (Yokogawa 510-01 LUX Meter), which measures light at a single point through a translucent silicon dome of approximately 25 mm, was used to record incident light measurements from 40 randomly selected points beneath the canopy of each tree. Ten additional light measurements were taken in direct unobstructed sunlight directly adjacent to each sample tree; five before and five after the measurements were recorded under each tree. All light measurements were recorded at a fixed distance of 30 cm above the sediment surface. Light readings were taken between 10 am and 2 pm, during clear sky conditions whenever possible. Note, weather and tide conditions during Post-Development Survey Year 2 resulted in some light readings being measured during times when high humidity and high cloud meant that ambient light levels were low, even between 10 am and 2 pm.

The ambient light readings relative to each sample tree were used as a direct comparison to below-canopy readings to determine light infiltration of each sample tree. Canopy density was inferred through the proportion of incident light intercepted by the canopy. This was done by calculating the ratio of mean below-canopy illuminance (n=40) to mean ambient illuminance (n=10) for each tree as:

$$Canopy\ density\ per\ tree = \frac{Mean\ below\ Canopy\ readings\ [lx]}{Mean\ ambient\ reading\ [lx]}$$

6.3.3.3 Pneumatophore Density

Pneumatophore density was measured at five random sample points along each of three transects per site using a 1 m^2 quadrat placed on the ground and centred on the transect. Each quadrat was photographed and the total number of exposed pneumatophores counted in situ. Digital photography was used for desk-based counts of pneumatophores using Adobe Photoshop Elements v.7 where required.

6.3.3.4 Leaf Pathology

Leaf pathology was assessed for five randomly selected trees within each site (the same trees selected for the quantitative light measurements). A count of pathology indicators was taken from a subsample of 100 randomly selected leaves per sample tree. The subsample of leaves was spread throughout a four-sectioned stratified canopy on each sample tree, which included coast-facing upper half, coast-facing lower half, dune-facing upper half, and dune-facing lower half. The leaf pathogen indicators assessed on each tree were leaf yellowing/discolouration, mould, galls, scaling, and spotting. A score out of 100 was determined for each indicator for each tree based on the indicator's presence (score of 1) or absence (score of zero) on each leaf, which were then summed to provide a total out of 100. A score out of 100 was also determined for the number of leaves that displayed none of the five indicators, i.e. the number of completely healthy leaves.

6.3.3.5 Qualitative Assessment of Mangrove Tree Health

At each site, qualitative visual health assessments were recorded for ten adult mangrove trees. Five of the trees corresponded with those selected for the leaf pathology assessment and five additional random trees were selected. Each tree was visually assessed and allocated a health score on six individual parameters based on the modified health score system developed by Eldridge *et al.* (1993) and Astron Environmental Services (2008) (Table 6-2). Based on the individual parameter scores, a total health score was derived to provide an overall estimate of mangrove health. The intent of the qualitative assessment was to complement and assist with the interpretation of the quantitative assessment.

Table 6-2 Qualitative Mangrove Health Scoring System

Damaged Leaves	
Total % Cover of Discoloured (Yellow) Leaves	**Health Score**
100 – 90%	0
90 – 70%	1
70 – 50%	2
50 – 30%	3
30 – 10%	4
10 – 1%	5
<1%	6
Defoliated Branches	
Total % Cover of Completely Defoliated Branches	**Health Score**
100 – 90%	0
90 – 70%	1
70 – 50%	2
50 – 30%	3
30 – 10%	4
10 – 1%	5
<1%	6
New Foliage	
Total % Cover of New Leaves	**Health Score**
100 – 90%	6
90 – 70%	5
70 – 50%	4
50 – 30%	3
30 – 10%	2
10 – 1%	1
<1%	0

Canopy Cover/Density	
Total % Canopy Cover	**Health Score**
100 – 90%	6
90 – 70%	5
70 – 50%	4
50 – 30%	3
30 – 10%	2
10 – 1%	1
<1%	0
Reproductive Parts (flowers/fruits)	
Crypto-viviparous fruit (rounded)/flowers	**Health Score**
Absent	0
Present	1
Lateral Roots	
Exposed lateral roots from tree base	**Health Score**
Absent (Covered)	1
Present (Exposed)	0
TOTAL HEALTH SCORE (Totalled from scores above)	
Qualitative Description	**Health Score**
Heavily Defoliated/Dead	≤6
Degraded	7–10
Poor	11–14
Moderate	15–18
Good	19–22
Excellent	23–26

6.3.4 Statistical Approach for Comparison against Baseline

A range of statistical analyses were employed, which included univariate and multivariate tests and parametric and non-parametric methods. Univariate analyses were conducted for transect-scale measurements of adult mangrove abundance and percentage cover of mangroves.

Analyses were performed using two-way ANOVA where data were parametric or could be transformed to be such. Where data were neither parametric nor able to be suitably transformed, PERMANOVA (Anderson 2001a) was used. Analyses aimed to determine whether there were significant differences between sites, survey dates, or whether there was a significant interaction between the two factors. Transect was also included as a factor in the model (nested within survey sites) for transect-scale measurements.

ANOVAs were undertaken using R statistical software (R Development Core Team 2012) with significance set at $p<0.05$. If one of the factors of interest (survey date or site) were found to be significant, multiple comparisons of the significant factor was performed using Tukey's Honestly Significant Difference (TukeyHSD), with confidence intervals set at 95%. PERMANOVA was conducted using PRIMER version 6.1.13 (Clarke and Gorley 2006) with Euclidean distance chosen as the distance measure.

A three-factor statistical design was used to test whether the dredging and dredge spoil disposal activities affected the abundance and percentage cover of mangroves (Figure 6-2).

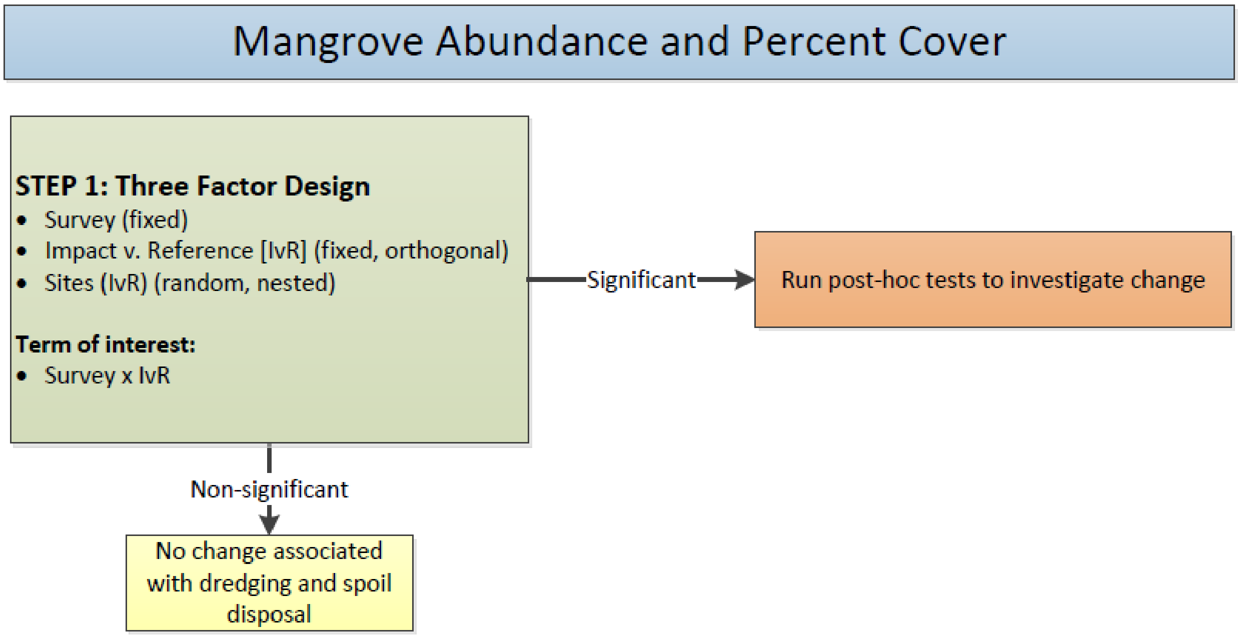


Figure 6-2 Step-wise Approach for the Assessment of Change in Mangrove Abundance and Percentage Cover

6.4 Results of Post-Development Survey Year 2

6.4.1 Description of Mangroves at Representative Areas of the Zone of Influence Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

A summary of the general site assessments, including dominant species and presence of seedlings for sites within the ZoI is provided in Table 6-3. From the qualitative health assessments in the ZoI, four sites recorded a ‘good’ mean health score, and the remaining two sites recorded a ‘moderate’ mean health score.

There was considerable variability in pneumatophore densities between sites and between transects at the same site (Figure 6-3). The highest pneumatophore densities were recorded at MTS (229.9 ± 65.5 pneumatophores/m^2) and the second highest counts were recorded at MTN (145.1 ± 37.8 pneumatophores/m^2). The lowest counts were recorded at P2S (27.9 ± 17.4 pneumatophores/m^2) and ST (38.9 ± 30.4 pneumatophores/m^2).

The site-averaged counts for each of the six leaf pathology indicators are presented in Figure 6-4. Leaf spots were the most prominent health indicator at all sites, affecting more than double the number of leaves compared to the other indicators. The highest incidence of leaf spots was recorded at SQ (mean of 80.4 affected leaves per 100 leaf sample) and the lowest at ST (mean of 49.0/100 leaf sample). The mean number of yellowing leaves was highest at SQ (5.8/100 leaf sample) and lowest at P2N (1.4/100 leaf sample). Mean leaf gall numbers were highest at MTN (17.8/100 leaf sample) and lowest at ST (3.6/100 leaf sample). The mean count of mould affected leaves varied from 0/100 leaf sample at P2N, SQ, and ST to 0.6/100 leaf sample at P2S. Scaling was highest at SQ (6.0/100 leaf sample) and lowest at ST (0.0/100 leaf sample). There were very few leaves with multiple pathology indicators, and most sites supported a substantial percentage of completely healthy leaves (20 to 40/100 leaf sample).

Table 6-3 General Site Assessment for Mangroves within the Zone of Influence

Site	Description
Square Bay	SB is a small, sandy bay and the limited size resulted in transects with varying aspects. Transect 1 and Transect 2 had south-south-east aspects, whereas Transect 3 had a northerly aspect. All mangroves were located on the beach/dune system with an understorey dominated by *Spinifex longifolius*. The mangroves at SB were in generally good condition. Pneumatophores at Transect 2 and Transect 3 were covered. While the community appeared to be expanding seaward with numerous seedlings across the whole site and within the drainage line near Transect 3, no seedlings were recorded along the three transects. At Transect 1 there were algae on pneumatophores and a large moss mat.
Mattress Bay North	MBN is a wide, open bay with expansive rocky tidal flats with a south-easterly orientation. A small dune system is located approximately 10 m behind the medium-sized mangrove community strip with mangroves at a height of approximately 2 m. The dominant understorey species was *S. longifolius*, which occurred on the primary dune and beyond. The mangrove community appeared to be healthy with little to no defoliation evident. Seedlings were noted across the site although none were recorded along the three transects.
Mattress Bay South	The mangrove community at MBS was located on a small tidal inlet with a sediment foreshore and a northerly aspect. The understorey on the tidal flats was a halophytic complex dominated by *Tecticornia halocnemoides* and *T. indica*. The small primary dune system behind the mangroves was dominated by *Triodia pungens*. The mangroves at MBS overall appeared healthy in Post-Development Survey Year 2 although some dieback was observed along Transect 3.
Perentie II Bay North	P2N is a small beach with expansive rocky tidal flats. The mangrove community had a southerly aspect with a halophytic complex understorey of *Tecticornia* spp. with *S. longifolius* dominant on the primary dune system. Seedlings were evident across the site, with two recorded in each of Transects 1and 2 and one seedling in Transect 3.
Perentie II Bay South	The tidal flats of P2S are predominantly extensive rocky outcrops with scattered oyster beds; the majority of the sparse mangroves were on the rocky outcrop with an east-north-east aspect. The dominant understorey was *Tecticornia* spp. with *S. longifolius*. The site appeared generally healthy with seedlings observed in Transects 1(two seedlings) and 2 (one seedling).
Stokes Bay	The three transects situated at ST had a generally southerly aspect. The tidal flats were predominantly rocky outcrops with a small narrow strip of mangrove community adjacent to the primary dune system. The understorey was predominantly a halophytic complex dominated by *T. halocnemoides* and *T. indica* on the tidal flats with *S. longifolius* on the primary dune system. The mangrove community at ST appeared healthy overall with some defoliation observed on the dune side of Transect 2. No seedlings were recorded across the three transects.

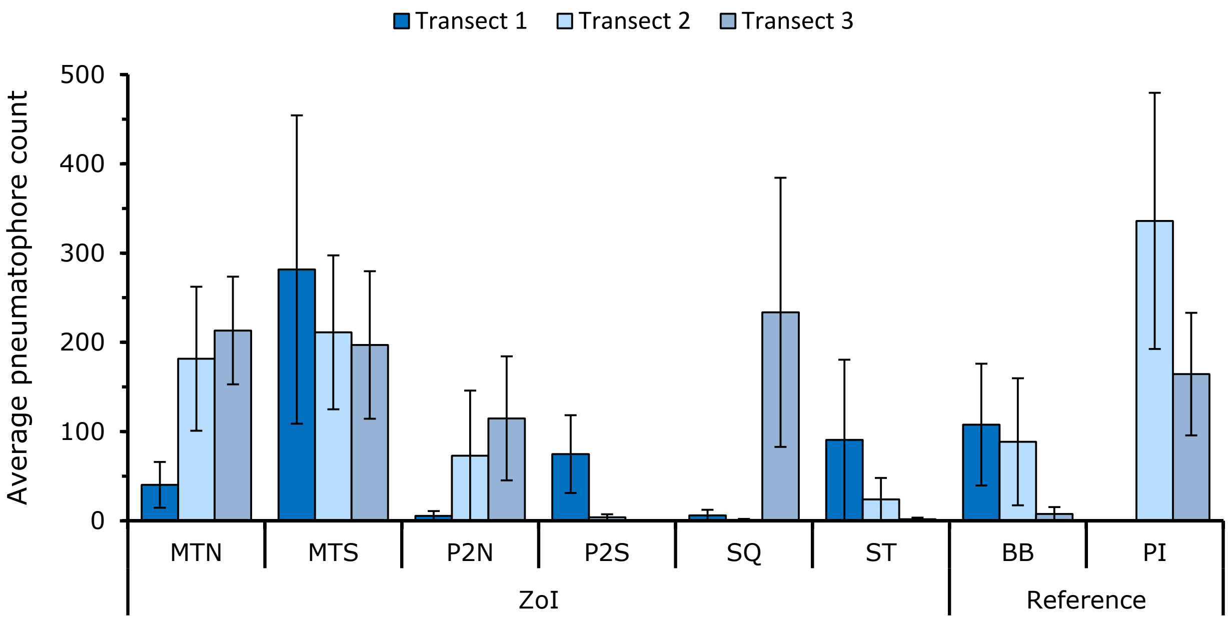


Figure 6-3 Mean (± SE) Pneumatophore Density Recorded on each Transect at each Post-Development Survey Year 2 Site

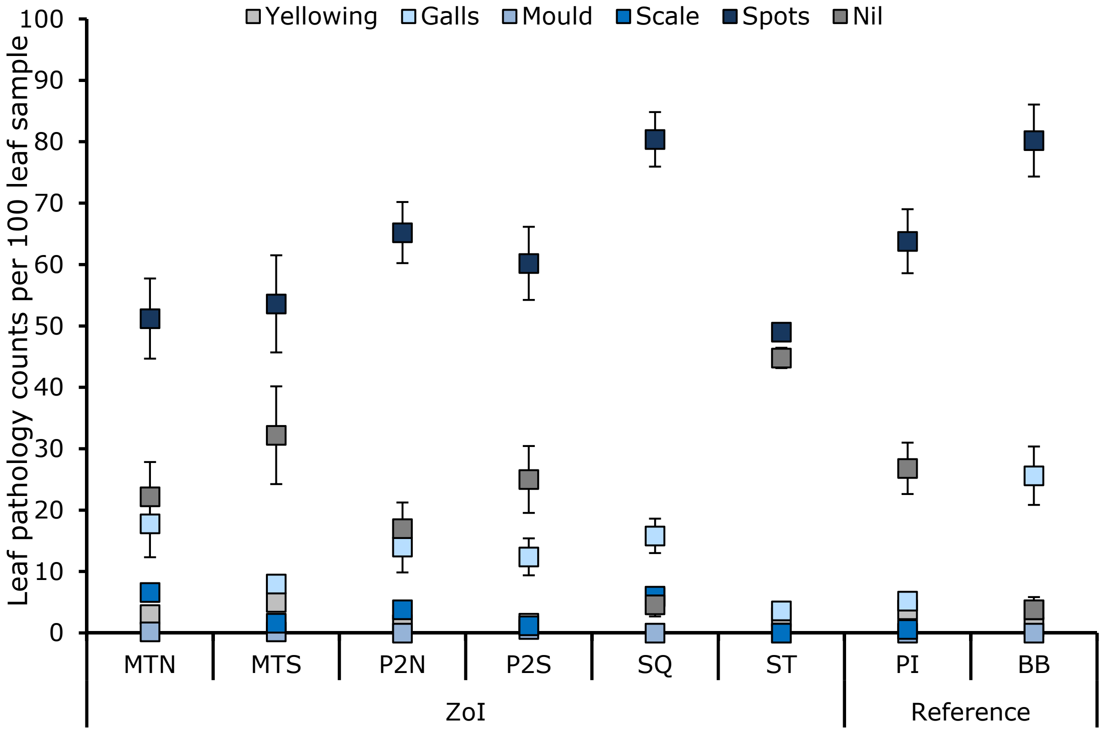


Figure 6-4 Mean (± SE) Leaf Pathology Counts per 100 Leaf Sample for each Post-Development Survey Year 2 Site

6.4.2 Description of Mangroves at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction of the MOF or LNG Jetty

A summary of the general site assessments, including dominant species and presence of seedlings for Reference Sites is provided in Table 6-4. From the qualitative health assessments, a 'good' mean health score was recorded at Bandicoot Bay (BB) and a 'moderate' mean health score at Pelican Island (PI).

Variation in canopy density was recorded at the Reference Sites, ranging from 79.6% at PI to 84.0% at BB.

There was considerable variability in pneumatophore densities among sites and among transects within the same site (Figure 6-3). The highest pneumatophore transect density was recorded at PI, with a mean of 336 pneumatophores/m^2 recorded on Transect 2. The lowest density was also recorded at PI on Transect 1 (0/m^2), demonstrating the high variability within a site.

The site-averaged counts for each of the six leaf pathology indicators were calculated (Figure 6-4). Leaf spotting was the most prevalent leaf pathology indicator at all sites, with the incidence varying between a mean of 63.8/100 leaf sample at PI to a mean of 80.2/100 leaf sample at BB. The mean number of yellowing leaves and scale was similar (and low) at both PI and BB. No mould was observed at PI or BB. Mean leaf gall numbers varied between the two sites, with PI recording 5.2/100 leaf sample, while BB recorded 25.6/100 leaf sample. The mean number of leaves per 100 leaf sample with 'nil' records also varied between the two sites, with 3.8/100 leaf sample at BB and 26.8/100 leaf sample at PI.

Table 6-4 General Site Assessment for Mangroves at Reference Sites

Site	Description
Bandicoot Bay	The small mangrove community at BB was located on the beach adjacent to the primary dune system and had a southeasterly aspect. The understory at BB comprises a halophytic complex dominated by *T. halocnemoides* and *T. indica* on the tidal flats and *S. longifolius* on the primary dune. Mangroves located within the tidal zone appeared to be in better condition than those near the primary dune. Large amounts of leaf litter were noted on the landward side of the mangrove community. No seedlings were observed along the three transects.
Pelican Island	The mangrove community of PI was located in the middle of the western shoreline where a small tidal inlet appeared to split the island in two. The shape of the island resulted in all three transects with a slightly different aspect: Transect 1 had a west-north-west aspect; Transect 2 had a southeast aspect; and Transect 3 had a south-south-east aspect. The mangrove community on all transects was located on tidal rocky outcrops with an understorey dominated by *Tecticornia* spp. Across the site, the mangrove community appears to be in good condition although some defoliation was observed along Transects 2 and 3. No seedlings were observed across the site.

6.5 Comparison between the Post-Development Surveys and the Marine Baseline Environmental State

6.5.1 Descriptive Comparison

6.5.1.1 Canopy Density

Mean canopy density across the six sites within the ZoI declined slightly in Post-Development Survey Year 2 compared to Post-Development Survey Year 1, but remained higher than that recorded in the Marine Baseline Program (Figure 6-5). Within-site declines in mean canopy density in Post-Development Survey Year 2 relative to Post-Development Survey Year 1 were observed at four of the six ZoI sites, with the largest decline observed at MTN, while mean canopy density at ST increased from 77.5% in Post-Development Survey Year 1 to 83.8% in Post-Development Survey Year 2. Mean canopy density at MTN, MTS, and P2N in Post-Development Survey Year 2 declined below levels recorded in the Marine Baseline Program. Mean within-site canopy density increased slightly between Post-Development Survey Year 1 and Post-Development Survey Year 2 at both the Reference Sites, leading to an overall increase in the Reference Site mean relative to Post-Development Survey Year 1 and Post-Development Survey Year 2. However, mean canopy density at PI remained lower than that recorded in the Marine Baseline Program. Although there were significant differences between sites, there was no significant interaction between sites and survey dates in the ANOVA analysis (Table 6-5). Further analysis examining contrasts between the Marine Baseline Program, Post-Development Survey Year 1 and Post-Development Survey Year 2 and ZoI and Reference Sites with PerMANOVA revealed similar results; there was a significant difference between survey sites, but not between Reference Sites and ZoI Sites, and no significant interaction between survey date and site type (Table 6-5).

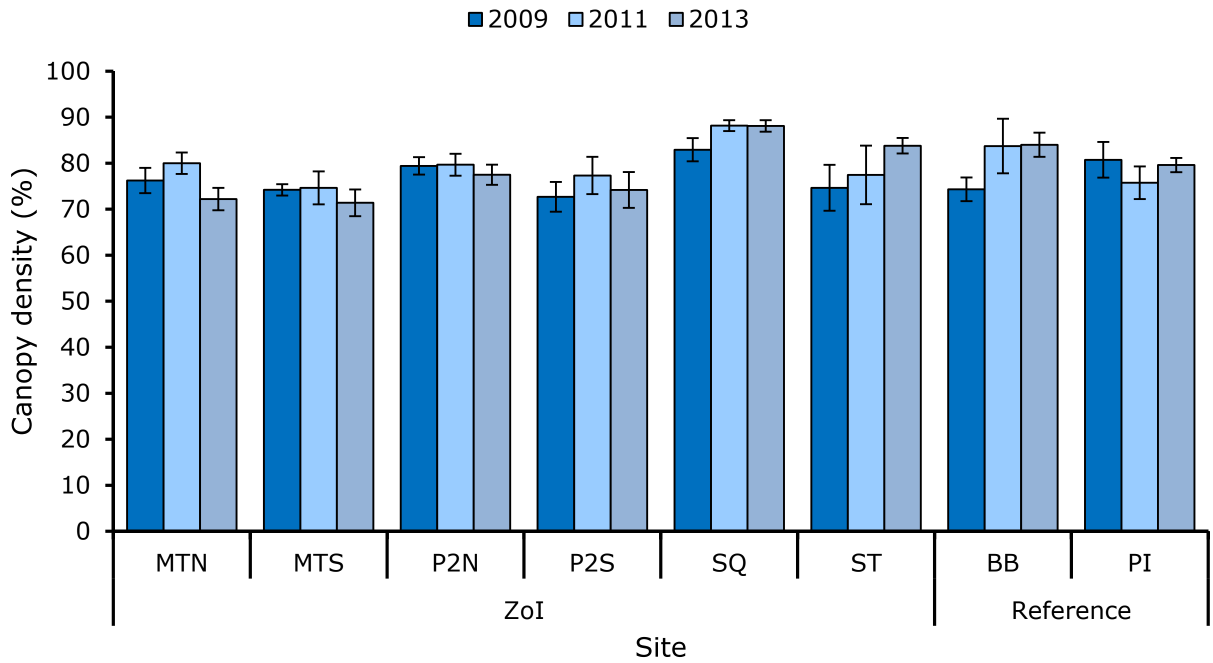


Figure 6-5 Mean (± SE) Canopy Density (%) at each Site during the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2

Table 6-5 Summary of PERMANOVA Analysis of Canopy Density Readings using Contrasts of Zone of Influence versus Reference Sites and Marine Baseline Program versus Post-Development Survey Year 1 and Post-Development Survey Year 2

Factor	df	SS	MS	Pseudo-F	P (PERMANOVA)	Unique Permutations	P (Monte Carlo)
Survey Date	2	154.18	77.09	1.48	0.2374	9951	
Contrast (2009) v (2011,2013)	1	142.93	142.93	2.79	0.0959	9818	
Site	7	1696.70	242.38	4.43	**0.0022**	9934	
Contrast (ZoI sites) v (Reference Sites)	1	61.56	61.56	0.98	0.3483	252	0.3395
Tree(Site)	32	1751.40	54.73	1.05	0.4199	9921	
Tree(Contrast (ZoI sites) v (Reference Sites))	8	497.66	62.21	0.95	0.4829	9946	

Factor	df	SS	MS	Pseudo-F	P (PERMANOVA)	Unique Permutations	P (Monte Carlo)
Survey Date × Site	14	782.58	55.90	1.07	0.3957	9934	
Contrast (2009) v (2011,2013) × Site	7	439.86	62.84	1.23	0.3035	9935	
Survey Date × Contrast (ZoI sites) v (Reference sites)	2	59.15	29.58	0.45	0.6382	9935	
Residuals	64	3329.60	52.02				
Total	119	7714.40					

Notes: Significant df = degrees of freedom; SS = sum of squares; MS = mean of squares; Bold type = statistically significant difference

6.5.1.2 Pneumatophore Density

Total pneumatophore counts increased substantially between Post-Development Survey Year 1 and Post-Development Survey Year 2 at ZoI sites MTN and MTS (Table 6-6), with increases in mean pneumatophore density observed across all but one transect at these sites (Figure 6-6). Site MTS recorded the largest total pneumatophore count for any site in Post-Development Survey Year 2 relative to Post-Development Survey Year 1. In contrast, total pneumatophore counts at the other four ZoI sites decreased between Post-Development Survey Year 1 and Post-Development Survey Year 2, with the largest decrease occurring at site ST (Table 6-6). Since the Marine Baseline Program, total and mean pneumatophore counts have decreased at the majority of sites within the ZoI, with the only exceptions being MTN and MTS. Decreases in mean pneumatophore density were observed in all but two transects across P2N, P2S, SQ, and ST from Post-Development Survey Year 1 to Post-Development Survey Year 2 (Figure 6-6c, d, e, and f). Site SQ was more variable than other sites between the Marine Baseline Program and Post-Development Survey Year 2 in that mean pneumatophore density decreased dramatically in Transect 1, increased dramatically in Transect 3, while remaining relatively stable in Transect 2.

At the two Reference Sites, total pneumatophore counts increased between Post-Development Survey Year 1 and Post-Development Survey Year 2, but decreased at BB between the Marine Baseline Program and Post-Development Survey Year 2; these declines were the smallest of all recorded between the Marine Baseline Program and Post-Development Survey Year 2 (Table 6-6). A small increase in total and mean pneumatophore counts between the Marine Baseline Program and Post-Development Survey Year 2 was recorded on PI. Mean pneumatophore density increased between the Marine Baseline Program and Post-Development Survey Year 2 across Transect 1 at BB, but declined across Transects 2 and 3 over the same period (Figure 6-6). Conversely, mean pneumatophore density across Transect 1 on PI declined in Post-Development Survey Year 2 relative to the Marine Baseline Program, but increased across Transects 2 and 3 (Figure 6-6h).

Table 6-6 Pneumatophore Density at Mangrove Survey Sites during the Marine Baseline Program, Post-Development Survey Year 1 and Post-Development Survey Year 2

Site	Marine Baseline Program (2009)		Post-Development Survey Year 1 (2011)		Post-Development Survey Year 2 (2013)		Change in Total		Change in Mean	
	Total	Mean/ Quadrat (SE)	Total	Mean/ Quadrat (SE)	Total	Mean/ Quadrat (SE)	2009–2013	2011–2013	2009–2013	2011–2013
Zone of Influence										
Square Bay	1569	104.6 (35.2)	1267	84.5 (53.1)	1205	80.3 (54.9)	-364	-62	-24.3	-4.2
Mattress Bay North	1512	100.8 (39.2)	1125	75.0 (34.4)	2176	145.1 (37.8)	664	1051	44.3	70.1
Mattress Bay South	2158	143.9 (38.5)	1634	108.9 (44.3)	3449	229.9 (65.5)	1291	1815	86	121
Perentie II Bay North	1792	119.5 (30.4)	1145	76.3 (28.4)	967	64.5 (33.4)	-825	-178	-55	-11.8
Perentie II Bay South	1083	72.2 (18.4)	570	38.0 (17.3)	390	27.9 (17.4)	-693	-180	-44.3	-10.1
Stokes Bay	1191	79.4 (43.1)	1247	83.1 (57.2)	583	38.9 (30.4)	-608	-664	-40.5	-44.2
Reference Sites										
Bandicoot Bay	1229	81.9 (20.8)	830	55.3 (23.2)	1021	68.1 (32.6)	-208	191	-13.8	12.8
Pelican Island	2431	162.1 (41.9)	1893	126.2 (48.7)	2502	166.8 (61.3)	71	609	4.7	40.6

Note: n=15 for all sites and Surveys except P2S in 2013 with n=14.

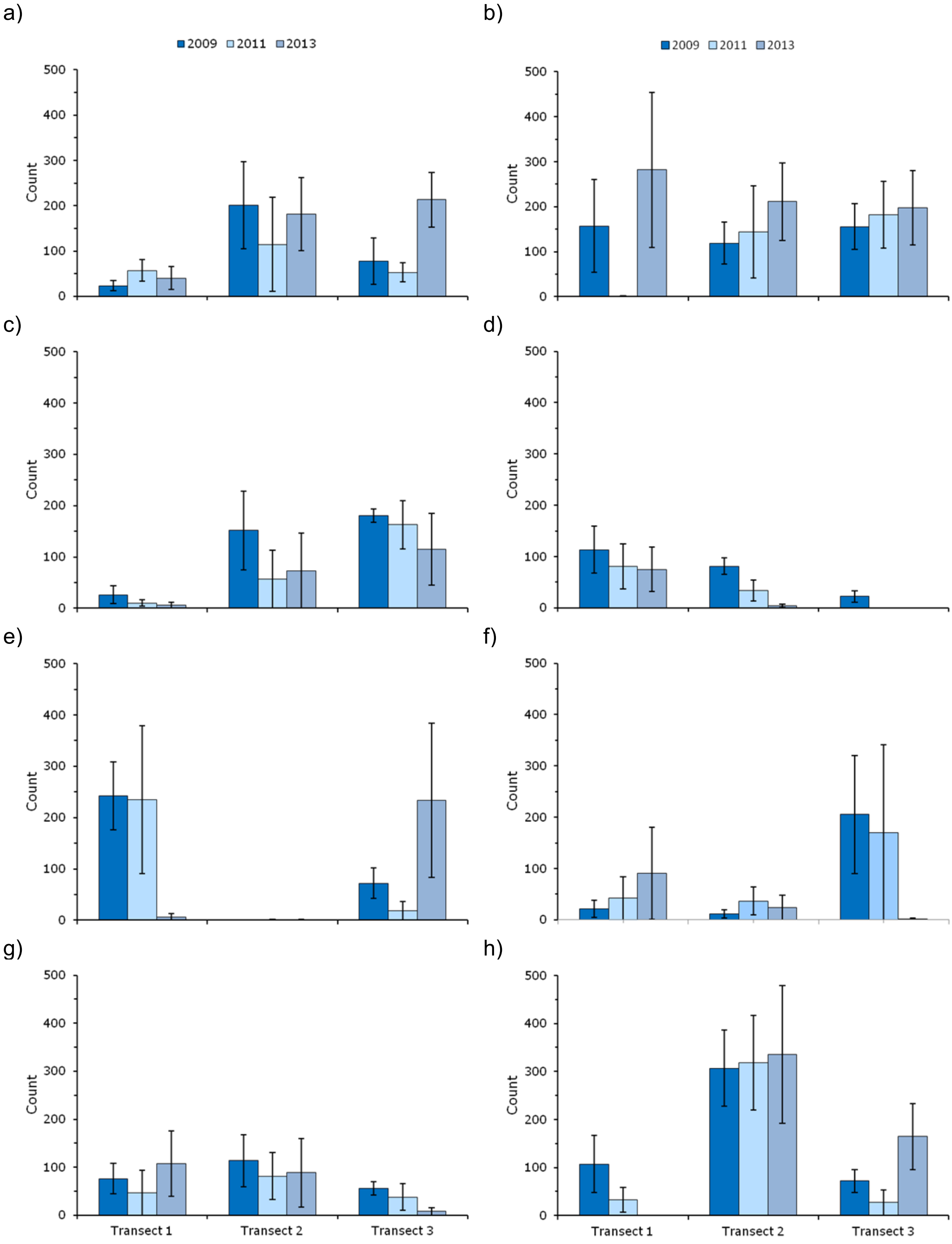


Figure 6-6 Mean (± SE) Pneumatophore Density at Mangrove Survey Sites during the Marine Baseline Program Post-Development Survey Year 1 and Post-Development Survey Year 2 for (a) Mattress Bay North, (b) Mattress Bay South, (c) Perentie II Bay North, (d) Perentie II Bay South, (e) Square Bay, (f) Stokes Bay, (g) Bandicoot Bay, and (h) Pelican Island

6.5.1.3 Leaf Pathology

Relative to the Marine Baseline Program, the incidence of leaf spots in Post-Development Survey Year 2 increased at all sites in the ZoI and in the Reference area (Figure 6-6). However, the incidence of leaf spots across the ZoI sites was primarily stable between Post-Development Survey Year 1 and Post-Development Survey Year 2, with an increase only seen at SQ and a decrease seen at P2S. The largest increase in the incidence of leaf spots between Post-Development Survey Year 1 and Post-Development Survey Year 2 was recorded at BB, with an increase also seen at PI. The degree of yellowing remained stable across most sites relative to Post-Development Survey Year 1 levels and was considerably lower than levels recorded in the Marine Baseline Program. There was a noticeable decrease in the incidence of mould to very low levels across all sites in Post-Development Survey Year 2 compared to levels recorded in the Marine Baseline Program. The incidence of galls increased at all sites in Post-Development Survey Year 2 compared to Post-Development Survey Year 1, except at ST and PI, although the incidence of galls in Post-Development Survey Year 2 was generally lower than that recorded in the Marine Baseline Program. Scale was recorded at all sites except ST in Post-Development Survey Year 2, compared to little or no scale recorded in Post-Development Survey Year 1 or the Marine Baseline Program. A general observation was made that there were very few leaves with multiple pathology indicators, and most sites supported a substantial percentage (20 to 40%) of completely healthy leaves.

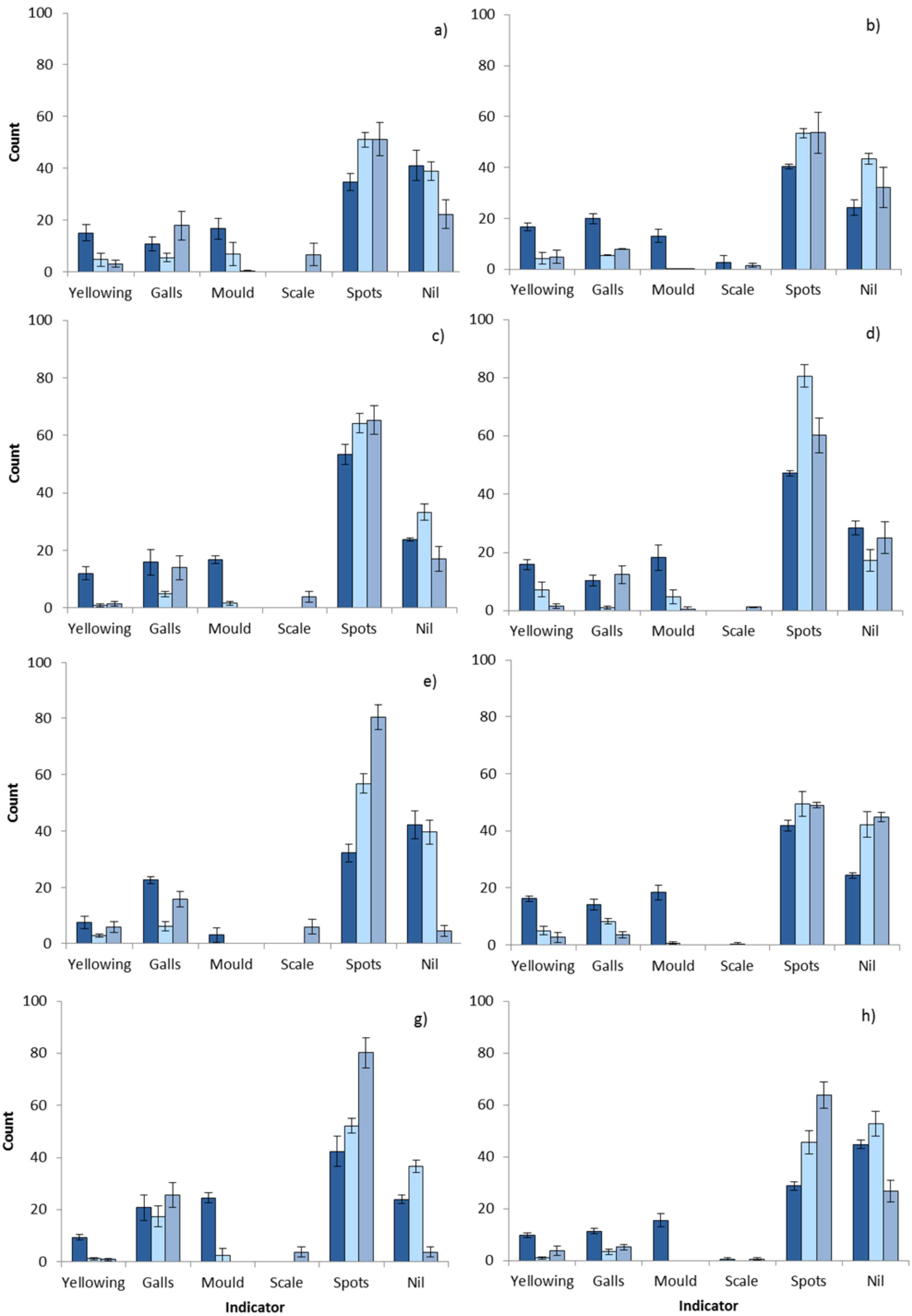


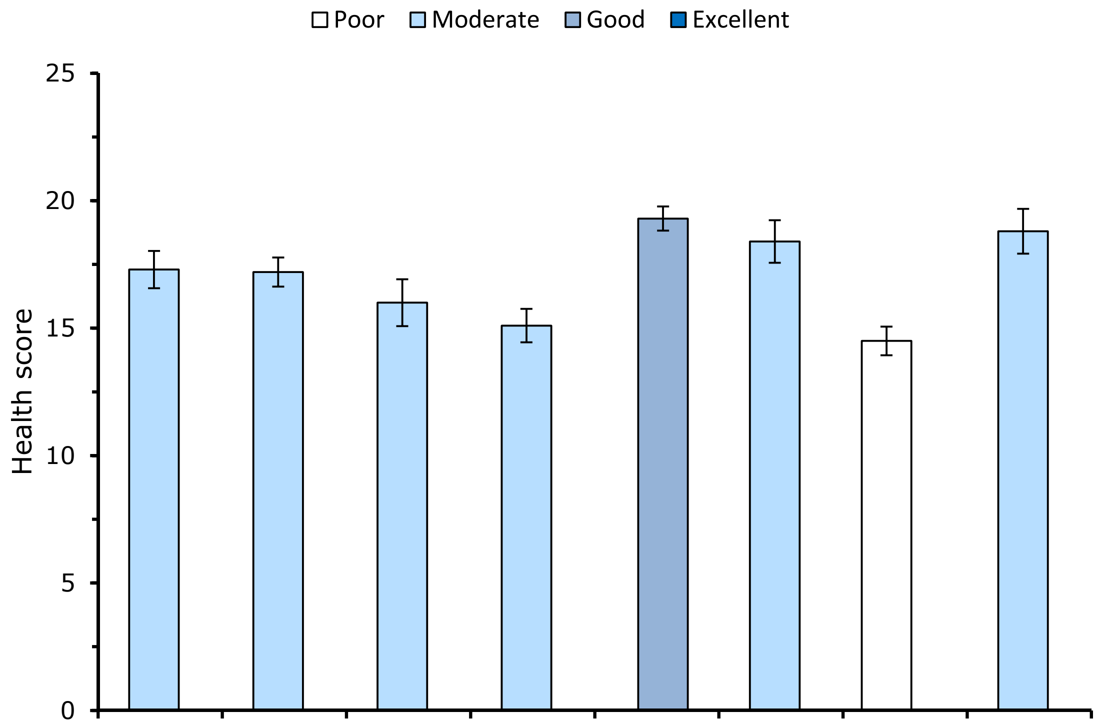
Figure 6-7 Mean (± SE) Individual Leaf Pathology Indicator Counts during the Marine Baseline Program, Post-Development Survey 1 and Post-Development Survey 2 for (a) Mattress Bay North, (b) Mattress Bay South, (c) Perentie II Bay North, (d) Perentie II Bay South, (e) Square Bay, (f) Stokes Bay, (g) Bandicoot Bay, and (h) Pelican Island

6.5.1.4 Mangrove Tree Health

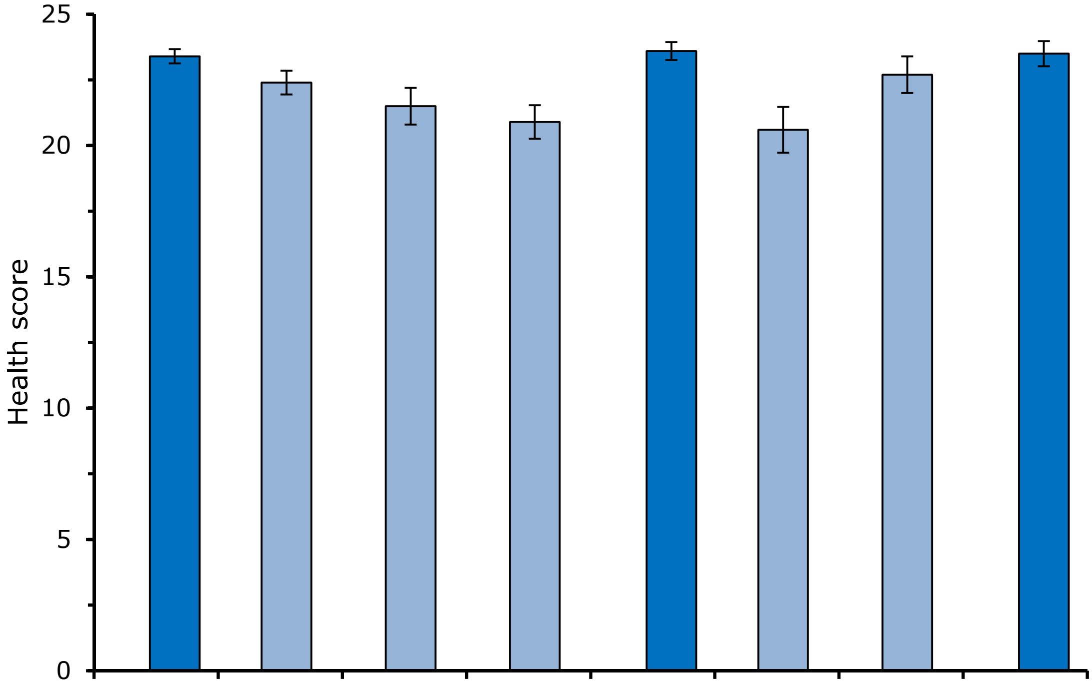
Three sites (ZoI sites MTN and SQ, and Reference Site PI) recorded a decline in mean tree health score from 'excellent' in Post-Development Survey Year 1 to 'moderate' in Post-Development Survey Year 2 (Figure 6-8). All other sites maintained a mean tree health rating of 'good', although there was a general decline in mean tree health across all sites between Post-Development Survey Year 1 and Post-Development Survey Year 2.

Since the Marine Baseline Program the largest change in mean tree health scores has been recorded at SQ in the ZoI. In the Marine Baseline Program, mean tree health at SQ was 'good', rising to 'excellent' in Post-Development Survey Year 1. However, mean tree health scores at SQ declined to 'moderate' in Post-Development Survey Year 2. Mean tree health at MTN (ZoI) and PI (Reference Site) improved from 'moderate' to 'excellent' between the Marine Baseline Program and Post-Development Survey Year 1, but declined to 'moderate' again in Post-Development Survey Year 2. Mean tree health improved at all other sites between the Marine Baseline Program and Post-Development Survey Year 2.

a)



b)



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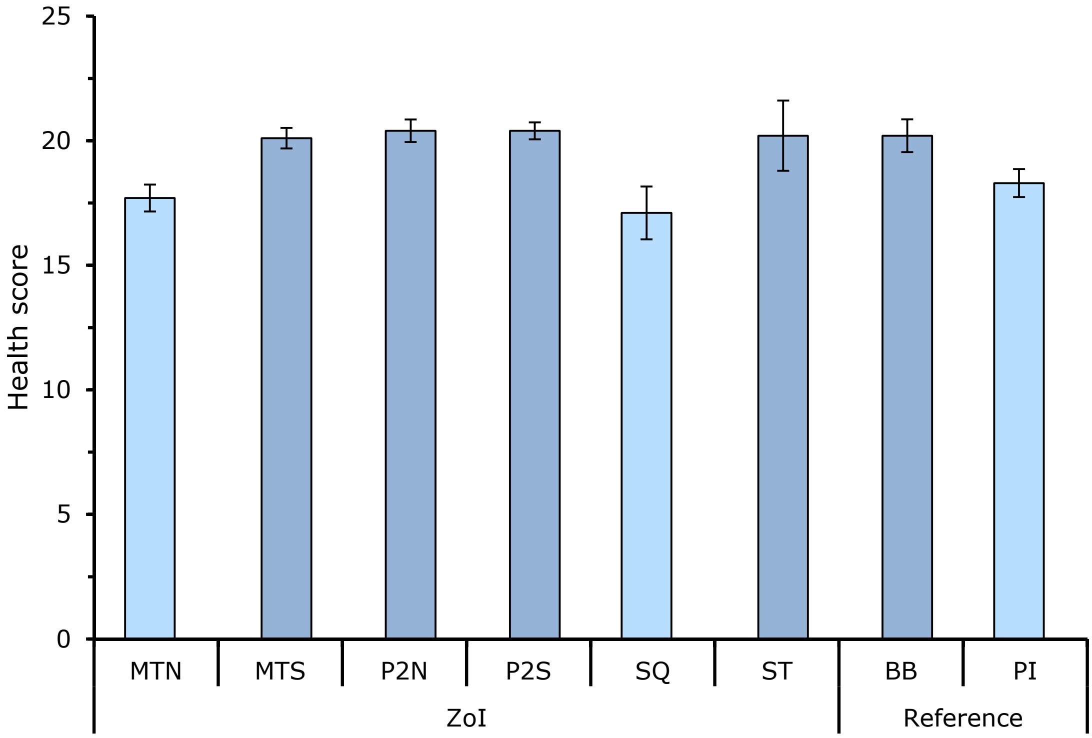


Figure 6-8 Mean (± SE) Mangrove Tree Health Score for each Site from: (a) Marine Baseline Program, (b) Post-Development Survey Year 1, and (c) Post-Development Survey Year 2

6.5.2 Statistical Comparison

Analysis of adult abundance at the transect scale across all ZoI and Reference Sites showed that there was a significant difference between sites, but no significant difference between sites over survey dates (Table 6-7). Mean percentage cover of mangrove trees per transect within each site showed significant differences between site, survey date, and the interaction between these factors (Table 6-8). Further analysis of comparisons over time at each site showed that decreases in cover at Reference Site PI between 2009 and 2013, and at ZoI site MTS between 2009 and 2013, and 2011 to 2013, were significantly different (Table 6-9).

Table 6-7 ANOVA (BoxCox transformation) Results for Mangrove Abundance between Sites and Survey Dates

Factor	df	SS	MS	F value	P
Survey Date	2	0.005494	0.0027469	1.7545	0.1892
Site	7	0.213596	0.0305138	19.4905	**<0.0001**
Survey Date × Site	14	0.037662	0.0026902	1.7183	0.1009
Transect(Site)	16	0.193922	0.0121201	7.7416	**<0.0001**
Residuals	32	0.050098	0.0015656		

Note: Bold font in P value column = significant difference for term of interest

Table 6-8 ANOVA Summary Results of Mean Percentage Canopy Cover between Sites and Survey Dates

Factor	df	SS	MS	F value	P
Survey Date	2	1132.1	566.1	15.6816	**<0.0001**
Site	7	26409.8	3772.8	104.5194	**<0.0001**
Survey Date × Site	14	2124.5	151.7	4.2039	**0.0004**
Transect(Site)	16	6313.6	394.6	10.9317	**<0.0001**
Residuals	32	1155.1	36.1		

Note: Bold font in P value column = significant difference for term of interest

Table 6-9 Tukey HSD (multiple comparisons of means test) Comparisons between Survey Date for Mean Percentage Canopy Cover by site

Site × Survey Date	Difference	Lower	Upper	P-Adjusted
Bandicoot Bay				
2011, 2009	-4.936	-24.384	14.512	1.0000
2011, 2013	4.215	-15.233	23.663	1.0000
2009, 2013	-0.721	-20.169	18.727	1.0000
Pelican Island				
2011, 2009	-8.179	-27.627	11.269	0.9867
2011, 2013	-19.039	-38.487	0.409	0.0607
2009, 2013	-27.218	-46.666	-7.770	**0.0008**
Square Bay				
2011, 2009	-3.525	-22.973	15.923	1.0000
2011, 2013	4.052	-15.396	23.500	1.0000

Site × Survey Date	Difference	Lower	Upper	P-Adjusted
2009, 2013	0.527	-18.921	19.975	1.0000
Stokes Bay				
2011, 2009	-8.223	-27.671	11.225	0.9859
2011, 2013	-5.919	-25.367	13.528	0.9998
2009, 2013	-14.142	-33.590	5.306	0.4191
Mattress Bay North				
2011, 2009	-3.758	-23.206	15.690	1.0000
2011, 2013	-3.221	-22.669	16.227	1.0000
2009, 2013	-6.979	-26.427	12.469	0.9998
Perentie II Bay North				
2011, 2009	6.166	-13.282	35.614	0.9997
2011, 2013	-2.939	-22.387	16.509	1.0000
2009, 2013	3.227	-16.221	22.675	1.0000
Mattress Bay South				
2011, 2009	9.979	-9.469	29.426	0.9118
2011, 2013	-30.996	-50.444	-11.548	**0.0001**
2009, 2013	-21.017	-40.465	-1.569	**0.0230**
Perentie II Bay South				
2011, 2009	-0.191	-19.639	19.257	1.0000
2011, 2013	-6.212	-25.660	13.236	0.9996
2009, 2013	-6.4029	-25.851	13.045	0.9994

Note: Bold font in P value column = significant difference for term of interest. 2009: Marine Baseline Report, 2011: Post-Development Survey Year 1, 2013: Post-Development Survey Year 2.

6.6 Discussion

Overall, the mangrove communities across all sites appeared in good condition. Statistical analysis showed no significant difference in mean percentage cover and tree abundance between ZoI and Reference Sites from the Marine Baseline Program to the Post-Development Surveys. However, mean percentage cover of mangrove trees showed significant differences between site, survey date, and the interaction between these factors; within both the ZoI and Reference Sites. This suggests that mangrove communities across Barrow Island are changing variably over time regardless of their location.

Avicennia sp. are considered sensitive biological indicators of coastal environmental change owing to their well-known ecological properties, in particular a tendency to sudden mortality resulting from changes in the daily duration and amplitude of flooding (Blasco *et al.* 1996). As the condition of mangroves appears to be similar to that recorded during the Marine Baseline Program with some improvements in health, the development of the marine facilities (MOF, LNG Jetty) is unlikely to have had any impact on the mangrove communities on the east coast of Barrow Island.

7.0 Demersal Fish

7.1 Introduction

There have been relatively few ecological studies conducted on the fish species of north-western Australia (e.g. Hutchins 2001, 2003, 2004; Fox and Beckley 2005; Travers *et al.* 2006, 2010; Watson *et al.* 2008; Cappo *et al*. 2011; Fitzpatrick *et al.* 2012), but survey work to date has revealed a species-rich assemblage, with the North West Shelf in particular being considered a hotspot in terms of species richness (Fox and Beckley 2005). The composition of fish assemblages in the region is strongly influenced by seasonal processes, tidal regime, turbidity, and habitat (Travers *et al.* 2006; Cappo *et al.* 2011). The most abundant families in the region have previously been identified as Apogonidae, Gobiidae, Labridae, Lethrinidae, Lutjanidae, Pomacentridae and Serranidae (Hutchins 2004; Travers *et al.* 2006).

The Montebello/Barrow Islands 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 multiannulatis* 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/Barrow Islands region (DEC 2007). Similarly, the Montebello/Barrow Islands region may act as a source of recruits for locations further south (DEC 2007).

A number of species occurring in the area are protected under State and Commonwealth legislation. These include, but are not limited to, the Potato Cod *(Epinephelus tukula)*, the Double-headed Maori Wrasse *(Cheilinus undulatus)*, and species of syngnathids *(Hippocampus hystrix* and *Phoxocampus belcheri)*. Most of these species are regionally widespread (DEC 2007). In addition, numerous commercial and recreationally important fish species such as Spangled Emperor (*Lethrinus nebulosus*) and Bar-cheeked Coral Trout (*Plectropomus maculatus*) occur around Barrow Island (Chevron Australia 2005).

The demersal fish assemblages in Barrow Island waters, as reported in the Marine Baseline Program, reflect the rich regional diversity of fish fauna, with a total of 347 species from 71 families recorded from intertidal and subtidal surveys (Chevron Australia 2012a). These results also revealed strong fish-habitat associations; coral assemblages were the most diverse, comprising large abundances of damselfish (pomacentrids), parrotfish (scarids), snappers (lutjanids), and groupers (serranids). Macroalgae habitats were considered important nursery areas for a diverse range of fish species, while large transient predators such as mackerel (scombrids) and trevally (carangids), and small leatherjackets (monacanthids), threadfin bream (nemipterids), and toadfish (tetraodontids) were characteristic of sand habitats. Emperors (lethrinids), threadfin bream, and trevally frequented areas that were high in sessile invertebrate coverage.

The Marine Baseline Program surveys of demersal fish characteristic of coral, macroalgae, sand, and soft sediment with sessile invertebrates communities reported no difference in fish assemblages present at sites in different predicted zones of impact; namely the Zone of High Impact (ZoHI), Zone of Moderate Impact (ZoMI), Zone of Influence (ZoI), and Reference Sites (Chevron Australia 2012a). However, there were some differences noted between the 2008 and 2009 baseline surveys with these differences largely due to: 1) the presence/absence of schooling species; 2) the varying habitat location of some schooling species; and 3) the varying presence of juvenile fish (Chevron Australia 2012a). The results also indicated that seasonal and interannual variability existed in fish assemblage structure at Barrow Island, but that the data collected provided a reasonable baseline against which future data could be compared (Chevron Australia 2012a).

7.2 Scope

This Section is in two parts. The first part presents the characteristics of demersal fish assemblages recorded during the Post-Development Survey Year 2:

- within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence, associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal activities required for the MOF and LNG Jetty
- at Reference Sites not at risk of Material or Serious Environmental Harm due to the construction of the MOF and LNG Jetty.

The second part compares the Post-Development Surveys and the Marine Baseline Program survey to determine if changes have occurred as per Condition 24.2 of Statement No. 800 and Condition 17.2 of EPBC Reference: 2003/1294 and 2008/4178.

As previously discussed (Section 2.1.5), no specific results or comparisons are made for the area in the vicinity of the marine upgrade of the existing WAPET Landing.

7.3 Methods

7.3.1 Site Locations

Surveys of the demersal fish assemblages that characterised hard and soft coral, macroalgae, soft sediments with sessile benthic macroinvertebrates, and bare sand communities (Subtidal Demersal Fish) were undertaken at 43 sites in the waters surrounding Barrow Island (Table 7-1, Figure 7-1).

Table 7-1 Post-Development Survey Sites for Subtidal Demersal Fish

Location	Site Code	Easting	Northing	Latitude	Longitude	Water Depth[2]
		(GDA94, MGA Zone 50)		(GDA94)		
Zones of High Impact	CI1	341785	7699202	20° 48.021' S	115° 28.788' E	5.1
	DSI1	348016	7691476	20° 52.240' S	115° 32.339' E	16
	DSI2	348016	7689239	20° 53.452' S	115° 32.328' E	14.9
	SI2	342952	7697366	20° 49.022' S	115° 29.451' E	12.5
Zones of Moderate Impact	CI2	342089	7698785	20° 48.249' S	115° 28.961' E	4.1
	CI3	344575	7695759	20° 49.901' S	115° 30.378' E	6.7
	MI1	341630	7700704	20° 47.206' S	115° 28.707' E	4
	MI2	341078	7698841	20° 48.213' S	115° 28.379' E	3.8
	SI1	343277	7698853	20° 48.218' S	115° 29.646' E	9.6
Zones of Influence	CFR1	341865	7709266	20° 42.567' S	115° 28.889' E	4.6
	CN1	340700	7692144	20° 51.841' S	115° 28.124' E	4.5
	CN2	344097	7694687	20° 50.480' S	115° 30.097' E	7.9
	CN3	344568	7700778	20° 47.181' S	115° 30.401' E	4.8
	CN4	347316	7692607	20° 51.623' S	115° 31.942' E	14.5
	DSN1	351119	7692085	20° 51.925' S	115° 34.132' E	16.6
	DSN3	347316	7687119	20° 54.598' S	115° 31.913' E	15.4
	MFR4	341593	7711656	20° 41.271' S	115° 28.745' E	7
	MN1	342037	7702542	20° 46.212' S	115° 28.952' E	4.9

Location	Site Code	Easting	Northing	Latitude	Longitude	Water Depth[2]
		(GDA94, MGA Zone 50)		(GDA94)		
	MN2	340620	7697336	20° 49.027' S	115° 28.107' E	4.1
	MN3	342518	7703961	20° 45.446' S	115° 29.237' E	3.7
	MN4	340737	7693377	20° 51.173' S	115° 28.152' E	6.2
	SIFR5[1]	344264	7705660	20° 44.534' S	115° 30.252' E	3.9
	SIN1	344409	7699903	20° 47.655' S	115° 30.304' E	8.1
	SIN2	342722	7695390	20° 50.092' S	115° 29.308' E	11.8
	SIN3	343402	7702998	20° 45.972' S	115° 29.741' E	14.1
	SIN4	342273	7693700	20° 51.006' S	115° 29.040' E	11.6
Reference Sites	CFR2	340279	7687729	20° 54.231' S	115° 27.857' E	8.9
	CFR3	342227	7681849	20° 57.428' S	115° 28.949' E	5
	CFR4	350731	7731850	20° 30.371' S	115° 34.110' E	8.4
	CN5	342823	7692363	20° 51.733' S	115° 29.350' E	6.3
	DGI3	351488	7684848	20° 55.849' S	115° 34.307' E	15.7
	MFR1	341252	7679792	20° 58.538' S	115° 28.375' E	4.2
	MFR3	349696	7726801	20° 33.102' S	115° 33.489' E	6.2
	MFR5	350668	7724842	20° 34.169' S	115° 34.039' E	5.4
	SAFR1	353578	7687306	20° 54.527' S	115° 35.526' E	15.3
	SAFR2	351563	7697793	20° 48.833' S	115° 34.417' E	17
	SAFR3	354461	7690944	20° 52.559' S	115° 36.053' E	16.8
	SAN1	352507	7681998	20° 57.398' S	115° 34.881' E	15.1
	SIFR2	343955	7684283	20° 56.118' S	115° 29.959' E	15.5
	SIFR3	348372	7677876	20° 59.612' S	115° 32.473' E	15.5
	SIN5	345289	7692529	20° 51.655' S	115° 30.772' E	15.2
	SIN6	341649	7689484	20° 53.287' S	115° 28.657' E	14.2
	SIN7	350254	7681367	20° 57.729' S	115° 33.577' E	16.8

Notes:

1. *Site SIFR5 was sampled in deeper water in 2009 as sampling at that time could occur within the channel. Sampling in 2012 was conducted as near to the channel as possible, but not within the channel due to shipping traffic.*
2. *Average water depth of stereo-BRUV.*

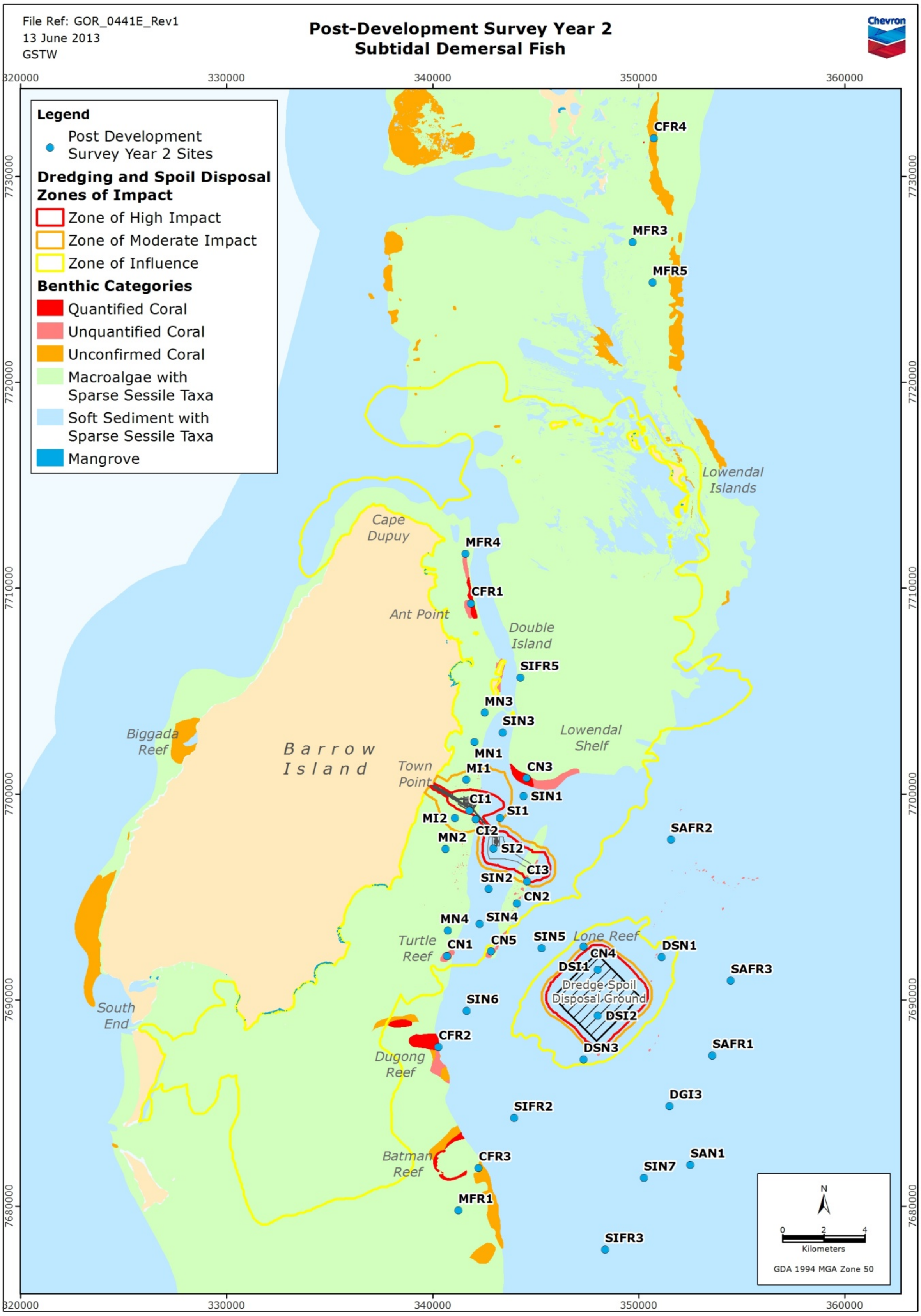


Figure 7-1 Post-Development Survey Year 2 Sites for Subtidal Demersal Fish

7.3.2 Timing and Frequency of Sampling

The Post-Development Survey Year 2 of the demersal fish assemblages that characterised hard and soft coral, macroalgae, soft sediments with sessile benthic macroinvertebrates, and bare sand communities was undertaken between 23 November and 2 December 2012 during daylight hours.

7.3.3 Survey Method

The demersal fish assemblages that characterised hard and soft coral, 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 as was used in the Marine Baseline Program and Post-Development Survey Year 1. Detailed information on the design and calibration of stereo-BRUV was reported in Chevron Australia (2012a) 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 at each site for at least one hour, with at least 250 m between each deployment location. Each stereo-BRUV consisted of two full high-definition (1080i) Sony Handycams (HDR CX12 models) in underwater housings, mounted 0.7 m apart on a base bar, and inwardly converged at eight degrees to provide an overlapping field of view from approximately 0.5 m in front of the cameras. A light-synchronising diode and bait bag were positioned midway 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 sagax*), crushed to maximise dispersal of the fish oil and flesh.

7.3.4 Treatment of Survey Data

Demersal fish assemblages that characterised hard and soft coral, macroalgae, soft sediments with sessile benthic macroinvertebrates, and bare sand communities were described in terms of the relative abundance of species, their commonality (number of sites), and size structure.

The general description of fish assemblages by habitat type off Barrow Island (Section 7.4.1) included the habitat 'seagrass' when observed. However, to allow comparison with the general descriptions provided in previous reports (Marine Baseline Program and Post-Development Survey Year 1) the habitat 'seagrass' was not included in the description of demersal fish assemblages by Zone, or in the statistical comparison between the Marine Baseline Program and the Post-Development Surveys.

7.3.5 Statistical Approach for Comparison against Marine Baseline

Examination of change in fish assemblage structure from the Marine Baseline Program to Post-Development Survey Year 2 was conducted using the following six-factor design:

- Factor 1: Survey (fixed factor, orthogonal; Baseline, Post-Development Survey Year 1 and Post-Development Survey Year 2)
- Factor 2: Year (random factor, nested in Survey; two levels in baseline and one in each Post-Development Survey)
- Factor 3: Impact v. Reference ('IvR', fixed factor, orthogonal; Impact and Reference)
- Factor 4: Zone (fixed factor, nested in IvR; ZoHI, ZoMI, ZoI [all nested in Impact] and Reference [Reference])
- Factor 5: Habitat (fixed factor, orthogonal; coral, macroalgae and sand/sessile*)
- Factor 6: Site (random factor, nested in Habitat × Zone(IvR), varying levels)
- n=5 replicate stereo-BRUV deployments per Site (with the exception of site CN4 where the size of the coral bombora restricted sampling to three replicate deployments).

The terms of interest that are potentially indicative of change associated with dredging and dredge spoil disposal activities are;

- Survey × IvR
- Survey × Zone(IvR)
- Survey × IvR × Habitat
- Survey × Zone(IvR) × Habitat

* Note that sand and sessile invertebrate habitats were combined for assessments of change for three reasons: 1) under the original survey design, sampling was stratified around the mapped habitat data, which delineated a combined sand/sessile habitat (see Chevron Australia 2012a); 2) there was high variability in the presence and extent of sessile invertebrates across small spatial scales (e.g. neighbouring deployments) and across sampling times (2008 v. 2009); and 3) the combined habitat category provided additional and required power for statistical tests.

The multivariate relative abundance dataset was analysed using permutational multivariate analysis of variance with 9999 permutations (PERMANOVA; Anderson 2001b) in the PRIMER v6 statistics 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. Univariate analyses of species richness and total number of individuals were conducted using the same five-factor design, but with Euclidean distance dissimilarities of fourth-root transformed data. Investigations of normality indicated that fourth-root transformations generated normally distributed data compared to non-transformed and square-root transformations, which were both skewed to the left. To provide additional power to statistically test the main effects of interest and to reduce the chance of a Type II error (statistical conclusion of no change when change has actually occurred) variation was partitioned and terms were pooled in the analysis.

Where significant differences were detected, pair-wise tests in PERMANOVA were performed to ascertain where differences occurred. Where necessary, these pair-wise tests were conducted for pairs of levels of the factor Survey for the significant interaction term of interest. This factor considers both baseline sampling events together as a single level of the factor, and post-development sampling events separately as the second and third levels of the factor. Therefore, post hoc pair-wise tests can be used to test any impact, lag effects or recovery, or other changes between these three surveys.

To most clearly illustrate the significant changes in the multivariate fish assemblage, an non-metric Multidimensional Scaling plot (MDS) of group centroids was plotted for the significant term of interest. Using the PERMANOVA+ add-on for PRIMER E, a Bray-Curtis resemblance matrix of the group centroids for the term of interest were calculated from the full Bray-Curtis resemblance matrix of fourth-root transformed multivariate assemblage data. An MDS ordination was made based on this group centroids resemblance matrix. This approach provides a suitable visual complement to the PERMANOVA output, by providing insight into the relative sizes and directions of effects in complex experimental designs (Anderson *et al.* 2008).

To further investigate significant differences detected from pair-wise tests, a canonical analysis of principal coordinates (CAP; Anderson and Robinson 2003; Anderson and Willis 2003) was performed on multivariate centroids. Individual species likely to be responsible for any observed differences were determined by examining Spearman correlations of fourth-root transformed species counts with canonical axes. A correlation of $|r| > 0.28$ was used as an arbitrary cut-off to display potential relationships between individual species and the canonical axes, and warrant further statistical analysis. Univariate PERMANOVAs were then conducted on species identified in the CAP plot that were also present at >25% of sites. Each species was analysed separately using the five-factor model (Year pooled). Mean relative abundance plots for each species were constructed to graphically illustrate how their relative abundance may have changed from the Marine Baseline Program to Post-Development Surveys Year 1 and Year 2 at Impact and Reference Sites.

For each year and zone histograms were used to represent length frequency information of assemblage structure and indicator species. Indicator species were only presented for the coral habitat sites. Assemblage length frequency structure was also represented across each habitat class (coral, macroalgae, sand/sessile invertebrates).

Cumulative PERMANOVAs of standardised length bins, based on the Manhattan distance measure, were used to analyse all length data. An established direct plug-in methodology was used to select the appropriate bin width for each analysis and for constructing histograms (Wand 1995).

Relative abundance and length information was summarised into tables for each of the 20 indicator species selected during the Marine Baseline Program (see Chevron Australia 2012a for criteria used to select indicator species). Indicator species are those fish species that characterise coral habitats and may indicate the environmental condition of those habitats. To assess change in the abundance of indicator species within coral habitats, multivariate PERMANOVA was performed on fourth-root transformed relative abundance data following a five-factor design (i.e. ‘Habitat’ has been removed from the six-factor design described above).

Where significant terms of interest were found in either multivariate or univariate tests, these were illustrated graphically and tested using pair-wise comparisons.

7.4 Results of Post-Development Survey Year 2

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

In Post-Development Survey Year 2, a total of 13,179 individuals from 237 species and 51 families were recorded from the 213 stereo-BRUV deployments. An average of 15.7 ± 0.7 species were observed on each deployment. The greatest species richness recorded on a single deployment was 50 on deployment CN3-3, and the least was two on deployments SI2-5 and SIFR2-2. The 20 most common fish species observed on stereo-BRUV deployments conducted during Post-Development Survey Year 2 are listed in Table 7-2.

The five most abundant families observed on stereo-BRUV deployments were: Nemipteridae (threadfin bream), Carangidae (trevally), Caesionidae (fusiliers), Lethrinidae (emperor) and Pomacentridae (damselfish) (Figure 7-2). The five most commonly observed families on stereo-BRUV deployments (% of deployments) were: Nemipteridae, Carangidae, Lethrinidae, Labridae (wrasse) and Scombridae (mackerel). The most speciose family was Labridae with 28 species, followed by Pomacentridae (22 species) and Chaetodontidae (butterflyfish) (17 species).

Table 7-2 Twenty Most Common Fish Species Viewed by Stereo-BRUV for Post-Development Survey Year 2

Species	Common Name	Rank	Viewed on % of deployments	Total # Fish	Mean MaxN per deployment (± SE)
Scombridae spp	Mackerel species*	1	57.7	190	0.89 ± 0.07
Choerodon cyanodus	Blue Tuskfish*	2	52.6	245	1.15 ± 0.09
Choerodon schoenleinii	Blackspot Tuskfish*	3	48.4	176	0.83 ± 0.07
Carangoides fulvoguttatus	Gold-Spotted Trevally*	4	41.3	410	1.92 ± 0.41
Pentapodus porosus	Northwest Threadfin Bream	5	41.3	951	4.46 ± 0.61
Choerodon cauteroma	Bluespotted Tuskfish*	6	38.0	159	0.75 ± 0.09
Gnathanodon speciosus	Golden Trevally*	7	37.1	731	3.43 ± 0.66
Pentapodus emeryii	Purple Threadfin Bream	8	37.1	221	1.04 ± 0.13
Lethrinus nebulosus	Spangled Emperor*	9	36.6	262	1.23 ± 0.22
Scarus ghobban	Bluebarred Parrotfish*	10	34.3	191	0.9 ± 0.13
Plectropomus spp	Coral Trout*	11	33.8	158	0.74 ± 0.09
Echeneis naucrates	Sharksucker	12	29.1	121	0.57 ± 0.08
Epinephelus bilobatus	Frostback Rockcod*	13	27.7	114	0.54 ± 0.08
Pentapodus vitta	Western Butterfish	14	27.7	649	3.05 ± 0.5
Symphorus nematophorus	Chinaman Fish*	15	26.8	65	0.31 ± 0.04
Lethrinus laticaudis	Grass Emperor*	16	25.8	95	0.45 ± 0.07
Acanthurus grammoptilus	Inshore Surgeonfish	17	23.0	200	0.94 ± 0.25
Lutjanus carponotatus	Stripey Snapper*	18	23.0	128	0.6 ± 0.1
Pomacentrus milleri	Miller's Damsel	19	21.6	136	0.64 ± 0.12
Lethrinus punctulatus	Bluespotted Emperor*	20	21.1	514	2.41 ± 0.59

Note: Ordered by rank from most common (1) to least (20). Those with an '' are considered targeted by commercial and/or recreational fishers. An additional species,* Parupeneus indicus *(Yellowspot Goatfish), was also placed at rank 20.*

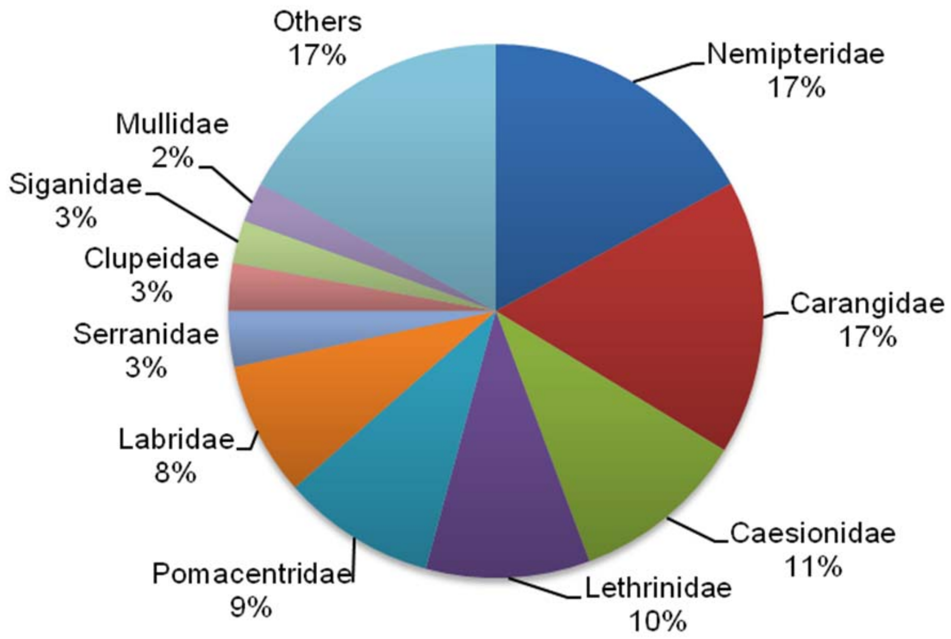


Figure 7-2 Contribution of the Ten Most Abundant Families to the Total Number of Fish Observed on Stereo-BRUV Deployments

During Post-Development Survey Year 2, the lengths of 9286 individual fish were measured from 214 species and 45 families from the 213 deployments. The smallest individual measured was a 21 mm juvenile Golden Trevally (*Gnathanodon speciosus*) and the largest a 2.9 m Tiger Shark (*Galeocerdo cuvier*). The median fish length was 178.7 mm and the mean length was 222.4 ± 2 mm.

A similar number of deployments were conducted in bare sand, macroalgae, and coral habitats; however, approximately double the number of individuals were observed in coral compared to bare sand and macroalgae habitats. The least number of deployments and individuals observed were in sessile invertebrate habitats. Species richness was largest in coral habitats, followed by macroalgae, seagrass, sessile invertebrates, and bare sand (Table 7-3).

Table 7-3 Summary of Relative Abundance and Species Richness Information for the Four Dominant Habitats Surveyed during Post-Development Survey Year 2

	Coral	Macroalgae	Bare Sand	Seagrass*	Sessile Invertebrates
No. deployments	58	50	60	25	20
Total No. individuals	6083	2643	2429	1201	823
Total No. species	175	104	60	70	56
Total No. families	40	34	33	29	27
Mean total MaxN (± SE)	104.9 ± 9.2	52.9 ± 4.3	40.5 ± 4.8	48.0 ± 8.6	41.2 ± 6.6
Mean species richness (± SE)	27.2 ± 1.3	16.2 ± 0.7	8.7 ± 0.5	9.6 ± 1	9.6 ± 0.9

*Note: * Seagrass, while not a ‘dominant habitat’ was included in this summary as seagrass was observed.*

7.4.1.1 Fish Recorded within Coral Habitat

In coral-dominated habitat, a total of 6083 individuals from 175 species and 40 families were recorded from the 58 stereo-BRUV deployments. The number of species observed on a single stereo-BRUV deployment ranged from five (CFR1-3) to 50 (CN3-3), with an average of 27.2 ± 1.3 per deployment. The ten most numerically abundant and commonly observed species and families in coral habitats were determined (Table 7-4, Table 7-5).

In coral-dominated habitat, the lengths of 3896 individual fish were measured from 58 deployments. The smallest individual measured was a 25.1 mm Brown Demoiselle (*Neopomacentrus filamentosus*) and the largest a 2.06 m Tiger Shark (*Galeocerdo cuvier*). The median fish length was 213.8 mm and the mean length was 229.6 ± 2.4 mm.

7.4.1.2 Fish Recorded within Macroalgae Habitat

In macroalgae habitats, a total of 2643 individuals from 104 species and 34 families were recorded from the 50 stereo-BRUV deployments. The number of species observed on a single stereo-BRUV deployment ranged from seven (MN3-5) to 29 (MFR1-3), with an average of 16.2 ± 0.7 per deployment. The ten most numerically abundant and commonly observed species and families in macroalgal habitats were determined (Table 7-4, Table 7-5).

In macroalgae habitat, the lengths of 2006 individual fish were measured from 50 deployments. The smallest individual measured was a 24.3 mm Neon Damsel (*Pomacentrus coelestis*) and the largest a 2.85 m Great Hammerhead Shark (*Sphyrna mokarran*). The median fish length was 166.5 mm and the mean length was 199.5 ± 4.1 mm.

7.4.1.3 Fish Recorded within Bare Sand Habitat

In bare sand habitats, a total of 2429 individuals from 60 species and 33 families were recorded from the 60 stereo-BRUV deployments. The number of species observed on a single stereo-BRUV deployment ranged from two (SI2-5, SIFR2-2) to 23 (SIFR2-4), with an average of 8.7 ± 0.5 per deployment. The ten most numerically abundant and commonly observed species and families in bare sand habitats were determined (Table 7-4, Table 7-5).

In bare sand habitat, the lengths of 1841 individual fish were measured from 60 deployments. The smallest individual measured was a 20.95 mm Golden Trevally (juvenile *Gnathanodon speciosus*) and the largest a 2.67 m Great Hammerhead Shark (*Sphyrna mokarran*). The median fish length was 155.9 mm and the mean length was 211.4 ± 5.05 mm.

7.4.1.4 Fish Recorded within Seagrass Habitat

In seagrass habitats, a total of 1201 individuals from 70 species and 29 families were recorded from the 25 stereo-BRUV deployments. The number of species observed on a single stereo-BRUV deployment ranged from three (DSN3-4) to 27 (DSI1-4), with an average of 9.6 ± 1 per deployment. The ten most numerically abundant and commonly observed species and families in seagrass habitats were determined (Table 7-4, Table 7-5).

In seagrass habitat, the lengths of 874 individual fish were measured from 25 deployments. The smallest individual measured was a 23.2 mm Gulf Damsel (*Pristotis obtusirostris*) and the largest a 2.9 m Tiger Shark (*Galeocerdo cuvier*). The median fish length was 232.5 mm and the mean length was 277.7 ± 8.3 mm.

7.4.1.5 Fish Recorded within Sessile Invertebrates Habitat

In sessile invertebrate habitats, a total of 823 individuals from 56 species and 27 families were recorded from the 20 stereo-BRUV deployments. The number of species observed on a single stereo-BRUV deployment ranged from four (DSI2-1) to 22 (SIN3-1), with an average of 9.6 ± 0.9 per deployment. The ten most numerically abundant and commonly observed species and families in sessile invertebrate habitats were determined (Table 7-4, Table 7-5).

In sessile invertebrate habitat, the lengths of 669 individual fish were measured from 10 deployments. The smallest individual measured was a 24.5 mm Gulf Damsel (*Pristotis* *obtusirostris*) and the largest a 2.5 m Whitespotted Guitarfish (*Rhynchobatus australiae*). The median fish length was 159.2 mm and the mean length was 206.6 ± 8.1 mm.

Table 7-4 Ten Most Abundant and Common Fish Species Observed in each Habitat during Post-Development Survey Year 2

	Coral		Macroalgae		Sand		Seagrass		Sessile Invertebrates	
Ten most abundant species (total # individuals)	*Pterocaesio* spp	943	*Lethrinus punctulatus*	361	*Pentapodus porosus*	441	*Gnathanodon speciosus*	191	*Pentapodus porosus*	219
	Herklotsichthys spp	378	*Pentapodus porosus*	154	*Pentapodus vitta*	333	*Carangoides gymnostethus*	172	*Pristotis obtusirostris*	110
	Carangoides fulvoguttatus	257	*Pentapodus emeryii*	137	*Selaroides leptolepis*	323	*Pentapodus porosus*	126	*Pentapodus vitta*	70
	Neopomacentrus filamentosus	245	*Pentapodus vitta*	136	*Gnathanodon speciosus*	193	*Pentapodus vitta*	108	*Gnathanodon speciosus*	57
	Caesio cuning	213	*Scaevius vitta*	134	*Nemipterus* spp	127	*Torquigener pallimaculatus*	79	*Lethrinus punctulatus*	46
	Gnathanodon speciosus	212	*Lethrinus genivittatus*	112	*Upeneus tragula*	127	*Pristotis obtusirostris*	57	*Nemipterus* spp	34
	Lethrinus atkinsoni	197	*Choerodon cyanodus*	101	*Atule mate*	105	*Lethrinus genivittatus*	54	*Carangoides fulvoguttatus*	25
	Acanthurus grammoptilus	176	*Carangoides fulvoguttatus*	91	*Paramona-canthus choiro-cephalus*	78	*Nemipterus* spp	50	*Chromis fumea*	23
	Lethrinus nebulosus	175	*Choerodon cauteroma*	91	*Scombridae* spp	70	*Upeneus tragula*	42	*Scaevius vitta*	22
	Thalassoma lunare	138	*Gnathanodon speciosus*	78	*Lethrinus punctulatus*	62	*Scombridae* spp	39	*Scombridae* spp	17
Ten most common species (% of deployments)	*Choerodon cyanodus*	91	*Choerodon cyanodus*	90	*Scombridae* spp	73	*Scombridae* spp	76	*Pentapodus porosus*	70
	Plectropomus spp	90	*Choerodon schoenleinii*	80	*Pentapodus porosus*	62	*Gnathanodon speciosus*	64	*Scombridae* spp	65
	Choerodon schoenleinii	86	*Pentapodus emeryii*	78	*Gnathanodon speciosus*	43	*Echeneis naucrates*	52	*Carangoides fulvoguttatus*	60
	Scarus ghobban	84	*Choerodon cauteroma*	72	*Echeneis naucrates*	40	*Pentapodus vitta*	48	*Choerodon cauteroma*	45
	Lutjanus carponotatus	72	*Lethrinus nebulosus*	60	*Paramona-canthus choiro-cephalus*	40	*Pentapodus porosus*	44	*Choerodon schoenleinii*	45
	Carangoides fulvoguttatus	69	*Lethrinus genivittatus*	54	*Nemipterus* spp	38	*Carangoides fulvoguttatus*	40	*Pentapodus vitta*	40
	Epinephelus bilobatus	69	*Pentapodus porosus*	46	*Pentapodus vitta*	37	*Nemipterus* spp	40	*Choerodon cyanodus*	35
	Lethrinus nebulosus	69	*Parupeneus indicus*	44	*Lagocephalus lunaris*	25	*Paramona-canthus choiro-cephalus*	36	*Symphorus nematophorus*	30
	Lethrinus atkinsoni	67	*Carangoides fulvoguttatus*	42	*Selaroides leptolepis*	25	*Torquigener pallimaculatus*	32	*Echeneis naucrates*	25
	Pomacanthus sexstriatus	62	*Lethrinus punctulatus**	42	*Upeneus tragula*	23	*Upeneus tragula*	32	*Gnathanodon speciosus**	25

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

Table 7-5 Ten Most Abundant and Common Families of Fish Observed in each Habitat during Post-Development Survey Year 2

	Coral		Macroalgae		Sand		Seagrass		Sessile Invertebrates	
10 most abundant families (Total # individuals)	Caesionidae	1251	Nemipteridae	590	Nemipteridae	906	Carangidae	461	Nemipteridae	356
	Pomacentridae	824	Lethrinidae	581	Carangidae	705	Nemipteridae	295	Pomacentridae	135
	Carangidae	735	Labridae	475	Mullidae	135	Tetraodontidae	95	Carangidae	107
	Labridae	507	Carangidae	182	Lethrinidae	93	Lethrinidae	71	Lethrinidae	73
	Lethrinidae	493	Pomacentridae	151	Monacanthidae	81	Pomacentridae	67	Labridae	35
	Clupeidae	378	Caesionidae	116	Scombridae	71	Mullidae	43	Scombridae	17
	Serranidae	351	Siganidae	91	Tetraodontidae	68	Scombridae	39	Echeneidae	12
	Acanthuridae	266	Mullidae	88	Pomacentridae	50	Echeneidae	27	Monacanthidae	12
	Lutjanidae	228	Serranidae	69	Echeneidae	47	Monacanthidae	19	Mullidae	11
	Siganidae	221	Scaridae	62	Labridae	36	Labridae	13	Chaetodontidae*	7
10 most common families (% of deployments)	Lethrinidae	98	Labridae	98	Nemipteridae	82	Carangidae	80	Nemipteridae	95
	Labridae	97	Lethrinidae	98	Carangidae	77	Nemipteridae	80	Carangidae	70
	Serranidae	93	Nemipteridae	98	Scombridae	73	Scombridae	76	Scombridae	65
	Scaridae	88	Mullidae	72	Tetraodontidae	47	Lethrinidae	56	Labridae	55
	Lutjanidae	86	Serranidae	64	Monacanthidae	43	Echeneidae	52	Lethrinidae	45
	Carangidae	84	Carangidae	60	Echeneidae	40	Tetraodontidae	48	Lutjanidae	30
	Pomacentridae	83	Pomacentridae	60	Carcharhinidae	30	Monacanthidae	40	Echeneidae	25
	Pomacanthidae	74	Lutjanidae	50	Mullidae	28	Mullidae	36	Pomacanthidae	25
	Chaetodontidae	72	Scaridae	44	Lethrinidae	27	Pomacentridae	28	Pomacentridae	25
	Siganidae	72	Scombridae	38	Labridae	25	Balistidae*	16	Monacanthidae*	20

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

7.4.2 Description of Demersal Fish Assemblages within the Zones of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

7.4.2.1 Fish Assemblages Characteristic of Hard and Soft Coral, Macroalgae, Soft Sediments with Sessile Benthic Invertebrates, and Bare Sand Communities in the Vicinity of the MOF, Causeway, and LNG Access Channel

The ZoHI generally had the lowest species richness and total number of individuals when compared to other zones (Figure 7-3). A total of 311 individuals from 63 species and 27 families were recorded from the ten stereo-BRUV deployments conducted within the ZoHI near the MOF, Causeway, and LNG Access Channel. On average, 15.2 ± 2.6 species were observed on each deployment (habitats combined). The largest species richness recorded on a single deployment was 29 at site CI1-3, while the least was two at SI2-5. A summary of relative abundance statistics for each habitat sampled in the ZoHI is presented in Table 7-6.

The lengths of 266 individual fish were measured from ten stereo-BRUV deployments. The smallest individual measured was a 26.8 mm Damsel (*Pomacentrus vaiuli)* and the largest a 2.3 m Tiger Shark (*Galeocerdo cuvier*). The median fish length was 229.0 mm and the mean length was 305.5 ± 15.6 mm. A summary of length statistics for each habitat sampled in the ZoHI was developed (Table 7-7).

Table 7-6 Summary of the Relative Abundance and Species Richness for each Habitat Type Sampled in the Zones of High Impact, Zones of Moderate Impact, and Zones of Influence near the MOF, Causeway, and LNG Access Channel during the Post-Development Survey Year 2

	Coral*	Macroalgae*	Sand*	Sessile Invertebrates*
Zone of High Impact				
# of deployments	5	0	5	0
Total # individuals	228	N/A	83	N/A
Total # species	52	N/A	28	N/A
Total # families	23	N/A	15	N/A
Mean total # individuals ± SE	45.6 ± 7.2	N/A	16.6 ± 2.2	N/A
Mean species richness ± SE	21.6 ± 2.3	N/A	8.8 ± 2.03	N/A
Five most abundant species	*Lethrinus nebulosus*	N/A	*Lethrinus punctulatus*	N/A
	Carangoides fulvoguttatus	N/A	*Caranx ignobilis*	N/A
	Lethrinus punctulatus	N/A	*Gnathanodon speciosus*	N/A
	Choerodon cyanodus	N/A	*Choerodon cyanodus*	N/A
	Caranx ignobilis	N/A	*Alepes* spp**	N/A
Five most common species	*Carangoides fulvoguttatus*	N/A	*Gnathanodon speciosus*	N/A
	Choerodon cyanodus	N/A	*Caranx ignobilis*	N/A
	Scarus ghobban	N/A	*Choerodon cyanodus*	N/A
	Choerodon schoenleinii	N/A	*Lethrinus punctulatus*	N/A
	*Choerodon cauteroma***	N/A	*Alepes* spp**	N/A
Zone of Moderate Impact				
# of deployments	10	10	0	5
Total # individuals	1481	432	N/A	169
Total # species	85	39	N/A	18
Total # families	27	20	N/A	12
Mean total # individuals ± SE	148.1 ± 22.2	43.2 ± 7.6	N/A	33.8 ± 6.8
Mean species richness ± SE	30.8 ± 2.1	12.3 ± 4.5	N/A	10 ± 1.4
Five most abundant species	*Pterocaesio* spp	*Lethrinus punctulatus*	N/A	*Pentapodus vitta*

	Coral*	Macroalgae*	Sand*	Sessile Invertebrates*
	Herklotsichthys spp	*Pentapodus vitta*	N/A	*Upeneus tragula*
	Neopomacentrus filamentosus	*Pentapodus porosus*	N/A	*Pentapodus porosus*
	Caesio teres	*Pentapodus emeryii*	N/A	*Scombridae* spp
	Acanthurus grammoptilus	*Scaevius vitta*	N/A	*Torquigener pallimaculatus*
Five most common species	*Choerodon cyanodus*	*Choerodon cauteroma*	N/A	*Paramonacanthus choirocephalus*
	Choerodon schoenleinii	*Choerodon cyanodus*	N/A	*Pentapodus vitta*
	Epinephelus bilobatus	*Lethrinus punctulatus*	N/A	*Scombridae* spp
	Acanthurus grammoptilus	*Pentapodus emeryii*	N/A	*Feroxodon multistriatus*
	*Plectropomus spp***	*Pentapodus porosus*	N/A	*Lagocephalus lunaris***
Zone of Influence				
# of deployments	20	30	0	20
Total # individuals	2319	1415	N/A	574
Total # species	123	77	N/A	57
Total # families	34	29	N/A	28
Mean total # individuals ± SE	115.95 ± 15.8	47.2 ± 5.2	N/A	28.7 ± 2.6
Mean species richness ± SE	28.7 ± 2.8	14.8 ± 0.7	N/A	8.9 ± 0.8
Five most abundant species	*Pterocaesio* spp	*Lethrinus punctulatus*	N/A	*Pentapodus porosus*
	Caesio cuning	*Pentapodus porosus*	N/A	*Torquigener pallimaculatus*
	Gnathanodon speciosus	*Carangoides fulvoguttatus*	N/A	*Lethrinus genivittatus*
	Lethrinus atkinsoni	*Scaevius vitta*	N/A	*Gnathanodon speciosus*
	Carangoides fulvoguttatus	*Lethrinus genivittatus*	N/A	*Pentapodus vitta*
Five most common species	*Choerodon cyanodus*	*Choerodon cyanodus*	N/A	*Scombridae* spp
	Choerodon schoenleinii	*Choerodon schoenleinii*	N/A	*Gnathanodon speciosus*
	Scombridae spp	*Choerodon cauteroma*	N/A	*Echeneis naucrates*
	Carangoides fulvoguttatus	*Pentapodus emeryii*	N/A	*Pentapodus porosus*

	Coral*	Macroalgae*	Sand*	Sessile Invertebrates*
	Choerodon cauteroma	*Lethrinus nebulosus*	N/A	*Carcharhinus limbatus***

Notes: All habitat types are as surveyed during the Marine Baseline Program.

*** indicates there were additional species present with the same relative abundance, or at the same number of sites that are not presented in the top five listed here (the first species listed alphabetically is presented).*

Table 7-7 Descriptive Statistics for the Length Structure of Fish Assemblages for each Habitat Type Sampled in the Zones of High Impact, Zones of Moderate Impact, and Zones of Influence near the MOF, Causeway, and LNG Access Channel during Post-Development Survey Year 2

	Coral*	Macroalgae*	Sand*	Sessile invertebrates*
Zone of High Impact				
Total # lengths measured	188	N/A	78	N/A
Length range (mm)	26.8 – 2064.6	N/A	46.6 – 2339.4	N/A
Median length (mm)	226.29	N/A	240.5	N/A
Mean length (mm ± SE)	288.3 ± 16.1	N/A	347.2 ± 35.9	N/A
Zone of Moderate Impact				
Total # lengths measured	899	308	N/A	134
Length range (mm)	25.1 – 1978.01	29.9 – 2162.1	N/A	35.3 – 2907.3
Median length (mm)	166.9	167.9	N/A	134.5
Mean length (mm ± SE)	205.5 ± 5.1	202.6 ± 12.9	N/A	267.4 ± 33.2
Zone of Influence				
Total # lengths measured	1440	1062	N/A	417
Length range (mm)	30.46 – 1103.2	25.14 – 2748	N/A	20.95 – 1796.7
Median length (mm)	211.9	161.7	N/A	172.5
Mean length (mm ± SE)	223.5 ± 3.5	198.3 ± 5.3	N/A	247.8 ± 12.8

Note: All habitat types are as surveyed during the Marine Baseline Program. Habitat type changed at some sites surveyed during Post-Development Survey Year 2

Within the ZoMI, a total of 2082 individuals from 107 species and 33 families were recorded from 25 stereo-BRUV deployments (Table 7-6). On average, 19.2 ± 2.2 species were observed on each deployment (Figure 7-3). The largest species richness recorded on a single deployment was 41 at site CI2-1, while the least was six at SI1-4. Sites were distributed within three habitats within the ZoMI (coral, macroalgae, and soft sediments with sessile benthic invertebrates) and the greatest relative abundance and species richness was recorded within coral habitat (Figure 7-3).

The lengths of 1341 individual fish were measured within the ZoMI. The smallest individual measured was a 25.1 mm Brown Demoiselle (*Neopomacentrus filamentosus*) and the largest a 2.9 m Tiger Shark (*Galeocerdo cuvier*). The median fish length was 162.4 mm and the mean fish length measured per deployment within the MOF ZoMI was 211 ± 5.6 mm. A summary of length statistics for each habitat sampled in the ZoMI was developed (Table 7-7).

7.4.2.2 Fish Assemblages Characteristic of Hard and Soft Coral, Macroalgae, Soft Sediments with Sessile Benthic Invertebrates, and Bare Sand Communities in the Vicinity of the Dredge Spoil Disposal Ground

A total of 702 individuals from 51 species and 23 families were recorded from the ten stereo-BRUVs deployed at sites DSI1 and DSI2 in the ZoHI for the Dredge Spoil Disposal Ground. In the Marine Baseline Program these sites were classified as sessile invertebrate habitats, but site DSI1 was seagrass (four of five deployments) at the time of Post-Development Survey Year 2, while site DSI2 remained sessile invertebrates. On average, 10.6 ± 2 species were observed per deployment. The largest species richness recorded on a single deployment was 27 at site DSI1-4, while the least was four at DSI2-1. A summary of relative abundance statistics for sites DSI1 and DSI2 in the ZoHI was developed (Table 7-8).

Within the ZoHI for the Dredge Spoil Disposal Ground, the lengths of 549 individual fish were measured from the ten stereo-BRUV deployments. The smallest individual measured was a 23.2 mm Gulf Damsel (*Pristotis obtusirostris*) and the largest a 940.7 mm Pickhandle Barracuda (*Sphyraena jello*). The median fish length was 192 mm and the mean fish length measured was 225.2 ± 7.3 mm. A summary of length statistics for fish sampled at sites DSI1 and DSI2 within the ZoHI for the Dredge Spoil Disposal Ground was developed (Table 7-9).

Table 7-8 Summary of Relative Abundance and Species Richness for each Habitat Type Sampled in the Zones of High Impact and Zones of Influence associated with the Dredge Spoil Disposal Ground during Post-Development Survey Year 2

	Coral*	Macroalgae*	Sand*	Sessile invertebrates*
Zone of High Impact				
# of deployments	0	0	0	10
Total # individuals	N/A	N/A	N/A	702
Total # species	N/A	N/A	N/A	51
Total # families	N/A	N/A	N/A	23
Mean total # individuals ± SE	N/A	N/A	N/A	70.2 ± 11.5
Mean species richness ± SE	N/A	N/A	N/A	10.6 ± 2
Five most abundant species	N/A	N/A	N/A	*Pentapodus porosus*
	N/A	N/A	N/A	*Pristotis obtusirostris*
	N/A	N/A	N/A	*Carangoides gymnostethus*
	N/A	N/A	N/A	*Gnathanodon speciosus*
	N/A	N/A	N/A	*Carangoides fulvoguttatus*
Five most common species	N/A	N/A	N/A	*Carangoides fulvoguttatus*
	N/A	N/A	N/A	*Scombridae* spp

	Coral*	Macroalgae*	Sand*	Sessile invertebrates*
	N/A	N/A	N/A	*Gnathanodon speciosus*
	N/A	N/A	N/A	*Pentapodus porosus*
	N/A	N/A	N/A	*Carangoides gymnostethus***
Zone of Influence				
# of deployments	3	0	10	0
Total # individuals	326	N/A	563	N/A
Total # species	61	N/A	35	N/A
Total # families	23	N/A	21	N/A
Mean total # individuals ± SE	108.7 ± 21.7	N/A	56.3 ± 19.1	N/A
Mean species richness ± SE	35.7 ± 1.2	N/A	7.7 ± 1.2	N/A
Five most abundant species	*Pomacentrus nagasakiensis*	N/A	*Pentapodus porosus*	N/A
	Neopomacentrus filamentosus	N/A	*Carangoides gymnostethus*	N/A
	Pterocaesio spp	N/A	*Gnathanodon speciosus*	N/A
	Carangoides gymnostethus	N/A	*Selaroides leptolepis*	N/A
	Carangoides fulvoguttatus	N/A	*Pentapodus vitta*	N/A
Five most common species	*Abalistes stellatus*	N/A	*Pentapodus porosus*	N/A
	Carangoides fulvoguttatus	N/A	*Gnathanodon speciosus*	N/A
	Choerodon cyanodus	N/A	*Nemipterus* spp	N/A
	Choerodon schoenleinii	N/A	*Scombridae* spp	N/A
	*Cromileptes altivelis***	N/A	*Carangoides fulvoguttatus**	N/A

Notes: All habitat types are as surveyed during the Marine Baseline Program.

*** indicates there were additional species present with the same relative abundance, or at the same number of sites that are not presented in the top five listed here (the first species listed alphabetically is presented).*

Table 7-9 Descriptive Statistics for the Length Structure of Fish Assemblages within each Habitat Type Sampled in the Zones of High Impact and Zones of Influence near the Dredge Spoil Disposal Ground during Post-Development Survey Year 2

	Coral*	Macroalgae*	Sand*	Sessile invertebrates*
Zone of High Impact				
Total # lengths measured	N/A	N/A	N/A	549
Length range (mm)	N/A	N/A	N/A	23.2 – 940.7
Median length (mm)	N/A	N/A	N/A	192
Mean length (mm ± SE)	N/A	N/A	N/A	225.2 ± 7.3
Zone of Influence				
Total # lengths measured	169	N/A	412	N/A
Length range (mm)	32.5 – 730.4	N/A	39 – 2445.6	N/A
Median length (mm)	260.32	N/A	185.3	N/A
Mean length (mm ± SE)	258.3 ± 13.1	N/A	267.5 ± 10.1	N/A

Note: All habitat types are as surveyed during the Marine Baseline Program. Habitat type changed at some sites during Post-Development Survey Year 2.

7.4.3 Description of Demersal Fish Assemblages at Representative Areas of the Zones of Influence Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

7.4.3.1 Fish Assemblages Characteristic of Hard and Soft Coral, Macroalgae, Soft Sediments with Sessile Benthic Invertebrates, and Bare Sand Communities in Representative Areas of the Zones of Influence in the Vicinity of the MOF, Causeway, and LNG Access Channel

A total of 4308 individuals from 170 species and 42 families were recorded from the 70 stereo-BRUV deployments within the ZoI in the vicinity of the MOF. Changes were observed to habitats sampled at some sites within the ZoI such that all deployments conducted at sessile invertebrate sites SIN1, SIN2, and SIN4 were now either seagrass (SIN1) or bare sand (SIN2 and SIN4). All other sites within the ZoI retained the dominant habitat observed during the Marine Baseline Survey. On average, 17.1 ± 1.3 species were observed on each deployment. The largest species richness recorded on a single deployment was 50 at site CN3-3, while the least was five at CFR1-3 and SIN1-5. A summary of relative abundance statistics for each habitat sampled in the ZoI was developed (Table 7-8).

Within the ZoI in the vicinity of the MOF, the lengths of 2919 individual fish were measured from 70 deployments. The smallest individual measured was a 20.95 mm juvenile Golden Trevally (*Gnathanodon speciosus*) and the largest a 2.8 m Tiger Shark (*Galeocerdo cuvier*). The median fish length was 182.3 mm and the mean length was 217.8 ± 3.2 mm. A summary of length statistics for each habitat sampled in the ZoI is presented in Table 7-9.

Sites were distributed within three habitat types: coral, macroalgae, and sessile benthic invertebrates. The coral habitat recorded the greatest species richness (123 species) and relative abundance, compared to sites within macroalgae habitats (77 species) and sessile invertebrate habitats (57 species) (Figure 7-3).

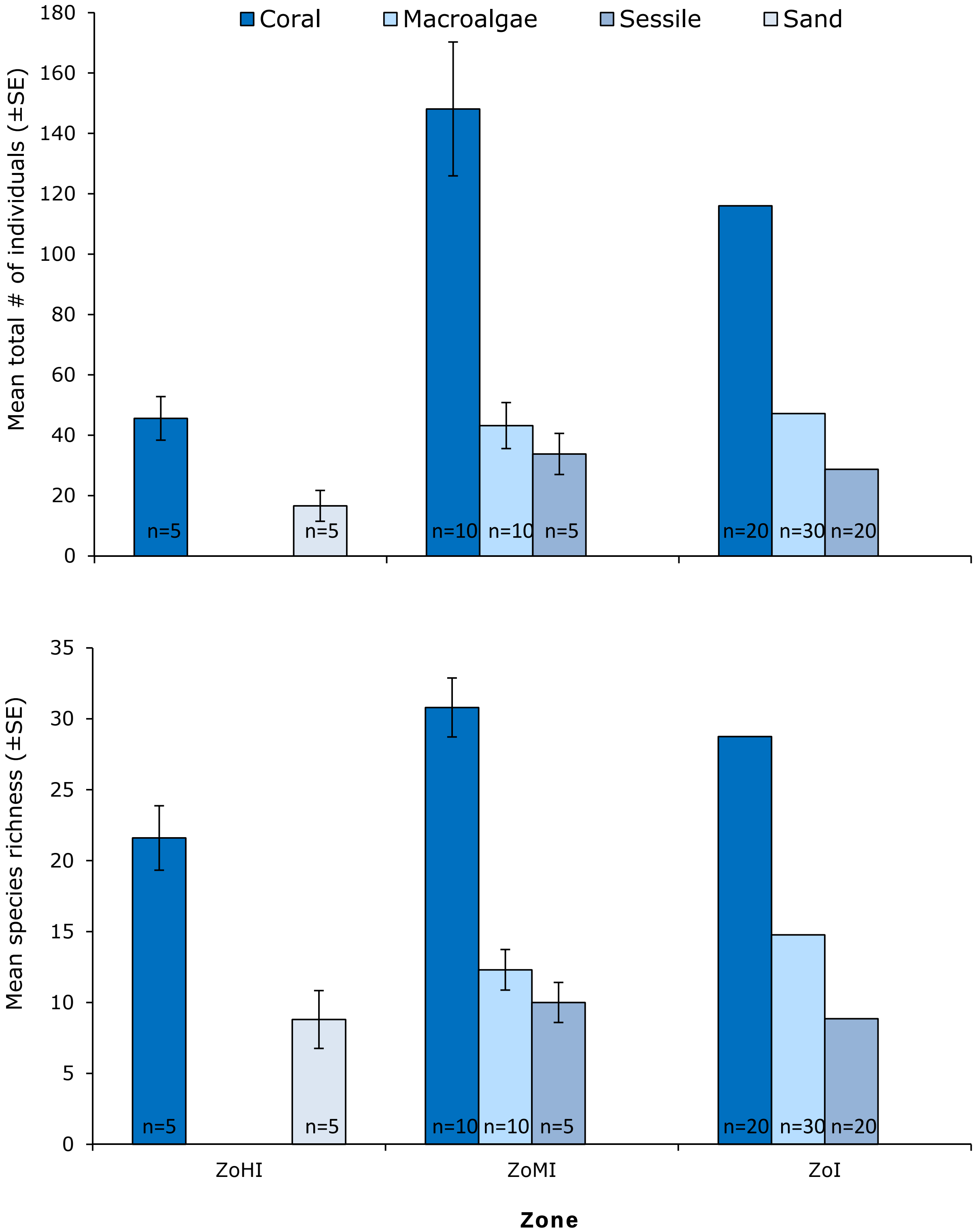


Figure 7-3 Mean Total Number of Individuals (top) and Species Richness (bottom) per Stereo-BRUV Deployment Conducted in each Habitat Type within each Zone in the Vicinity of the MOF, Causeway, and LNG Access Channel during Post-Development Survey Year 2

Note: n = number of deployments

7.4.3.2 Fish Assemblages Characteristic of Hard and Soft Coral, Macroalgae, Soft Sediments with Sessile Benthic Invertebrates, and Bare Sand Communities in Representative Areas of the Zones of Influence in the Vicinity of the Dredge Spoil Disposal Ground

A total of 889 individuals from 84 species and 29 families were recorded from the 13 stereo-BRUV deployments made at sites CN4, DSN1, and DSN3 within the ZoI in the vicinity of the Dredge Spoil Disposal Ground during Post-Development Survey Year 2. On average, 14.2 ± 3.5 species were observed on each deployment. The greatest species richness recorded on a single deployment was 38 at CN4-3, while the least was three at DSN3-4. A summary of relative abundance statistics for sites CN4, DSN1, and DSN3 within the ZoI is presented in Table 7-8.

Within the ZoI in the vicinity of the Dredge Spoil Disposal Ground, the lengths of 581 individual fish were measured from the 13 stereo-BRUV deployments. The smallest individual measured was a 32.5 mm Miller's Damsel (*Pomacentrus milleri*) and the largest a 2.5 m White Spotted Guitarfish (*Rhynchobatus australiae*). The median fish length was 195.3 mm and the mean length was 264.8 ± 8.1 mm. A summary of length statistics for fish sampled at sites CN4, DSN1, and DSN3 within the ZoI for the Dredge Spoil Disposal Ground was developed (Table 7-9).

Sites were distributed within three habitat types: coral, sand, and sessile benthic invertebrates. The greatest species richness and mean number of individuals was observed at the coral sites (Figure 7-4).

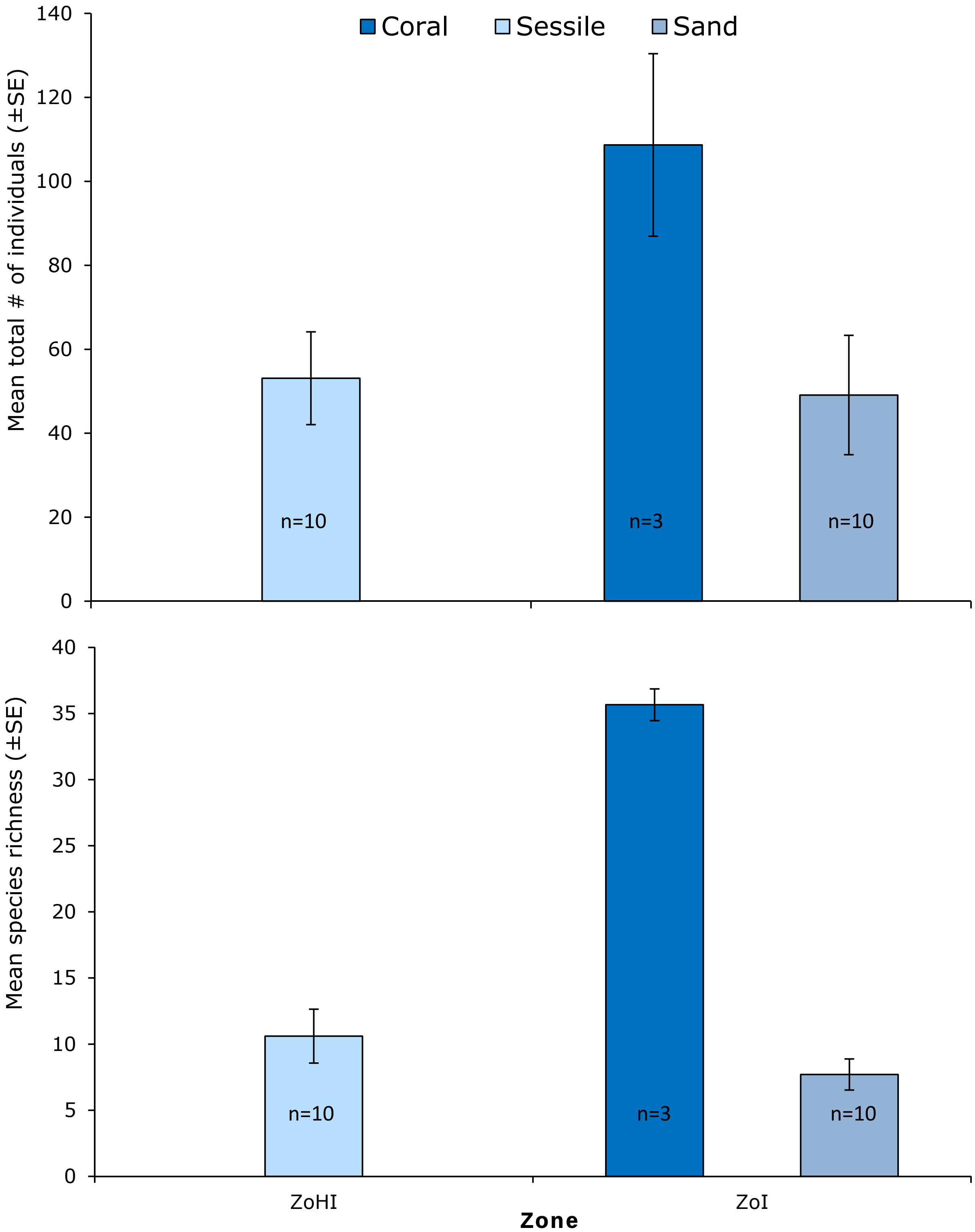


Figure 7-4 Mean Total Number of Individuals (top) and Species Richness (bottom) per Stereo-BRUV Deployment in each Benthic Habitat Type within each Zone in the Vicinity of the Dredge Spoil Disposal Ground during Post-Development Survey Year 2

7.4.4 Description of Demersal Fish Assemblages at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction of the MOF and LNG Jetty

During the Post-Development Survey Year 2, a total of 4886 individuals from 184 species and 4 families were recorded from the 85 stereo-BRUV deployments conducted at Reference Sites. On average, 14.4 ± 0.9 species were observed on each deployment. The greatest species richness recorded on a single deployment was 42 at CFR4-2, while the least was two at SIFR2-2.

At Reference Sites, the lengths of 3630 individual fish (170 species) were measured from the 85 stereo-BRUV deployments. The smallest individual measured was a 24.3 mm Neon Damsel (*Pomacentrus coelestis*) and the largest a 2.85 m Great Hammerhead Shark (*Sphyrna mokarran*). The median fish length was 172.5 mm while the mean length was 216.9 ± 3.1 mm. A summary of length statistics for each habitat sampled at Reference Sites is presented in Table 7-10.

Species richness was greatest within coral habitats (122 species) as was the mean number of individuals (86.4 ± 13). The lowest species richness was observed in the sand habitat (47 species) and the lowest mean number of individuals was observed in sessile invertebrate habitat (38.5 ± 6.3) (Table 7-11, Figure 7-5).

Table 7-10 Descriptive Statistics for the Length Structure of Fish Assemblages within each Habitat at Reference Sites for Post-Development Survey Year 2

	Coral	Macroalgae	Sand	Sessile invertebrates
Reference Sites				
Total # lengths measured	1200	741	1130	559
Length range (mm)	32.6 – 1030	24.3 – 2853.4	24.4 – 2673	28.6 – 1143.8
Median length (mm)	229.9	179	143.1	177
Mean length (mm ± SE)	241.7 ± 4.2	209.3 ± 7.4	186.9 ± 6.4	234.4 ± 7.5

Table 7-11 Summary of Relative Abundance and Species Richness for each Habitat Type Sampled at Reference Sites during Post-Development Survey Year 2

	Coral	Macroalgae	Sand	Sessile invertebrates
Reference Sites				
# of deployments	20	15	30	20
Total # individuals	1728	942	1446	770
Total # species	122	80	47	65
Total # families	36	27	25	27
Mean total # individuals ± SE	86.4 ± 13	62.8 ± 9	48.2 ± 7.4	38.5 ± 6.3
Mean species richness ± SE	24.1 ± 1.7	19.7 ± 1.2	8.9 ± 0.5	9.05 ± 1.1
Five most abundant species	*Pentapodus vitta*	*Pentapodus emeryii*	*Pentapodus vitta*	*Pentapodus porosus*

	Coral	Macroalgae	Sand	Sessile invertebrates
	Pentapodus porosus	*Pterocaesio* spp	*Selaroides leptolepis*	*Nemipterus* spp
	Selaroides leptolepis	*Scaevius vitta*	*Gnathanodon speciosus*	*Gnathanodon speciosus*
	Gnathanodon speciosus	*Choerodon cyanodus*	*Upeneus tragula*	*Pentapodus vitta*
	Herklotsichthys spp	*Halichoeres nebulosus*	*Nemipterus* spp	*Atule mate*
Five most common species	*Choerodon cyanodus*	*Choerodon cyanodus*	*Pentapodus vitta*	*Scombridae* spp
	Pentapodus emeryii	*Pentapodus emeryii*	*Paramonacanthus choirocephalus*	*Pentapodus porosus*
	Upeneus tragula	*Choerodon schoenleinii*	*Pentapodus porosus*	*Nemipterus* spp
	Gnathanodon speciosus	*Scarus ghobban*	*Scombridae* spp	*Gnathanodon speciosus*
	Pomacentrus milleri	*Lethrinus nebulosus*	*Selaroides leptolepis**	*Echeneis naucrates**

Notes: All habitat types are as surveyed during the Marine Baseline Program.

*** indicates there were additional species present with the same relative abundance, or at the same number of sites that are not presented in the top five listed here (the first species listed alphabetically is presented).*

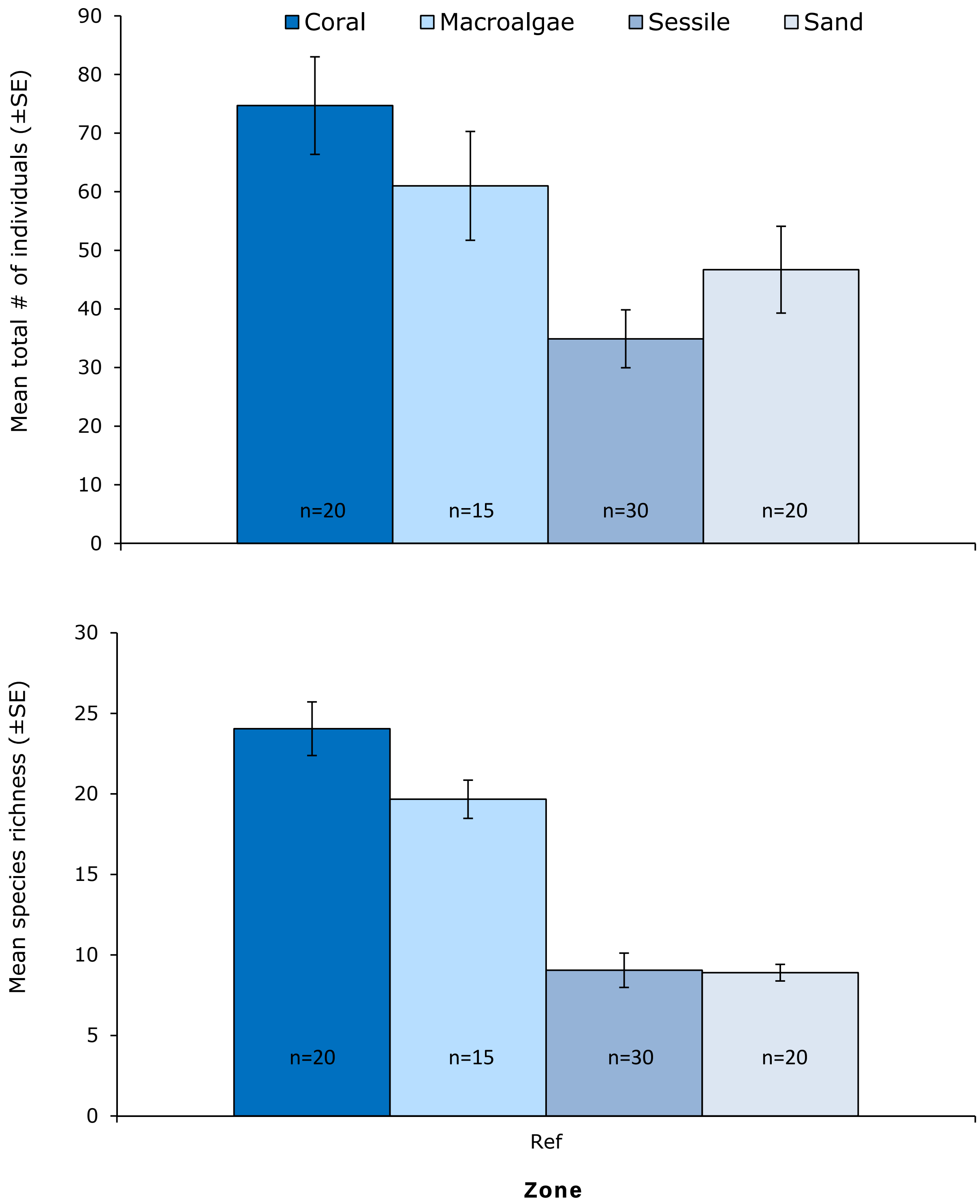


Figure 7-5 Mean Total Number of Individuals (top) and Species Richness (bottom) per Stereo-BRUV Deployment in each Benthic Habitat Type at Reference Sites during Post-Development Survey Year 2

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

7.5.1 Relative Abundance

Statistical analysis of the relative abundance of fish using the full six-factor design did not reveal any significant changes in the terms of interest for comparisons of sites or the MOF versus Reference Sites only. Therefore, the five-factor design with Year pooled was used to test all sites. This design yielded a significant term of interest with the interaction of Survey × IvR (Table 7-12). Pair-wise tests for this term showed that the relative abundance of fish at Impact Sites differed from the Marine Baseline Survey to Post-Development Survey Year 1 and Post-Development Survey Year 2, and from Post-Development Survey Year 1 to Post-Development Survey Year 2 (Table 7-13). The relative abundance of fish also differed at Reference Sites between each survey occasion (Table 7-13). When centroids for the term Survey × IvR were plotted in an MDS ordination, this disparity between Marine Baseline Surveys and Post-Development Surveys was evident for Impact Sites (Figure 7-6), however, the difference between fish assemblages surveyed during Post-Development Survey Year 1 and Post-Development Survey Year 2 at Impact Sites was less clear. For Reference Sites, the plot shows distinct separation of Post-Development Survey Year 2 from both Post-Development Survey Year 1 and the Marine Baseline Program.

Table 7-12 Multivariate PERMANOVA Results for Relative Abundance (Five-factor Design with Year Pooled)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	30340.00	15170.00	4.52	<0.001	9866
IvR	1	21485.00	21485.00	1.75	0.079	9931
Habitat	2	493040.00	246520.00	20.21	<0.001	9938
Zone(IvR)	2	23796.00	11898.00	0.96	0.472	9898
Survey×IvR	*2*	*11328.00*	*5663.80*	*1.70*	***0.018***	*9884*
Survey×Habitat	4	33413.00	8353.30	2.52	<0.001	9864
IvR×Habitat	2	31238.00	15619.00	1.28	0.177	9928
Survey×Zone(IvR)	*4*	*16948.00*	*4237.00*	*1.26*	*0.135*	*9861*
Zone(IvR)×Habitat**	3	36432.00	12144.00	0.98	0.462	9919
Survey×IvR×Habitat	*4*	*16426.00*	*4106.50*	*1.24*	*0.109*	*9843*
Site(Zone(IvR)×Habitat)	32	382050.00	11939.00	7.11	<0.001	9563
Survey×Zone(IvR)×Habitat*	*6*	*17136.00*	*2856.00*	*0.86*	*0.762*	*9830*
Survey×Site(Zone(IvR)×Habitat)	64	209630.00	3275.50	1.95	<0.001	9390
Res	625	1049000.00	1678.50			
Total	753	2589100.00				

*Notes: Bold font in P(perm) column = significant difference for term of interest; ** = Term has one or more empty cells*

Table 7-13 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × IvR for Relative Abundance

Zone	t	P(perm)	Permutations
Impact			
Post-Development Survey Year 2, Post-Development Survey Year 1	1.60	**0.004**	9921
Post-Development Survey Year 2, Marine Baseline Program	1.87	**0.003**	9937
Post-Development Survey Year 1, Marine Baseline Program	1.80	**0.009**	9933
Reference			
Post-Development Survey Year 2, Post-Development Survey Year 1	1.80	**0.001**	9933
Post-Development Survey Year 2, Marine Baseline Program	1.97	**<0.001**	9934
Post-Development Survey Year 1, Marine Baseline Program	1.47	**0.020**	9929

Notes: Bold font in P(perm) column = significant difference for term of interest

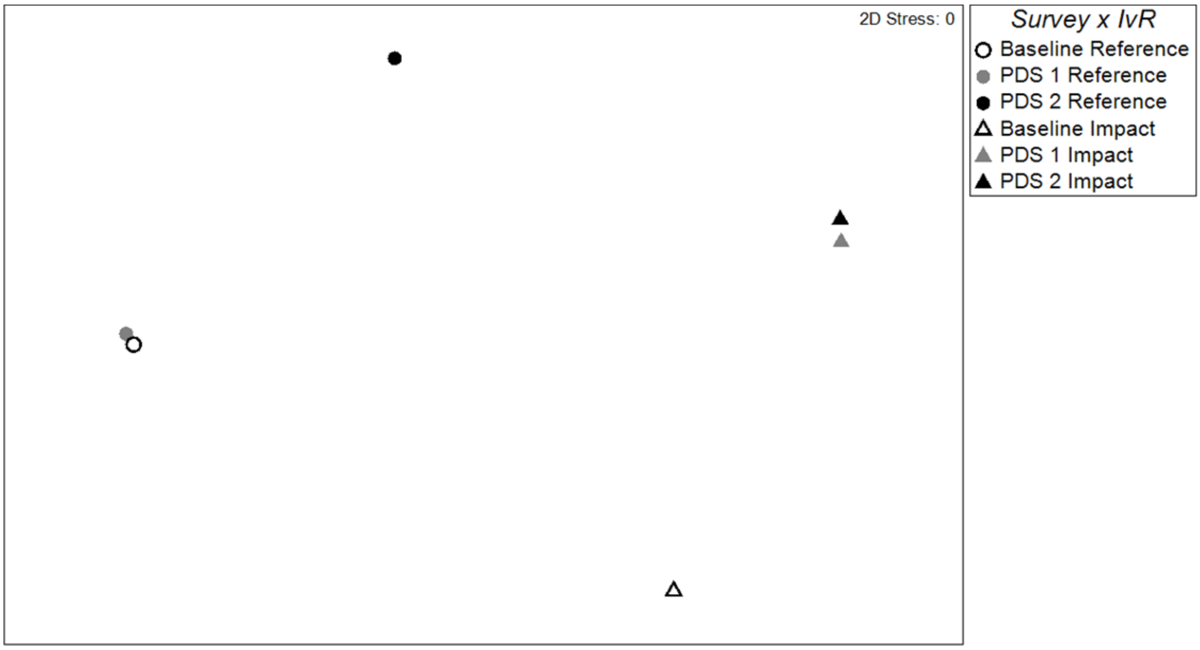


Figure 7-6 MDS Ordination of Relative Abundance of Demersal Fish showing the Group Centroids for the Significant Interaction Term Survey × IvR

The CAP analysis, while significant (P<0.01), did not distinguish between groups well (Figure 7-7). Despite this, the CAP plot illustrates separation of both Impact and Reference Sites (along CAP2 axis) as well a shift from the Marine Baseline Program to Post-Development Survey Year 1 and Post-Development Survey Year 2 (CAP1 axis). The CAP analysis identified 25 species with correlations of |r| >0.28 to at least one canonical axis, of which 13 were present at >25% of sites. Seven of these species were correlated with Impact Sites (i.e. were more abundant, on average, at Impact Sites than at Reference Sites): An*ampses lennardi, Chaetodontoplus duboulayi, Choerodon cauteroma, Lethrinus laticaudis, Parupeneus indicus, Pentapodus emeryii,* and *Scolopsis monogramma* (Figure 7-8). PERMANOVAs on each of these seven species identified only two with significant results for terms of interest: *A. lennardi* and *L. laticaudis*, reflecting a significant decline in abundance at Impact Sites from the Marine Baseline Program to Post-Development Survey Year 1 and Year 2 (Figure 7-7, Figure 7-8).

Two species exhibited correlations to Reference Sites (i.e. were more abundant, on average, at Reference Sites than Impact Sites): *Herklotsichthys* spp. and *Nemipterus* spp. (Figure 7-7,

Figure 7-9). However, the five-factor PERMANOVA test found no significant result for any term of interest and that this higher abundance at Reference Sites appears driven by habitat (significant results for habitat). Similarly, there were a number of species correlated with the Marine Baseline Program (*Scarus schlegeli, Siganus fuscescens*; Figure 7-10) and with Post-Development Survey Year 2 sampling (*Gnathanodon speciosus, Scaevius vitta*; Figure 7-11). Higher abundances on each of these survey occasions reflect changes in habitat and are not indicative of an impact, i.e. there were no significant terms of interest in their PERMANOVA tests.

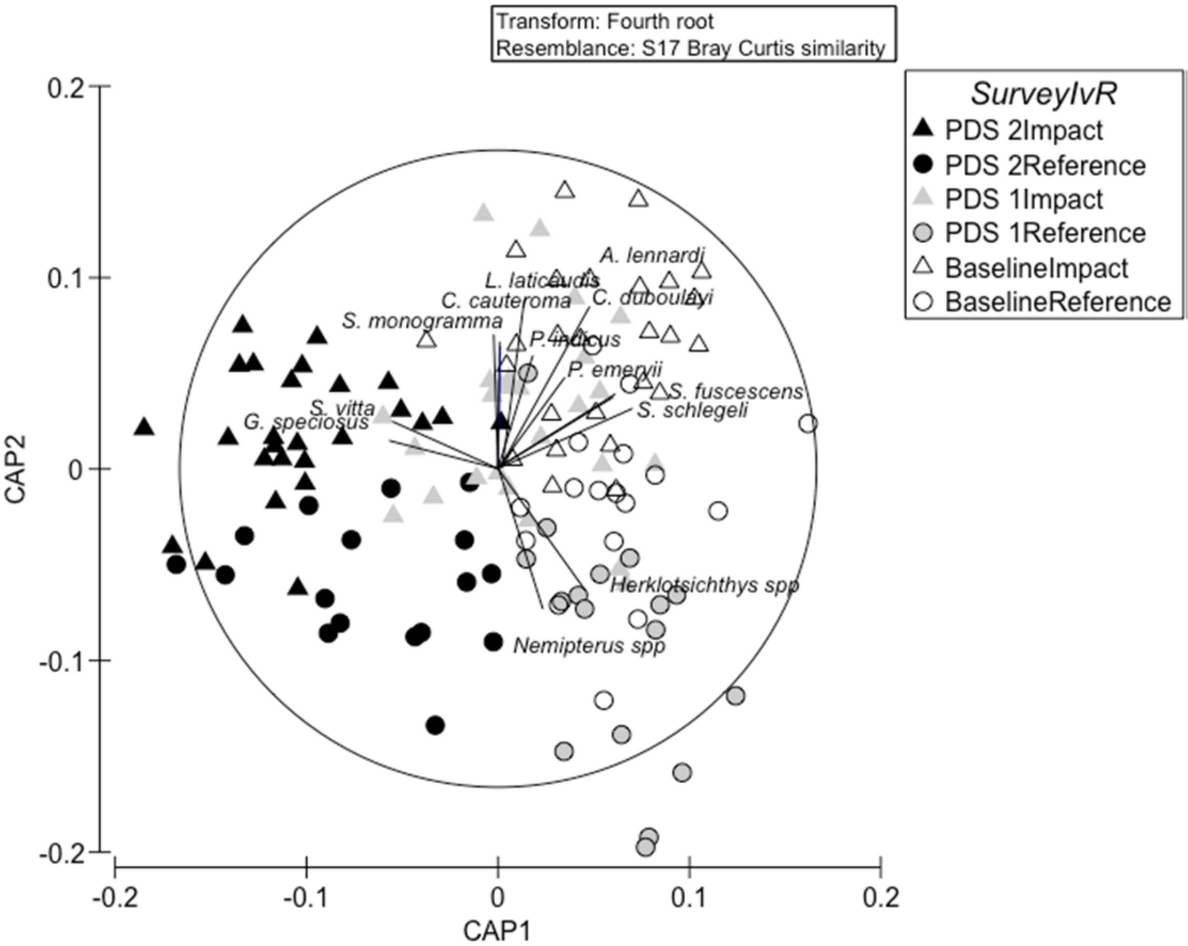
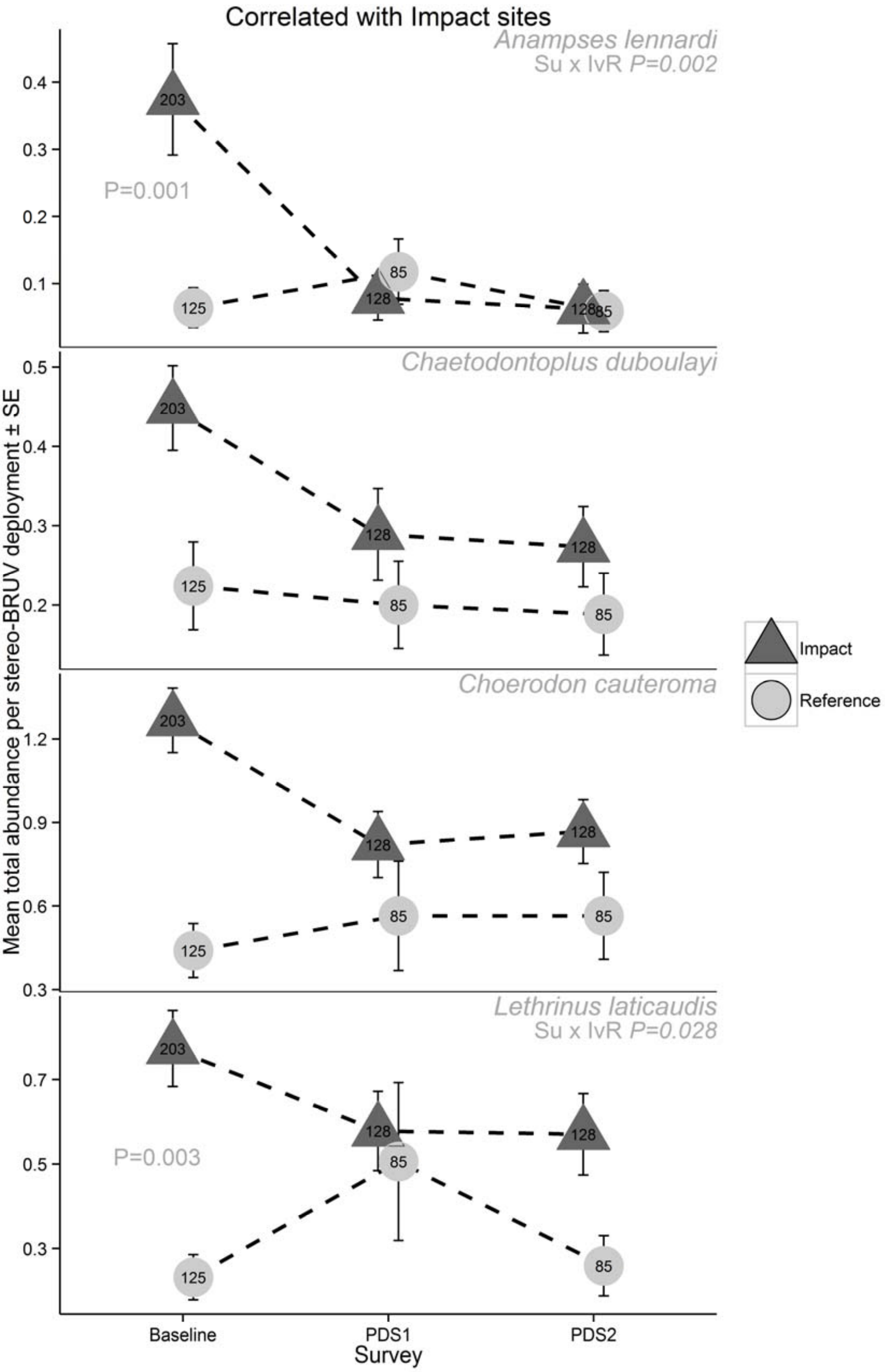


Figure 7-7 Canonical Analysis of Principal Coordinates (CAP; using Bray-Curtis dissimilarity measure) of Demersal Fish showing Centroids for Impact (triangles) and Reference (circles) Sites for the Marine Baseline Program (open symbols), Post-Development Survey Year 1 (grey) and Post-Development Survey Year 2 (black)

Note: Species with Spearman correlations of |r| >0.28 that were present at more than 25% of sites are overlaid in the bi-plot.


Correlated with Impact sites
Anampses lennardi
Su x IvR P=0.002
P=0.001
Chaetodontoplus duboulayi
Choerodon cauteroma
Lethrinus laticaudis
Su x IvR P=0.028
P=0.003
Mean total abundance per stereo-BRUV deployment ± SE
Baseline
PDS1
PDS2
Survey
Impact
Reference

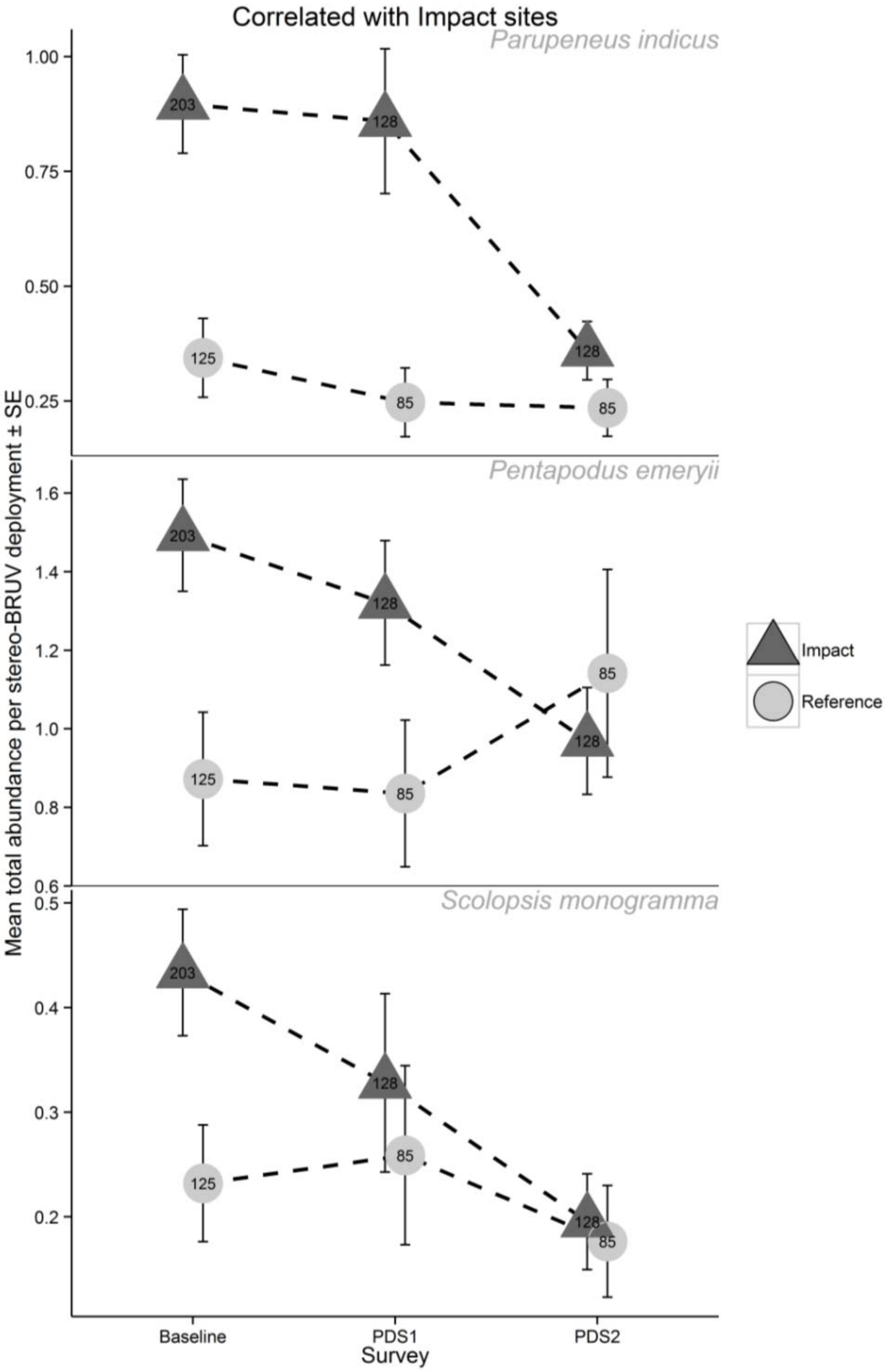


Figure 7-8 Demersal Fish Species identified using CAP Analyses to Correlate with Impact Sites for the Marine Baseline Program, Post-Development Survey Year 1 and Post-Development Survey Year 2 at Impact (triangle) and Reference (circle) Sites

Note: The number of stereo-BRUV deployments used to calculate the means are provided within plots. Anampses lennardi and Lethrinus laticaudis were the only two species to exhibit significant results for a term of interest (results of pair-wise comparisons displayed on the plot); Scale differs between species.

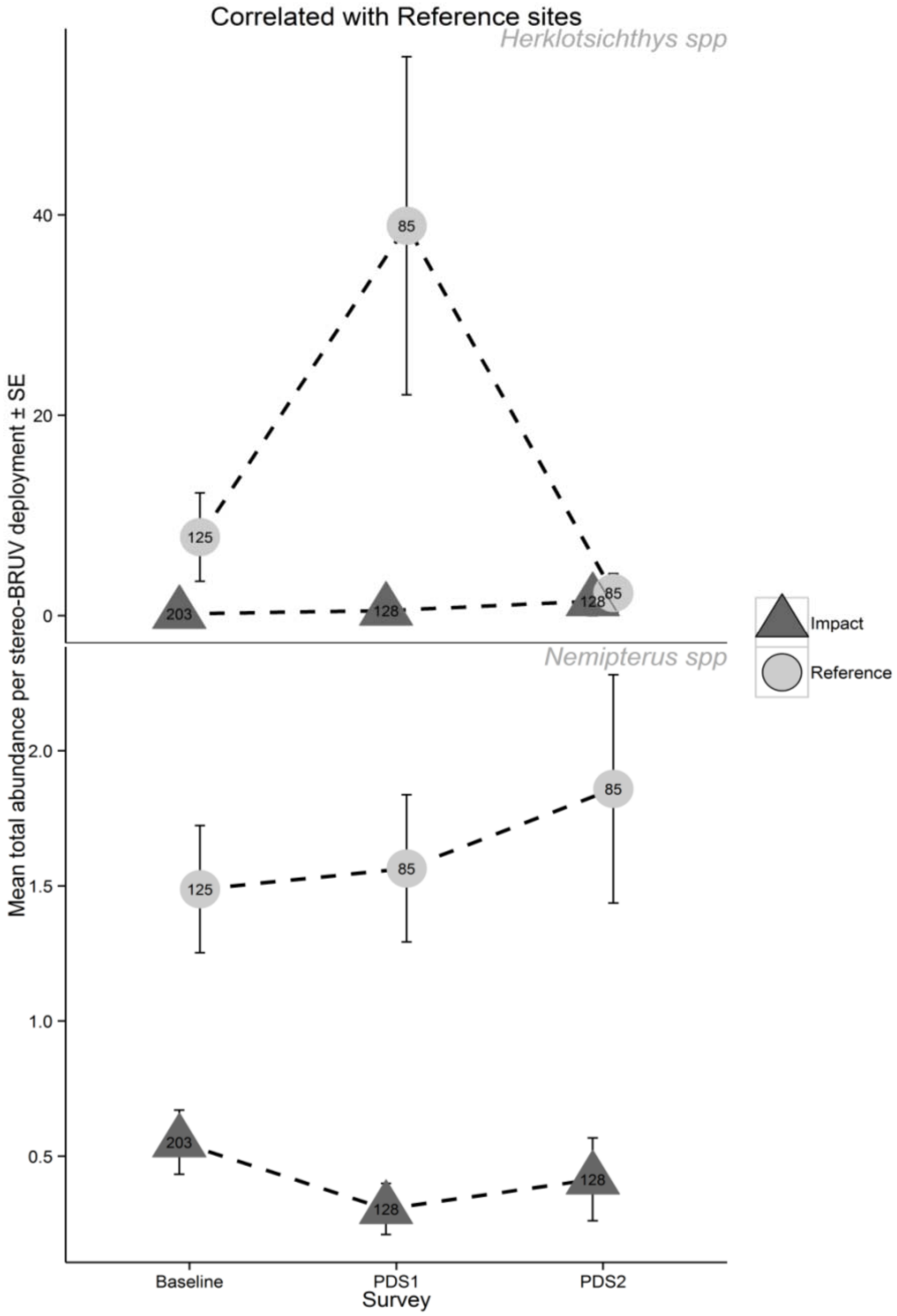


Figure 7-9 Demersal Fish Species identified using CAP Analyses to Correlate with Reference Sites for the Marine Baseline Program, Post-Development Survey Year 1 and Post-Development Survey Year 2 at Impact (triangle) and Reference (circle) Sites

Note: The number of stereo-BRUV deployments used to calculate the means are provided within plots. None of these species exhibited a significant result for any term of interest; Scale differs between species.

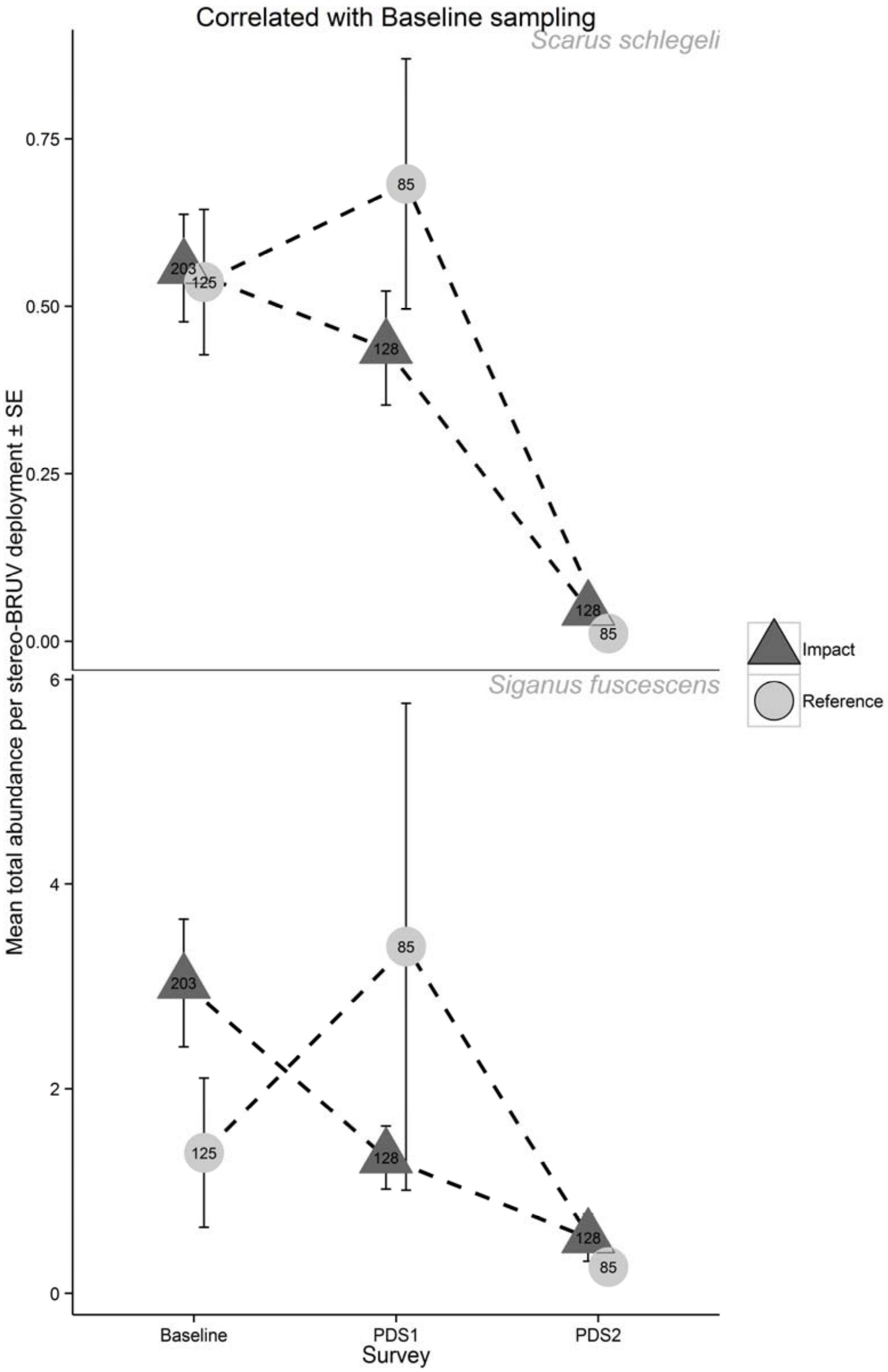


Figure 7-10 Demersal Fish Species identified using CAP Analyses to Correlate with Marine Baseline Program Surveys for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2 at Impact (triangle) and Reference (circle) Sites

Note: The number of stereo-BRUV deployments used to calculate the means are provided within plots. None of these species exhibited a significant result for any term of interest; Scale differs between species.

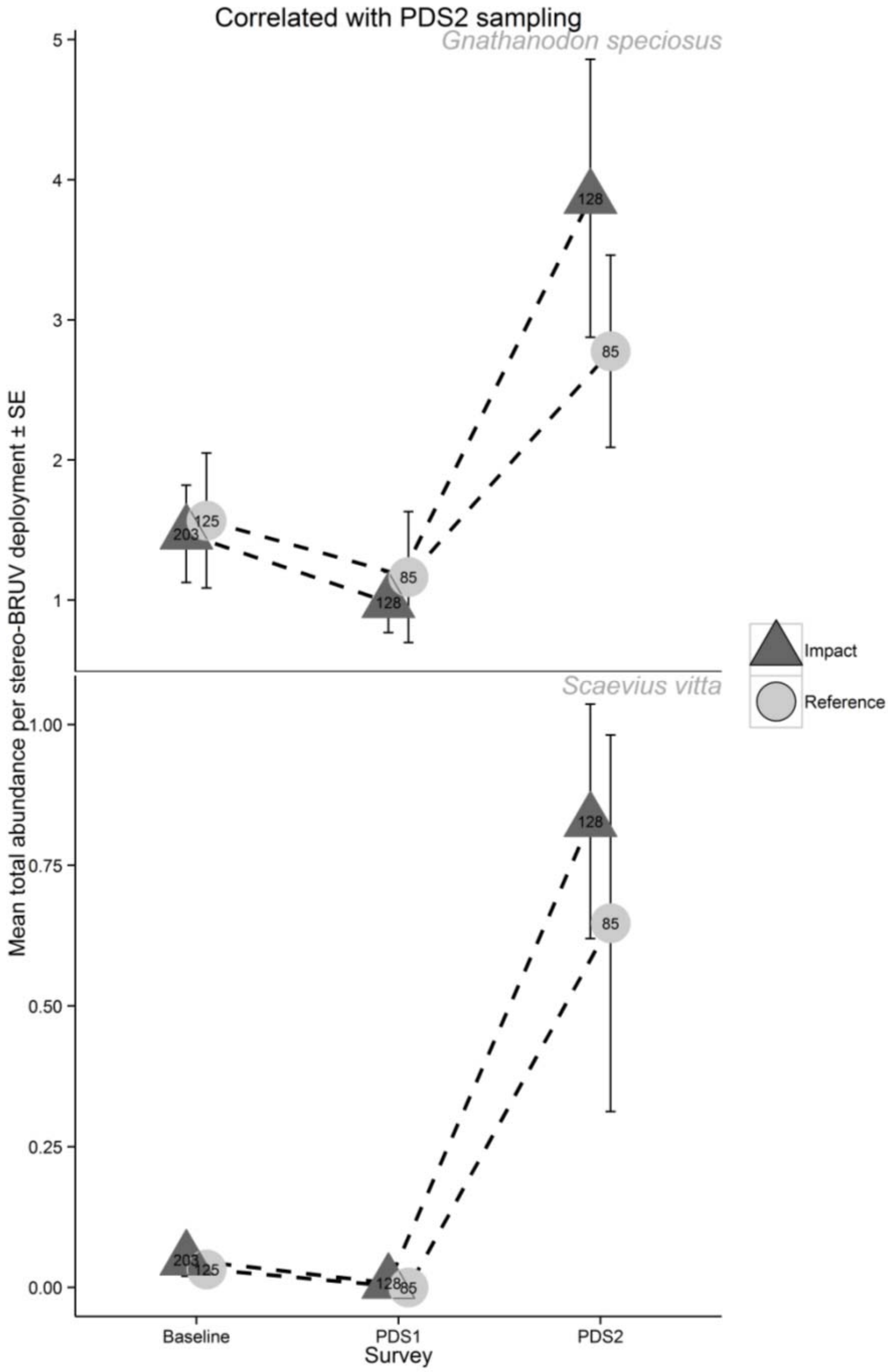


Figure 7-11 Demersal Fish Species identified using CAP Analyses to Correlate with Post-Development Survey Year 2 for the Marine Baseline Program, Post-Development Survey Year 1 and Post-Development Survey Year 2 at Impact (triangle) and Reference (circle) Sites

Note: The number of stereo-BRUV deployments used to calculate the means are provided within plots. None of these species exhibited a significant result for any term of interest; Scale differs between species.

7.5.2 Total Number of Fish

Statistical analysis of the total number of fish using the full six-factor design did not reveal any significant changes in the terms of interest for either all sites or the MOF and Reference Sites only. Therefore, the five-factor design with Year pooled was used to test all sites. However, this also yielded no significant results for the terms of interest. Following on, the four-factor design (Year and Site pooled) was then used, with this design revealing a significant term of interest with the interaction of Survey × IvR (Table 7-14). Pair-wise tests showed that, for Impact Sites, there was a significant change in the total number of fish from the Marine Baseline Surveys to Post-Development Survey Year 1 (4% increase), but a significant decrease from the Marine Baseline Surveys to Post-Development Survey Year 2 (16% decline) (Table 7-15). There was no significant difference in the total number of fish surveyed from Post-Development Survey Year 1 to Post-Development Survey Year 2. For Reference Sites, the total number of fish increased significantly from the Marine Baseline Surveys to Post-Development Survey Year 1 (82% increase). Total numbers of fish exhibited a significant 55% decrease from Post-Development Survey Year 1 to Post-Development Survey Year 2 such that numbers observed during Post-Development Survey Year 2 did not differ from those recorded during the Marine Baseline Surveys (Figure 7-12).

Table 7-14 Univariate PERMANOVA Results for Total Number of Fish (Four-factor Design with Year and Site Pooled)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	2.93	1.46	5.50	0.005	9950
IvR	1	2.09	2.09	7.83	0.006	9845
Habitat	2	15.03	7.51	28.22	<0.001	9956
Zone(IvR)	2	3.39	1.70	6.37	0.002	9945
Survey×IvR	*2*	*2.82*	*1.41*	*5.29*	***0.004***	*9947*
Survey×Habitat	4	4.10	1.03	3.85	0.004	9940
IvR×Habitat	2	4.25	2.12	7.97	0.001	9960
Survey×Zone(IvR)	*4*	*1.36*	*0.34*	*1.28*	*0.269*	*9939*
Zone(IvR)×Habitat**	3	3.96	1.32	4.96	0.002	9952
Survey×IvR×Habitat	*4*	*1.09*	*0.27*	*1.03*	*0.392*	*9958*
Survey×Zone(IvR)×Habitat*	*6*	*2.82*	*0.47*	*1.77*	*0.107*	*9935*
Res	721	191.94	0.27			
Total	753	256.24				

*Notes: Bold font in P(perm) column = significant difference for term of interest; ** = Term has one or more empty cells*

Table 7-15 Pair-wise Comparison in PERMANOVA for the Significant Interaction Term Survey × IvR for Total Number of Fish

Zone	t	P(perm)	Permutations
Impact			
Post-Development Survey Year 2, Post-Development Survey Year 1	0.86	0.392	9840
Post-Development Survey Year 2, Marine Baseline Program	3.48	**0.001**	9832
Post-Development Survey Year 1, Marine Baseline Program	2.18	**0.032**	9815

Zone	t	P(perm)	Permutations
Reference			
Post-Development Survey Year 2, Post-Development Survey Year 1	2.74	**0.007**	9805
Post-Development Survey Year 2, Marine Baseline Program	1.25	0.219	9832
Post-Development Survey Year 1, Marine Baseline Program	2.12	**0.037**	9825

Notes: Bold font in P(perm) column = significant difference for term of interest

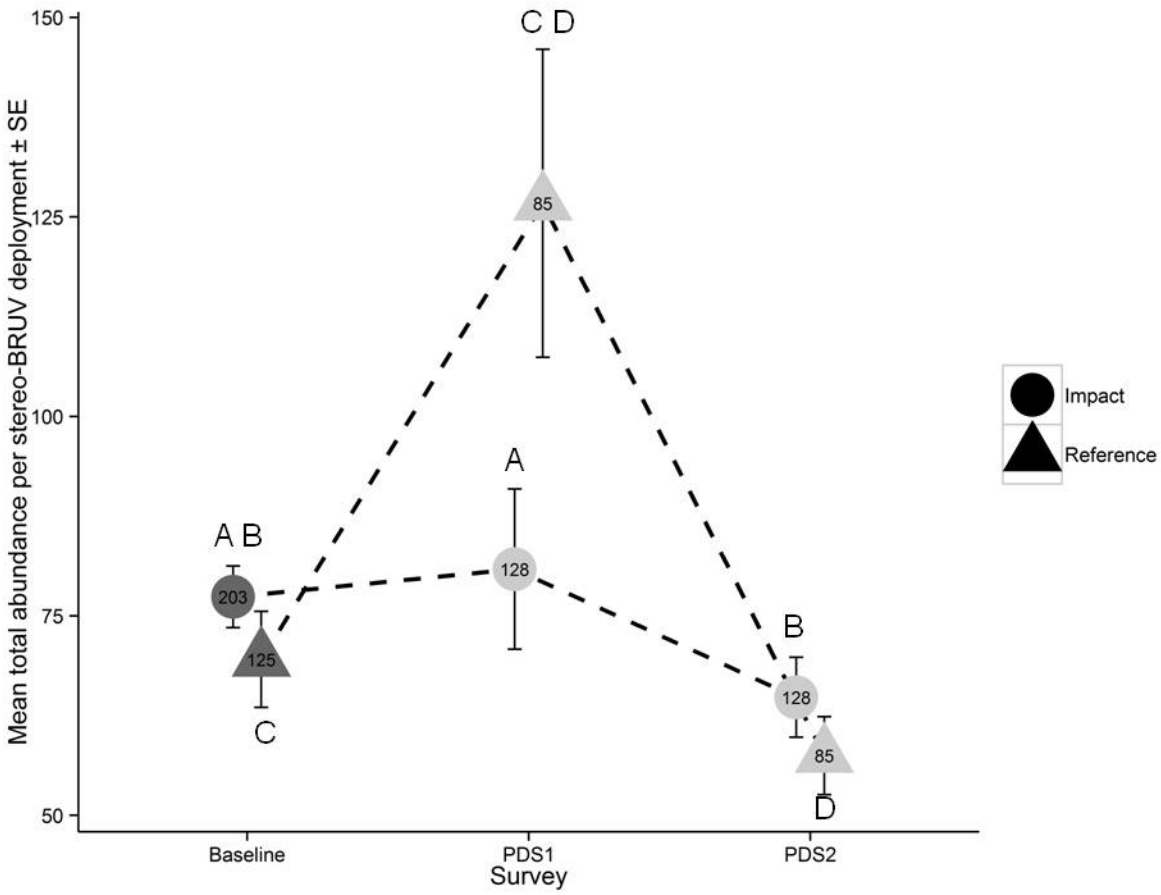


Figure 7-12 Mean Total Number of Fish per Stereo-BRUV Deployment

Notes: The significant interaction of Survey × IvR is illustrated; n = number of stereo-BRUV deployments conducted to calculate the means; Points marked with the same letter (e.g. 'A') differ significantly.

7.5.3 Species Richness

Statistical analysis of species richness using the full six-factor design detected a significant interaction of Survey × Zone(IvR) (Table 7-16). Pair-wise tests (Table 7-17) for levels of the factor 'Survey' found that species richness in the ZoHI declined by a significant 38% from the Marine Baseline Surveys to Post-Development Survey Year 1 (Figure 7-13). No other significant changes were observed for species richness across all Zones surveyed.

Table 7-16 Univariate PERMANOVA Results for Species Richness (Six-factor Design)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	0.13554	6.78E-02	1.0208	0.562	9960
IvR	1	0.29	0.29	1.96	0.222	9962
Habitat	2	24.96	12.48	51.75	<0.001	9941
Year(Survey)	1	0.07	0.07	1.18	0.288	9837
Zone(IvR)	2	0.42	0.21	2.42	0.099	9955
Survey×IvR	*2*	*0.32*	*0.16*	*1.84*	*0.255*	*9964*
Survey×Habitat	4	0.12	0.03	0.60	0.819	9953
IvR×Habitat	2	0.68	0.34	2.89	0.058	9950
Survey×Zone(IvR)	*4*	*0.51*	*0.13*	*3.53*	***0.018***	*9966*
Year(Survey)×IvR	1	0.06	0.06	0.99	0.332	9854
Year(Survey)×Habitat	2	0.19	0.10	1.68	0.219	9948
Zone(IvR)×Habitat**	3	0.62	0.21	1.78	0.165	9936
Survey×IvR×Habitat	*4*	*0.41*	*0.10*	*2.11*	*0.125*	*9951*
Site(Zone(IvR)×Habitat)	32	3.46	0.11	1.74	0.124	9929
Year(Survey)×Zone(IvR)	2	0.00	0.00	0.06	0.923	9939
Survey×Zone(IvR)×Habitat*	*6*	*0.14*	*0.02*	*1.02*	*0.513*	*9951*
Year(Survey)×IvR×Habitat	2	0.05	0.03	0.44	0.645	9945
Survey×Site(Zone(IvR)×Habitat)	64	3.23	0.05	0.84	0.699	9932
Year(Survey)×Zone(IvR)×Habitat**	3	0.10	0.03	0.60	0.583	9961
Year(Survey)×Site(Zone(IvR)× Habitat)**	20	1.15	0.06	1.88	0.014	9912
Res	594	18.18	0.03			
Total	753	69.29				

*Notes: Bold font in P(perm) column = significant difference for term of interest; ** = Term has one or more empty cells*

Table 7-17 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × Zone(IvR) for Species Richness

Zone	t	P(perm)	Permutations
ZoHI			
Post-Development Survey Year 2, Post-Development Survey Year 1	3.15	0.086	1027
Post-Development Survey Year 2, Marine Baseline Program	1.16	0.394	9927
Post-Development Survey Year 1, Marine Baseline Program	5.02	**0.013**	9931
ZoMI			
Post-Development Survey Year 2, Post-Development Survey Year 1	1.14	0.376	8851
Post-Development Survey Year 2, Marine Baseline Program	0.28	0.969	9976
Post-Development Survey Year 1, Marine Baseline Program	0.42	0.895	9974
ZoI			
Post-Development Survey Year 2, Post-Development Survey Year 1	0.31	0.763	9865
Post-Development Survey Year 2, Marine Baseline Program	0.94	0.591	9970

Zone	t	P(perm)	Permutations
Post-Development Survey Year 1, Marine Baseline Program	0.92	0.618	9958
Reference			
Post-Development Survey Year 2, Post-Development Survey Year 1	1.38	0.190	9844
Post-Development Survey Year 2, Marine Baseline Program	0.76	0.745	9967
Post-Development Survey Year 1, Marine Baseline Program	0.97	0.561	9970

Notes: Bold font in P(perm) column = significant difference for term of interest

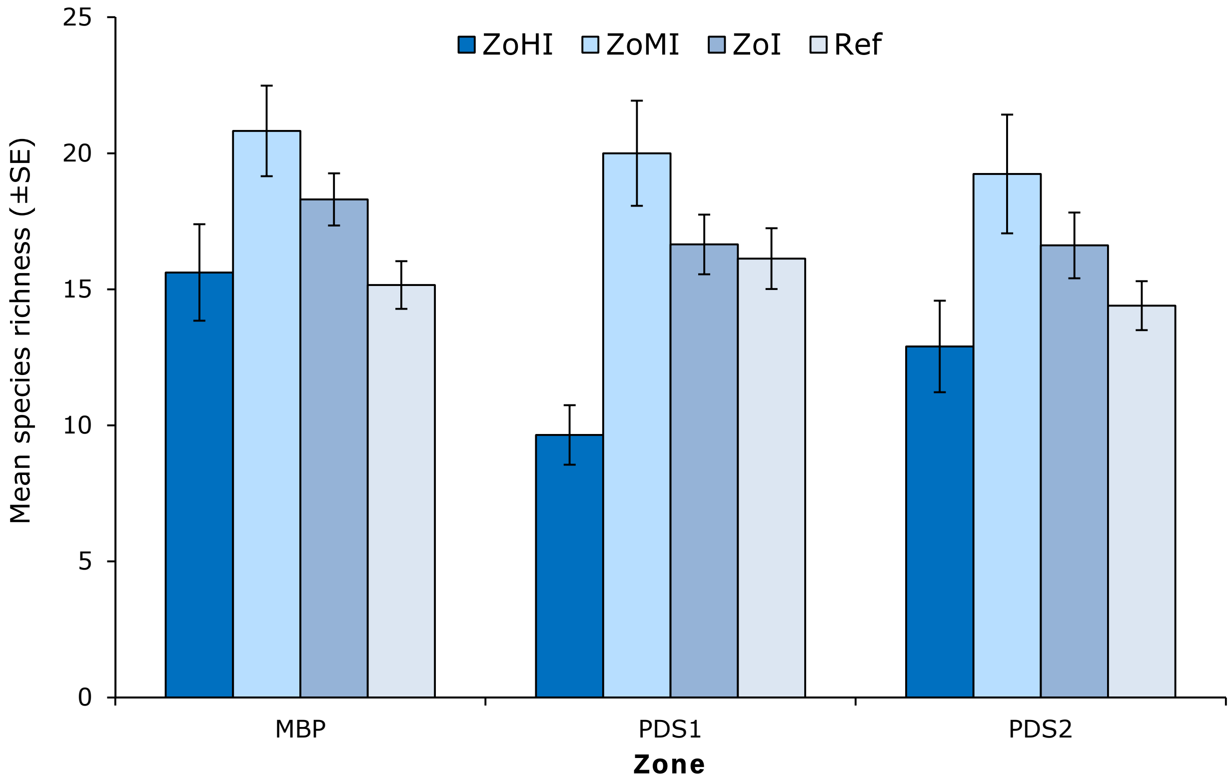


Figure 7-13 Mean Species Richness Recorded per Stereo-BRUV Deployment during the Marine Baseline Program and Post-Development Survey for each Zone (top) and Sites within the ZoHI (bottom)

Note: n = number of stereo-BRUV deployments conducted to calculate the means.

7.5.4 Fish Length

The step-wise approach for detecting change in the fish assemblage length-structure did not detect any significant differences in the terms of interest at any level of pooling (see Section 7.3 for an explanation of the terms of interest). The length frequency histograms for the interaction of Survey and Zone were plotted and no patterns or changes were evident in these length-frequency distributions.

Length-frequency distribution histograms were produced for each site surveyed during the Marine Baseline and Post-Development Surveys. These are presented in Figure 7-14 to Figure 7-19 and are organised by Zone and by Habitat. There were no obvious trends in the length-frequency histograms among zones or survey periods.

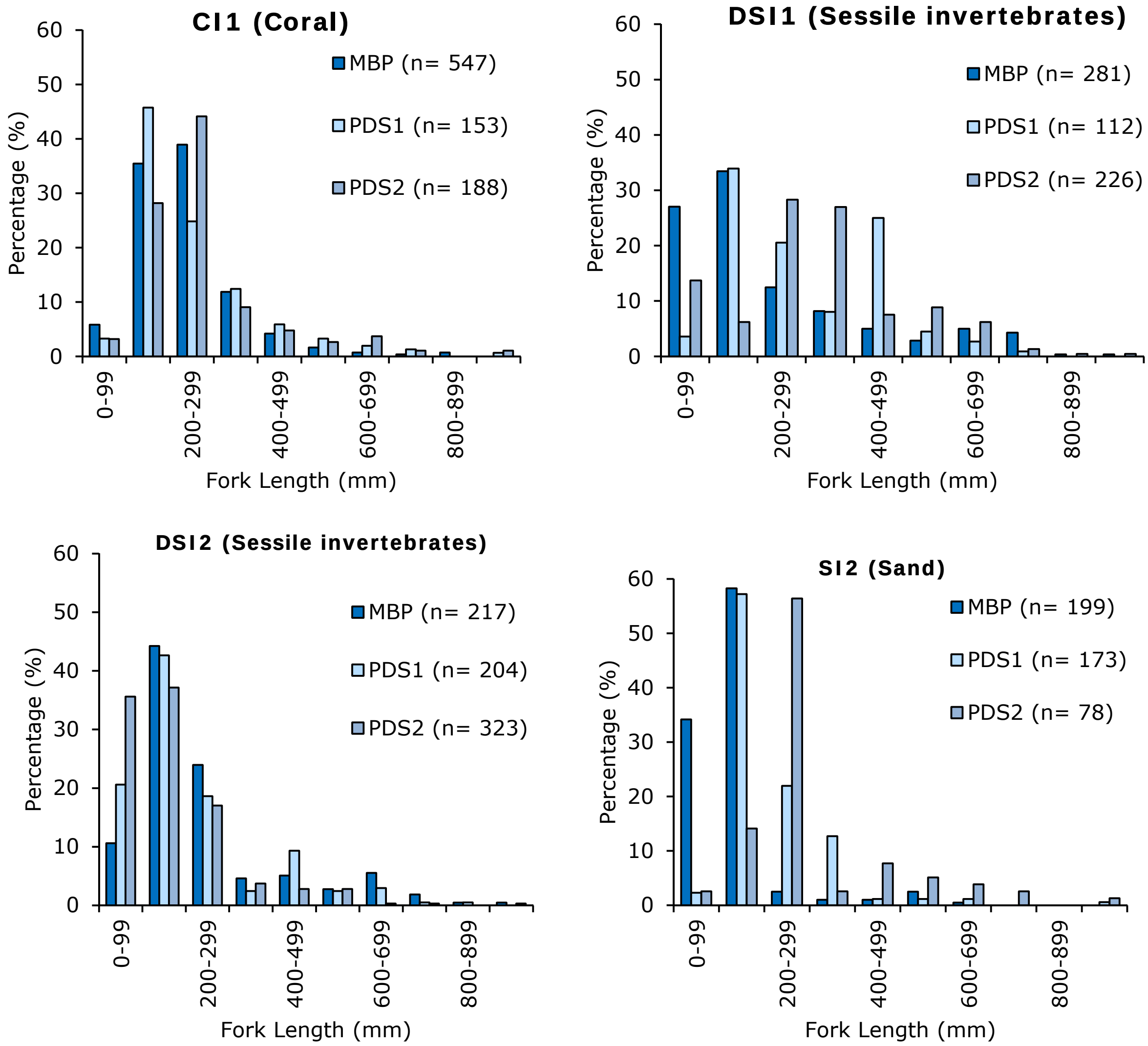


Figure 7-14 Length-frequency of Demersal Fish Species at Sites (Benthic Habitat) within the Zones of High Impact for the Marine Baseline Program (MBP), Post-Development Survey Year 1 (PDS1) and Post-Development Survey Year 2 (PDS2)

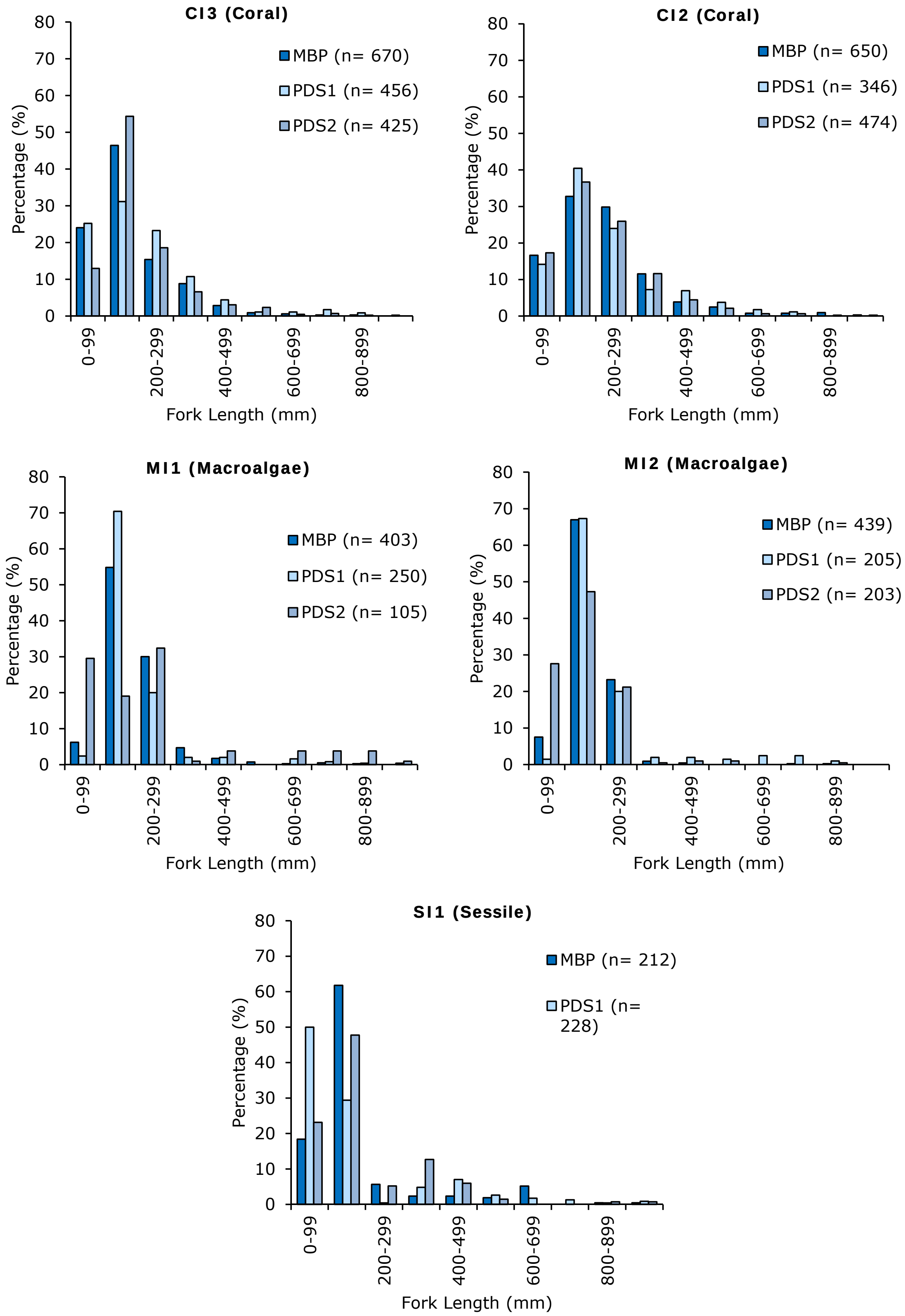
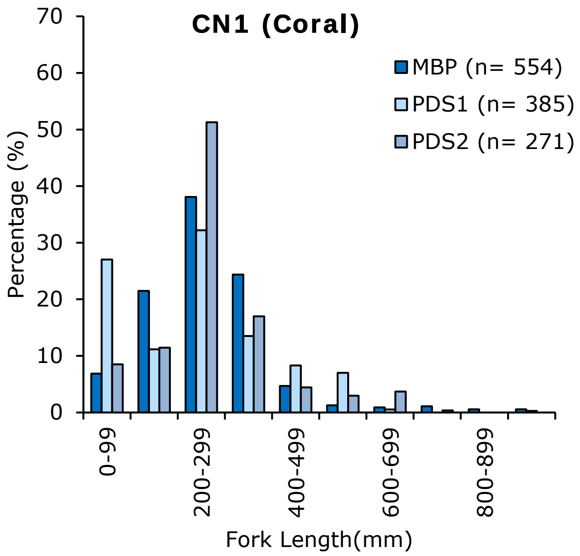
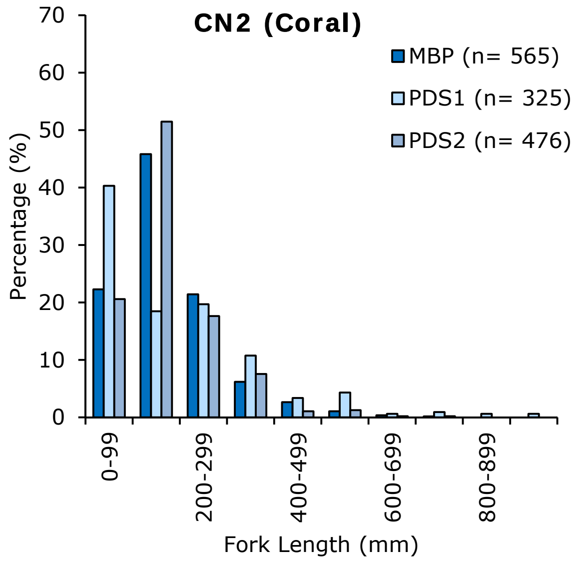
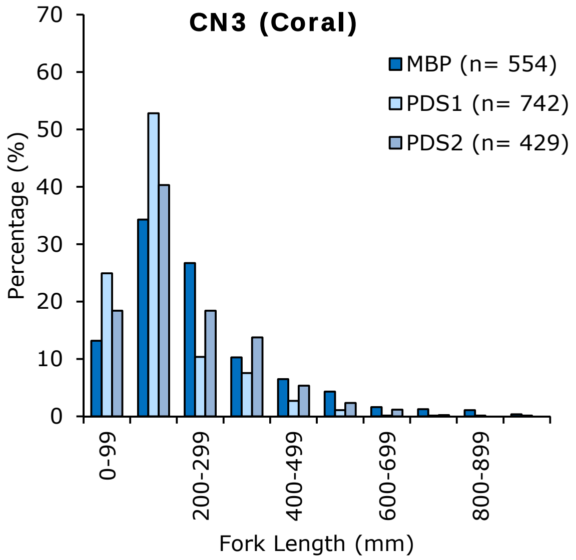


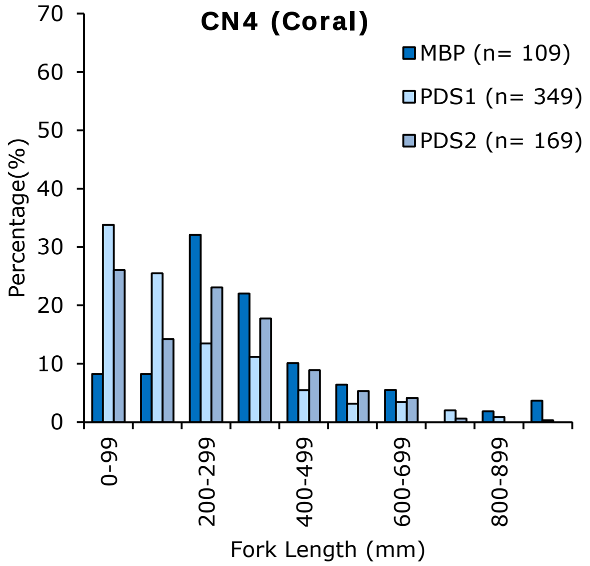
Figure 7-15 Length-frequency of Demersal Fish Species at Sites (Benthic Habitat) within the Zones of Moderate Impact for the Marine Baseline Program (MBP), Post-Development Survey Year 1 (PDS1) and Post-Development Survey Year 2 (PDS2)

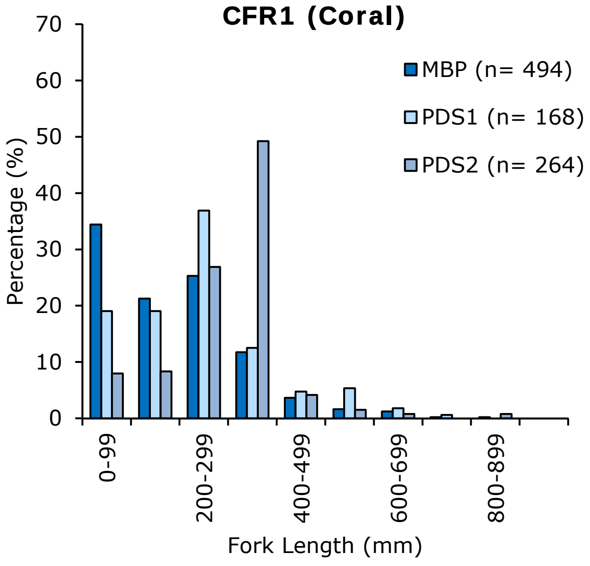
Note: Any outliers (e.g. sharks, large mackerel) have been excluded.


CN1 (Coral)
MBP (n= 554)
PDS1 (n= 385)
PDS2 (n= 271)
Percentage (%)
0
10
20
30
40
50
60
70
0-99
200-299
400-499
600-699
800-899
Fork Length(mm)


CN2 (Coral)
MBP (n= 565)
PDS1 (n= 325)
PDS2 (n= 476)
Percentage (%)
0
10
20
30
40
50
60
70
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


CN3 (Coral)
MBP (n= 554)
PDS1 (n= 742)
PDS2 (n= 429)
Percentage (%)
0
10
20
30
40
50
60
70
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


CN4 (Coral)
MBP (n= 109)
PDS1 (n= 349)
PDS2 (n= 169)
Percentage(%)
0
10
20
30
40
50
60
70
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


CFR1 (Coral)
MBP (n= 494)
PDS1 (n= 168)
PDS2 (n= 264)
Percentage (%)
0
10
20
30
40
50
60
70
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)

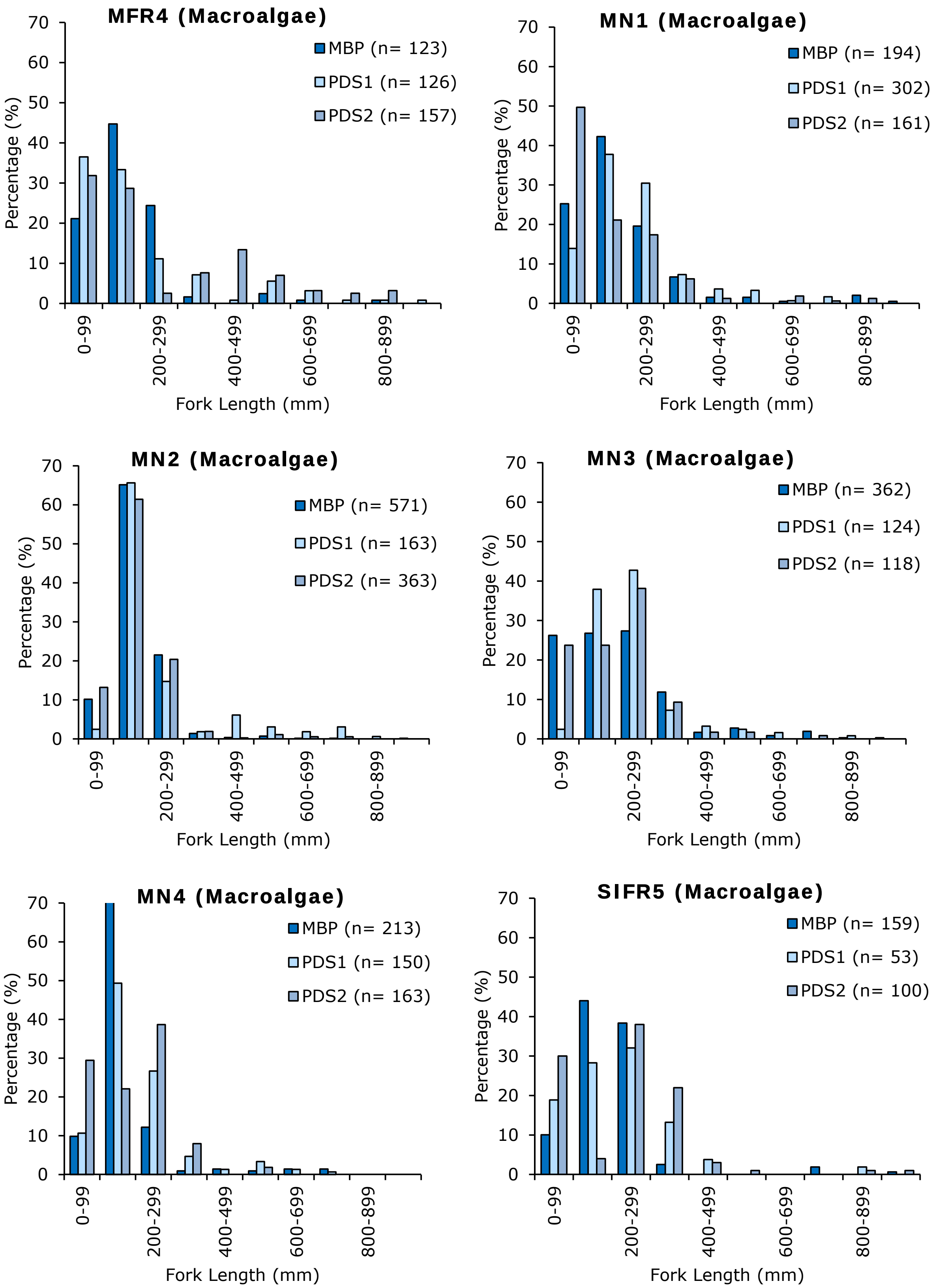


Figure 7-16 Length-frequency of Demersal Fish Species at Sites (Benthic Habitats: Coral and Macroalgae) within the Zones of Influence for the Marine Baseline Program (MBP), Post-Development Survey Year 1 (PDS1) and Post-Development Survey Year 2 (PDS2)

Note: Any outliers (e.g. sharks, large mackerel) have been excluded.

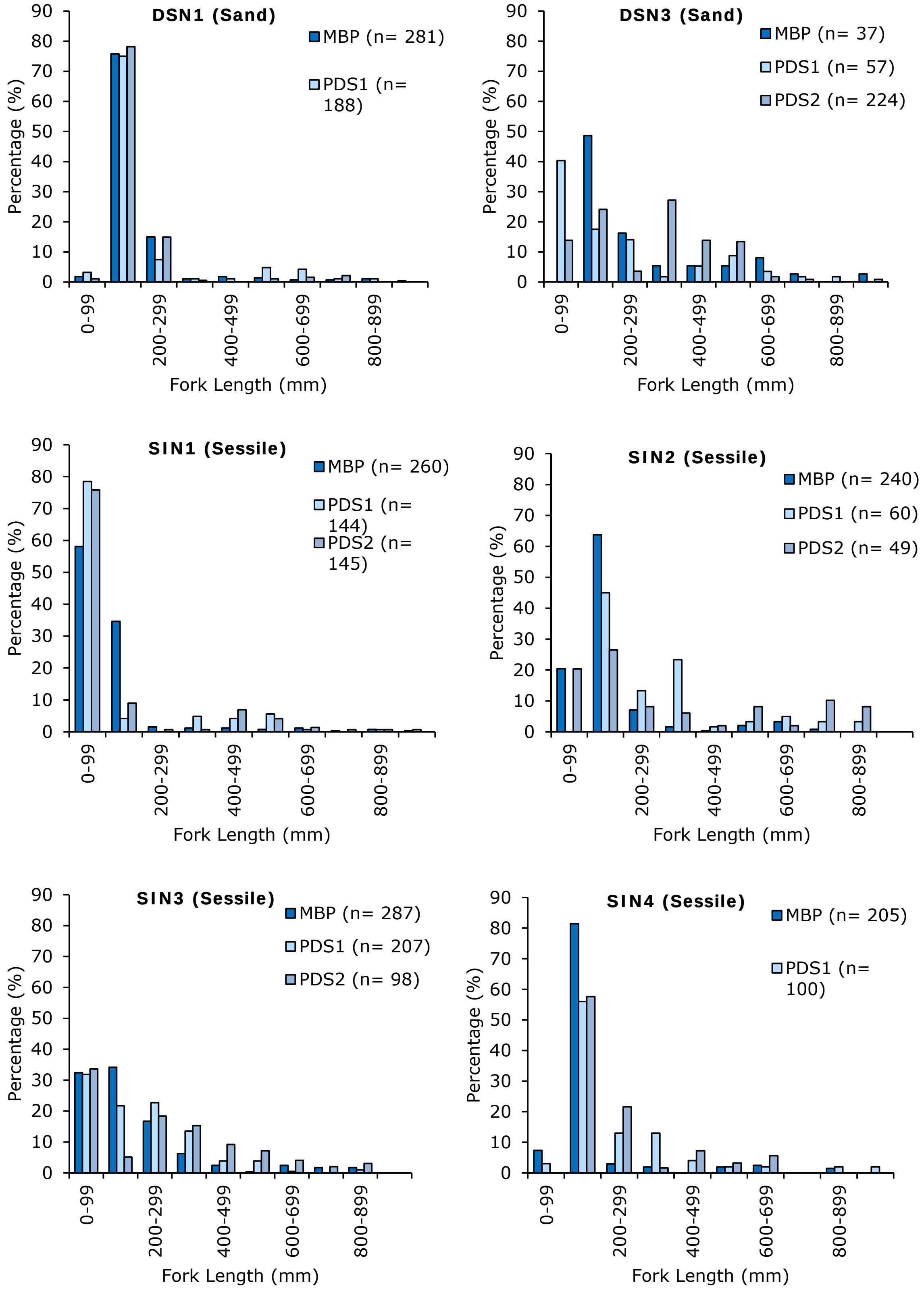


Figure 7-17 Length-frequency of Demersal Fish Species at Sites (Benthic Habitats: Sand and Sessile Invertebrates) within the Zones of Influence for the Marine Baseline Program (MBP), Post-Development Survey Year 1 (PDS1) and Post-Development Survey Year 2 (PDS2)

Note: Any outliers (e.g. sharks, large mackerel) have been excluded.

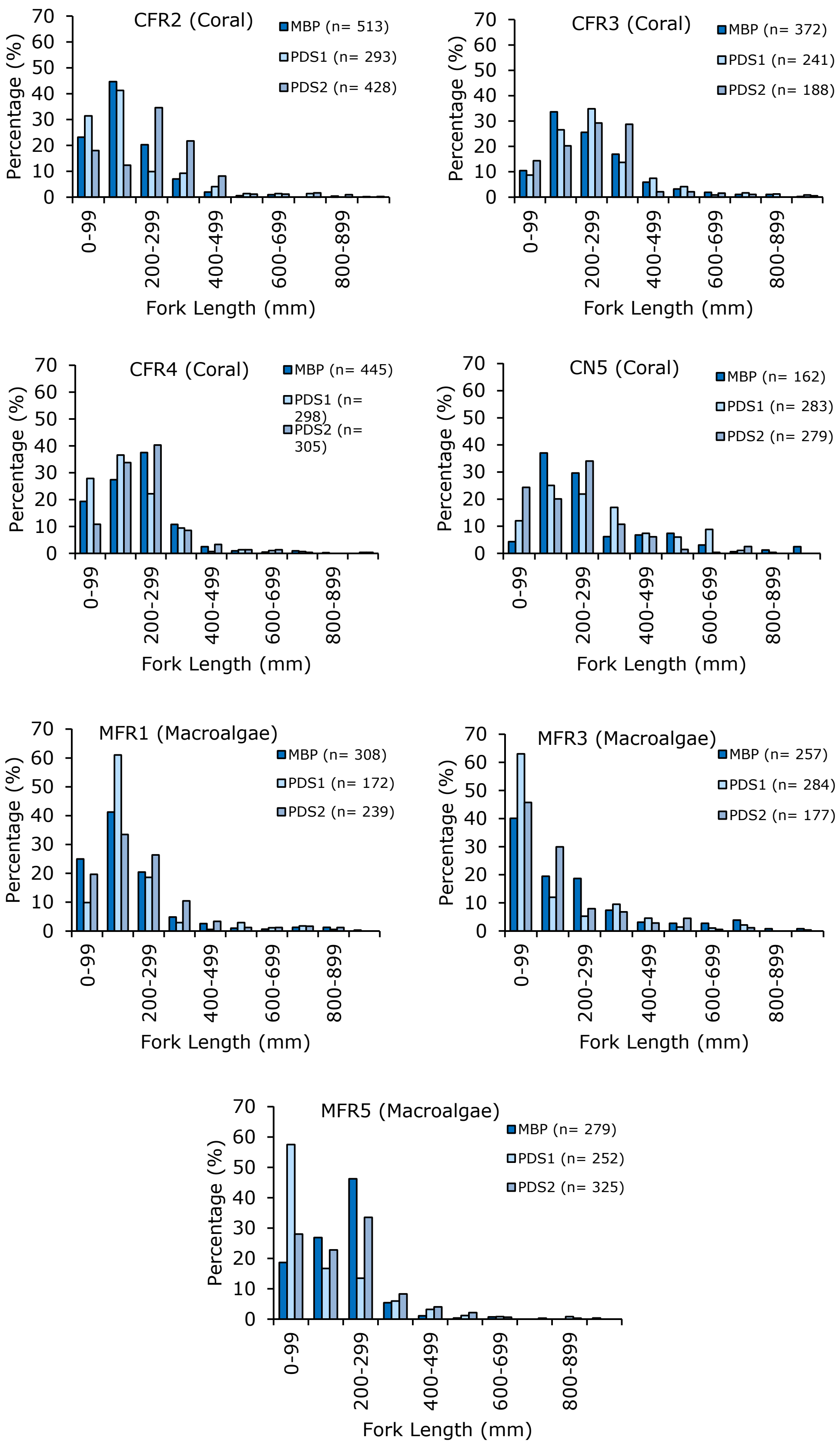
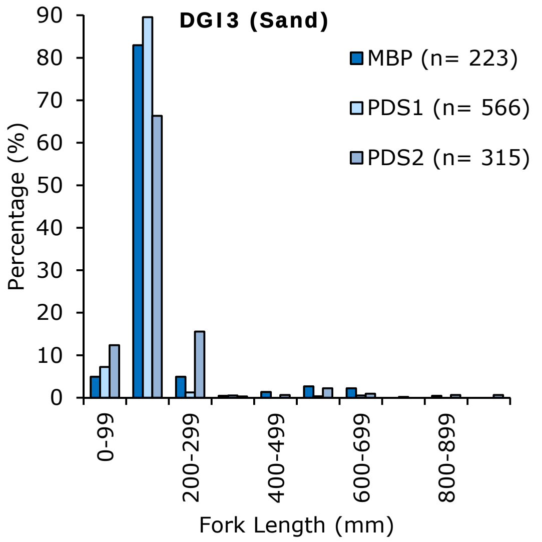
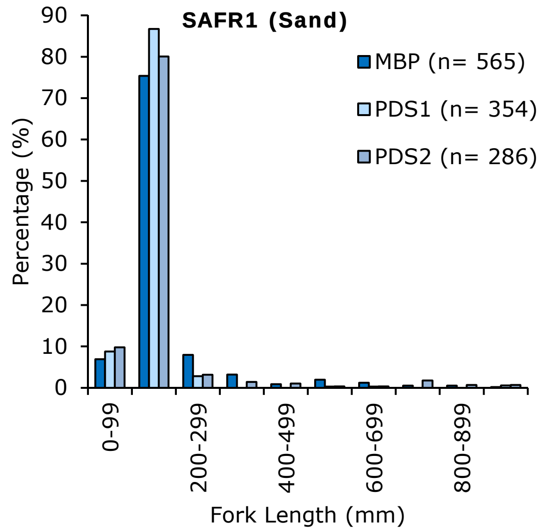
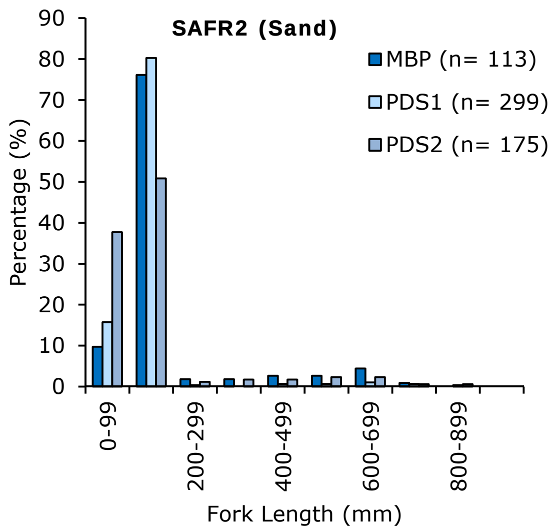


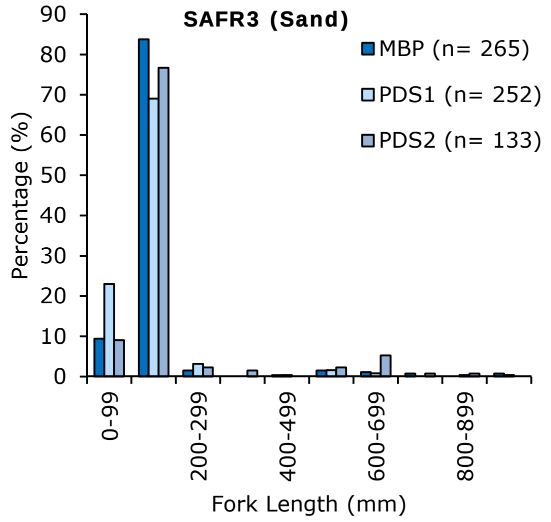
Figure 7-18 Length-frequency of Demersal Fish Species at Reference Sites (Benthic Habitats: Coral and Macroalgae) for the Marine Baseline Program (MBP), Post-Development Survey Year 1 (PDS1) and Post-Development Survey Year 2 (PDS2)

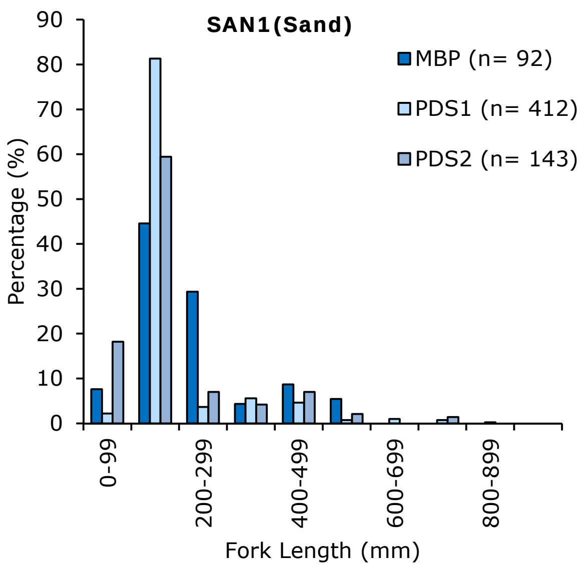
Note: Any outliers (e.g. sharks, large mackerel) have been excluded.

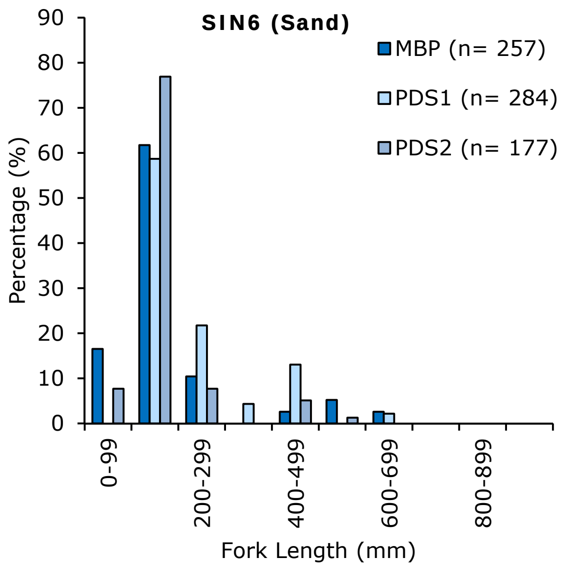

DGI3 (Sand)
MBP (n= 223)
PDS1 (n= 566)
PDS2 (n= 315)
Percentage (%)
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


SAFR1 (Sand)
MBP (n= 565)
PDS1 (n= 354)
PDS2 (n= 286)
Percentage (%)
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


SAFR2 (Sand)
MBP (n= 113)
PDS1 (n= 299)
PDS2 (n= 175)
Percentage (%)
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


SAFR3 (Sand)
MBP (n= 265)
PDS1 (n= 252)
PDS2 (n= 133)
Percentage (%)
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


SAN1(Sand)
MBP (n= 92)
PDS1 (n= 412)
PDS2 (n= 143)
Percentage (%)
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)


SIN6 (Sand)
MBP (n= 257)
PDS1 (n= 284)
PDS2 (n= 177)
Percentage (%)
0-99
200-299
400-499
600-699
800-899
Fork Length (mm)

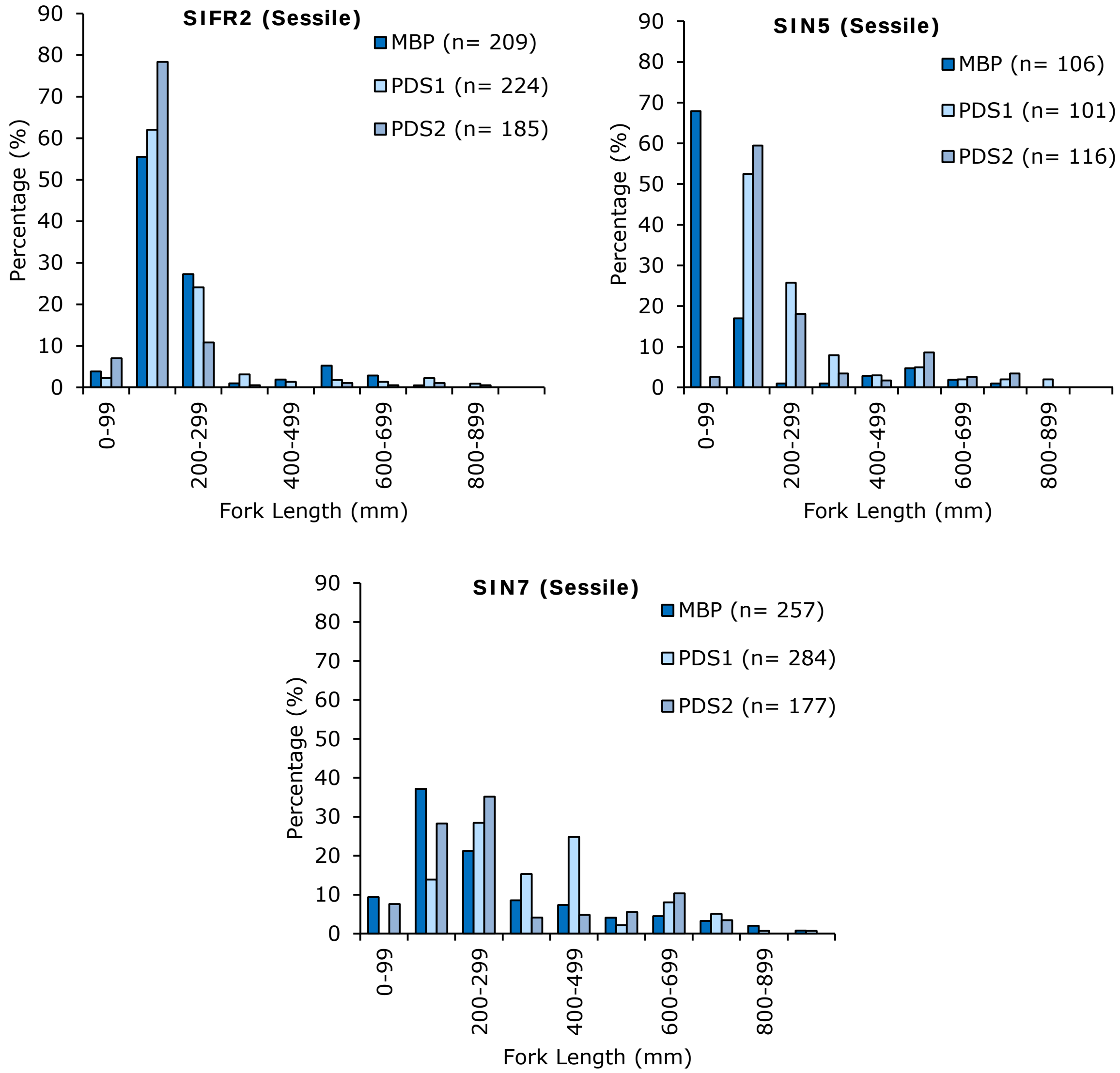


Figure 7-19 Length-frequency of Demersal Fish Species at Reference Sites (Benthic Habitats: Sand and Sessile Invertebrates) for the Marine Baseline Program (MBP), Post-Development Survey Year 1 (PDS1) and Post-Development Survey Year 2 (PDS2)

Note: Any outliers (e.g. sharks, large mackerel) have been excluded.

7.5.5 Indicator Species for Coral Habitats

The mean relative abundance and mean length of each of the 20 indicator species observed in coral habitats during the Marine Baseline Surveys and Post-Development Surveys are presented in Table 7-19 and Table 7-21. The most abundant indicator species in coral habitats were *Thalassoma lunare, Neopomacentrus filamentosus, Lethrinus atkinsoni, Plectropomus* spp., and *Choerodon cyanodus.* The most common were *T. lunare, L. atkinsoni*, and *Lutjanus carponotatus.*

There was no consistent pattern of increase or decrease in mean relative abundance observed between the Marine Baseline Survey and Post-Development Surveys when all four zones were considered together (Table 7-18). Multivariate assemblage tests of the relative abundance of all 20 indicator species for coral habitat were carried out following the step-wise approach for indicator species (see Section 7.3.5). No significant results were found for any PERMANOVA test, regardless of the level of pooling.

The relative abundance of the indicator species were individually statistically tested following the step-wise approach (see Section 7.3.5). Six of the 20 species tested produced significant results for the terms of interest: *Acanthurus grammoptilus, Choerodon cauteroma*, *Choerodon schoenleinii*, *Pentapodus emeryii, Plectropomus* spp., and *Symphorus nematophorus* (Appendix 2, Tables A1.1 to A1.12).

Table 7-18 Multivariate PERMANOVA Results for Relative Abundance of 20 Indicator Species for Coral Habitat (Five-factor Design)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	6483.10	3241.60	1.45	0.252	9940
IvR	1	3129.30	3129.30	1.15	0.426	9939
Year(Survey)	1	1470.60	1470.60	2.29	0.103	9955
Zone(IvR)	2	12301.00	6150.40	1.56	0.200	9933
Survey×IvR	2	1865.70	932.83	2.33	0.074	9942
Site(Zone(IvR))	8	28317.00	3539.60	5.29	<0.001	9921
Survey×Zone(IvR)	4	5536.90	1384.20	1.29	0.293	9925
Year(Survey)×IvR	1	-170.03	-170.03	No Test		
Survey×Site(Zone(IvR))	16	15114.00	944.60	1.47	0.138	9925
Year(Survey)×Zone(IvR)	2	1148.50	574.24	0.92	0.492	9957
Year(Survey)×Site(Zone(IvR))**	6	3840.70	640.11	0.74	0.840	9890
Res	165	143110.00	867.35			
Total	210	222920.00				

Table 7-19 Relative Abundance (MaxN) of the 20 Indicator Demersal Fish Species for Coral Habitats at Barrow Island for the Marine Baseline Program and Post-Development Survey

Family	Common Name	Species	Marine Baseline Program		Post-Development Survey	
			2008 mean MaxN ± SE (total number recorded)	2009 mean MaxN ± SE (total number recorded)	2011 mean MaxN ± SE (total number recorded)	2012 mean MaxN ± SE (total number recorded)
Acanthuridae	Ring-Tailed Surgeonfish	*Acanthurus grammoptilus*	1.6 ± 0.3 (79)	2.1 ± 0.4 (96)	1.9 ± 0.3 (109)	3 ± 0.9 (176)
Chaetodontidae	Golden-Striped Butterflyfish	*Chaetodon aureofasciatus*	0.7 ± 0.2 (36)	0.8 ± 0.2 (37)	0.7 ± 0.1 (42)	0.7 ± 0.1 (38)
	Margined Coralfish	*Chelmon marginalis*	0.6 ± 0.1 (31)	0.5 ± 0.1 (23)	0.4 ± 0.1 (26)	0.4 ± 0.1 (22)
Labridae	Bluespotted Tuskfish	*Choerodon cauteroma**	0.7 ± 0.1 (35)	1.2 ± 0.2 (55)	0.6 ± 0.2 (36)	0.8 ± 0.1 (48)
	Blue Tuskfish	*Choerodon cyanodus*	2 ± 0.2 (98)	1.9 ± 0.2 (84)	2.3 ± 0.2 (131)	2.1 ± 0.1 (122)
	Blackspot Tuskfish	*Choerodon schoenleinii*	1.7 ± 0.1 (83)	1.6 ± 0.2 (72)	1.1 ± 0.1 (61)	1.5 ± 0.1 (88)
	Moon Wrasse	*Thalassoma lunare*	5.1 ± 0.8 (257)	3.5 ± 0.6 (157)	3.6 ± 0.6 (209)	2.4 ± 0.4 (138)

Family	Common Name	Species	Marine Baseline Program		Post-Development Survey	
			2008 mean MaxN ± SE (total number recorded)	2009 mean MaxN ± SE (total number recorded)	2011 mean MaxN ± SE (total number recorded)	2012 mean MaxN ± SE (total number recorded)
Lethrinidae	Yellow-Tailed Emperor	*Lethrinus atkinsoni*	2 ± 0.3 (98)	2.4 ± 0.6 (108)	3.1 ± 0.6 (181)	3.4 ± 0.7 (197)
	Spangled Emperor	*Lethrinus nebulosus*	1.5 ± 0.4 (74)	0.8 ± 0.2 (35)	2 ± 0.4 (114)	3 ± 0.7 (175)
Lutjanidae	Stripey Seaperch	*Lutjanus carponotatus*	2.8 ± 0.8 (138)	5.7 ± 1.5 (255)	2.8 ± 1 (162)	2 ± 0.3 (116)
	Chinaman Fish	*Symphorus nematophorus*	0.7 ± 0.1 (37)	0.6 ± 0.2 (28)	0.4 ± 0.1 (24)	0.5 ± 0.1 (30)
Nemipteridae	Purple Threadfin-Bream	*Pentapodus emeryii**	1.5 ± 0.2 (77)	1.7 ± 0.3 (76)	1.3 ± 0.2 (78)	1.3 ± 0.2 (74)
Pomacanthidae	Six-Banded Angelfish	*Pomacanthus sexstriatus*	0.9 ± 0.1 (46)	1.1 ± 0.1 (49)	0.7 ± 0.1 (38)	0.7 ± 0.1 (41)
Pomacentridae	Narrow-Banded Sergeant Major	*Abudefduf bengalensis*	1.9 ± 0.4 (95)	1.8 ± 0.4 (83)	2.8 ± 0.6 (162)	1.6 ± 0.3 (95)
	Brown Demoiselle	*Neopomacentrus filamentosus*	5.5 ± 2.3 (273)	11.2 ± 3 (506)	4.4 ± 1.5 (253)	4.2 ± 1.5 (245)
Serranidae	Barramundi Cod	*Cromileptes altivelis*	0.2 ± 0.1 (9)	0.3 ± 0.1 (13)	0.1 ± 0 (6)	0.2 ± 0.1 (14)
	Frostback Cod	*Epinephelus bilobatus*	0.7 ± 0.1 (36)	0.6 ± 0.2 (29)	1.1 ± 0.2 (63)	1.5 ± 0.2 (89)
	Camouflage Grouper	*Epinephelus polyphekadion*	0.2 ± 0.1 (9)	0.6 ± 0.1 (25)	0.5 ± 0.1 (30)	0.6 ± 0.1 (34)
	Coral Trout	*Plectropomus spp**	2 ± 0.2 (98)	2.4 ± 0.2 (108)	1.4 ± 0.2 (81)	2.1 ± 0.2 (124)
Siganidae	Doublebar Spinefoot	*Siganus doliatus*	3.1 ± 0.8 (154)	1.8 ± 0.5 (79)	1 ± 0.3 (59)	2.1 ± 0.6 (120)

*Note: Data presented is the mean relative abundance per stereo-BRUV deployment in coral habitats during the Marine Baseline Program (separate and combined) and the Post-Development Survey. * = indicates that a significant change was detected for this species.*

7.5.5.1 Relative Abundance

Using data from the MOF and Reference Sites only, a significant term of interest was found for the indicator species *A. grammoptilus* (Ring-tailed Surgeonfish) with the interaction of Survey × Zone(IvR) for the four-factor design (Year pooled) (Appendix 2, Table A1.1). Pair-wise tests found that, at coral sites within the ZoI, there was a significant increase in the abundance of *A. grammoptilus* from the Marine Baseline Program to Post-Development Survey Year 1 (51% increase) (Appendix 1, Table A1.2). The abundance of this species did not differ from the Marine Baseline Program to the two Post-Development Surveys in other zones.

A significant term of interest was found for the coral indicator species *C. cauteroma* (Bluespotted Tuskfish) with the interaction of Survey × IvR for the two-factor design (Year, Site, and Zone pooled) (Appendix 2, Table A1.3). Pair-wise tests showed a significant decline in the relative abundance of this species from the Marine Baseline Program to Post-Development Survey Year 1 at coral sites in Impact zones (40% decline) (Appendix 2, Table A1.4). The relative abundance of *C. cauteroma* in Impact zones was found to increase significantly from Post-Development Survey Year 1 to Post-Development Survey Year 2 (30% increase).

A significant term of interest was found for the coral indicator species *C. schoenleinii* (Blackspot Tuskfish) with the interaction of Survey × IvR for the three-factor design (Year and Site pooled) (Appendix 2, Table A1.5). Pair-wise tests showed a significant decline in the relative abundance of this species from the Marine Baseline Program to Post-Development Survey Year 1 at coral sites in Impact zones (38% decline) (Appendix 2, Table A1.6). The relative abundance of *C. schoenleinii* in Impact zones was found to increase significantly from Post-Development Survey Year 1 to Post-Development Survey Year 2 (35% increase).

The term of interest Survey × IvR was found to be significant for the coral indicator species *P. emeryii* (Purple Threadfin Bream) in the full five-factor design (Appendix 2, Table A1.7). Pair-wise tests using Monte Carlo bootstrapping were carried out on the term Survey × Zone (IvR) (Appendix 2, Table A1.8). Monte Carlo boot strapping was used due to low numbers of permutations for pair-wise tests when using the full five-factor design. These pair-wise tests showed that in the ZoHI there was a significant decrease in the relative abundance of *P. emeryii* from the Marine Baseline Program to both Post-Development Survey Year 1 (82% decrease) and Post-Development Survey Year 2 (65% decrease).

Two significant terms of interest, Survey × IvR and Survey × Zone (IvR), were found using the three-factor design (Year, Site pooled) for the indicator species group *Plectropomus* spp. (coral trout) in coral habitats (Appendix 2, Table A1.9). Pair-wise tests were carried out on the term Survey × Zone (IvR) as these are more informative than the term Survey × IvR (Appendix 2, Table A1.10). The pair-wise tests showed a significant decrease in the relative abundance of *Plectropomus* spp. from the Marine Baseline Program to Post-Development Survey Year 1 (92% decrease) in the ZoHI. The abundance of *Plectropomus* spp. also declined in the ZoI from the Marine Baseline Surveys to Post-Development Survey Year 1 (30% decline). At Reference Sites, this species group was present in significantly greater abundance (58% increase) during Post-Development Survey Year 2 compared to Post-Development Survey Year 1.

A significant term of interest was found for the coral indicator species *Symphorus nematophorus* (Chinaman Fish) with the interaction of Survey × IvR for the four-factor design (Year pooled) (Appendix 2, Table A1.11). However, pair-wise tests detected no significant differences between the survey occasions for either Impact of Reference Sites for this species.

7.5.5.2 Length

The mean lengths of the indicator species are summarised in (Table 7-21). Generally, too few fish were able to be measured to compare each Marine Baseline Survey separately to both Post-Development Surveys and as such the Marine Baseline Surveys were pooled and Post-Development Surveys were pooled. For information on the mean length of indicator species in each of the separate Marine Baseline Surveys (and zones), see Table 7-22.

Some indicator species were relatively rare across the sampling design and between years, even when replicate samples were pooled to the site level. These low numbers of individuals at the site level meant that formal statistical analyses were not conducted for most of the individual indicator species. Figure 7-20 graphically represents the trends in the mean lengths of the indicator species across the zones and between years; no trends suggestive of any impact were observed.

The length-frequency distributions of the three most common indicator species—*Thalassoma lunare* (Moon Wrasse), *Lethrinus atkinsoni* (Yellow-tailed Emperor), and *Lutjanus carponotatus* (Stripey Seaperch)—were analysed. No significant terms of interest were found for *T. lunare* or *L. carponotatus*. For *L. atkinsoni* a significant difference was detected for the term of interest Survey × IvR when using the modified step-wise design without pooling (Table 7-20). However, pair-wise tests for levels of Survey for this significant term did not detect any significant changes. Pair-wise tests could not be carried out between Marine Baseline Surveys and Post-Development Survey Year 1 and Post-Development Survey Year 2 for Reference Sites as insufficient numbers of fish were measured. Further testing following the modified step-wise approach and using pooled terms to increase statistical power did not detect any further significant terms of interest for this species.

Table 7-20 Univariate PERMANOVA Results for Length-frequency Distribution of *Lethrinus atkinsoni* for Coral Habitat (Four-factor Design)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations	P(MC)
Survey	2	144.97	72.49	1.00	0.508	12	0.641
IvR	1	107.60	107.60	12.81	0.068	1323	0.052
Year(Survey)	1	140.36	140.36	0.35	0.670	9943	0.688
Zone(IvR)	2	2743.00	1371.50	6.16	0.289	9921	0.119
Survey×IvR	*2*	*646.40*	*323.20*	*36.38*	***0.037***	*6361*	***0.015***
Survey×Zone(IvR)**	*3*	*423.50*	*141.17*	*0.73*	*0.630*	*9954*	*0.710*
Year(Survey)×IvR	1	9.34	9.34	0.02	0.974	9941	0.971
Year(Survey)×Zone(IvR)**	1	216.53	216.53	0.53	0.526	9933	0.546
Res	28	11341.00	405.05				
Total	41	16567.00					

*Notes: Bold font in P-value column = significant difference for term of interest; ** = Term has one or more empty cells; Pair-wise comparison tests revealed no further significant differences for term of interest Survey × IvR*

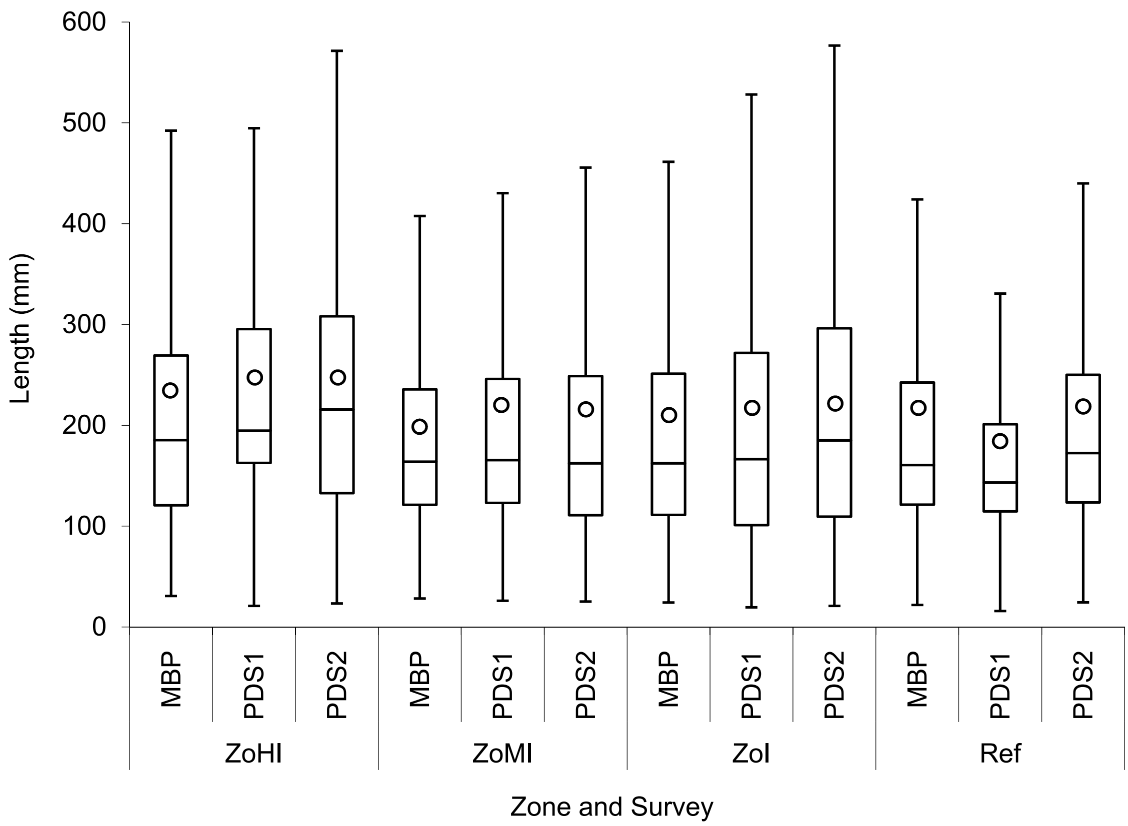


Figure 7-20 Mean Length (o), Median Length (-), and 25th and 75th Percentiles for Indicator Species across all Zones, and between Years.

Note: Any outliers (e.g. sharks, large mackerel) have been excluded.

Table 7-21 Mean Length of the 20 Indicator Demersal Fish Species for Coral Habitats at Barrow Island for the Marine Baseline Program (Surveys Pooled) and Post-Development Surveys (Year 1 and Year 2 Pooled)

Family	Common Name	Species	Baseline mean length mm ± SE (n)	Post-Development mean length mm ± SE (n)
Acanthuridae	Ring-Tailed Surgeonfish	*Acanthurus grammoptilus*	226 ± 4.3 (154)	215.7 ± 3 (234)
Chaetodontidae	Golden-Striped Butterflyfish	*Chaetodon aureofasciatus*	80.3 ± 3.4 (49)	80.8 ± 5 (57)
	Margined Coralfish	*Chelmon marginalis*	125.7 ± 3.8 (40)	126.4 ± 4.2 (40)
Labridae	Bluespotted Tuskfish	*Choerodon cauteroma*	229.2 ± 5.6 (65)	224.1 ± 5.8 (72)
	Blue Tuskfish	*Choerodon cyanodus*	259.5 ± 6.1 (144)	250.3 ± 4.5 (206)
	Blackspot Tuskfish	*Choerodon schoenleinii*	381.3 ± 12 (128)	327.5 ± 11.9 (118)
	Moon Wrasse	*Thalassoma lunare*	111.7 ± 2.4 (252)	122.1 ± 1.8 (287)
Lethrinidae	Yellow-Tailed Emperor	*Lethrinus atkinsoni*	272.1 ± 4.7 (141)	272.8 ± 2.1 (334)
	Spangled Emperor	*Lethrinus nebulosus*	363.5 ± 10.9 (87)	376.6 ± 5.1 (246)
Lutjanidae	Stripey Seaperch	*Lutjanus carponotatus*	255.5 ± 4.4 (235)	259.1 ± 5.1 (207)
	Chinaman Fish	*Symphorus nematophorus*	553.8 ± 29.7 (50)	518.4 ± 31 (42)
Nemipteridae	Purple Threadfin-Bream	*Pentapodus emeryii*	215.8 ± 4.6 (123)	204.3 ± 3.9 (144)
Pomacanthidae	Six-Banded Angelfish	*Pomacanthus sexstriatus*	219 ± 7.1 (76)	217.8 ± 7.4 (60)
Pomacentridae	Narrow-Banded Sergeant Major	*Abudefduf bengalensis*	135.8 ± 2 (148)	126.8 ± 1.5 (222)
	Brown Demoiselle	*Neopomacentrus filamentosus*	44.4 ± 0.7 (146)	40.7 ± 0.6 (166)
Serranidae	Barramundi Cod	*Cromileptes altivelis*	374.1 ± 24.2 (17)	307.2 ± 16.7 (14)
	Frostback Cod	*Epinephelus bilobatus*	298.1 ± 8.1 (44)	281.5 ± 5.6 (95)
	Camouflage Grouper	*Epinephelus polyphekadion*	462.4 ± 17 (19)	440.5 ± 16.8 (38)
	Coral Trout	*Plectropomus* spp	353.9 ± 10.6 (141)	349.7 ± 9.2 (161)
Siganidae	Doublebar Spinefoot	*Siganus doliatus*	205.1 ± 3.8 (150)	188.6 ± 5.4 (88)

Notes: n = the number of fish that could be measured, which is not indicative of relative abundance.

Coral habitats were characterised during the baseline survey. The habitat may have changed at the time of the Post-Development Surveys. Marine Baseline Surveys were pooled and Post-Development Surveys were pooled

7.5.5.3 ZoHI Coral Site C1

In addition to the changes in indicator species that were identified in Section 7.5.5.1 and 7.5.5.2 some noteworthy observations were apparent at site CI1 (the only ZoHI coral site). One indicator species (*Chaetodon aureofasciatus*) was present at site CI1 during both Marine Baseline Surveys, but was not recorded during either Post-Development Survey (Table 7-22). *Lethrinus nebulosus* was observed in greater abundance during the Post-Development Surveys (12 and 22 individuals) compared to the Marine Baseline Surveys (5 and 4 individuals) at this coral site. This increase was not due to a single school of individuals but rather to consistently higher numbers on each deployment.

The mean length of each of the 20 indicator species at coral site CI1 is presented in Figure 7-22. In general, too few individuals could be measured from the five stereo-BRUV deployments to enable any meaningful assessment of change in fish length at this site. A decrease in the mean length of *Choerodon schoenleinii* and *Lutjanus carponotatus* is suggested from this limited data (Figure 7-21).

Table 7-22 Mean Length of the 20 Indicator Species for Coral Site CI1 Located within the Zone of High Impact for the Marine Baseline Program and Post-Development Surveys

Family	Common Name	Species	Marine Baseline Program		Post-Development Survey	
			2008 mean MaxN ± SE (total number recorded)	2009 mean MaxN ± SE (total number recorded)	2011 mean MaxN ± SE (total number recorded)	2012 mean MaxN ± SE (total number recorded)
Acanthuridae	Ring-Tailed Surgeonfish	*Acanthurus grammoptilus*	3.6 ± 1.17 (18)	4.4 ± 0.83 (22)	0.8 ± 0.89 (4)	0.8 ± 0.37 (4)
Chaetodontidae	Golden-Striped Butterflyfish	*Chaetodon aureofasciatus*	0.2 ± 0.45 (1)	0.2 ± 0.45 (1)	0	0
	Margined Coralfish	*Chelmon marginalis*	0.6 ± 0.52 (3)	0.8 ± 0.42 (4)	0.4 ± 0.63 (2)	1 ± 0.45 (5)
Labridae	Bluespotted Tuskfish	*Choerodon cauteroma*	1.2 ± 0.34 (6)	2.2 ± 0.69 (11)	1.8 ± 0.98 (9)	1.4 ± 0.51 (7)
	Blue Tuskfish	*Choerodon cyanodus*	2 ± 0.45 (10)	2.4 ± 0.33 (12)	2 ± 0.39 (10)	2.6 ± 0.24 (13)
	Blackspot Tuskfish	*Choerodon schoenleinii*	1.4 ± 0.34 (7)	2.6 ± 0.32 (13)	0.8 ± 0.65 (4)	1.2 ± 0.2 (6)
	Moon Wrasse	*Thalassoma lunare*	1.8 ± 0.72 (9)	1.6 ± 0.73 (8)	0	0.2 ± 0.2 (1)
Lethrinidae	Yellow-Tailed Emperor	*Lethrinus atkinsoni*	0.2 ± 0.45 (1)	0	0.4 ± 0.63 (2)	0
	Spangled Emperor	*Lethrinus nebulosus*	1 ± 0.77 (5)	0.8 ± 0.42 (4)	2.4 ± 0.48 (12)	4.4 ± 2.06 (22)
Lutjanidae	Stripey Seaperch	*Lutjanus carponotatus*	1.2 ± 0.67 (6)	8 ± 2.39 (40)	0.2 ± 0.45 (1)	2 ± 1.76 (10)
	Chinaman Fish	*Symphorus nematophorus*	0.6 ± 0.52 (3)	0.6 ± 0.32 (3)	0.4 ± 0.39 (2)	0.8 ± 0.2 (4)
Nemipteridae	Purple Threadfin-Bream	*Pentapodus emeryii*	3.2 ± 0.37 (16)	3.6 ± 0.86 (18)	0.6 ± 0.52 (3)	1.2 ± 0.58 (6)

Family	Common Name	Species	Marine Baseline Program		Post-Development Survey	
			2008 mean MaxN ± SE (total number recorded)	2009 mean MaxN ± SE (total number recorded)	2011 mean MaxN ± SE (total number recorded)	2012 mean MaxN ± SE (total number recorded)
Pomacanthidae	Six-Banded Angelfish	*Pomacanthus sexstriatus*	1.2 ± 0.67 (6)	1 ± 0.32 (5)	0	0.4 ± 0.4 (2)
Pomacentridae	Narrow-Banded Sergeant Major	*Abudefduf bengalensis*	1.8 ± 0.55 (9)	1.4 ± 0.57 (7)	0.6 ± 0.77 (3)	1.2 ± 0.8 (6)
	Brown Demoiselle	*Neopomacentrus filamentosus*	0.4 ± 0.63 (2)	9.8 ± 2.82 (49)	0	0.8 ± 0.8 (4)
Serranidae	Barramundi Cod	*Cromileptes altivelis*	0	0.2 ± 0.45 (1)	0	0
	Frostback Cod	*Epinephelus bilobatus*	1 ± 0.55 (5)	1.2 ± 0.89 (6)	0.4 ± 0.63 (2)	1 ± 0.45 (5)
	Camouflage Grouper	*Epinephelus polyphekadion*	0	0.4 ± 0.39 (2)	0	0
	Coral Trout	*Plectropomus* spp	1.8 ± 0.43 (9)	3 ± 0.37 (15)	0.2 ± 0.45 (1)	0.8 ± 0.37 (4)
Siganidae	Doublebar Spinefoot	*Siganus doliatus*	3 ± 0.77 (15)	1.4 ± 0.83 (7)	0	0.4 ± 0.4 (2)

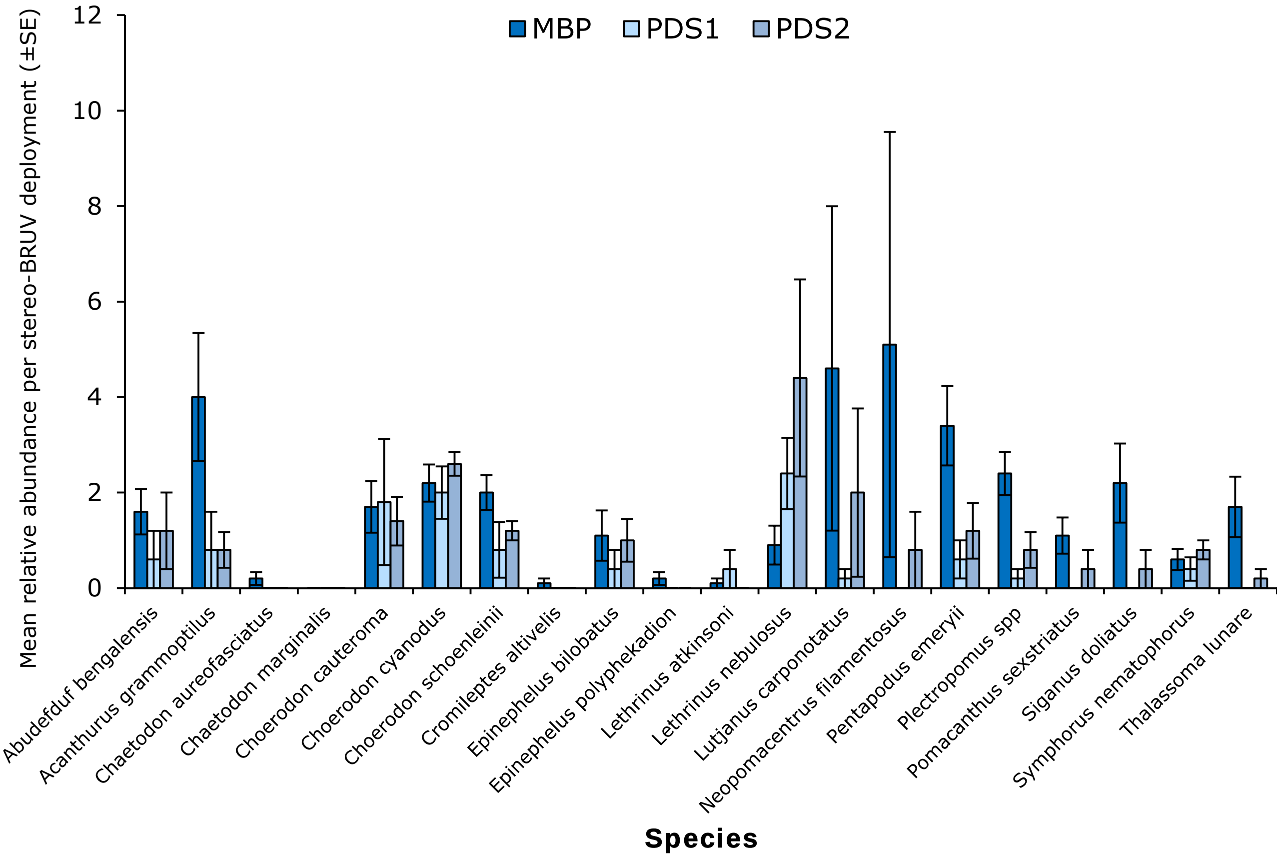


Figure 7-21 Mean Relative Abundance (±SE) of each of the 20 Indicator Species for Coral Habitat at the Zone of High Impact Site CI1

Note: Marine Baseline n=10, Post-Development n=5 deployments

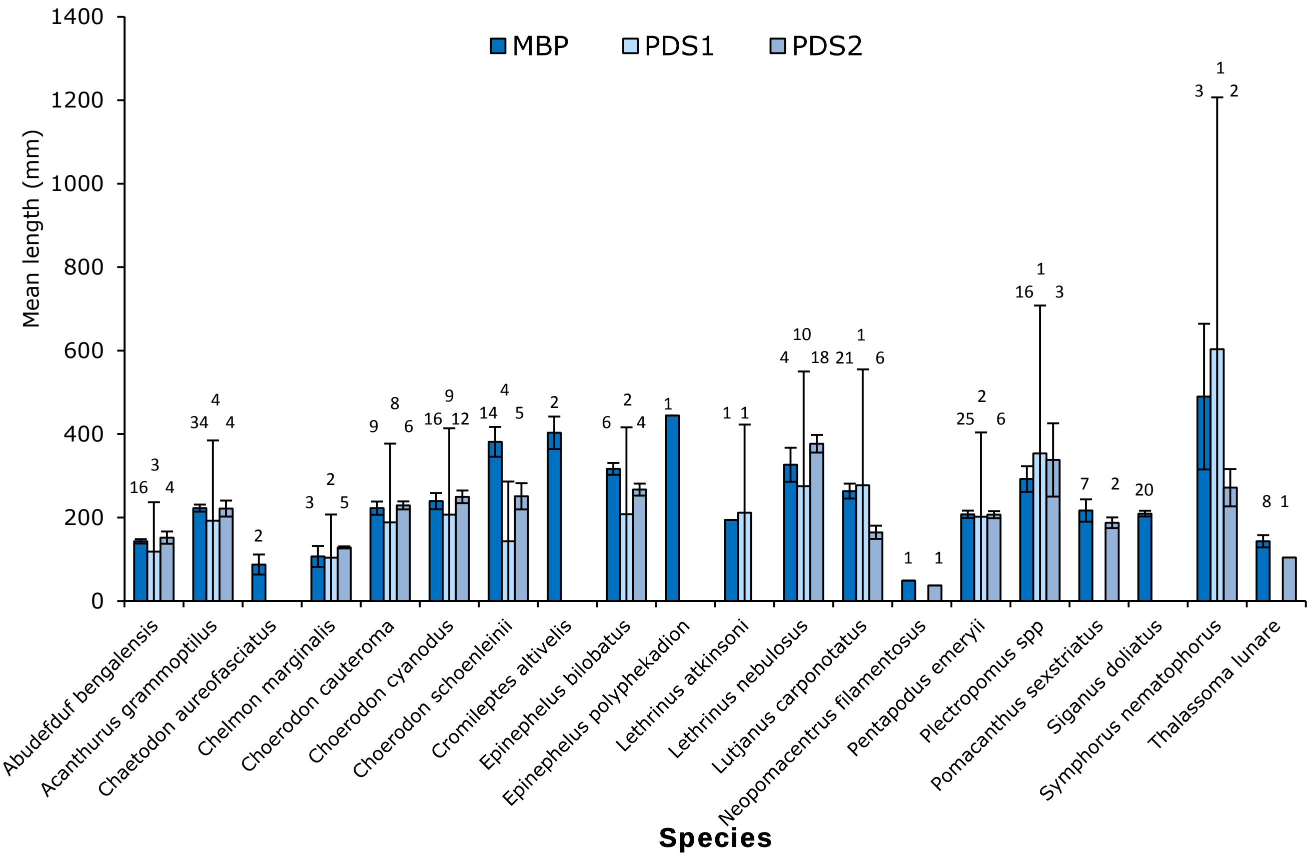


Figure 7-22 Mean Length (±SE) of each of the 20 Indicator Species for Coral Habitat at the Zone of High Impact Site CI1

Note: The numbers above each series indicate the number of fish that could be measured free from obstruction and are not indicative of relative abundance.

7.6 Discussion

The Marine Baseline Program and Post-Development Surveys have provided a substantial amount of information on fish assemblages present in different habitats around Barrow Island. A total of 58 699 fish from 358 species and 66 families were observed on video obtained from 754 stereo-BRUV deployments.

Changes in the fish assemblage were detected between the Marine Baseline Program and both Post-Development Surveys. Significant changes were found among surveys in both Impact Sites and Reference Sites. The significant Survey × IvR result for the multivariate relative abundance dataset appears driven by a shift in the composition of fish assemblages from the Marine Baseline Program to Post-Development Surveys Year 1 and Year 2. Natural variability in habitat (as observed on stereo BRUVs) appears to drive these changes at Reference Sites and also to a degree at Impact sites. However, there is also an indication of a dredging effect at Impact Sites where several common fish species exhibited significant declines in abundance from Marine Baseline Surveys to Post-Development Surveys Year 1 and Year 2. Two species, *A. lennardi* and *L. laticaudis*, displayed significant patterns consistent with an impact with no recovery due to dredging and dredge spoil disposal activities. *A. lennardi* is an Australian endemic species that occurs in depths to 24 m over corals and in surge zones (see Fishbase http://www.fishbase.org/summary/Anampses-lennardi.html). While no information on their degree of site fidelity could be found in the literature, it would be predicted to be high and as such make them quite susceptible to dredging in these shallow depths around Barrow Island. Similarly, the Emperor *L. laticaudis* have been shown in Shark Bay to move very little between reef habitats that are separated by non-reef habitats (Ayvazian *et al.* 2004). This high degree of site fidelity would likely also make them more susceptible to localised impacts. *A. lennardi* and *L. laticaudis* have similar life characteristics as the indicator species Bluespotted Tuskfish (*C. cauteroma*) (see below for further information). As a significant impact with recovery pattern was observed for *C. cauteroma*, it is likely that *A. lennardi* and *L. laticaudis* may also recover and exhibit increased abundance in Post-Development Survey Year 3.

No significant changes were detected in the length-frequency distributions of the fish assemblage.

During Post-Development Survey Year 1, the total abundance of fish (sum of all MaxNs) was greater than in either the Marine Baseline Surveys or Post-Development Survey Year 2. On further investigation, this increase in total abundance was due to large schools of the herring species *Herklotsichthys* spp. During Marine Baseline Surveys, 980 individuals of this species were recorded in Reference Sites; however, in Post-Development Survey Year 1 3309 individuals were recorded in Reference Sites, in five schools of more than 200 fish and one school of more than 1000. During Post-Development Survey Year 2, only 193 *Herklotsichthys* spp. were recorded in Reference Sites. Caution should be applied in the interpretation of any changes in fish abundance between Surveys. Post-Development Survey Year 1 and Post-Development Survey Year 2 were undertaken in November and February and November to December respectively (as per survey timeframe requirements; see Section 1.5.3). The Marine Baseline Program was undertaken in October and March. As such, any differences in fish abundance between Surveys may be partially explained by the different survey timeframes.

Patterns of change in species richness suggest a 'pulse' response to a disturbance and recovery in the ZoHI. A short-term reduction in species richness was recorded in the ZoHI during Post-Development Survey Year 1. However, species richness observed during Post-Development Survey Year 2 did not differ to the Marine Baseline Surveys, nor had species richness at this time increased enough to be significantly different from Post-Development Survey Year 1. These results suggest that species richness in the ZoHI may be recovering after a pulse response of significant decrease to a short-term disturbance. Such a perturbation is known as a 'discrete pulse' (Glasby and Underwood 1996) and is consistent with the pattern of impact and recovery.

Assessment of indicator species separately to the entire assemblage is extremely important as effects of dredging can be obscured in mean fish community measures by high diversity and regular influx of species (Bilkovic 2011). No change was observed in coral habitats for the indicator species assemblage as a whole. For 14 of the 20 indicator species, no detectable change in abundance was found for the terms of interest. Of the remaining six indicator species, two species, *A. grammoptilus* and *S. Nematophorus*, were found to be significant for terms of interest Survey × Zone(IvR) and Survey × IvR respectively. However, for both species, the changes were not indicative of impact associated with dredging and dredge spoil disposal activities.

Suggestion of a 'discrete pulse' perturbation reflected in the species richness data is supported by changes in the abundance of three indicator species—*Choerodon cauteroma*, *Choerodon schoenleinii*, and *Plectropomus* spp. For *C. cauteroma* and *C. schoenleinii* a significant decrease in abundance in coral habitat in Impact zones was detected from the Marine Baseline Program to Post-Development Survey Year 1. This decrease was followed by an increase in abundance from Post-Development Survey Year 1 to Post-Development Survey Year 2. *Plectropomus* spp. decreased in abundance significantly from the Marine Baseline Survey to Post-Development Survey Year 1 in the ZoHI and ZoI. During Post-Development Survey Year 2 no significant difference in abundance was detected from the Marine Baseline Survey. These three species show evidence of a pulse decrease in abundance in response to disturbance, followed by some recovery (Table 7-19).

One indicator species, *Pentapodus emeryii*, decreased in abundance in coral habitat in the ZoHI after the Marine Baseline Surveys. The abundance of this species remained low in the ZoHI during Post-Development Survey Year 2. No significant change was observed elsewhere. This pattern is consistent with a negative impact in the ZoHI, and there is no evidence of a recovery in the abundance of this species. This pattern is consistent with a ‘protracted pulse’ perturbation (Glasby and Underwood 1996) and is consistent with the pattern of impact and no recovery.

No significant changes were detected in the length-frequency distributions of the three indicator species tested.

When interpreting changes that were observed only in the ZoHI it should be noted that this zone is limited in size, it contains only one coral site (site CI1), and five replicate stereo-BRUV deployments. Therefore, any observed declines in species at this site may reflect natural spatial variation, rather than indirect impacts from dredging activities.

8.0 Surficial Sediments

8.1 Introduction

Barrow Island is situated on the shallow (generally <5 m depth) limestone shelf that underlies the Montebello/Barrow Islands group. There is a broad intertidal platform adjacent to Barrow Island that grades to the subtidal limestone shelf. On the east coast of Barrow Island, the intertidal limestone reef flats and shallow pavement reef are overlain by sands and gravels, with more rubble in areas where the water currents are stronger. The unconsolidated sediments overlying the limestone pavement range in thickness between 0.5 m and 3 m, with the thicker sediment layers being in the deeper water offshore of the nearshore platform (Chevron Australia 2006).

Results from the Marine Baseline Program showed that the sediments in the waters surrounding Barrow Island were characterised by six sediment types (Sand, gravelly Sand, sandy Gravel, muddy Sand, gravelly muddy Sand, muddy sandy Gravel).

Comparisons made between the Marine Baseline Program and the Post-Development Survey Year 1 indicated that, overall, dredging and spoil disposal activities may have caused a change in the sediment characteristics towards a finer particle size distribution in the vicinity of, and to the south of, the LNG jetty. However, it was also apparent that the surficial sediments in the region around Barrow Island were naturally variable, which may have contributed to the changes observed in the predicted Zone of High Impact (ZoHI), Zone of Moderate Impact (ZoMI) and Zone of Influence (ZoI).

8.2 Scope

This Section is in two parts. The first part presents the characteristics of surficial sediments recorded during the Post-Development Survey Year 2:

- within the Zones of High Impact and the Zones of Moderate Impact and representative areas in the Zones of Influence, associated with the generation of turbidity and sediment deposition from dredging and dredge spoil disposal activities required for the MOF and LNG Jetty
- at Reference Sites not at risk of Material or Serious Environmental Harm due to the construction of the MOF and LNG Jetty.

The second part compares the Post-Development Surveys and the Marine Baseline Program survey to determine if changes have occurred as per Condition 24.2 of Statement No. 800 and Condition 17.2 of EPBC Reference: 2003/1294 and 2008/4178.

As previously discussed (Section 2.1.5), no specific results or comparisons are made for the area in the vicinity of the marine upgrade of the existing WAPET Landing.

8.3 Methods

8.3.1 Site Locations

The Marine Baseline Program established 185 surficial sediment sampling locations (Chevron Australia 2012a). As per the requirements in the approved Scope of Works (RPS 2009 [amended 2012]), a subset of 99 of these sites were sampled as part of the Post-Development Survey Year 1 (Table 8-1). During the Post-Development Survey Year 2, a subset of 93 sites out of the 99 Post-Development Survey Year 1 sites were sampled (Table 8-1, Figure 8-1). Six sites were not sampled because they were located in the DomGas Pipeline Exclusion Zone, thereby making them inaccessible for sampling.

Table 8-1 Number of Surficial Sediment Samples Collected in the Zones of High Impact, Zones of Moderate Impact, Zones of Influence, and at Reference Sites

Locations	Number of Samples: Post-Development Survey Year 2	Number of Samples: Post-Development Survey Year 1	Number of Samples: Marine Baseline Program
Zone of High Impact	11	11	32
Zone of Moderate Impact	10	11	15
Zone of Influence	38	41	77
Reference Sites	34	36	61
TOTAL	93	99	185

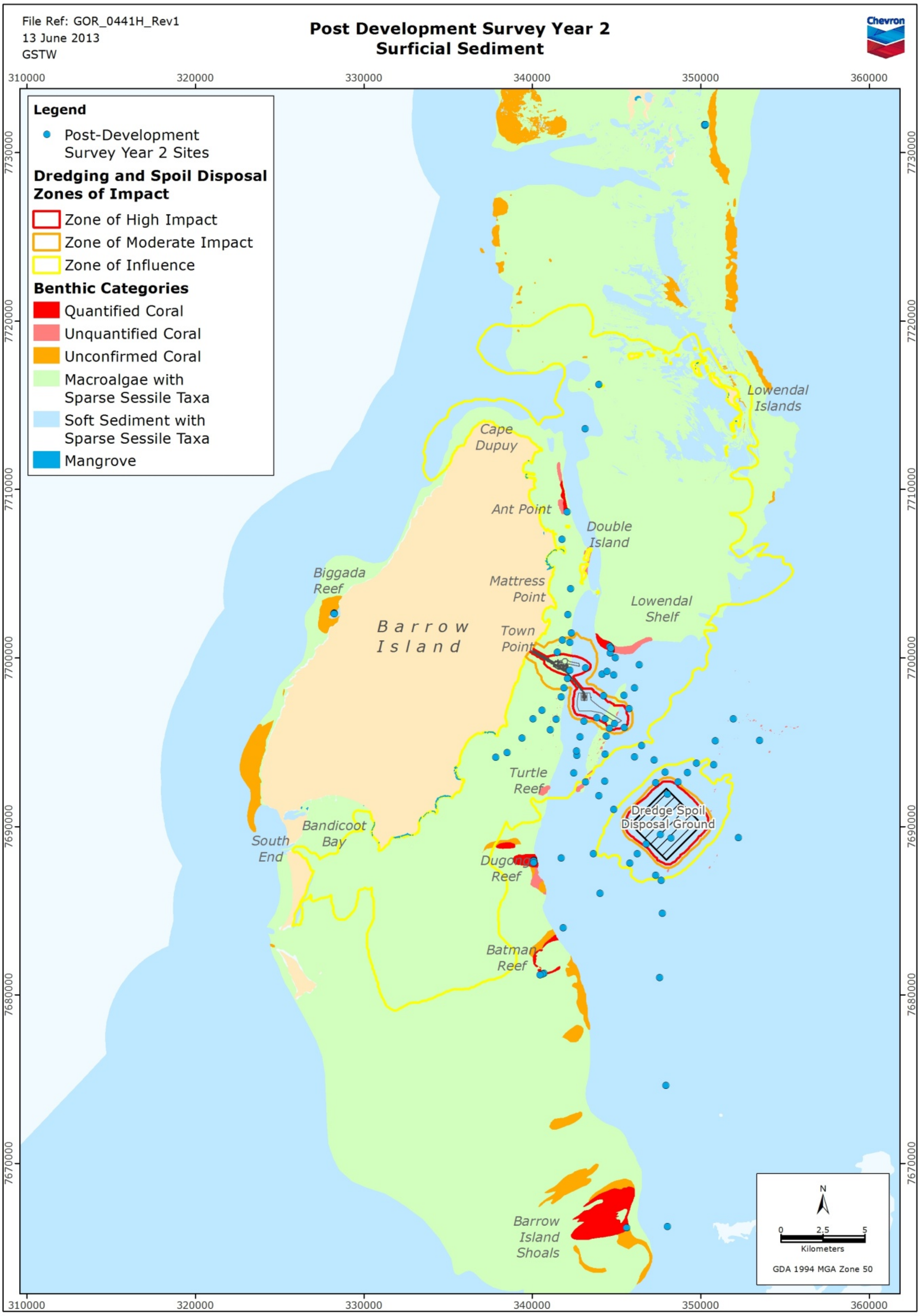


Figure 8-1 Post-Development Survey Year 2 Sites for Surficial Sediment

8.3.2 Timing and Frequency of Sampling

Surficial sediment samples for the Post-Development Survey Year 2 were collected between December 2012 and April 2013.

8.3.3 Survey Method

At each site, sediment samples were collected using multiple scrapes of the surficial sediments (<5 cm) within a 4 m^2 area; these were collected directly into 250 mL sample containers to form two composite samples. Where visibility permitted, photographs were taken of the seabed at each site for visual documentation of the sediments.

Standard laboratory analytical procedures were employed and laboratories with demonstrated quality assurance/quality control (QA/QC) procedures in place carried out the analyses. The sediment samples were analysed for Particle-size Distribution (PSD) by laser diffraction and wet sieving. The results are expressed as a cumulative percentage volume of particles that occupy six different size ranges: clay (0.02–4.0 µm), silt (4.0–62 µm), fine sand (62–250 µm), medium sand (250–500 µm), coarse sand (500–2000 µm), and gravel (2000–10 000 µm).

Revised Marine Baseline Program data relevant to measures of surficial sediment classification are presented in Appendix 1

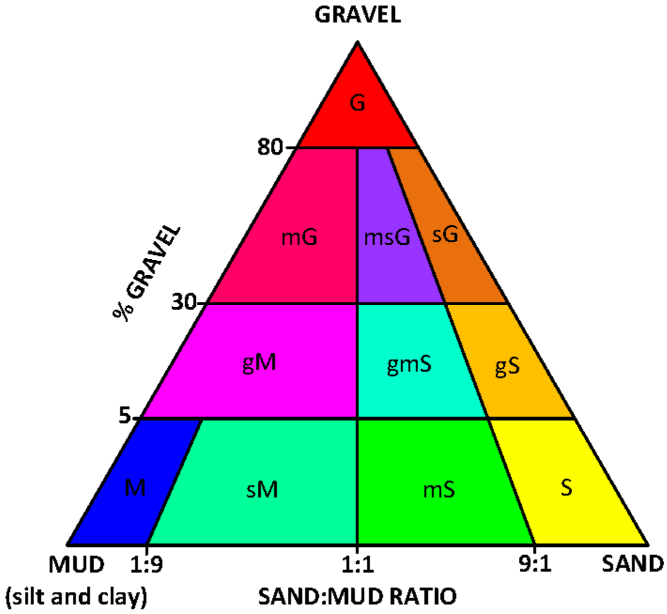
8.3.4 Treatment of Survey Data

Based on the results of particle-size analysis, each sediment sample was classified into a sediment type according to a simplified version of the scheme proposed by Folk (1954). The simplified version has four fewer categories than the full version as it amalgamates some categories that contain less than 5% gravel. The sediment classification scheme is based on a triangular diagram divided into sediment textural groups, according to measured percentages of gravel, sand, and mud constituents (Figure 8-2). The method provides an approach to describing the sediments with a complete range of mixtures of the three components, producing a single description and classification value (Passlow *et al.* 2005).

According to the classification scheme, sediment grains were first categorised into three size-classes based on their diameter:

- mud <0.062 mm
- sand 0.062–2 mm
- gravel >2 mm.

The percentage composition of each of the grain size-classes and the ratios between them were then used to classify the sediment into 11 discrete sediment types (Figure 8-2).



Abbreviation	Description
G	Gravel
mG	muddy Gravel
msG	muddy sandy Gravel
sG	sandy Gravel
gM	gravelly Mud
gmS	gravelly muddy Sand
gS	gravelly Sand
M	Mud
sM	sandy Mud
mS	muddy Sand
S	Sand

Figure 8-2 Simplified Folk Triangle Sediment Classification Scheme

Note: This diagram is not to scale – it is a representation of the classification subdivisions.

8.4 Results of Post-Development Survey Year 2

The spatial distribution of the Post-Development Survey Year 2 sediment classifications around Barrow Island are presented as spatially rectified point observations (Figure 8-3). During the Post-Development Survey Year 2 the sediments on the seafloor surrounding Barrow Island were characterised by six sediment classifications; gravelly muddy sand, gravelly sand, sand, sandy mud, sandy gravel, muddy sand. In general, gravelly sand and sand dominated the Barrow Island region.

The sediments along the east coast of Barrow Island to the north and the south of the MOF were characterised by gravelly sands at most sites, and sand at a low number of sites (Figure 8-3). Sand was the dominant component, constituting >75% of the material. Gravel and mud comprised <25% and <10% of material, respectively.

Further offshore in the vicinity of the LNG Jetty, there were two groups of sediment classifications observed: one north and one south of the LNG Jetty (Figure 8-3). North of the LNG jetty, the sediments were dominated by gravelly sand and sand. Sand comprised >80% in the majority (~80%) of samples, with gravel and mud comprising <15% and <10%, respectively. South of the LNG jetty the sediments had larger mud fractions. They were characterised by muddy sand and gravelly muddy sand and most samples comprised 10–60% mud. It should be noted that most sediments containing >10% mud were localised in the vicinity and to the south of, the LNG Jetty (Figure 8-3).

Between the LNG Jetty and the Dredge Spoil Disposal Ground the sediments were characterised by gravelly sand and gravelly muddy sand, with sand at one site. In the vicinity of the Dredge Spoil Disposal Ground, and directly to the north-east and south-west of it, the sediments were dominated by sand, with gravelly sand, sandy gravel and gravelly muddy sand also occurring (Figure 8-3). In most (~75%) of the samples, sand comprised >90% of the material, and gravel and mud each comprised <5% of the material.

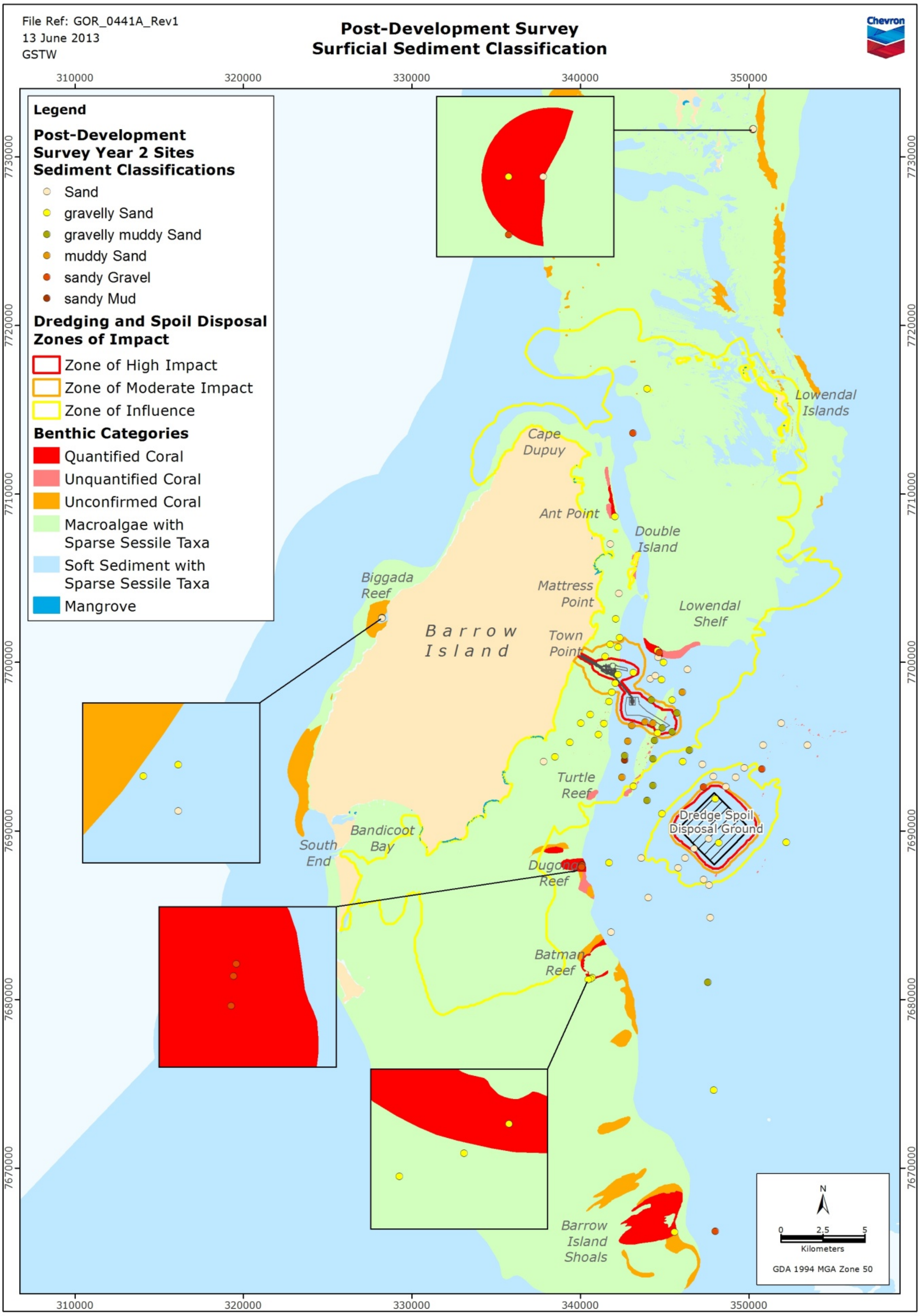


Figure 8-3 Surficial Sediment Classifications during the Post-Development Survey Year 2

8.4.1 Surficial Sediment Characteristics within the Zones of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

8.4.1.1 Surficial Sediment Characteristics at Sites in the Vicinity of the MOF and the LNG Jetty

During the Post-Development Survey Year 2, most (~80%) of the sediment samples collected in the vicinity of the MOF and LNG Jetty comprised >75% sand, with the remaining 25% comprising a combination of gravel and mud (Plate 8-1).

All the sediments collected in the vicinity of the MOF were characterised by gravelly sand. The sediments collected near the LNG Jetty were dominated by gravelly muddy sand, with muddy sand occurring at two sites and gravelly sand occurring at one site.

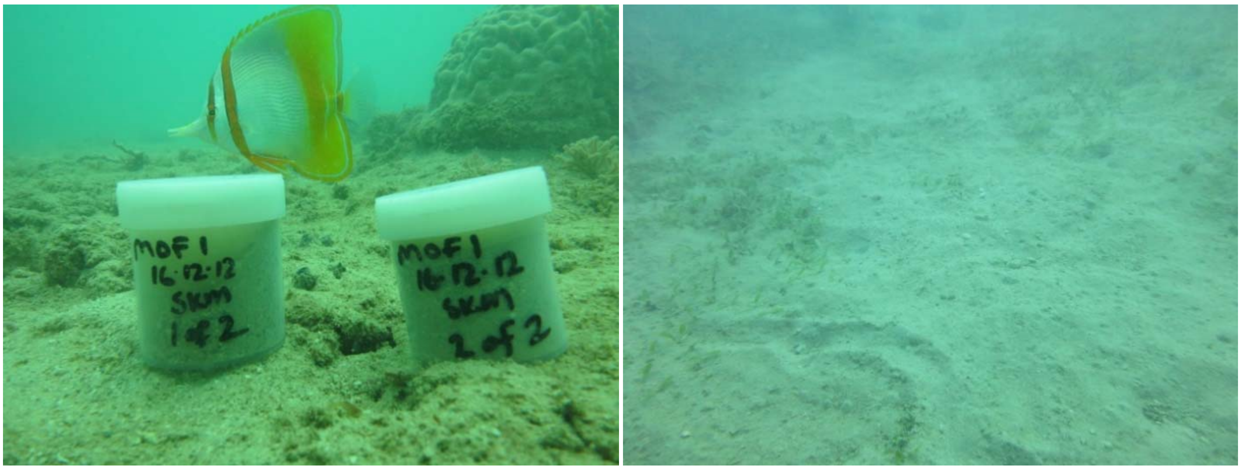


Plate 8-1 Sea Floor at MOF1 (left) and TP7 (right) in the Vicinity of the MOF and the LNG Jetty on the East Coast of Barrow Island during the Post-Development Survey Year 2

8.4.1.2 Surficial Sediment Characteristics at Sites in the Vicinity of the Dredge Spoil Disposal Ground

The sediments in the vicinity of the Dredge Spoil Disposal Ground were characterised by sand, gravelly sand, gravelly muddy sand, and sandy gravel. Most (~70–85%) of these sediments were composed of >80% sand with gravel and mud fractions of <10% (Plate 8-2).

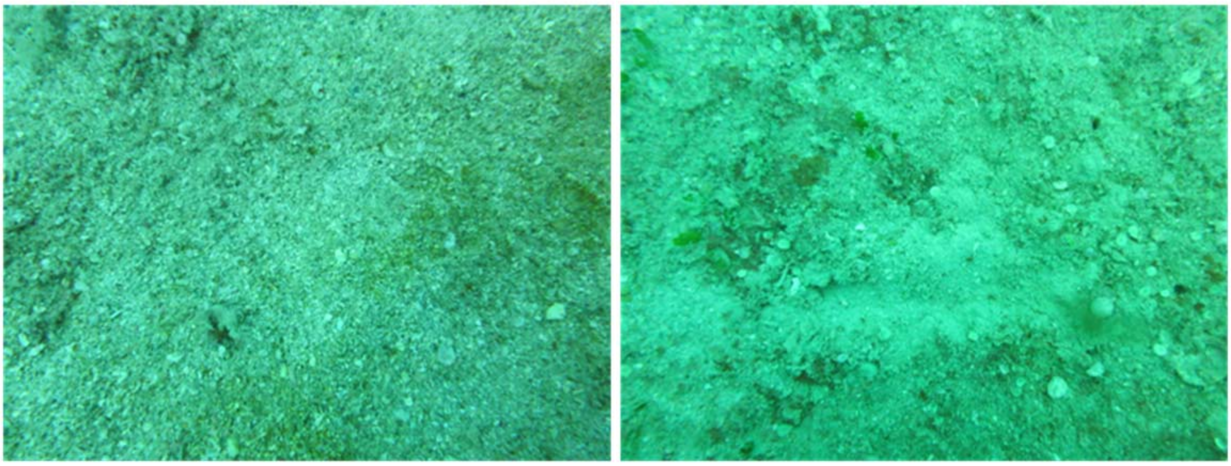


Plate 8-2 Sea Floor at SS28 (left) and HM-7 (right) near the Dredge Spoil Disposal Ground during the Post-Development Survey Year 2

8.4.2 Surficial Sediment Characteristics within the Zones of Influence Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

The sediments within the predicted ZoI were dominated by gravelly sand and sand, with muddy sand, gravelly muddy sand, sandy gravel, and sandy mud occurring at some sites. Most (~75%) of the sediments comprised >75% sand, <15% gravel, and <10% mud.

8.4.3 Surficial Sediment Characteristics at Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction of the MOF and LNG Jetty

The sediments at the Reference Sites were dominated by gravelly sand and sand, with sandy gravel and gravelly muddy sand occurring at some sites. Most (~70–80%) of the sediment samples collected from the Reference Sites comprised >70% sand, <25% gravel, and <5% mud.

8.5 Comparison between the Post-Development Surveys and Marine Baseline Environmental State

Six sediment classifications were observed in the Barrow Island region during the Post-Development Survey Year 2. These were the same sediment classifications observed during the Marine Baseline Program, except that sandy mud was observed during the Post-Development Year 2 instead of muddy sandy gravel, which was observed during the Marine Baseline Program. This contrasts with the eight sediment classifications observed during the Post-Development Survey Year 1, which also included the categories gravel and gravelly mud.

During all three surveys, sand was the dominant constituent of the sediments, comprising more than 60% of the sediments in 90% of samples during the Marine Baseline Program and Post-Development Survey Year 2, and in 80% of samples during Post-Development Survey Year 1. The sediment particle size data for all three surveys were plotted on a Folk triangle for comparison (Figure 8-4). The distribution between sand and gravel was similar during all three surveys, but approximately one-third of the sediments collected during the Post-Development Survey Year 1 and Post-Development Survey Year 2 were finer than those collected during the Marine Baseline Program. This was largely the result of an increased mud fraction in the sediments (Figure 8-4). The largest mud fractions collected were 60% and 75% for Post-Development Survey Year 2 and Post-Development Survey Year 1 respectively, which were both greater than that recorded during Marine Baseline Program (20% mud). During the Post-Development Survey Year 2, 20% of sediments were coarser and 30% were finer relative to the sediments collected during the Marine Baseline Program. The sediment particle size distributions at more than half the sites remained similar between Post-Development Survey Year 1 and Post-Development Survey Year 2, with sediments at ~25% of sites being coarser and sediments at ~15% of sites being finer.

The comparison of sediment classification data between the Post-Development Survey Year 2 and the Marine Baseline Program, and between the Post-Development Survey Year 2 and the Post-Development Survey Year 1, are presented as spatially rectified point observations (Figure 8-5, Figure 8-6).

On the east coast shelf of Barrow Island south of the MOF, most sediments collected during Post-Development Survey Year 2 had the same sediment classifications relative to the Marine Baseline Program and the Post-Development Survey Year 1. Immediately north of the MOF, sediments were coarser during Post-Development Survey Year 2 at three out of five sites relative to the Marine Baseline Program and the Post-Development Survey Year 1. Most sites with sediment classifications that remained the same between the Post-Development Survey Year 2 and the Marine Baseline Program also remained the same between the Post-

Development Survey Year 2 and the Post-Development Survey Year 1 and therefore have not changed over the three surveys.

The distinction between the sediments to the north and south of the LNG Jetty, previously observed in the Post-Development Survey Year 1 and not during the Marine Baseline Program (Chevron Australia 2012a), was still apparent during Post-Development Survey Year 2 (Section 8.4, Figure 8-3). North of the LNG Jetty the sediment classifications at most sites remained the same relative to the Marine Baseline Program and Post-Development Survey Year 1. Relative to the Marine Baseline Program, most of the remaining sediments north of the LNG Jetty were finer during Post-Development Survey Year 2. In contrast, relative to Post-Development Survey Year 1, most of the remaining sediments were coarser during Post-Development Survey Year 2.

Most sediments south of the LNG Jetty were finer during Post-Development Survey Year 2 relative to the Marine Baseline Program, as a result of the higher mud fractions in the sediments. Approximately two-thirds of Post-Development Survey Year 2 sediments were similar to those collected during Post-Development Survey Year 1, with the remaining being coarser.

Between the LNG Jetty and the Dredge Spoil Disposal Ground, ~40% of the sediments collected during the Post-Development Survey Year 2 were finer relative to the Marine Baseline Program. A similar proportion of samples (~40%) were coarser relative to Post-Development Survey Year 1.

In the vicinity of the Dredge Spoil Disposal Ground and directly to the north-east and south-west, most Post-Development Survey Year 2 sediment classifications were the same relative to the Marine Baseline Program and Post-Development Survey Year 1. The majority of the remaining sediments, which were mostly localised towards the south-west of the Dredge Spoil Disposal Ground, were finer relative to the Marine Baseline Program.

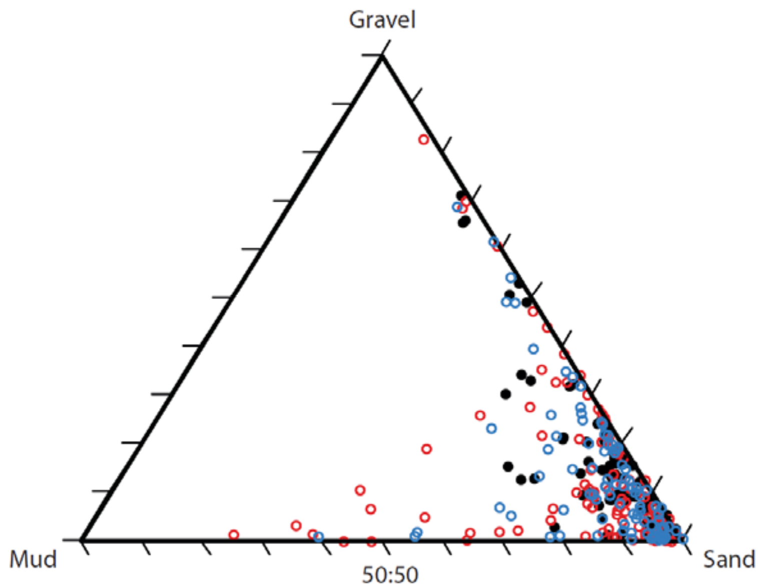


Figure 8-4 Comparison of Post-Development Survey Sediment Year 2 Sediment PSD (blue), Post-Development Survey Year 1 Sediment PSD (red) and Marine Baseline Program Sediment PSD (black)

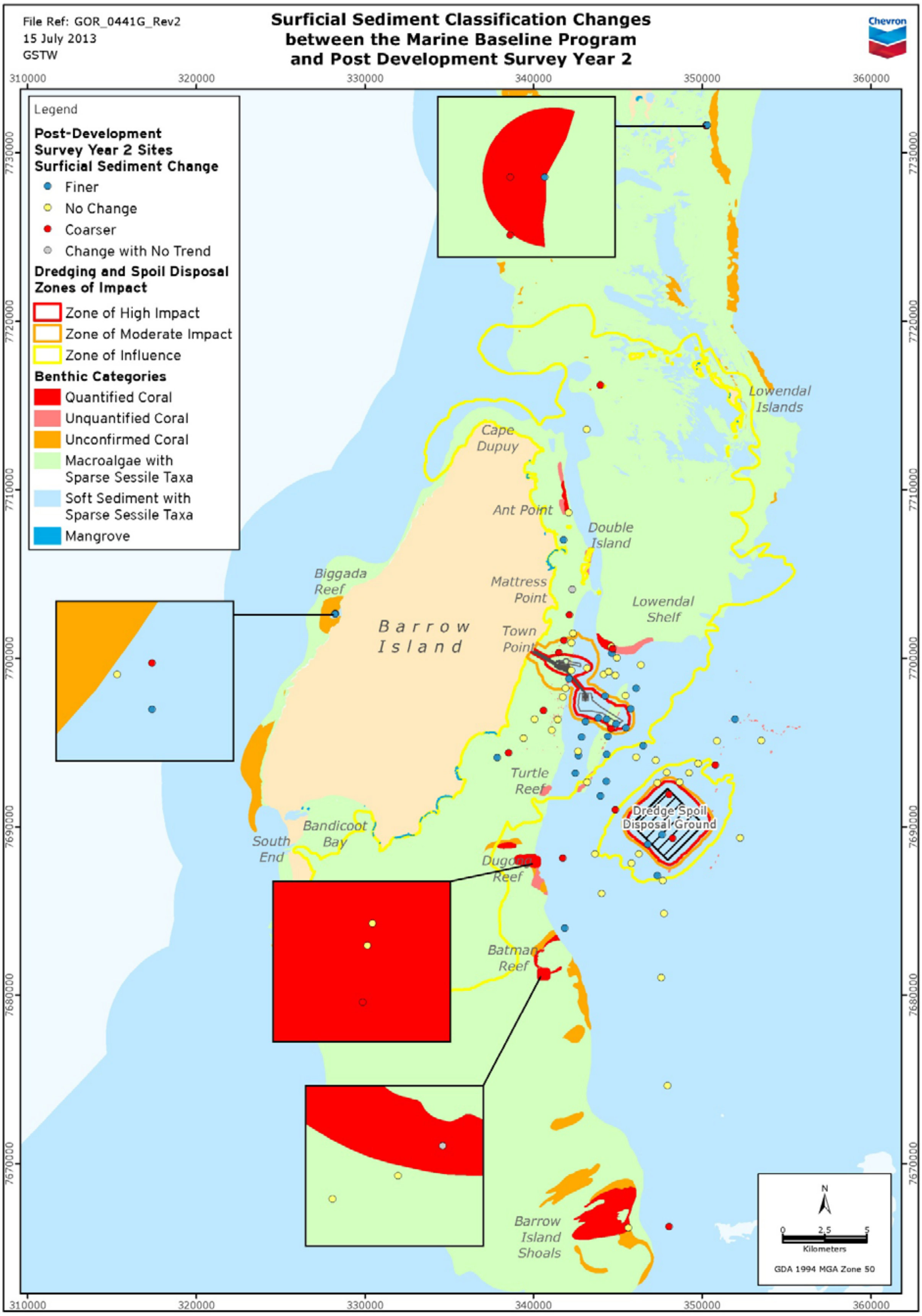


Figure 8-5 Spatial Distribution of Sediment Classification Changes between the Marine Baseline Program and Post-Development Survey Year 2

Note: No Change = Folk's sediment class is the same as previously observed; Change with no trend = there has been a change in the Folk's sediment class but there was no trend towards finer or coarser.

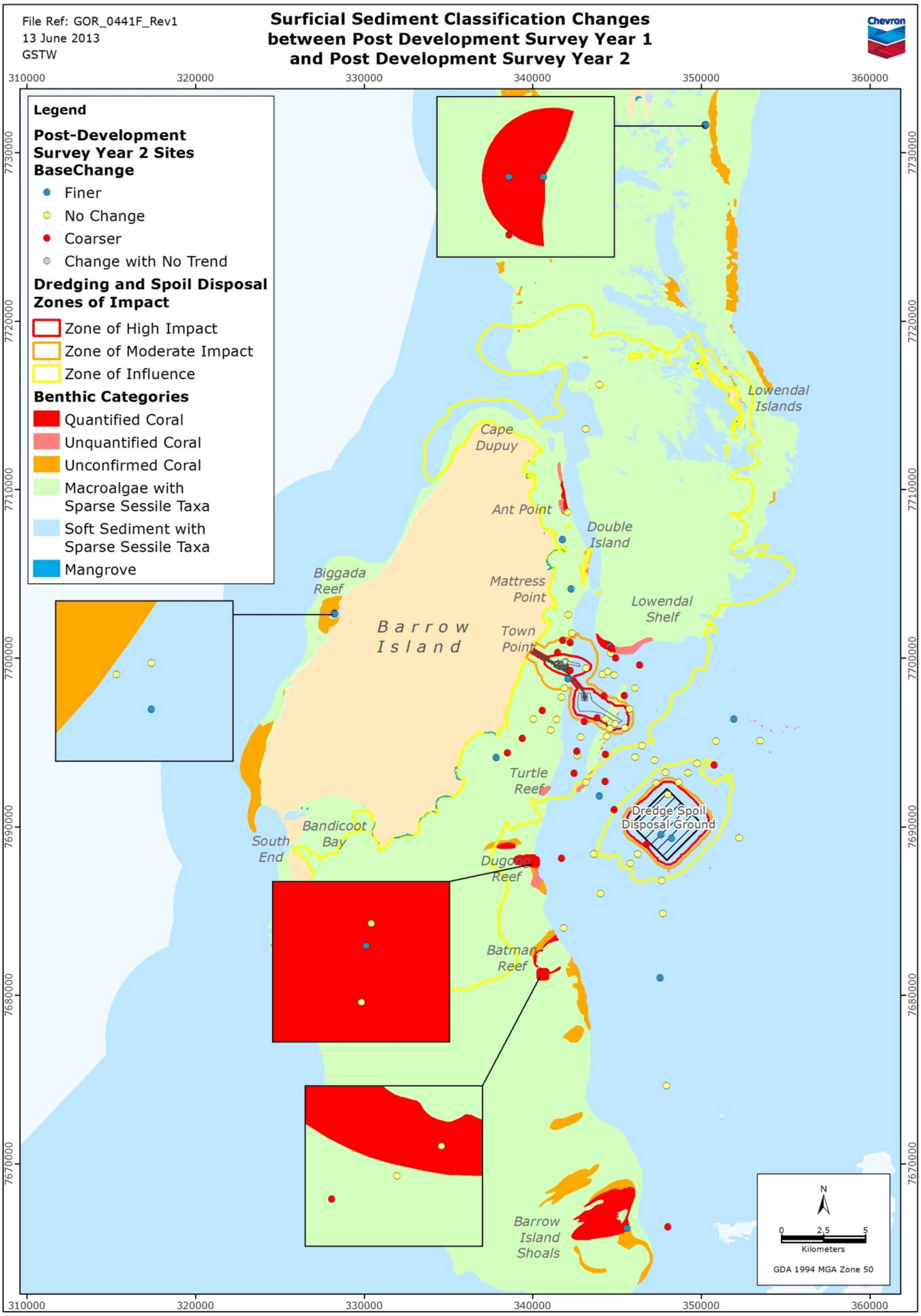


Figure 8-6 Spatial Distribution of Sediment Classification Changes between Post-Development Survey Year 1 and Post-Development Survey Year 2

Note: No Change = Folk's sediment class is the same as previously observed; Change with no trend = there has been a change in the Folk's sediment class but there was no trend towards finer or coarser.

8.5.1 Surficial Sediment Characteristics within the Zones of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

8.5.1.1 Surficial Sediment Characteristics at Sites in the Vicinity of the MOF and the LNG Jetty

The particle size data for all three surveys in the vicinity of the MOF and the LNG Jetty within the predicted ZoHI and ZoMI were plotted on a Folk triangle for comparison (Figure 8-7). In the vicinity of the MOF, half the sediments collected during Post-Development Survey Year 2 had particle size distributions similar to those collected during the Marine Baseline Program, with the remaining samples being either coarser or finer (Figure 8-5). Most Post-Development Survey Year 2 sediments were coarser than Post-Development Survey Year 1 sediments (Figure 8-6). Specifically, sediments containing >10% gravel occurred at ~70% of sites during Post-Development Survey Year 2 and at only ~40% of sites during Post-Development Survey Year 1.

In the vicinity of the LNG Jetty within the predicted ZoHI and ZoMI, Post-Development Survey Year 2 sediments at all but one site were finer relative to the Marine Baseline Program (Figure 8-5). This was the same result observed between Post-Development Survey Year 1 and the Marine Baseline Program (Chevron Australia 2012a). Specifically, the largest mud constituent in the sediment at these sites was ~10% during the Marine Baseline Program, ~50% during Post-Development Survey Year 1, and ~25% during Post-Development Survey Year 2. Therefore, although there was less mud in the Post-Development Survey Year 2 sediments relative to Post-Development Survey Year 1, the mud constituent of the Post-Development Survey Year 2 sediments remained greater than the Marine Baseline Program.

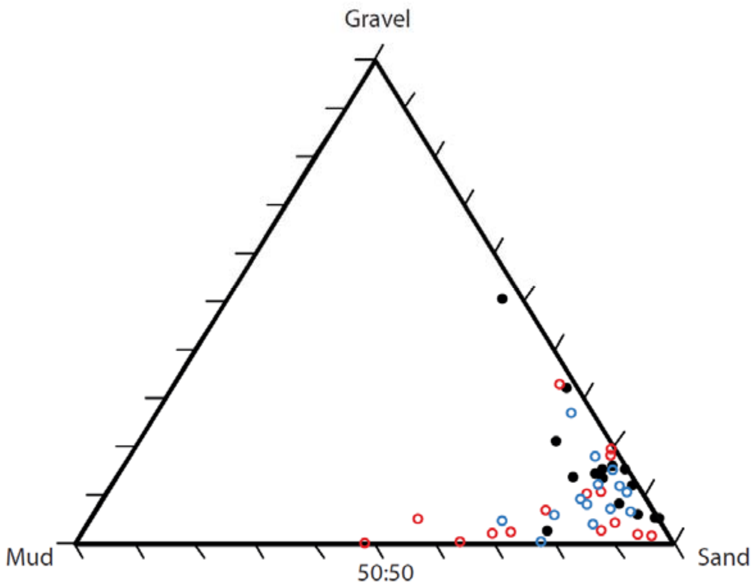


Figure 8-7 Comparison of Post-Development Survey Sediment Year 2 Sediment PSD (blue), Post-Development Survey Year 1 Sediment PSD (red), and Marine Baseline Program Sediment PSD (black) in the Predicted ZoHI and ZoMI near the MOF and the LNG Jetty

8.5.1.2 Surficial Sediment Characteristics at Sites in the Vicinity of the Dredge Spoil Disposal Ground

The sediment particle size data for all three surveys in the vicinity of the Dredge Spoil Disposal Ground within the predicted ZoHI and ZoMI were plotted on a Folk triangle for comparison

(Figure 8-8). Post-Development Survey Year 2 sediments at nearly half the sites were finer relative to the Marine Baseline Program (Figure 8-5). These sites were located on the south-west side of the Dredge Spoil Disposal Ground. Of the remaining four sites, two had sediment classifications that were the same during the Marine Baseline Program and two had sediment classifications that were coarser. Most of the Post-Development Survey Year 2 sediment classifications were the same as Post-Development Survey Year 1.

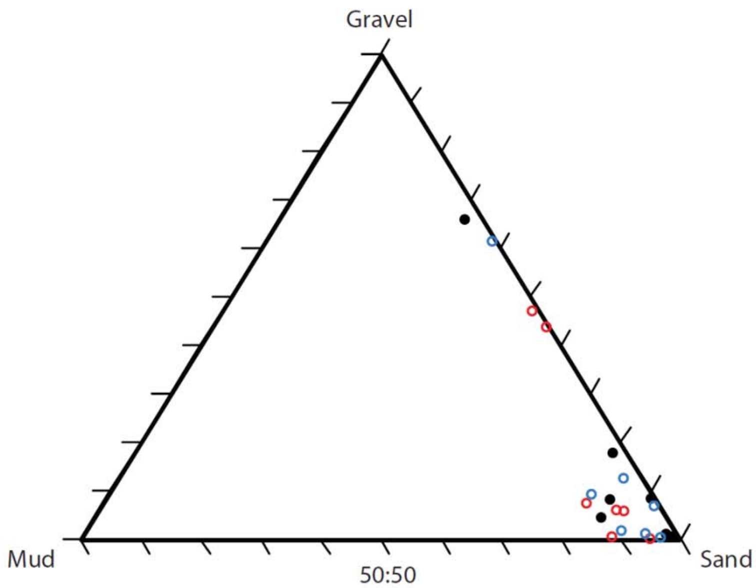


Figure 8-8 Comparison of Post-Development Survey Year 2 Sediment PSD (blue), Post-Development Survey Year 1 Sediment PSD (red), and Marine Baseline Program Sediment PSD (black) in the Predicted ZoHI and ZoMI, near the Dredge Spoil Disposal Ground

8.5.2 Surficial Sediment Characteristics within the Zones of Influence Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal

The sediment particle size data for all three surveys within the predicted ZoI were plotted on a Folk triangle for comparison (Figure 8-9). The sediment classifications at just over half the Post-Development Survey Year 2 sites were the same as those observed during the Marine Baseline Program and Post-Development Survey Year 1 (Figure 8-5, Figure 8-6). Of the remaining sites, most sediments were finer relative to the Marine Baseline Program, and coarser relative to the Post-Development Survey Year 1.

The sediment particle size distribution of the Post-Development Survey Year 2 sediments indicated that there was a greater proportion of mud relative to the Marine Baseline Program. Specifically, in ~75% of samples the largest mud fraction was 10% during Post-Development Survey Year 2 compared to 5% mud during the Marine Baseline Program. This was the same trend as that observed during the Post-Development Survey Year 1 (Chevron Australia 2012b). However, the degree of change in the Post-Development Survey Year 2 sediments in comparison to the Marine Baseline Program was smaller relative to that observed during the Post-Development Survey Year 1 (Chevron Australia 2012b); in ~75% of samples the largest mud component was ~15% mud during Post-Development Survey Year 1.

As observed during Post-Development Survey Year 1, most sites where sediments were finer relative to the Marine Baseline Program were in the vicinity of, and to the south of, the LNG Jetty due to higher mud fractions in the sediments (Chevron Australia 2012b).

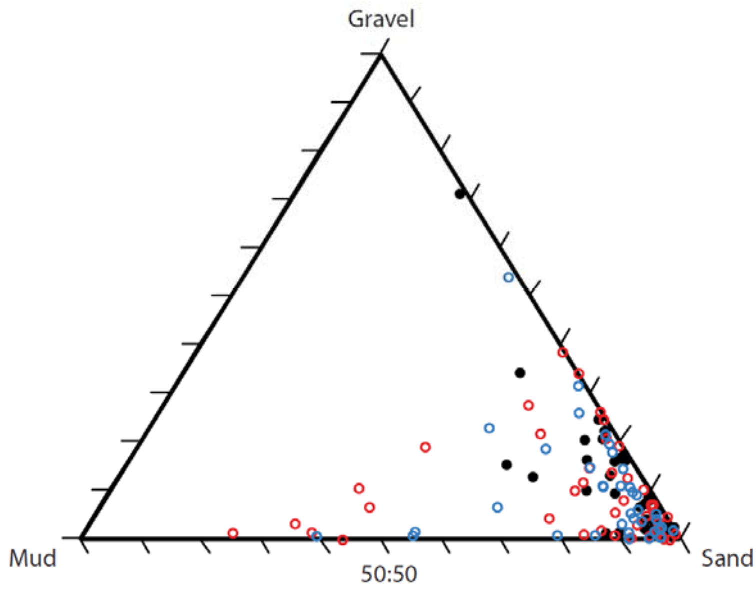


Figure 8-9 Comparison of Post-Development Survey Year 2 Sediment PSD (blue), Post-Development Survey Year 1 Sediment PSD (red), and Marine Baseline Program Sediment PSD (black) in the Predicted ZoI

8.5.3 Surficial Sediment Characteristics at Reference Sites not at risk of Material or Serious Environmental Harm due to the Construction of the MOF, LNG Jetty, and the Marine Upgrade of the Existing WAPET Landing

During Post-Development Survey Year 2, the sediment classifications at approximately half the Reference Sites were the same relative to the Marine Baseline Program and Post-Development Survey Year 1 (Figure 8-5, Figure 8-6, Figure 8-10). Of the sediments at the remaining sites, approximately equal numbers were coarser or finer relative to the Marine Baseline Program and Post-Development Survey Year 1. During all three surveys, at 75–80% of sites, the sediments comprised >70% sand, up to 25% gravel, and up to 5% mud.

During Post-Development Survey Year 2, sediments at three Reference Sites located south and south-east of the LNG Jetty (between the LNG Jetty and the Dredge Spoil Disposal Ground) were finer relative to the Marine Baseline Program sediments due to higher mud fractions in the sediments.

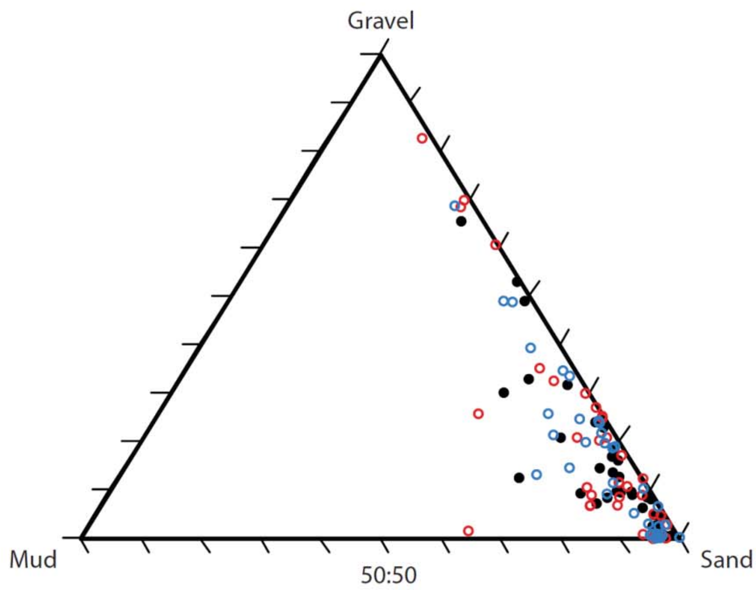


Figure 8-10 Post-Development Survey Year 2 Sediment PSD (blue), Post-Development Survey Year 1 Sediment PSD (red), and Marine Baseline Program Sediment PSD (black) at Reference Sites

8.6 Discussion

At the Reference Sites, approximately half the sediment samples collected during Post-Development Survey Year 2 had similar particle size distributions relative to the Marine Baseline Program and Post-Development Survey Year 1. The sediment particle size distributions at the remaining sites changed but there was no overall trend, which was similar to the findings of Post-Development Survey Year 1 (Chevron Australia 2012b). This suggests that the sediment particle size distribution in the Barrow Island region is naturally variable. Part of any change in the sediment particle size distributions at sites within the ZoHI, ZoMI and ZoI may therefore be attributable to variability observed across the region. However, given the lack of observed patterns in natural variability, it may equally be inferred that trends in changes in the sediment particle size distribution within the ZoHI, ZoMI and ZoI could be partially attributable to the dredging and dredge spoil disposal activities.

Within the ZoI the sediments at just over half the sites had similar particle size distributions as reported in the Marine Baseline Program. Most of the remaining samples had a finer particle size distribution relative to the Marine Baseline Program and most of the corresponding sites were located in the vicinity of, and to the south of, the LNG Jetty (Figure 8-5). A similar trend was observed in the ZoHI and ZoMI in the vicinity of the LNG Jetty, where sediments at all but one site were finer relative to the Marine Baseline Program (Figure 8-5). Furthermore, sediments at three Reference Sites located south and south-east of the LNG Jetty (between the LNG Jetty and the Dredge Spoil Disposal Ground) were observed to be finer relative to the Marine Baseline Program as a result of higher mud fractions in the sediments (Figure 8-5). It should be noted that the majority of sediments containing >10% mud were localised in an area near to and south of the LNG Jetty (Figure 8-3).

Some of the changes observed in this area may be attributable to the dredging and dredge spoil disposal activities. During dredging and dredge spoil disposal activities, the dredge plume was typically observed to extend south from the dredge area, so it could be expected that the finer sediment material would settle on to the south of the dredge area (Chevron Australia 2012c).

Within the ZoHI, ZoMI, and ZoI, the sediments at sites immediately north of the MOF were observed to be coarser during the Post-Development Survey Year 2 relative to the Marine Baseline Program (Figure 8-5).

The different dredging methods that were predominantly used in the area of the MOF (bucket dredge and grab dredge) compared to the LNG Jetty (cutter suction dredge and trailer suction hopper dredge) may explain the lack of a consistent trend in the sediment particle size distribution changes observed in the areas near the MOF and near the LNG Jetty.

Within the ZoHI and the ZoMI near the Dredge Spoil Disposal Ground, there were changes in the sediment particle size distribution at all but two sites, which were located at the northern edge of the ZoMI, between the Post-Development Survey Year 2 and the Marine Baseline Program. There was no overall trend in these changes; however, finer sediments relative to the Marine Baseline Program were localised in an area south-west of the Dredge Spoil Disposal Ground. Within the ZoI near the Dredge Spoil Disposal Ground, the sediment particle size distributions at all sites but one were similar to those collected during the Marine Baseline Program (Figure 8-5).

Within the predicted ZoHI, ZoMI and ZoI, the sediments at more than half the sites retained a similar particle size distribution as reported in Post-Development Survey Year 1. However, most of the remaining sediments (one-third of all sites, distributed across the predicted ZoHI, ZoMI, and ZoI) had coarser particle size distributions relative to Post-Development Survey Year 1 sediments (Figure 8-6). Those sites with coarser particle size distributions in the vicinity of, and to the south of, the LNG Jetty may represent the gradual return of sediment particle size distribution towards baseline conditions.

9.0 Conclusions and Recommendations

This Post-Development Survey Report has been prepared to meet the requirements of Condition 24 of Statement No. 800 and Condition 17 of EPBC Reference: 2003/1294 and 2008/4178. The purpose of this Report, as stated in Condition 24.2 of Statement No. 800, and Condition 17.2 of EPBC Reference: 2003/1294 and 2008/4178 is to determine if changes have occurred to marine ecological elements, including the Area of Loss of Coral Assemblages expressed as hectares, compared with the pre-development baseline marine environmental state.

Table 9-1 summarises the findings of this Post-Development Survey Year 2: 2012–2013 with regard to this purpose.

Table 9-1 Summary of Findings for each Ecological Element for the Post-Development Survey Year 2

Ecological Element	Conclusions
Coral	• The estimated net Area of Loss of Coral Assemblages in the ZoHI and ZoMI in the worst case was estimated to be 3.46 ha (adopting the upper 95% CL) and therefore did not exceed the Permanent Loss of Coral Assemblages limit of 8.47 ha (95% CL), as per Condition 18.1ii.b of Statement No. 800. • No significant difference in the size-class frequency of corals between Impact Sites (ZoHI and ZoMI) and Reference Sites from the Marine Baseline Program to and Post-Development Survey Year 2. • No indication of a major shift in the dominant coral taxa between the Marine Baseline Program and Post-Development Survey Year 2; however, some of the variation in certain coral families may be associated with the dredging and dredge spoil disposal activities. • No significant difference in recruitment success was observed between the Marine Baseline Program and the Post-Development Survey Year 2. • A significant decline in the percentage live coral cover detected in the ZoMI between the Marine Baseline Program and the Post-Development Survey Year 2 is likely to be associated with the dredging and dredge spoil disposal activities. However, signs of recovery are evident in both the ZoHI and ZoMI as the Post-Development Survey Year 2 live coral cover has increased from Post-Development Survey Year 1. • No significant decline in coral growth was observed between the Marine Baseline Program and the Post-Development Survey Year 2 that may be associated with dredging and dredge spoil disposal activities.
Non-coral Benthic Macroinvertebrate	• The change in benthic macroinvertebrate assemblage for soft sediment substrates between the Marine Baseline Program and the Post-Development Survey Year 2 was an increase in abundance, and is not considered to be associated with the dredging and dredge spoil disposal activities. • The change in benthic macroinvertebrate assemblage for limestone pavement in the ZoHI between the Marine Baseline Program and Post-Development Survey Year 2 was driven by a decline of three individuals from one taxonomic group and is based only on sites within two potential Impact zones: ZoHI and ZoI Sth.
Mangroves	• Overall, the mangrove communities across all sites appeared in good condition. • No significant changes were detected in the mean percentage cover and abundance of mangroves attributable to dredging and dredge spoil disposal activities.

Ecological Element	Conclusions
Demersal Fish	• Species richness in the ZoHI may be recovering from the significant decrease detected during Post-Development Survey Year 1 in comparison to that recorded during the Marine Baseline Program. • A single (one of 20) indicator species for coral habitat showed a decline in abundance in the ZoHI between the Marine Baseline Program and the Post-Development Survey Year 2 and is likely to be associated with the dredging and dredge spoil disposal activities • Two species of fish, commonly observed at Impact and Reference Sites showed a decline in abundance in Impact Sites between the Marine Baseline Program and Post-Development Survey Year 1 and Year 2 that is likely to be associated with dredging and dredge spoil disposal activities.
Surficial Sediment	• For those sites within the vicinity of, and to the south of, the LNG Jetty, the changes in composition of surficial sediment to finer sediments in the Post-Development Survey Year 2 relative to that recorded during the Marine Baseline Program is likely to be associated with the dredging and dredge spoil disposal activities.

Given the above results, Chevron Australia proposes that the Scope of Work for the subsequent Post-Development Survey (Year 3: 2013–2014) comprises only the following ecological elements:

- Coral: Area of Coral Assemblage, survival (fixed and random transects), size-class frequency, dominant and subdominant taxa and recruitment success, size-class frequency, and coral survival and growth (tagged colonies)
- Subtidal (i.e. stereo-BRUV) Demersal Fish
- Surficial Sediment.

Any changes to currently approved scopes and methods are to be confirmed with regulatory authorities prior to the Post-Development Survey (Year 3: 2013–2014).

Chevron Australia recommends the removal of the remaining elements (i.e. non-coral benthic macroinvertebrates and mangroves) from the Scope of Work for the Post-Development Survey Year 3: 2013–2014, for the following reasons:

- No definitive association with dredging and dredge spoil disposal activities could be identified, and continuation of the existing programs will not provide conclusive evidence (applicable to: non-coral benthic macroinvertebrates and mangroves).
- No significant statistical difference between the Marine Baseline Program and this Post-Development Survey associated with dredging and dredge spoil disposal activities was recorded (applicable to: non-coral benthic macroinvertebrates on soft sediment substrate and mangroves).

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Appendix 1 Revised Marine Baseline Program Results

The revisions to the Marine Baseline Program data from that previously presented in the Coastal and Marine Baseline State and Environmental Impact Report (Chevron Australia 2012a) and used within this Post-Development Survey Report are summarised below. These changes were required to ensure consistency in analysis techniques and results between these two surveys. These changes to the Marine Baseline Program data will be incorporated into the revised Coastal and Marine Baseline State and Environmental Impact Report, and submitted in accordance with Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178. The proposed changes are in accordance with the Scope of Works (RPS 2009 [amended 2012]); no revision of that document is required.

Different consultants undertook the Marine Baseline Program and the Post-Development Surveys. RPS undertook the field sampling, analysis, and reporting for the Marine Baseline Program; while SKM (with RPS as a subcontractor) undertook the field sampling, and Oceanica Consulting undertook the analysis and reporting for the Post-Development Surveys. To ensure consistency in the analysis of the field data between the different consultants (and to ensure that any changes found as part of the comparison between the Marine Baseline Program and the Post-Development Surveys are ‘real’ changes and not an artefact of different analysis techniques) a QA/QC check was undertaken. A subset of Marine Baseline Program raw data (for these ecological elements: coral, non-coral benthic macroinvertebrates, macroalgae, seagrass, and surficial sediments) was reanalysed by Oceanica Consulting and the results compared against those results reported in the Coastal and Marine Baseline State and Environmental Impact Report (Chevron Australia 2012a).

For all elements (or sub-elements) where the QA/QC checks revealed inconsistencies between the reported Marine Baseline Program data (Chevron Australia 2012a) and the analysis by Oceanica Consulting; these Marine Baseline Program data were revised.

Below is a summary of changes to the Marine Baseline Program data (as used in Post-Development Survey Report Year 2):

- **Coral Size-class Frequency:** Any site that has been used in the comparison against the Post-Development Surveys has been reanalysed:
  - *Number of Colonies*: Mean±SE values were recalculated using an alternate method (i.e. calculation of a mean from pooled site data, rather than the mean of the means of each of the three transects). Note: Additional genera (e.g. Faviidae Goniastrea, Faviidae Leptastrea etc.) have been included and their associated values revised.
  - *Average Size of Colonies*: Mean±SE values were recalculated using an alternate method (i.e. calculation of a mean from pooled site data, rather than the mean of the means of each of the three transects).
- **Coral Cover and Survival**: Any site that was used in the comparison against the Post-Development Surveys was reanalysed:
  - *Percentage live cover*: Mean±SE values and composition of corals at each site were recalculated through CPCe analysis of photoquadrats.
  - *Changes in live coral cover*: Percentage change in live coral cover measured from random and fixed transects, and percentage change in live tissue from tagged colonies were recalculated using CPCe analysis.
- **Coral Growth**: Any site that was used in the comparison against the Post-Development Surveys was reanalysed:
  - *Non-branching colonies*: Growth rates (%) per month of non-branching, tagged colonies were recalculated using CPCe analysis of photographs. Note: Sites Dugong Reef, Batman Reef, and Southern Lowendal Shelf were excluded from analysis of coral growth as photo-quadrats did not contain a scale bar required for colony growth measurements.

- *Branching colonies*: Linear extension rates per month (mm) of branching colonies were revised to report growth rate as an average of coral colonies not individual branches.

- **Non-coral Benthic Macroinvertebrates**: Any site that was used in the comparison against the Post-Development Surveys had all video footage reanalysed.
  - *Substrate type*: (i.e. soft sediment, limestone pavement, or coral) was redefined based on actual video footage rather than being defined from the broadscale habitat map. Note: The reanalysis also included some additional/changed categories; these additional taxonomic groups were based on the benthic macroinvertebrates observed frequently in the Marine Baseline Program and Post-Development Surveys video footage.
  - *Assemblages/abundance*: Mean±SE values of macro-invertebrate abundance, and the percentage contribution of macro-invertebrate taxa to the total number of individuals on each substrate type were recalculated through reanalysis of video footage.
- **Surficial Sediments**: Sediment classifications at any coastal zone or coral monitoring site that was used in the comparison against the Post-Development Surveys was reanalysed:
  - *Classification of sediment characteristics*: Reclassification of sites to coastal 'zones' required revision of the description of Surficial Sediment classifications for each area.

Dominant and Subdominant Coral Taxa

Data from the Marine Baseline Program were re-analysed due to the change of survey method (from Rapid Visual Assessment in the Marine Baseline Program to the use of size-class frequency data in the Post-Development Survey; see RPS 2009 [amended 2012]) to derive new measures of dominant and subdominant coral taxa. The following table provides the new Marine Baseline Program data for dominant and subdominant coral taxa using the same methods as the Post-Development Surveys (see Section 4.5.1.3 in this Report).

Table A1.1 Dominant and Subdominant Coral Taxa by Family and Genus for the Marine Baseline Program

Family/genus	Zone/site									
	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Acropora	3	3	3	**5**	3	1	2	3	**4**	3
Astreopora				1	2					3
Montipora	3	3	3	**4**	3	**4**		**5**	3	**5**
Acroporidae	**4**	**4**	**4**	**5**	**4**	**4**	2	**5**	**4**	**5**
Agariciidae unidentified			1							
Pachyseris	1	3	1	3	1			3	1	
Pavona		2				1		3		1
Agariciidae	1	3	2	3	1	1		4	1	1
Euphyllia								1		
Caryophyllidae								1		

Family/genus	**Zone/site**									
	ZoHI	**ZoMI**			**Reference**					
	LNG0	**LNG1**	**LONE**	**MOF1**	**AHC**	**BAT**	**BIG**	**DUG**	**LNG3**	**SBS**
Turbinaria	3	**4**	3	3	1	2		3	**4**	2
Dendrophylliidae	3	**4**	3	3	1	2		3	**4**	2
Caulastrea			1			1				
Cyphastrea					3	1	3	1		2
Diploastrea				**4**						
Echinopora	2	1			3	3	3	3	1	1
Faviidae unidentified	**5**	**4**	**4**	**5**	**5**	**5**	3	5	**5**	**5**
Goniastrea				2	**4**	1	**5**	3		1
Leptastrea					2		2			
Oulophyllia/Oulastrea								1		
Platygyra					**4**					
Faviidae	**5**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Fungiidae unidentified	1	2		3	2	3	1	3	3	
Herpolitha	1					1		1		
Podabacia										1
Fungiidae	1	2		3	2	3	1	3	3	1
Hydnophora	1	2		1		1	1	3	1	1
Merulina	1	1	2	3	**4**	**4**	2	3		1
Merulinidae	2	2	2	3	**4**	**4**	2	**4**	1	2
Millepora	3	2	3		1	2				3
Milleporidae	3	2	3		1	2				3
Lobophyllia	3	3	1	3	**4**	3	1	**4**	3	3
Mussidae unidentified								3	2	
Symphyllia	2	1			2					
Mussidae	**4**	3	1	3	**4**	3	1	**4**	3	3
Galaxea	1		2	2	**4**	2		**4**		1
Oculinidae	1		2	2	**4**	2		**4**		1
Echinophyllia	1	1			3	3	1	3	1	
Mycedium	1				2		2	1		
Oxypora		1	1	3	1	3		3	2	
Pectinia	1	1	2	1	1	3	1	**4**	1	1
Pectiniidae	2	2	3	3	3	**4**	2	**5**	3	1
Pocillopora	1	1	3		2	2	3	2	2	2
Seriatopora					3					

Family/genus	Zone/site									
	ZoHI	ZoMI			Reference					
	LNG0	LNG1	LONE	MOF1	AHC	BAT	BIG	DUG	LNG3	SBS
Stylophora		3	1	1	1	3				3
Pocilloporidae	1	3	3	1	3	3	3	2	2	3
Goniopora	1	1			2		1	1		
Porites	**5**	**5**	**5**	3	**5**	3	3	**4**	**5**	**4**
Porites branching	2	**4**	**4**	1		**5**		3	3	3
Poritidae	**5**	**5**	**5**	3	**5**	**5**	3	**5**	**5**	**4**
Coscinaraea	1									
Psammocora							1			
Siderastreidae	1						1			
Unidentified genus	3	3	3	3	3	3		3	3	3
Unidentified family	3	3	3	3	3	3		3	3	3
Total colonies	*298*	*294*	*256*	*337*	*479*	*368*	*148*	*494*	*353*	*358*
Total genera	*23*	*22*	*18*	*19*	*27*	*24*	*17*	*27*	*17*	*21*
Total families	*14*	*12*	*12*	*12*	*13*	*13*	*9*	*13*	*11*	*13*

Note: Bold font in coral taxa = Family; Bold font in abundance scale = Dominant and Subdominant coral taxa.

Coral Size-Class Frequency

Table A1.2 Size-Class Frequency Count and Size Statistics of Hard Corals at MOF1

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	5	19.2 ± 3.1	19.2	3.1	96	31.2 ± 4.2	29.5	2.5
	Astreopora	1	0.2 ± 0.2	0.2	0.2	1	26.0 ± 0.0	26.0	-
	Montipora	4	5.0 ± 1.9	5.0	1.9	25	36.7 ± 13.1	28.4	4.2
Agariciidae	*Pachyseris*	3	1.6 ± 0.9	1.6	0.9	8	67.4 ± 33.7	56.4	28.2
Dendrophylliidae	*Turbinaria*	3	1.6 ± 0.9	1.6	0.9	8	16.5 ± 3.8	14.4	2.9
Faviidae	*Diploastrea*	3	2.2 ± 0.9	2.2	0.9	11	160.6 ± 7.5	160.9	27.3
	Unidentified	5	15.6 ± 4.2	15.0	4.0	75	21.5 ± 2.4	23.0	2.1
	Goniastrea	2	Not reported	0.6	0.4	3	Not reported	23.3	4.6
Fungiidae	*Unidentified*	3	1.6 ± 0.8	1.6	0.8	8	10.4 ± 3.6	12.8	5.0
Merulinidae	*Hydnophora*	1	0.2 ± 0.2	0.2	0.2	1	48.0 ± 0.0	48.0	-
	Merulina	5	3.0 ± 1.0	3.0	1.0	15	29.0 ± 4.0	24.4	3.3
Mussidae	*Lobophyllia*	5	3.8 ± 1.0	3.8	1.0	19	24.3 ± 6.2	22.3	3.9
Oculinidae	*Galaxea*	3	1.0 ± 0.5	1.0	0.5	5	24.8 ± 5.8	20.2	4.3
Pectiniidae	*Oxypora*	4	2.6 ± 0.9	2.6	0.9	13	33.0 ± 3.7	33.1	5.1
	Pectinia	1	0.2 ± 0.2	0.2	0.2	1	20.0 ± 0.0	20.0	-
Pocilloporidae	*Stylophora*	1	0.2 ± 0.2	0.2	0.2	1	16.0 ± 0.0	16.0	-
Poritidae	*Porites* (Massive)	4	2.0 ± 0.5	2.0	0.5	10	59.3 ± 19.4	60.5	23.1
	Porites (Branching)	1	0.2 ± 0.2	0.2	0.2	1	23.0 ± 0.0	23.0	-
Unidentified	Unidentified	4	2.8 ± 1.0	2.8	1.0	14	21.2 ± 5.7	20.4	4.9

Table A1.3 Size-Class Frequency Count and Size Statistics of Hard Corals at LNG0

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	5	2.6 ± 1.1	2.6	1.1	13	4.8 ± 0.6	5.5	1.3
	Montipora	3	1.8 ± 1.0	1.8	1.0	9	9.8 ± 4.1	10.6	3.7
Agariciidae	*Pachyseris*	1	0.2 ± 0.2	0.2	0.2	1	43.0 ± 0.0	43.0	-
Dendrophylliidae	*Turbinaria*	4	3.4 ± 1.1	3.4	1.1	17	9.7 ± 2.8	9.5	1.7
Faviidae	*Unidentified*	5	14.8 ± 3.5	14.8	3.5	74	10.7 ± 4.7	9.3	0.9
	Echinopora	3	1.0 ± 0.4	1.0	0.4	5	8.9 ± 1.1	11.8	5.2
Fungiidae	*Unidentified*	1	0.2 ± 0.2	0.2	0.2	1	17.0 ± 0.0	17.0	-
	Herpolitha	1	0.2 ± 0.2	0.2	0.2	1	33.0 ± 0.0	33.0	-
Merulinidae	*Hydnophora*	1	0.2 ± 0.2	0.2	0.2	1	112.0 ± 0.0	112.0	-
	Merulina	1	0.2 ± 0.2	0.2	0.2	1	2.0 ± 0.0	2.0	-
Milleporidae	*Millepora*	5	3.0 ± 1.1	3.0	1.1	15	34.0 ± 11.2	38.8	11.0
Mussidae	*Lobophyllia*	5	4.0 ± 1.0	4.0	1.0	20	4.7 ± 0.7	5.2	0.9
	Symphyllia	2	0.6 ± 0.4	0.6	0.4	3	2.0 ± 0.8	3.0	0.6
Oculinidae	*Galaxea*	1	0.2 ± 0.2	0.2	0.2	1	3.0 ± 0.0	3.0	-
Pectiniidae	*Echinophyllia*	1	0.2 ± 0.2	0.2	0.2	1	18.0 ± 0.0	18.0	-
	Mycedium	1	0.2 ± 0.2	0.2	0.2	1	5.0 ± 0.0	5.0	-
	Pectinia	1	0.2 ± 0.2	0.2	0.2	1	100.0 ± 0.0	100.0	-
Pocilloporidae	*Pocillopora*	1	0.2 ± 0.2	0.2	0.2	1	16.0 ± 0.0	16.0	-
Poritidae	*Goniopora*	1	0.2 ± 0.2	0.2	0.2	1	5.0 ± 0.0	5.0	-
	Porites (Massive)	5	20.4 ± 2.5	20.4	2.5	102	42.8 ± 3.6	41.5	4.7
	Porites (Branching)	2	0.8 ± 0.5	0.8	0.5	4	31.8 ± 0.8	31.8	3.8
Siderastreidae	*Coscinaraea*	1	0.2 ± 0.2	0.2	0.2	1	16.0 ± 0.0	16.0	-
Unidentified	*Unidentified*	5	2.2 ± 0.6	2.2	0.6	11	4.1 ± 0.7	3.4	0.5

Table A1.4 Size-Class Frequency Count and Size Statistics of Hard Corals at LNG1

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	4	2.2 ± 1.1	2.2	1.1	11	11.5 ± 3.8	13.1	2.2
	Montipora	3	2.6 ± 1.2	2.6	1.2	13	11.1 ± 4.7	8.5	2.7
Agariciidae	*Pachyseris*	2	1.4 ± 1.2	1.4	1.2	7	29.3 ± 2.3	30.9	6.1
	Pavona	3	0.8 ± 0.4	0.8	0.4	4	19.3 ± 5.8	21.8	4.8
Dendrophylliidae	*Turbinaria*	5	5.0 ± 1.4	5.0	1.4	25	14.0 ± 2.4	15.0	3.0
Faviidae	*Unidentified*	5	9.6 ± 2.5	9.6	2.5	48	9.4 ± 1.3	9.4	0.9
	Echinopora	1	0.2 ± 0.2	0.2	0.2	1	59.0 ± 0.0	59.0	-
Fungiidae	*Unidentified*	2	0.8 ± 0.6	0.8	0.6	4	12.0 ± 5.0	14.5	7.8
Merulinidae	*Hydnophora*	2	0.4 ± 0.2	0.4	0.2	2	79.0 ± 71.0	79.0	71.0
	Merulina	1	0.2 ± 0.2	0.2	0.2	1	57.0 ± 0.0	57.0	-
Milleporidae	*Millepora*	1	0.2 ± 0.2	0.2	0.2	1	200.0 ± 0.0	200.0	-
Mussidae	*Lobophyllia*	5	3.6 ± 1.0	3.6	1.0	18	11.1 ± 2.2	12.7	2.9
	Symphyllia	1	0.2 ± 0.2	0.2	0.2	1	7.0 ± 0.0	7.0	-
Pectiniidae	*Echinophyllia*	2	0.4 ± 0.2	0.4	0.2	2	13.5 ± 1.5	13.5	1.5
	Oxypora	1	0.2 ± 0.2	0.2	0.2	1	15.0 ± 0.0	15.0	-
	Pectinia	2	0.4 ± 0.2	0.4	0.2	2	41.0 ± 28.0	41.0	28.0
Pocilloporidae	*Pocillopora*	1	0.2 ± 0.2	0.2	0.2	1	15.0 ± 0.0	15.0	-
	Stylophora	2	1.8 ± 1.4	1.8	1.4	9	20.3 ± 3.3	22.1	3.8
Poritidae	*Goniopora*	1	0.4 ± 0.4	0.4	0.4	2	32.0 ± 0.0	32.0	2.0
	Porites (Massive)	5	14.2 ± 5.0	14.2	5.0	71	96.1 ± 30.5	59.3	9.1
	Porites (Branching)	5	6.8 ± 5.1	6.8	5.1	34	25.8 ± 7.1	40.8	9.1
Unidentified	*Unidentified*	5	2.2 ± 0.7	2.2	0.7	11	9.3 ± 2.7	10.2	2.6

Table A1.5 Size-Class Frequency Count and Size Statistics of Hard Corals at Lone Reef

Family	Genera	# Transects Present	Number of Colonies per Transect (n=4)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	4	3.5 ± 1.2	3.5	1.2	14	18.9 ± 7.7	16.9	4.3
	Montipora	3	2.8 ± 1.5	2.8	1.5	11	36.9 ± 15.1	46.3	16.6
Agariciidae	Unidentified	1	0.3 ± 0.3	0.3	0.3	1	11.0 ± 0.0	11.0	-
	Pachyseris	2	0.5 ± 0.3	0.5	0.3	2	32.5 ± 29.5	32.5	29.5
Dendrophylliidae	*Turbinaria*	4	3.3 ± 0.6	3.3	0.6	13	15.5 ± 2.5	14.7	2.5
Faviidae	*Caulastrea*	1	0.3 ± 0.3	0.3	0.3	1	13.0 ± 0.0	13.0	-
	Unidentified	4	11.3 ± 3.7	11.3	3.7	45	11.4 ± 2.1	10.1	1.0
Merulinidae	*Merulina*	3	1.0 ± 0.4	1.0	0.4	4	18.2 ± 7.4	21.3	9.4
Milleporidae	*Millepora*	2	1.5 ± 1.0	1.5	1.0	6	42.3 ± 13.8	37.7	8.0
Mussidae	*Lobophyllia*	2	0.5 ± 0.3	0.5	0.3	2	11.5 ± 4.5	11.5	4.5
Oculinidae	*Galaxea*	2	1.0 ± 0.7	1.0	0.7	4	12.3 ± 4.7	10.0	3.8
Pectiniidae	*Oxypora*	1	0.3 ± 0.3	0.3	0.3	1	23.0 ± 0.0	23.0	-
	Pectinia	2	1.3 ± 0.8	1.3	0.8	5	7.3 ± 0.3	7.2	0.7
Pocilloporidae	*Pocillopora*	4	2.5 ± 0.9	2.5	0.9	10	29.5 ± 5.8	33.2	4.5
	Stylophora	1	0.3 ± 0.3	0.3	0.3	1	5.0 ± 0.0	5.0	-
Poritidae	*Porites* (Massive)	4	17.0 ± 2.1	17.0	2.1	68	91.6 ± 7.4	91.0	10.5
	Porites (Branching)	4	6.3 ± 1.3	6.3	1.3	25	37.5 ± 1.1	38.3	4.9
Unidentified	Unidentified	4	2.5 ± 0.6	2.5	0.6	10	8.9 ± 3.7	11.8	4.4

Table A1.6 Size-Class Frequency Count and Size Statistics of Hard Corals at Ah Chong

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	4	2.0 ± 0.7	2.0	0.7	10	13.2 ± 4.7	14.7	3.5
	Astreopora	2	1.0 ± 0.8	1.0	0.8	5	10.6 ± 0.4	10.4	1.9
	Montipora	4	1.8 ± 0.7	1.8	0.7	9	12.2 ± 3.4	12.1	2.4
Agariciidae	*Pachyseris*	1	0.4 ± 0.4	0.4	0.4	2	34.5 ± 0.0	34.5	0.5
Dendrophylliidae	*Turbinaria*	2	0.4 ± 0.2	0.4	0.2	2	21.5 ± 4.5	21.5	4.5
Faviidae	Unidentified	5	26.8 ± 4.9	14.8	3.3	11	11.6 ± 0.9	6.8	1.0
	Cyphastrea	4	2.2 ± 1.0	2.2	1.0	12	6.6 ± 0.6	13.1	1.4
	Echinopora	4	2.4 ± 0.8	2.4	0.8	74	13.7 ± 1.6	10.1	0.7
	Goniastrea	5	Not reported	4.6	1.3	23	Not reported	8.9	1.3
	Leptastrea	3	Not reported	0.8	0.4	4	Not reported	12.8	3.3
	Platygyra	5	Not reported	6.6	1.0	33	Not reported	14.4	0.8
Fungiidae	Unidentified	3	0.6 ± 0.2	0.6	0.2	3	11.3 ± 3.7	11.3	3.7
Merulinidae	*Merulina*	5	5.2 ± 1.0	5.2	1.0	26	8.1 ± 0.6	8.5	1.0
Milleporidae	*Millepora*	1	0.2 ± 0.2	0.2	0.2	1	90.0 ± 0.0	90.0	-
Mussidae	*Lobophyllia*	5	5.8 ± 1.2	5.8	1.2	29	20.0 ± 5.5	17.8	3.4
	Symphyllia	3	0.8 ± 0.4	0.8	0.4	4	10.0 ± 1.0	9.5	1.2
Oculinidae	*Galaxea*	5	5.6 ± 1.1	5.6	1.1	28	19.9 ± 2.4	18.6	2.2
Pectiniidae	*Echinophyllia*	5	2.0 ± 0.6	2.0	0.6	10	12.7 ± 2.3	15.3	2.9
	Mycedium	3	1.0 ± 0.5	1.0	0.5	5	15.8 ± 4.1	14.4	5.0
	Oxypora	1	0.4 ± 0.4	0.4	0.4	2	43.5 ± 0.0	43.5	36.5
	Pectinia	1	0.2 ± 0.2	0.2	0.2	1	11.0 ± 0.0	11.0	-
Pocilloporidae	*Pocillopora*	3	1.0 ± 0.4	1.0	0.4	5	14.8 ± 4.6	13.0	4.1
	Seriatopora	4	2.6 ± 0.7	2.6	0.7	13	26.7 ± 5.0	24.7	3.3
	Stylophora	1	0.2 ± 0.2	0.2	0.2	1	11.0 ± 0.0	11.0	-
Poritidae	*Goniopora*	2	1.0 ± 0.8	1.0	0.8	5	17.4 ± 4.6	14.6	2.1
	Porites (Massive)	5	28.0 ± 3.0	28.0	3.0	140	35.5 ± 4.3	35.9	3.8
Unidentified	Unidentified	4	1.2 ± 0.4	1.2	0.4	6	16.0 ± 11.7	19.8	16.0

Table A1.7 Size-Class Frequency Count and Size Statistics of Hard Corals at Biggada Reef

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE[2]	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	2	0.8 ± 0.5	0.8	0.5	4	15.9 ± 6.6	15.9	5.3
Faviidae	Unidentified	4	13.8 ± 2.1	4.0	1.5	20	57.6 ± 3.7	28.9	2.5
	Cyphastrea	4	4.0 ± 1.5	4.0	1.5	20	21.6 ± 4.9	22.7	3.4
	Echinopora	3	1.4 ± 0.7	1.4	0.7	7	60.6 ± 10.3	61.7	10.8
	Goniastrea	5	Not reported	9.2	2.4	46	Not reported	71.6	7.8
	Leptastrea	2	Not reported	0.6	0.4	3	Not reported	39.3	7.8
Fungiidae	Unidentified	2	0.4 ± 0.2	0.4	0.2	2	11.0 ± 1.0	11.0	1.0
Merulinidae	*Hydnophora*	1	0.4 ± 0.4	0.4	0.4	2	36.0 ± 0.0	36.0	34.0
	Merulina	1	0.6 ± 0.6	0.6	0.6	3	17.0 ± 0.0	17.0	6.7
Mussidae	*Lobophyllia*	1	0.2 ± 0.2	0.2	0.2	1	50.0 ± 0.0	50.0	-
Pectiniidae	*Echinophyllia*	1	0.2 ± 0.2	0.2	0.2	1	67.0 ± 0.0	67.0	-
	Mycedium	2	0.6 ± 0.4	0.6	0.4	3	26.5 ± 13.5	31.0	12.9
	Pectinia	1	0.2 ± 0.2	0.2	0.2	1	9.0 ± 0.0	9.0	-
Pocilloporidae	*Pocillopora*	3	1.2 ± 0.6	1.2	0.6	6	17.0 ± 7.0	17.0	5.1
Poritidae	*Goniopora*	1	0.4 ± 0.4	0.4	0.4	2	4.0 ± 0.0	4.0	0.0
	Porites (Massive)	5	2.2 ± 0.5	2.2	0.5	11	17.3 ± 2.9	16.5	2.7
Siderastreidae	*Psammocora*	1	0.2 ± 0.2	0.2	0.2	1	17.0 ± 0.0	17.0	-

Table A1.8 Size-Class Frequency Count and Size Statistics of Hard Corals at LNG3

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	5	5.2 ± 1.2	5.2	1.2	26	6.2 ± 1.4	6.2	0.9
	Montipora	4	1.8 ± 0.7	1.8	0.7	9	16.5 ± 2.9	18.6	1.6
Agariciidae	*Pachyseris*	2	0.4 ± 0.2	0.4	0.2	2	12.0 ± 5.0	12.0	5.0
Dendrophylliidae	*Turbinaria*	5	5.4 ± 1.2	5.4	1.2	27	13.1 ± 1.0	13.4	1.0
Faviidae	Unidentified	5	21.2 ± 6.1	21.2	6.1	106	9.6 ± 0.8	9.3	0.6
	Echinopora	1	0.2 ± 0.2	0.2	0.2	1	11.0 ± 0.0	11.0	-
Fungiidae	Unidentified	4	1.4 ± 0.4	1.4	0.4	7	6.3 ± 3.8	6.9	2.8
Merulinidae	*Hydnophora*	2	0.4 ± 0.2	0.4	0.2	2	72.5 ± 18.5	72.5	18.5
Mussidae	*Lobophyllia*	4	1.2 ± 0.4	1.2	0.4	6	9.8 ± 1.4	9.0	1.1
	Unidentified	3	0.6 ± 0.2	0.6	0.2	3	3.7 ± 0.3	3.7	0.3
Pectiniidae	*Echinophyllia*	2	0.4 ± 0.2	0.4	0.2	2	14.0 ± 8.0	14.0	8.0
	Oxypora	2	0.6 ± 0.4	0.6	0.4	3	9.5 ± 2.5	8.7	1.7
	Pectinia	1	0.4 ± 0.4	0.4	0.4	2	29.0 ± 0.0	29.0	11.0
Pocilloporidae	*Pocillopora*	3	0.6 ± 0.2	0.6	0.2	3	22.3 ± 12.3	22.3	12.3
Poritidae	*Porites* (Massive)	5	23.4 ± 9.3	23.4	9.3	117	27.6 ± 15.5	24.1	6.4
	Porites (Branching)	4	2.4 ± 1.1	2.4	1.1	12	36.9 ± 10.2	29.1	4.2
Unidentified	Unidentified	3	2.0 ± 1.0	2.0	1.0	10	8.2 ± 3.1	10.4	2.8

Table A1.9 Size-Class Frequency Count and Size Statistics of Hard Corals at Dugong Reef

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acroporidae*	5	3.8 ± 1.1	3.8	1.1	19	35.4 ± 17.7	26.1	8.1
	Montipora	5	10.4 ± 2.4	10.4	2.4	52	35.0 ± 7.5	32.9	2.9
Agariciidae	*Pachyseris*	4	2.2 ± 0.7	2.2	0.7	11	54.0 ± 10.4	60.4	18.4
	Pavona	5	1.8 ± 0.4	1.8	0.4	9	50.6 ± 12.9	51.6	11.7
Caryophylliidae	*Euphyllia*	2	0.4 ± 0.2	0.4	0.2	2	12.5 ± 7.5	12.5	4.7
Dendrophylliidae	*Turbinaria*	4	2.2 ± 0.9	2.2	0.9	11	13.3 ± 1.3	14.2	5.3
Faviidae	Unidentified	5	23.8 ± 3.1	22.4	3.1	112	24.8 ± 2.4	21.8	2.2
	Cyphastrea	1	0.2 ± 0.2	0.2	0.2	1	16.0 ± 0.0	16.0	-
	Echinopora	2	1.4 ± 1.0	1.4	1.0	7	28.7 ± 4.7	30.7	6.9
	Goniastrea	2	Not reported	1.2	0.7	6	Not reported	56.2	29.9
	Oulophyllia/ Oulastrea	1	Not reported	0.2	0.2	1	Not reported	37.0	-
Fungiidae	Unidentified	3	3.2 ± 1.7	3.2	1.7	16	7.3 ± 4.3	4.7	10.4
	Herpolitha	1	0.2 ± 0.2	0.2	0.2	1	30.0 ± 0.0	30.0	-
Merulinidae	*Hydnophora*	4	2.6 ± 1.1	2.6	1.1	13	101.9 ± 35.4	70.2	15.3
	Merulina	4	3.0 ± 0.9	3.0	0.9	15	25.4 ± 3.1	26.9	6.2
Mussidae	*Lobophyllia*	5	7.6 ± 1.2	7.6	1.2	38	27.4 ± 2.3	26.4	2.0
	Unidentified	5	2.2 ± 0.6	2.2	0.6	11	3.3 ± 1.2	3.4	0.9
Oculinidae	*Galaxea*	5	4.2 ± 1.6	4.2	0.6	21	69.1 ± 26.2	80.8	38.4
Pectiniidae	*Echinophyllia*	5	3.4 ± 0.8	3.4	0.8	17	28.2 ± 5.4	24.8	5.1
	Mycedium	1	0.2 ± 0.2	0.2	0.2	1	13.0 ± 0.0	13.0	-
	Oxypora	5	3.4 ± 1.1	3.4	1.1	17	44.3 ± 10.7	33.3	4.7
	Pectinia	4	4.0 ± 1.4	4.0	1.4	20	30.6 ± 5.4	26.6	5.3
Pocilloporidae	*Pocillopora*	2	0.2 ± 0.2	0.6	0.4	3	29.5 ± 13.5	34.0	10.4
Poritidae	*Goniopora*	1	0.2 ± 0.2	0.2	0.2	1	38.0 ± 0.0	38.0	-
	Porites (Massive)	5	5.0 ± 1.6	5.0	1.6	25	168.1 ± 75.3	120.9	5.1
	Porites (Branching)	5	2.2 ± 0.5	2.2	0.5	11	56.9 ± 18.4	45.3	10.0
Unidentified	Unidentified	4	1.6 ± 0.9	1.6	0.9	8	6.4 ± 2.0	5.9	1.8

Table A1.10 Size-Class Frequency Count and Size Statistics of Hard Corals at Batman Reef

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	1	0.2 ± 0.2	0.2	0.2	1	30.0 ± 0.0	30.0	-
	Montipora	5	4.0 ± 0.9	4.0	0.9	20	43.4 ± 8.4	42.8	5.6
Agariciidae	*Pavona*	1	0.2 ± 0.2	0.2	0.2	1	104.0 ± 0.0	104.0	-
Dendrophylliidae	*Turbinaria*	3	0.8 ± 0.4	0.8	0.4	4	18.2 ± 10.1	16.5	7.4
Faviidae	Unidentified	5	26.2 ± 3.4	26.0	1.9	130	19.8 ± 1.2	19.9	1.2
	Caulastrea	1	0.2 ± 0.2	0.2	0.2	1	6.0 ± 0.0	6.0	-
	Cyphastrea	1	0.4 ± 0.4	0.4	0.4	2	25.5 ± 0.0	25.5	13.5
	Echinopora	5	4.0 ± 1.3	4.0	1.3	20	46.2 ± 6.3	47.7	5.4
	Goniastrea	1	Not reported	0.2	0.2	1	Not reported	18.0	-
Fungiidae	Unidentified	4	1.4 ± 0.5	1.4	0.5	7	12.5 ± 1.6	12.7	3.0
	Herpolitha	1	0.2 ± 0.2	0.2	0.2	1	13.0 ± 0.0	13.0	-
Merulinidae	*Hydnophora*	1	0.4 ± 0.4	0.4	0.4	2	58.5 ± 0.0	58.5	22.5
	Merulina	5	4.0 ± 0.3	4.0	0.3	20	57.1 ± 9.0	59.2	7.0
Milleporidae	*Millepora*	3	1.0 ± 0.4	1.0	0.4	5	42.7 ± 5.5	44.4	7.4
Mussidae	*Lobophyllia*	5	1.6 ± 0.4	1.6	0.4	8	23.9 ± 7.8	23.3	5.1
Oculinidae	*Galaxea*	2	0.8 ± 0.5	0.8	0.5	4	32.5 ± 0.0	32.5	10.9
Pectiniidae	*Echinophyllia*	3	2.0 ± 0.9	2.0	0.9	10	25.6 ± 4.6	27.4	5.1
	Oxypora	3	2.2 ± 1.3	2.2	1.3	11	37.2 ± 0.6	37.6	5.0
	Pectinia	4	4.0 ± 1.5	4.0	1.5	20	45.9 ± 2.9	47.3	4.6
Pocilloporidae	*Pocillopora*	3	1.0 ± 0.5	1.0	0.5	5	28.7 ± 7.7	22.8	7.1
	Stylophora	4	1.4 ± 0.4	1.4	0.4	7	15.1 ± 2.6	15.9	3.1
Poritidae	*Porites* (Massive)	5	1.8 ± 0.4	1.8	0.4	9	40.7 ± 24.3	50.3	27.0
	Porites (Branching)	5	12.4 ± 3.4	12.4	3.4	62	45.9 ± 7.3	40.0	3.1
Unidentified	Unidentified	3	1.8 ± 1.0	1.8	1.0	9	9.7 ± 3.1	7.7	2.3

Table A1.11 Size-Class Frequency Count and Size Statistics of Hard Corals at Southern Barrow Shoals

Family	Genera	# Transects Present	Number of Colonies per Transect (n=5)			# Colonies Sampled	Average size (cm)		
			Chevron Australia (2012a)	Revised Data used in this Report			Chevron Australia (2012a)	Revised Data used in this Report	
			Mean ± SE	Mean	SE		Mean ± SE	Mean	SE
Acroporidae	*Acropora*	4	3.0 ± 1.0	3.0	1.0	15	27.8 ± 5.6	28.3	3.5
	Astreopora	5	2.4 ± 0.4	2.4	0.4	12	31.2 ± 6.1	32.2	6.1
	Montipora	5	19.2 ± 2.1	19.2	2.1	96	27.7 ± 2.4	27.7	1.9
Agariciidae	*Pavona*	1	0.2 ± 0.2	0.2	0.2	1	22.0 ± 0.0	22.0	-
Dendrophylliidae	*Turbinaria*	2	0.8 ± 0.5	0.8	0.5	4	17.5 ± 5.5	17.5	5.5
Faviidae	Unidentified	5	30.8 ± 7.3	30.6	7.1	153	18.5 ± 1.0	18.2	1.4
	Goniastrea	1	Not reported	0.2	0.2	1	Not reported	30.0	-
	Cyphastrea	2	0.6 ± 0.4	0.6	0.4	3	21.5 ± 6.5	23.7	4.9
	Echinopora	1	0.2 ± 0.2	0.2	0.2	1	59.0 ± 0.0	59.0	-
Fungiidae	Unidentified	Not reported	0.4 ± 0.4	Not reported	Not reported	Not reported	34.5 ± 0.0	Not reported	Not reported
	Podobacia	1	Not reported	0.4	0.4	2	Not reported	34.5	0.5
Merulinidae	*Hydnophora*	2	0.4 ± 0.2	0.4	0.2	2	26.0 ± 11.0	26.0	11.0
	Merulina	1	0.2 ± 0.2	0.2	0.2	1	38.0 ± 0.0	38.0	-
Milleporidae	*Millepora*	3	1.2 ± 0.7	1.2	0.7	6	26.8 ± 9.9	36.2	14.6
Mussidae	*Lobophyllia*	3	1.2 ± 0.6	1.2	0.6	6	16.1 ± 2.3	15.5	1.4
Oculinidae	*Galaxea*	1	0.2 ± 0.2	0.2	0.2	1	37.0 ± 0.0	37.0	-
Pectiniidae	*Pectinia*	1	0.2 ± 0.2	0.2	0.2	1	32.0 ± 0.0	32.0	-
Pocilloporidae	*Pocillopora*	2	0.6 ± 0.4	0.6	0.4	3	20.3 ± 5.3	22.0	3.6
	Stylophora	5	1.6 ± 0.4	1.6	0.4	8	16.0 ± 3.3	15.3	2.5
Poritidae	*Porites* (Massive)	4	4.0 ± 1.9	4.0	1.9	20	49.9 ± 15.9	56.9	15.1
	Porites (Branching)	3	1.2 ± 0.6	1.2	0.6	6	25.6 ± 5.5	26.5	6.8
Unidentified	Unidentified	2	1.4 ± 1.2	1.4	1.2	7	11.7 ± 9.7	18.6	3.6

Live Coral Cover Measured from Random Transects

Table A1.12 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at MOF1

Cover	% Cover in Chevron Australia 2012a at each survey date						Revised % Cover used in this Report at each survey date					
	Oct-08		Apr-09		Oct-09		Oct-08		Apr-09		Oct-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	5.2	1.2	3.7	1.1	5	1.2	5.3	1.3	3.8	1.1	3.7	1
Agariciidae	0	0	0.1	0.1	0.3	0.2	0	0	0.1	0.1	0.3	0.2
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0	0	0	0	0	0	0	0	0	0	0	0
Faviidae	7.9	2.1	7.5	2.1	7.6	1.8	8	2.1	7.8	2.2	7.7	1.8
Fungiidae	0	0	0	0	0.1	0.1	0	0	0	0	0.1	0.1
Merulinidae	0.9	0.6	0.4	0.3	0.4	0.3	0.9	0.6	0.4	0.3	0.4	0.3
Mussidae	0.7	0.3	0.3	0.2	0.1	0.1	0.7	0.3	0.3	0.2	0.1	0.1
Oculinidae	0.2	0.2	0	0	0.1	0.1	0.2	0.2	0	0	0.1	0.1
Pectiniidae	1.2	0.6	0.5	0.3	0.5	0.2	1.3	0.7	0.5	0.3	0.3	0.2
Pocilloporidae	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Poritidae	1	0.5	2.1	1.5	2.3	1	1	0.5	2.1	1.5	2.3	1
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0.1	0.1	0	0	0	0	0.1	0.1	0	0	0	0
Unidentified Coral	1.6	0.6	1.2	0.4	0.8	0.3	1.5	0.6	1.3	0.4	2.1	0.7
Hydro Corals - Milleporidae	0.4	0.3	0.6	0.6	0.1	0.1	0	0	0	0	0.1	0.1
Soft Corals - Alcyoniidae	0	0	0	0	0.1	0.1	0	0	0	0	0	0
Sessile Invertebrates	0.5	0.3	1.1	0.4	2.1	0.5	0.9	0.4	1.7	0.8	2.3	0.5
Macroalgae	2.1	0.6	0	0	0.4	0.2	2.1	0.6	0	0	0.4	0.2
Turf Algae	37.8	3	25.7	3.5	40.4	3.5	38.6	3.1	26.1	3.5	40.4	3.5
Coralline Algae	1.4	0.5	0.1	0.1	0.1	0.1	1.4	0.5	0.1	0.1	0.1	0.1
Pavement/Rock/Rubble	4.7	1.1	2.7	1.4	0.1	0.1	4.8	1.1	2.7	1.4	0.1	0.1
Sediment	32.7	4.2	53.1	5.7	39.3	4.8	33.1	4.2	53.1	5.7	39.3	4.8
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	1.7	0.5	0.8	0.4	0	0	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.13 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at LNG0

Cover	% Cover in Chevron Australia 2012a at each survey date						Revised % Cover used in this Report at each survey date					
	Jan-09		Aug-09		Nov-09		Jan-09		Aug-09		Nov-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	1	0.4	0.3	0.2	0.1	0.1	1	0.4	0.3	0.2	0.1	0.1
Agariciidae	1	0.8	0	0	0.1	0.1	0.3	0.3	0	0	0.1	Jan-00
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.1
Faviidae	0.2	0.1	0	0	0.4	0.2	0.2	0.1	0	0	0.4	0.2
Fungiidae	0	0	0	0	0.2	0.1	0	0	0	0	0.2	0.1
Merulinidae	1.7	1.2	0.1	0.1	0.3	0.2	1.7	1.2	0	0	0.3	0.2
Mussidae	0	0	0	0	0	0	0	0	0	0	0	0
Oculinidae	0	0	0	0	0	0	0	0	0	0	0	0
Pectiniidae	0	0	0	0	0.1	0.1	0	0	0	0	0.1	0.1
Pocilloporidae	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Poritidae	28.5	3.9	18	3	16.3	3.4	29.1	4	18.2	3	16.2	3.4
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Coral	0.7	0.4	3.8	0.9	1.2	0.6	0.7	0.4	2.7	0.5	1.2	0.6
Hydro Corals - Milleporidae	23	5.1	13.7	3.3	3.6	2	0	0	0	0	3.6	2
Soft Corals - Alcyoniidae	1.1	0.9	0.3	0.2	1.7	0.8	0	0	0	0	0.1	0.1
Other Benthic Invertebrates	0.1	0.1	0.2	0.1	1	0.3	24.3	5.1	14.3	3.4	2.8	0.9
Macroalgae	0	0	0	0	0	0	0	0	0	0	0	0
Turf Algae	41.5	4.4	58.5	3.8	58.4	3.2	42.1	4.4	59.4	3.8	58.4	3.2
Coralline Algae	0	0	0	0	0	0	0	0	0	0	0	0
Pavement/Rock/Rubble	0.1	0.1	0.9	0.3	0.2	0.1	0.1	0.1	0.9	0.3	0.2	0.1
Sand	0.2	0.2	3.9	0.9	16.1	2.8	0.2	0.2	4	1	16.1	2.7
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0.7	0.2	0.2	0.1	0	0	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.14 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at LNG1

Cover	% Cover in Chevron Australia 2012a at each survey date								Revised % Cover used in this Report at each survey date							
	Oct-08		Apr-09		Aug-09		Nov-09		Oct-08		Apr-09		Aug-09		Nov-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	0	0	0	0	0.1	0.1	0.1	0.1	0.2	0.2	0	0	0.1	0.1	0.1	0.1
Agariciidae	0.5	0.4	0	0	0	0	0	0	0.5	0.4	0	0	0	0	0	0
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0.4	0.4	0.1	0.1	0.2	0.1	0.1	0.1	0.4	0.4	0.1	0.1	0.2	0.1	0.1	0.1
Faviidae	1.4	0.5	0.1	0.1	0.8	0.3	0.1	0.1	1.4	0.5	0.1	0.1	0.8	0.3	0.1	0.1
Fungiidae	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0
Merulinidae	0.1	0.1	0	0	0	0	0.8	0.8	0	0	0	0	0	0	0.8	0.8
Mussidae	0.8	0.3	0.5	0.4	0	0	0	0	0.7	0.3	0.4	0.4	0	0	0	0
Oculinidae	0.4	0.4	0	0	0.1	0.1	0	0	0.4	0.4	0	0	0.1	0.1	0	0
Pectiniidae	0.4	0.4	0	0	0	0	0	0	0.4	0.4	0	0	0	0	0	0
Pocilloporidae	0	0	0	0	0.2	0.1	0	0	0	0	0	0	0.2	0.1	0	0
Poritidae	21.1	3.5	22.3	3.7	13.8	2.8	5.4	1.8	21.2	3.6	22.6	3.8	13.8	2.8	5.3	1.8
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Coral	2.8	0.9	1.4	0.7	0.2	0.1	0.2	0.1	2.8	0.9	1.3	0.7	0.2	0.1	0.2	0.1
Hydro Corals - Milleporidae	1.2	0.7	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Soft Corals - Alcyoniidae	1.4	1	0.7	0.3	0.9	0.6	0	0	0.4	0.3	0	0	0.9	0.6	0	0
Other Benthic Invertebrates	0.4	0.2	0.3	0.2	1	0.4	0.3	0.1	2.6	1.2	1.4	0.5	1	0.4	0.4	0.1
Macroalgae	0.1	0.1	0	0	0.7	0.3	1.6	0.8	0.1	0.1	0	0	0.7	0.3	1.6	0.8
Turf Algae	62.1	3.5	61.9	4.2	68.1	2.7	31.2	4.3	62.9	3.5	62.4	4.2	68.1	2.7	31.2	4.3
Coralline Algae	0.2	0.1	0	0	0.5	0.2	0	0	0.2	0.1	0	0	0.5	0.2	0	0
Pavement/Rock/Rubble	3.4	1.1	0	0	4.8	1	0.4	0.2	3.5	1.1	0	0	4.8	1	0.4	0.2
Sand	2.3	0.8	11.6	3.6	8.7	1.9	59.7	5	2.4	0.8	11.6	3.6	8.7	1.9	59.7	5
Seagrass	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0.1	0.1
Unidentified (other)	0.9	0.2	0.8	0.2	0	0	0	0	-	-	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.15 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at LONE

Cover	% Cover in Chevron Australia 2012a at each survey date								Revised % Cover used in this Report at each survey date							
	Oct-08		Apr-09		Jun-09		Nov-09		Oct-08		Apr-09		Jun-09		Nov-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	2.8	1.1	1.3	0.7	2.7	1	1	0.5	3	1.1	0.8	0.6	2.7	1	0.3	0.2
Agariciidae	0.5	0.3	0.2	0.2	0	0	0.4	0.3	0.5	0.3	0.3	0.3	0	0	0.4	0.3
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0.2	0.1	0.4	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.4	0.3	0.1	0.1	0.2	0.1
Faviidae	2.7	1.8	0.4	0.2	0.9	0.4	0.5	0.2	2.7	1.8	0.4	0.2	0.9	0.4	0.6	0.2
Fungiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merulinidae	0.1	0.1	0.3	0.3	0	0	0.3	0.3	0.1	0.1	0.3	0.3	0	0	0.3	0.3
Mussidae	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oculinidae	2.6	1.8	0.9	0.7	0.3	0.2	1.3	0.7	2.6	1.8	0.9	0.7	0.3	0.2	1.3	0.7
Pectiniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pocilloporidae	0.3	0.2	0	0	0.2	0.2	0.2	0.1	0.3	0.2	0	0	0.2	0.2	0.2	0.1
Poritidae	48.5	4.4	53.6	3.6	49.8	4.6	40.9	4.2	48.5	4.4	53.6	3.6	49.8	4.6	41.1	4.2
Siderastreidae	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0
Unidentified Coral	1.3	0.3	2.1	0.6	2.1	0.6	1.2	0.4	1.2	0.3	2.1	0.6	2.1	0.6	2.9	0.9
Hydro Corals - Milleporidae	0.1	0.1	0.4	0.3	0.9	0.6	1.6	0.6	0	0	0	0	0.9	0.6	1.6	0.6
Soft Corals - Alcyoniidae	3.6	1.8	0.3	0.2	0	0	1.7	0.9	0	0	0	0	0	0	0	0
Other Benthic Invertebrates	0.4	0.4	0.3	0.2	1.1	0.4	0.3	0.2	4.4	1.9	1.1	0.4	1.1	0.4	0.6	0.2
Macroalgae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turf Algae	32.6	3.7	31.8	2.9	33.5	3.6	35.1	3.3	33	3.8	32.2	3	33.5	3.6	35.4	3.4
Coralline Algae	0	0	0	0	3	0.8	0.4	0.2	0	0	0	0	3	0.8	0.4	0.2
Pavement/Rock/Rubble	0.8	0.3	0.1	0.1	1.8	0.8	5.7	2	0.8	0.3	0.1	0.1	1.8	0.8	5.7	2
Sand	2.7	0.9	7.6	1.9	3.7	1.4	9	1.8	2.7	0.9	7.7	2	3.7	1.4	9	1.8
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0.6	0.3	0.1	0.1	0	0	0	0	-	-	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.16 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at ANT

Cover	% Cover in Chevron Australia 2012a at each survey date										Revised % Cover used in this Report at each survey date									
	May-08		Nov-08		Mar-09		Jun-09		Aug-09		May-08		Nov-08		Mar-09		Jun-09		Aug-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	72.9	3.3	45.3	3.1	14.3	1.4	11.6	2.7	2.6	1	72.9	3.3	45.4	3.1	14.3	1.4	2.8	0.8	2.6	1
Agariciidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0.1	0.1	0	0
Faviidae	0	0	0.2	0.1	0.2	0.2	0.1	0.1	0.7	0.4	0	0	0.2	0.1	0.2	0.2	0.1	0.1	0.7	0.4
Fungiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merulinidae	0	0	1	0.7	0	0	2.1	0.9	1.7	1.2	0	0	1	0.7	0	0	3.2	1.5	1.7	1.2
Mussidae	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0	0
Oculinidae	0	0	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0	0	0.2	0.2	0.1	0.1
Pectiniidae	0	0	0.3	0.3	0.1	0.1	0.2	0.2	0	0	0	0	0.3	0.3	0.1	0.1	0.2	0.2	0	0
Pocilloporidae	0.1	0.1	0	0	0.2	0.2	0.1	0.1	0	0	0.1	0.1	0	0	0.2	0.2	0.1	0.1	0	0
Poritidae	3.1	1.9	0.9	0.5	0.6	0.4	3.5	1.4	2.2	1.2	3.1	1.9	0.9	0.5	0.6	0.4	5.6	2.3	2.2	1.2
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0.2	0.2	0	0	0	0	0	0	0.7	0.4	0.2	0.2	0	0	0	0	0	0	0.7	0.4
Unidentified Coral	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0	0	0.1	0.1	0.6	0.3	0	0
Hydro Corals - Milleporidae	0	0	1.1	1.1	0	0	0.7	0.7	0	0	0	0	0	0	0	0	0.7	0.7	0	0
Soft Corals - Alcyoniidae	0	0	0	0	0	0	0.3	0.2	0.1	0.1	0	0	0	0	0	0	0.3	0.2	0.1	0.1
Other Benthic Invertebrates	0	0	0	0	0.1	0.1	0.7	0.5	0.4	0.2	0	0	1.1	1.1	0.1	0.1	0.8	0.6	0.3	0.2
Macroalgae	0.3	0.2	26.1	2.5	0	0	0.2	0.1	3.2	0.6	0.3	0.2	26.1	2.5	0	0	0.2	0.1	3.2	0.6
Turf Algae	17.3	2.1	21.2	2.4	76.8	2.1	64.3	4.4	82.1	2.6	17.3	2.1	21.3	2.4	76.9	2.1	68.2	4	82.5	2.6
Coralline Algae	0	0	0	0	0	0	0.5	0.4	2.7	0.7	0	0	0	0	0	0	0.7	0.5	2.5	0.7
Pavement/Rock/Rubble	4.9	1	0.6	0.3	4.9	1.5	11.2	2.1	1.8	0.5	4.9	1	0.6	0.3	4.9	1.5	11.7	2.1	1.8	0.5
Sand	1.1	0.8	3.2	1.5	2.6	0.9	4.3	1.2	1.7	0.6	1.1	0.8	3.2	1.5	2.6	0.9	4.5	1.3	1.6	0.6
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0	0	0.1	0.1	0.1	0.1	0	0	0	0	-	-	-	-	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.17 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at LOW

Cover	% Cover in Chevron Australia 2012a at each survey date						Revised % Cover used in this Report at each survey date					
	May-08		Nov-08		May-09		May-08		Nov-08		May-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	46.9	2.8	49.1	3.9	43.6	3.6	47.2	2.8	49.1	3.9	43.6	3.6
Agariciidae	0	0	0	0	0	0	0	0	0	0	0	0
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0	0	0	0	0	0	0	0	0	0	0	0
Faviidae	0.2	0.1	0	0	0.1	0.1	0	0	0	0	0.1	0.1
Fungiidae	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1
Merulinidae	0	0	0	0	0	0	0	0	0	0	0	0
Mussidae	0	0	0	0	0	0	0	0	0	0	0	0
Oculinidae	0.4	0.2	0	0	0	0	0.4	0.2	0	0	0	0
Pectiniidae	0	0	0	0	0	0	0	0	0	0	0	0
Pocilloporidae	1	0.5	0.1	0.1	0.3	0.2	0.2	0.1	0.1	0.1	0.3	0.2
Poritidae	0	0	0	0	0	0	0.2	0.1	0	0	0	0
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0	0	0	0	0.1	0.1	0	0	0	0	0.1	0.1
Unidentified Coral	0	0	0.2	0.1	0	0	0	0	0.2	0.1	0	0
Hydro Corals - Milleporidae	0	0	0.1	0.1	0	0	0	0	0	0	0	0
Soft Corals - Alcyoniidae	0	0	0.1	0.1	0	0	0	0	0	0	0	0
Other Benthic Invertebrates	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1
Macroalgae	0.5	0.2	0	0	0	0	0.5	0.2	0	0	0	0
Turf Algae	44.2	2.5	48	3.6	39.6	2.7	44.5	2.5	48.1	3.6	39.6	2.7
Coralline Algae	5.6	1.5	0	0	4	0.8	5.8	1.6	0	0	4	0.8
Pavement/Rock/Rubble	0.4	0.4	0.5	0.4	5	1.3	0.4	0.4	0.5	0.4	5	1.3
Sand	0.7	0.4	1.9	1.4	7.1	2.6	0.7	0.4	1.9	1.4	7.1	2.6
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0	0	0.1	0.1	0	0	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.18 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at AHC

Cover	% Cover in Chevron Australia 2012a at each survey date								Revised % Cover used in this Report at each survey date							
	Sep-08		Mar-09		Jun-09		Oct-09		Sep-08		Mar-09		Jun-09		Oct-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	0.9	0.4	0.2	0.1	1.3	0.5	1.2	0.5	0.9	0.4	0.2	0.1	1.3	0.5	1	0.5
Agariciidae	0	0	0	0	0.1	0.1	0.2	0.2	0	0	0	0	0.1	0.1	0.2	0.2
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0	0	0	0	0.2	0.1	0	0	0	0	0	0	0.2	0.1	0	0
Faviidae	2	0.5	2.8	0.9	1.1	0.3	2.8	0.6	2	0.5	2.8	0.9	1.1	0.3	2.8	0.6
Fungiidae	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.1	0.1	0.1
Merulinidae	0.1	0.1	1.4	1.3	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0
Mussidae	0.3	0.2	0.7	0.4	0.9	0.3	1.3	0.5	0.3	0.2	0.7	0.4	0.9	0.3	1.3	0.5
Oculinidae	0.3	0.2	0	0	0.2	0.1	0.1	0.1	0.3	0.2	0	0	0.2	0.1	0.1	0.1
Pectiniidae	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0
Pocilloporidae	0.6	0.3	0.4	0.3	0.7	0.3	0.6	0.2	0.6	0.3	0.4	0.3	0.7	0.3	0.6	0.2
Poritidae	42.9	4.3	30.2	3	37.1	3.8	33.9	3	42.8	4.3	30.2	3	37.1	3.8	34	3
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0
Unidentified Coral	4.9	0.8	2.6	0.6	0.9	0.3	2.1	1.3	4.8	0.8	3.9	1.4	0.9	0.3	2.2	1.3
Hydro Corals - Milleporidae	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0	0
Soft Corals - Alcyoniidae	7.5	2	5	1.6	3	1	3.8	1.1	1.6	0.8	0.6	0.4	3	1	1.1	0.7
Other Benthic Invertebrates	0.2	0.1	0.3	0.1	0.5	0.3	0.4	0.2	6.4	1.9	4.7	1.6	0.5	0.3	3.1	0.9
Macroalgae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turf Algae	33.6	3	39.9	2.6	40.7	2.9	43.6	2.4	33.8	3	40.3	2.7	40.7	2.9	43.6	2.4
Coralline Algae	0.4	0.2	0	0	1.9	0.5	0.1	0.1	0.4	0.2	0	0	1.9	0.5	0.1	0.1
Pavement/Rock/Rubble	1.8	0.4	0.8	0.2	1.6	0.7	0.1	0.1	1.8	0.4	0.8	0.2	1.6	0.7	0.1	0.1
Sand	4	1.2	15.3	2.9	9.7	2.8	9.8	2.3	4	1.2	15.3	2.9	9.7	2.8	9.8	2.3
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0.3	0.2	0.5	0.5	0	0	0	0	-	-	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.19 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at BIG

Cover	% Cover in Chevron Australia 2012a at each survey date								Revised % Cover used in this Report at each survey date							
	Oct-08		Mar-09		Jun-09		Oct-09		Oct-08		Mar-09		Jun-09		Oct-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	1.7	1.1	0.1	0.1	1.4	1.1	0.2	0.1	1.6	1	0.6	0.4	1.4	1.1	0.2	0.1
Agariciidae	0	0	0.3	0.3	0.6	0.6	0	0	0	0	0.3	0.2	0.6	0.6	0	0
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0.3	0.3	0	0	0	0	0	0	0.3	0.3	0	0	0	0	0	0
Faviidae	8.1	1.2	8.9	2.1	7.1	1.9	6.2	1.2	8.1	1.3	10.8	1.5	7.1	1.9	6.4	1.3
Fungiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merulinidae	0.3	0.2	0.2	0.2	0.2	0.2	0	0	0.2	0.2	0.1	0.1	0.2	0.2	0	0
Mussidae	0	0	0	0	0.1	0.1	0	0	0	0	0.1	0.1	0.1	0.1	0	0
Oculinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pectiniidae	0	0	0.1	0.1	0	0	0.1	0.1	0	0	0	0	0	0	0	0
Pocilloporidae	0.1	0.1	0.3	0.2	1	0.4	0.1	0.1	0.1	0.1	0.3	0.2	1	0.4	0.1	0.1
Poritidae	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Coral	0.2	0.1	0.4	0.3	0.3	0.2	0.2	0.1	0.7	0.3	0.9	0.3	0.3	0.2	0.2	0.1
Hydro Corals - Milleporidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soft Corals - Alcyoniidae	16	2.4	7.1	2	16.1	4	15.3	2.5	8	1.8	4.2	1.2	16.1	4	4.9	1.2
Other Benthic Invertebrates	0.2	0.2	0.6	0.3	0.5	0.5	0.1	0.1	8.2	2	4.1	1.3	0.5	0.5	10.9	2.3
Macroalgae	0	0	0	0	1.3	0.5	0	0	0	0	0.1	0.1	1.3	0.5	0	0
Turf Algae	45.9	3.3	64	3.5	44.7	4.3	50	3.5	46.1	3.3	63.6	3	44.7	4.3	49.6	3.6
Coralline Algae	0.1	0.1	0.1	0.1	0.9	0.3	0	0	0.1	0.1	0.3	0.2	0.9	0.3	0	0
Pavement/Rock/Rubble	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.1
Sand	26.8	3.6	17.3	3.4	25.4	4.4	27.2	3.2	26.5	3.6	14.8	2.5	25.4	4.4	27	3.3
Seagrass	0	0	0	0	0.2	0.1	0.5	0.2	0	0	0	0	0.2	0.1	0.5	0.2
Unidentified (other)	0.2	0.1	0.4	0.2	0	0	0	0	-	-	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.20 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at LNG3

Cover	% Cover in Chevron Australia 2012a at each survey date								Revised % Cover used in this Report at each survey date							
	Sep-08		Mar-09		Aug-09		Nov-09		Sep-08		Mar-09		Aug-09		Nov-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	0.2	0.1	0.3	0.3	0.2	0.1	0.2	0.1	0.2	0.1	0.3	0.3	0.2	0.1	0.1	0.1
Agariciidae	0.3	0.2	0	0	0	0	0	0	0.3	0.2	0	0	0	0	0	0
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0	0	0.1	0.1	0.4	0.2	0.1	0.1	0	0	0.1	0.1	0.4	0.2	0.2	0.1
Faviidae	1.1	0.4	1.7	0.4	1	0.3	1.3	0.3	1.1	0.4	1.7	0.4	1	0.3	1.7	0.4
Fungiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merulinidae	0	0	1.7	1.2	0	0	0	0	0	0	0.7	0.7	0	0	0	0
Mussidae	0.2	0.1	0	0	0.1	0.1	0	0	0.1	0.1	0	0	0.1	0.1	0	0
Oculinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pectiniidae	0	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0.1	0.1
Pocilloporidae	0	0	0.2	0.2	0.1	0.1	0.1	0.1	0	0	0.2	0.2	0.1	0.1	0.1	0.1
Poritidae	11.6	3.6	12	2.9	5.2	1.6	11.6	3.1	11.6	3.6	12	2.9	5.2	1.6	11.6	3.1
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1
Unidentified Coral	2.3	0.6	1.8	0.4	0.2	0.1	0.5	0.2	2.3	0.6	2.8	1	0.2	0.1	0.7	0.3
Hydro Corals - Milleporidae	1.3	1.3	1.4	1.4	0.8	0.7	0	0	0	0	0	0	0.8	0.7	0	0
Soft Corals - Alcyoniidae	0.2	0.1	0.1	0.1	0.2	0.2	0.6	0.3	0.1	0.1	0	0	0.2	0.2	0	0
Other Benthic Invertebrates	1	0.5	0.4	0.2	0.2	0.1	0.3	0.1	2.4	1.4	2	1.4	0.2	0.1	0.9	0.4
Macroalgae	0.4	0.2	0	0	0.6	0.4	1.2	0.3	0.4	0.2	0	0	0.6	0.4	1.2	0.3
Turf Algae	60.3	3.8	67.3	3.2	75.2	2.4	69.7	3	60.6	3.8	67.4	3.2	75.2	2.4	69.3	3
Coralline Algae	0.2	0.2	0.1	0.1	1.8	0.9	0.5	0.2	0.2	0.2	0.1	0.1	1.8	0.9	0.5	0.2
Pavement/Rock/Rubble	15.8	2.7	5.9	1.6	7.3	1.3	10.3	1.8	15.8	2.7	5.9	1.6	7.3	1.3	10.1	1.7
Sand	4.8	1	6.9	1.7	6.5	1.9	3.5	0.9	4.8	1	6.9	1.7	6.5	1.9	3.5	0.9
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0.3	0.2	0.2	0.1	0	0	0	0	-	-	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.21 Differences in Mean Percentage Cover ± SE Data and Composition of Corals between Chevron Australia (2012a) and this Report at DUG

Cover	% Cover in Chevron Australia 2012a at each survey date						Revised % Cover used in this Report at each survey date					
	May-08		Nov-08		Jun-09		May-08		Nov-08		Jun-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	8.2	1.8	6.6	1.5	10.6	1.8	7.6	1.7	6.9	1.6	10.6	1.8
Agariciidae	7.4	2.9	3.9	1.1	7.1	2.3	7.5	2.9	4	1.2	7.1	2.3
Caryophylliidae	0.1	0.1	0	0	0.3	0.3	0.1	0.1	0	0	0.3	0.3
Dendrophylliidae	0.1	0.1	0	0	0	0	0.1	0.1	0	0	0	0
Faviidae	6.5	1.3	10.6	1.7	6.7	1.3	6.5	1.3	11	1.7	6.7	1.3
Fungiidae	1	0.5	0.1	0.1	1	0.3	0.9	0.4	0.2	0.1	1	0.3
Merulinidae	0.9	0.4	3.3	1.1	0.8	0.3	0.5	0.3	1.1	0.4	0.8	0.3
Mussidae	2.7	0.7	3.5	0.9	1.7	0.4	2.8	0.7	3.6	0.9	1.7	0.4
Oculinidae	14.5	2.8	10.7	2.3	14.3	2.3	14.7	2.8	10.8	2.3	14.3	2.3
Pectiniidae	9.2	1.9	8.4	2.1	6.3	1.3	9.4	1.9	8.5	2.1	6.3	1.3
Pocilloporidae	0.8	0.3	0.2	0.2	0.3	0.2	0.4	0.2	0.2	0.2	0.3	0.2
Poritidae	12.2	2.6	14.8	2.4	13.9	2.5	12.3	2.6	15.2	2.4	13.9	2.5
Siderastreidae	0.6	0.6	0	0	0	0	0.1	0.1	0	0	0	0
Bleached Coral	0	0	0	0	0.1	0.1	0	0	0	0	0.1	0.1
Unidentified Coral	2.5	0.6	5.1	0.8	1.1	0.3	3.1	0.7	7.3	1.3	1.1	0.3
Hydro Corals - Milleporidae	1.3	0.8	0.5	0.3	0.9	0.4	0	0	0	0	0.9	0.4
Soft Corals - Alcyoniidae	0	0	0.2	0.2	0	0	0	0	0	0	0	0
Other Benthic Invertebrates	0	0	0.2	0.1	0.3	0.1	1.4	0.8	0.9	0.5	0.3	0.1
Macroalgae	0.1	0.1	0	0	0	0	0.1	0.1	0	0	0	0
Turf Algae	28.2	2.6	23.1	2.6	32.1	2.6	29.1	2.8	23.9	2.7	32.1	2.6
Coralline Algae	0	0	1.9	0.6	0.2	0.1	0	0	2.1	0.6	0.2	0.1
Pavement/Rock/Rubble	2.1	0.7	0.7	0.3	0.1	0.1	2.2	0.7	0.7	0.3	0.1	0.1
Sand	1.1	0.4	3.5	1.2	2.3	0.8	1.2	0.4	3.6	1.2	2.3	0.8
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0.4	0.3	2.8	0.7	0	0	-	-	-	-	-	-

Note: - indicates nil recorded

Table A1.22 Differences in Percentage Cover (Mean ± SE) Data and Composition of Corals between Chevron Australia (2012a) and this Report at BAT

Cover	% Cover in Chevron Australia 2012a at each survey date						Revised % Cover used in this Report at each survey date					
	Jun-08		Oct-08		Aug-09		Jun-08		Oct-08		Aug-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	3.5	0.9	1.8	0.5	1.5	0.4	2.3	0.8	1.1	0.4	1.5	0.4
Agariciidae	0	0	0	0	0	0	0	0	0	0	0	0
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0	0	0.3	0.2	0	0	0.6	0.3	1	0.5	0	0
Faviidae	14.8	2.5	12.4	2.1	11	1.5	14.9	2.5	12.4	2.1	11	1.5
Fungiidae	0.4	0.2	0.6	0.2	0.3	0.1	0.4	0.2	0.6	0.2	0.3	0.1
Merulinidae	13	2.4	13.8	2.3	12.5	2.4	12.2	2.4	13.1	2.2	12.5	2.4
Mussidae	0.4	0.3	0	0	0.6	0.3	0.5	0.3	0	0	0.6	0.3
Oculinidae	1.7	0.7	1.2	0.6	0.8	0.4	1.7	0.7	1.2	0.6	0.8	0.4
Pectiniidae	9.5	2.5	7.7	1.7	8.2	2.2	9.6	2.5	7.9	1.8	8.2	2.2
Pocilloporidae	0.8	0.3	0.4	0.2	0.4	0.2	0.5	0.2	0.4	0.2	0.4	0.2
Poritidae	14.1	2.9	20.2	2.3	14.3	1.8	14.2	2.9	20.6	2.4	14.3	1.8
Siderastreidae	0	0	0	0	0	0	0	0	0	0	0	0
Bleached Coral	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Coral	0.8	0.3	1.7	0.4	0.4	0.2	1.7	0.6	2.6	0.6	0.4	0.2
Hydro Corals - Milleporidae	0.4	0.3	0.4	0.2	0.4	0.3	0	0	0	0	0.4	0.3
Soft Corals - Alcyoniidae	0	0	0	0	0.3	0.3	0	0	0	0	0.3	0.3
Other Benthic Invertebrates	0.1	0.1	0	0	0.1	0.1	0.5	0.3	0.4	0.2	0.1	0.1
Macroalgae	0	0	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1
Turf Algae	35.2	2.7	29.1	2	45.1	2.3	36.1	2.8	29.4	2	45.1	2.3
Coralline Algae	0.1	0.1	0	0	0.5	0.2	0.1	0.1	0	0	0.5	0.2
Pavement/Rock/Rubble	2.5	1.4	5.4	1.2	0.4	0.2	2.5	1.4	5.5	1.3	0.4	0.2
Sand	2.6	0.6	4.6	1.1	2.9	0.9	2.1	0.5	3.8	1	2.9	0.9
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0.3	0.2	0.2	0.1	0	0	-	-	-	-	-	-

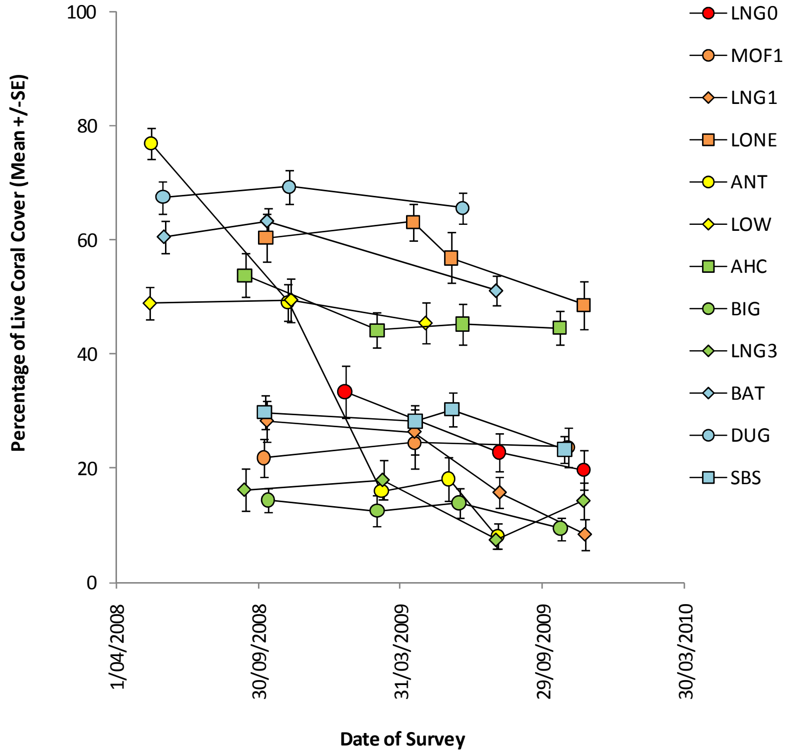
Note: - indicates nil recorded

Table A1.23 Differences in Percentage Cover (Mean ± SE) Data and Composition of Corals between Chevron Australia (2012a) and this Report at SBS

Cover	% Cover in Chevron Australia 2012a at each survey date								Revised % Cover used in this Report at each survey date							
	Oct-08		Apr-09		Jun-09		Oct-09		Oct-08		Apr-09		Jun-09		Oct-09	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acroporidae	6	1.2	7.9	1.8	9.6	1.5	6.3	1.4	6	1.2	7.9	1.8	9.6	1.5	1.9	0.6
Agariciidae	0.1	0.1	0.7	0.4	0.6	0.3	0.9	0.5	0.1	0.1	0.8	0.4	0.6	0.3	0.9	0.5
Caryophylliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrophylliidae	0	0	0.1	0.1	0.7	0.3	0	0	0	0	0.1	0.1	0.7	0.3	0	0
Faviidae	3.4	0.8	3.5	1	2.1	0.4	3.7	0.7	3.5	0.8	3.9	1	2.1	0.4	3.7	0.7
Fungiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merulinidae	0.8	0.5	0.3	0.2	0.2	0.2	0.5	0.3	0.1	0.1	0.3	0.2	0.2	0.2	0.5	0.3
Mussidae	2.2	1.1	0.3	0.2	0.6	0.4	1.3	0.8	2.3	1.2	0.2	0.2	0.6	0.4	1.3	0.8
Oculinidae	0.1	0.1	0.2	0.2	0	0	0	0	0.1	0.1	0.2	0.2	0	0	0	0
Pectiniidae	0.3	0.2	0	0	0.1	0.1	0	0	0.3	0.2	0	0	0.1	0.1	0	0
Pocilloporidae	0	0	0	0	0.6	0.4	0.1	0.1	0	0	0	0	0.6	0.4	0.1	0.1
Poritidae	11.4	2.3	5.9	1.7	8	1.9	6.2	1.2	10.7	2.4	5	1.7	8	1.9	6.2	1.2
Siderastreidae	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0	0
Bleached Coral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified Coral	3	0.6	3	0.8	1.2	0.4	2.6	0.6	2.8	0.7	2.7	0.8	1.2	0.4	7	1.3
Hydro Corals - Milleporidae	1.3	0.9	2.3	1.4	0.7	0.4	1.8	0.9	0	0	0	0	0.7	0.4	1.8	0.9
Soft Corals - Alcyoniidae	0	0	0.1	0.1	0	0	0.1	0.1	0	0	0	0	0	0	0	0
Other Benthic Invertebrates	0.1	0.1	0.2	0.1	1.1	0.4	0.1	0.1	1.4	1	2.7	1.5	1.1	0.4	0.1	0.1
Macroalgae	6.1	1	0.1	0.1	0.9	0.4	3	0.6	6.3	1.1	0.1	0.1	0.9	0.4	3	0.6
Turf Algae	47.2	2.5	45.6	3.3	34.2	2.4	61.2	2.3	48.7	2.6	45.8	3.3	34.2	2.4	61.2	2.3
Coralline Algae	0.2	0.1	0	0	2.2	0.6	0.8	0.2	0.2	0.1	0	0	2.2	0.6	0.8	0.2
Pavement/Rock/Rubble	3.8	0.9	1.2	0.4	8.8	1.5	0.6	0.3	3.8	0.9	1.2	0.4	8.8	1.5	0.6	0.3
Sand	13.3	2	27.9	3.9	28.3	3.9	10.9	1.9	13.7	2.1	28.9	3.9	28.3	3.9	10.9	1.9
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified (other)	0.8	0.2	0.5	0.2	0	0	0	0	-	-	-	-	-	-	-	-

Note: - indicates nil recorded.

Differences in Change in Live Coral Cover as Measured from Random Transects



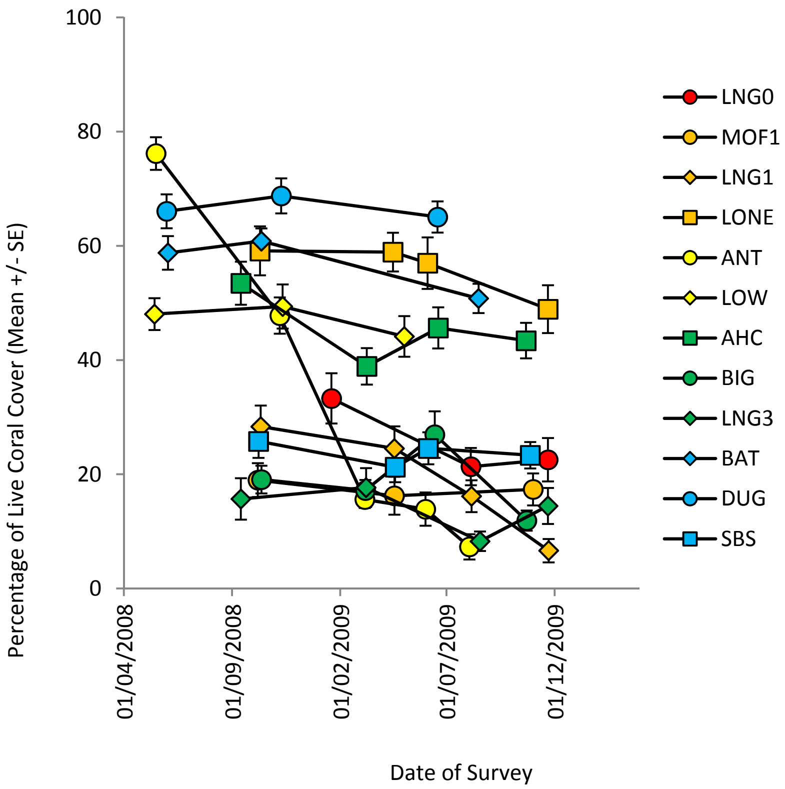


Figure A1.1 Temporal Changes in the Cover of Live Corals. (Mean ± SE) Based on the Mean of Five Random Transects at Each Monitoring Site/Time for Original Marine Baseline Data (Chevron Australia 2012a) (above) and Revised Data used in this Report (below).

Note: Coloured symbols denote; red: Zone of High Impact, orange: Zone of Moderate Impact, yellow: Zone of Influence, green: Reference, blue: Regionally Significant Area.

Differences in the Change in Live Coral Cover as Measured from Fixed Transects

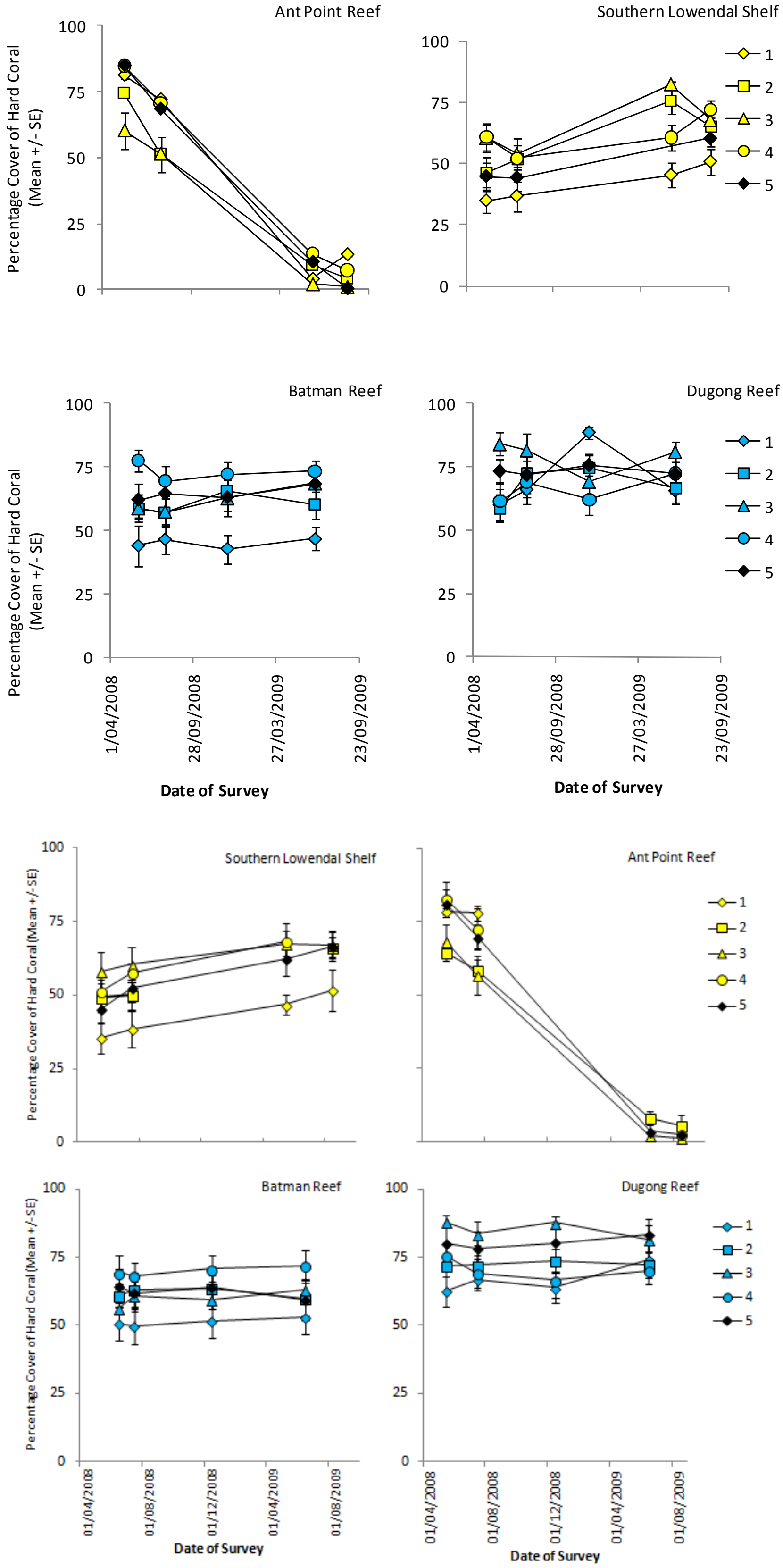


Figure A1.2 Change in Percentage Cover of Live Cover (Mean ± SE) over 12 Months from Fixed Transects for Original Marine Baseline data (Chevron Australia 2012a) (above) and Revised data used in this Report (below).

Table A1.24 Differences in Change in Percentage Live Tissue Cover in each Genus/Family in Tagged Colonies between Chevron Australia (2012a) and this Report

Site	Genus/ Family	Mean ± SE change in live tissue (%) Time 0–Time 1		Count T1-T0		Mean ± SE change in live tissue (%) Time 0– Time 2		Count T2-T0	
		(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report
LNG0	Acropora	-1.8 ± 5.2	0.7 ± 4.9	9	9	-2.1 ± 6.4	-2.7 ± 4.2	9	9
MOF1	Acropora	-0.5 ± 0.5	-2.1 ± 1.4	7	7	0.0 ± 0.0	-0.2 ± 0.9	7	7
	Lobophyllia	0.0 ± 0.0	-2.9 ± 1.1	7	7	-1.4 ± 1.4	-2.0 ± 1.1	6	6
LNG1	Acropora	-12.7 ± 12.5	-12.9 ± 12.5	8	8	-14.7 ± 12.3	-15.5 ± 12.4	8	8
	Lobophyllia	2.8 ± 3.5	-2.3 ± 1.7	6	6	0.0 ± 0.0	-1.8 ± 1.4	6	6
LONE	Acropora	-10.9 ± 8.8	-9.9 ± 5.7	16	16	0.8 ± 0.7	-6.4 ± 3.3	12	15
	Lobophyllia	0.0 ± 0.0	2.9 ± 2.9	2	2	0.0 ± 0.0	-1.9	1	1
ANT	Acropora	-0.6 ± 1.3	0.6 ± 0.6	16	13	-28.3 ± 15.9	-13.1 ± 11.4	8	7
AHC	Acropora	-1.8 ± 1.2	-0.6 ± 0.6	10	10	0.0 ± 0.0	0.0 ± 0.0	10	10
	Lobophyllia	0.3 ± 0.6	-0.8 ± 0.9	10	10	0.2 ± 0.2	-1.0 ± 1.0	5	5
BIG	Acropora	-11.9 ± 4.1	-5.8 ± 4.5	14	12	-45.4 ± 12.4	-37.5 ± 18.2	9	7
	Faviidae	-13.5 ± 13.9	-1.7 ± 1.0	3	3	-26.4 ± 19.7	-26.5 ± 22.2	3	2
LNG3	Acropora	0.0 ± 0.0	0.0 ± 0.0	10	10	0.0 ± 0.0	0.0 ± 0.0	10	10
	Lobophyllia	0.0 ± 0.0	-0.6 ± 0.6	8	8	-0.8 ± 0.8	-2.7 ± 1.3	6	6
LOW	Acropora	-3.3 ± 3.0	-3.2 ± 4.0	33	26	-14.9 ± 6.6	-11.3 ± 5.8	23	26
	Montipora	0.6 ± 0.6	0.4 ± 1.2	11	8	0.8 ± 0.8	-1.1 ± 1.8	8	7
DUG	Acropora	1.7 ± 1.7	0.0 ± 0.0	5	4	-1.7 ± 1.7	-0.1 ± 0.1	4	3
	Lobophyllia	-6.1 ± 6.1	-9.4 ± 4.2	3	2	-23.5 ± 23.5	-28.4 ± 19.8	3	2
	Montipora	-8.3 ± 9.9	0.0 ± 1.8	10	8	0.2 ± 2.1	-2.8 ± 2.9	10	7
	Pectinia	-0.8 ± 0.8	-0.7 ± 0.7	4	4	0.0 ± 0.0	-2.7 ± 1.6	4	4
BAT	Faviidae	-9.9 ± 8.2	-10.8 ± 9.2	11	11	-16.5 ± 9.3	-13.1 ± 11.4	11	9
	Lobophyllia	0.0 ± 0.0	-0.9 ± 10.9	3	2	-1.6 ± 1.6	5.3 ± 5.3	3	2
	Pectinia	4.6 ± 3.3	-1.4 ± 3.3	6	5	-7.4 ± 4.7	1.2 ± 3.0	5	6
SBS	Acropora	0.3 ± 0.3	-1.1 ± 1.1	9	9	-0.4 ± 0.8	-2.4 ± 1.6	8	7
	Montipora	0.0 ± 0.0	-1.8 ± 1.4	11	11	-8.1 ± 3.5	-1.5 ± 3.1	8	8

Table A1.25 Differences in Coral Growth Rates (%) per Month of Non-branching Colonies at Coral Monitoring Sites at Time 1 (T1) and Time 0 (T0) between Chevron Australia (2012a) and this Report

Site	Genus/ Family	Mean Growth Rate (%) ± SE per 31 days at Time 1 (first six months)		n (T0 - T1)		Mean Growth Rate (%) ± SE per 31 days at Time 2 (second six months)		n (T1 - T2)		Mean Growth Rate (%) ± SE per 31 days over 12 months		n (T0 - T2)	
		(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report
LNG0	Acropora	1.4 ± 1.1	3.5_±_1.1	9	9	-0.5 ± 1.2	-0.9_±_9.0	9	9	0.6 ± 0.8	1.8_±_0.7	9	9
MOF1	Acropora	2.0 ± 0.7	2.0_±_0.7	7	7	0.8 ± 1.2	1.5_±_5.0	5	5	2.0 ± 0.6	2.4_±_0.5	7	7
	Lobophyllia	-2.4 ± 0.8	-1.7_±_0.8	7	7	4.9 ± 2.7	4.0_±_6.0	6	6	0.9 ± 1.3	1.0_±_1.3	6	6
LNG1	Acropora	5.2 ± 2.4	6.3_±_2.9	8	7	3.8 ± 2.1	5.1_±_7.0	7	7	6.4 ± 2.7	7.6_±_3.0	7	7
	Lobophyllia	-1.0 ± 1.5	0.2_±_1.5	6	6	2.7 ± 3.0	3.2_±_5.0	6	5	0.3 ± 0.4	1.1_±_0.4	6	6
LONE	Acropora	2.6 ± 0.8	3.3_±_0.8	14	14	1.1 ± 0.8	0.8_±_14.0	14	14	1.9 ± 0.7	2.1_±_0.7	15	15
	Lobophyllia	0.8 ± 1.6	1.6_±_1.7	2	2	-1.7	-2.8	1	1	0.1	-0.3	1	1
ANT	Acropora	1.2 ± 0.7	-0.1_±_0.5	16	16	4.3 ± 3.4	3.7_±_5.0	6	5	1.9 ± 2.7	1.7_±_2.9	6	5
AHC	Acropora	7.0 ± 1.2	6.8_±_1.1	10	10	3.1 ± 0.6	2.8_±_10.0	10	10	5.7 ± 1.0	5.3_±_1.0	10	10
	Lobophyllia	0.5 ± 1.2	1.5_±_0.9	10	10	1.8 ± 2.2	10.0_±_5.0	5	5	0.1 ± 0.6	1.0_±_0.9	5	5
BIG	Acropora	1.9 ± 2.6	3.8_±_3.2	13	12	-2.0 ± 2.6	-3.6_±_7.0	6	7	1.4 ± 2.3	0.7_±_2.8	6	7
	Faviidae	4.1 ± 1.9	5.9_±_1.8	3	3	-0.1 ± 6.4	2.4_±_2.0	3	2	1.9 ± 4.7	4.5_±_2.3	3	2
LNG3	Acropora	5.1 ± 2.3	7.0_±_2.2	10	10	2.1 ± 1.9	1.9_±_9.0	9	9	3.5 ± 1.3	4.2_±_1.3	9	9
	Lobophyllia	1.9 ± 1.5	2.3_±_1.6	7	7	0.4 ± 0.4	0.8_±_5.0	6	5	1.3 ± 1.2	1.3_±_0.8	5	6
SBS	Acropora	5.2 ± 0.8	4.2_±_1.0	9	9	1.4 ± 2.6	3.3_±_5.0	8	5	3.3 ± 1.7	3.7_±_1.7	8	5
	Montipora	2.0 ± 0.9	2.1_±_0.9	11	11	0.7 ± 1.4	2.5_±_8.0	8	8	1.9 ± 1.1	3.1_±_1.5	8	8

Note: Non-branching colonies from Sites LOW, Dugong Reef and Batman Reef were excluded from reanalysis of growth as photo-quadrats lacked a scale bar for growth measurements to take place.

Table A1.26 Differences in Linear Extension Rates (mm) per Month and Range of Branching *Acropora* and *Porites* at Coral Monitoring Sites between Chevron Australia (2012a) and this Report

Site	Family / Genus	Average Linear Extension (mm) ± SE per 31 days at Time 1 (first six months)		n (colonies)		Average Linear Extension (mm) ± SE per 31 days at Time 2 (second six months)		n (colonies)		Average Linear Extension (mm) ± SE per 31 days calculated over 12 months		n (colonies)	
		(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report	(Chevron Australia 2012a)	Revised Data used in this Report
ANT	Acropora	1.8 ± 0.5	2.0 ± 0.7	18	10	-0.6 ± 0.2	-0.4 ± 0.2	22	10	1.1 ± 0.2	1.0 ± 0.3	3	2
LOW	Acropora	5.0 ± 0.8	5.4 ± 1.0	23	10	1.8 ± 0.5	2.0 ± 0.7	15	7	3.4 ± 0.8	3.8 ± 1.2	15	7
AHC	Porites	2.2 ± 0.2	2.1 ± 0.2	26	10	1.6 ± 0.2	1.6 ± 0.2	27	10	2.1 ± 0.1	2.0 ± 0.2	21	9
BAT	Porites	1.6 ± 0.3	1.4 ± 0.2	14	9	-		-		-		-	
SBS	Acropora	3.2 ± 0.6	3.0 ± 0.6	16	9	1.5 ± 0.4	1.6 ± 0.4	9	6	3.3 ± 0.7	3.7 ± 0.9	9	6

Non-coral Benthic Macroinvertebrates

Table A1.27 Differences in Benthic Habitat Classification for Non-coral Benthic Macroinvertebrates Survey Sites between Chevron Australia (2012a) and this Report

Location	Site Code	Chevron Australia 2012a	Revised Data used in this Report
Zones of High Impact	TP6	Limestone Pavement	Soft Sediment
	LNGI2	Limestone Pavement	Limestone Pavement
	DS1	Soft Sediment	Soft Sediment
Zone of Moderate Impact	TP2	Limestone Pavement	Soft Sediment
Zones of Influence (South)	DSS1	Soft Sediment	Soft Sediment
	LNGR1	Limestone Pavement	Soft Sediment
	LNGR3	Limestone Pavement	Limestone Pavement
	TP10	Limestone Pavement	Limestone Pavement
	TP9	Limestone Pavement	Soft Sediment
	TPC1	Soft Sediment	Soft Sediment
	TPC3	Soft Sediment	Soft Sediment
Zones of Influence (North)	TP1	Limestone Pavement	Soft Sediment
	LC1	Soft Sediment	Soft Sediment
	LC4	Soft Sediment	Soft Sediment
	LNGR2	Limestone Pavement	Soft Sediment
Reference Sites	DSR3	Soft Sediment	Soft Sediment
	DSR5	Soft Sediment	Soft Sediment
	DSR6	Soft Sediment	Limestone
	DGI0	Soft Sediment	Soft Sediment

Table A1.28 Differences in the Abundance of Benthic Macroinvertebrates (mean abundance per transect ±SE) between Chevron Australia (2012a) and this Report at sites located in the Zones of High and Moderate Impact

Zone	Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
			Other soft corals	Sponges (branching)	Ascidians combined	Sponge (barrel)	Crinoids	Sponge (cup)	Sponge (digitate)	Sponge (fan)	Sponge (globular)	Gorgonians	Hydroids	Sea whips	Sponge s(tubular)	*Turbinaria* spp.	Sponge s(variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
ZoHI	DS1	Revised	0.3 (0.3)	0.7 (0.7)	-	-	-	-	0.3 (0.3)	1.0 (0.6)	0.7 (0.7)	1.0 (0.6)	-	10.0 (1.0)	-	1.7 (1.2)	1.7 (0.9)	0.7 (0.3)	-	-	-	3.6 (2.1)	-	-	-	-	0.0 (0.0)
		Chevron Australia (2012a)	0.3 (0.3)	2.0 (0.0)	1.0 (1.0)	-	-	0.3 (0.3)	1.0 (0.6)	2.0 (0.6)	1.3 (0.9)	0.3 (0.3)	1.0 (0.6)	7.3 (2.9)	-	0.3 (0.3)	3.3 (0.9)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	DS2	Revised	0.3 (0.3)	1.0 (0.6)	-	0.3 (0.3)	-	-	-	-	1.3 (0.9)	-	-	2.7 (1.5)	-	1.3 (0.7)	2.0 (0.6)	0.3 (0.3)	-	-	-	1.6 (0.6)	0.3 (0.3)	-	-	-	0.0 (0.0)
		Chevron Australia (2012a)	0.3 (0.3)	1.0 (0.6)	-	0.3 (0.3)	-	-	-	-	1.0 (0.6)	-	0.3 (0.3)	2.3 (1.2)	-	1.0 (0.6)	1.0 (0.0)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	LNGI2	Revised	1.3 (0.7)	0.3 (0.3)	-	-	0.7 (0.3)	-	0.3 (0.3)	0.7 (0.3)	0.3 (0.3)	-	0.3 (0.3)	0.7 (0.7)	-	1.7 (0.9)	10.7 (6.7)	1.3 (0.7)	1.0 (0.6)	-	0.7 (0.3)	16.6 (6.1)	1.0 (0.6)	-	-	1.3 (1.3)	2.3 (1.9)

Public

Zone	Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
			Other soft corals	**Sponges (branching)**	**Ascidians combined**	**Sponge (barrel)**	**Crinoids**	**Sponge (cup)**	**Sponge (digitate)**	**Sponge (fan)**	**Sponge (globular)**	**Gorgonians**	**Hydroids**	**Sea whips**	**Sponge s(tubular)**	***Turbinaria* spp.**	**Sponge s(variable)**	**Ascidians (colonial)**	**Ascidians (solitary)**	**Gastropods**	**Nudibranchs**	**Other hard corals**	**Sea cucumbers**	**Sea pens**	**Sea stars**	**Sea urchins**	**Unidentified**
		Chevron Australia (2012a)	2.3 (2.3)	-	-	-	1.0 (0.6)	-	0.3 (0.3)	-	-	-	-	1.0 (0.6)	0.3 (0.3)	1.3 (1.3)	0.3 (0.3)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	TP6	Revised	1.7 (1.2)	4.0 (1.5)	-	0.3 (0.3)	0.7(0.7)	-	-	1.3 (0.9)	-	0.3 (0.3)	1.3 (1.3)	5.0 (2.1)	0.7(0.7)	5.3 (1.7)	3.0 (1.2)	2.3 (0.9)	-	-	-	2.6 (2.1)	0.7 (0.3)	-	-	-	0.7 (0.3)
		Chevron Australia (2012a)	-	3.0 (1.5)	7.0 (2.6)	0.7 (0.7)	1.0 (0.6)	-	2.7 (1.4)	2.0 (1.1)	-	2.3 (0.7)	10.7 (1.8)	4.3 (2.0)	-	4.0 (0.6)	2.7 (0.3)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	TPCI1	Revised	-	-	-	-	0.7 (0.7)	-	-	-	-	0.3 (0.3)	-	5.3 (0.9)	1.0 (0.6)	-	0.7 (0.3)	-	-	-	-	-	-	-	-	0.3 (0.3)	1.3 (0.3)
		Chevron Australia (2012a)	-	0.3 (0.3)	-	-	0.7 (0.3)	-	-	-	0.7 (0.3)	-	-	9.7 (0.3)	0.3 (0.3)	-	1.3 (0.3)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Zone	Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
			Other soft corals	Sponges (branching)	Ascidians combined	Sponge (barrel)	Crinoids	Sponge (cup)	Sponge (digitate)	Sponge (fan)	Sponge (globular)	Gorgonians	Hydroids	Sea whips	Sponge s(tubular)	*Turbinaria* spp.	Sponge s(variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
	TPCI2	Revised	-	-	-	-	0.7 (0.7)	-	-	-	-	-	-	3.7 (1.5)	-	-	-	-	-	-	-	-	-	-	0.3 (0.3)	2.0 (2.0)	1.3 (0.3)
		Chevron Australia (2012a)	-	-	-	-	1.3 (1.3)	-	0.3 (0.3)	-	1.3 (0.7)	-	-	3.3 (1.2)	-	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	LNGI1	Revised	1.0 (0.6)					0.3 (0.3)	1.0 (0.0)	0.7 (0.7)			1.0 (0.0)	6.3 (2.3)		0.7 (0.7)	3.3 (0.9)		1.0 (0.6)				1.3 (0.3)				0.3 (0.3)
		Chevron Australia (2012a)	2.7 (1.2)	0.7 (0.3)		0.7 (0.7)	1.0 (0.6)	-	0.7 (0.3)	2.0 (1.0)	1.0 (0.6)	-	0.7 (0.3)	10.7 (1.4)	2.3 (1.2)	2.0 (0.6)	2.7 (1.2)	-	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	
ZoMI	TP2	Revised	1.0 (0.6)	1.3 (0.3)	-	-	0.7 (0.3)	-	0.3 (0.3)	0.7 (0.3)	-	-	0.3 (0.3)	5.0 (1.5)	1.7 (0.9)	1.3 (0.7)	3.0 (1.0)	6.3 (1.8)	-	-	-	2.3 (0.8)	0.3 (0.3)	-	-	-	0.7 (0.7)

Zone	Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
			Other soft corals	Sponges (branching)	Ascidians combined	Sponge (barrel)	Crinoids	Sponge (cup)	Sponge (digitate)	Sponge (fan)	Sponge (globular)	Gorgonians	Hydroids	Sea whips	Sponge s(tubular)	*Turbinaria* spp.	Sponge s(variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
		Chevron Australia (2012a)	-	1.3 (0.3)	11.3 (1.2)	-	1.0 (0.0)	-	1.0 (0.6)	0.7 (0.3)	0.3 (0.3)	-	5.0 (2.0)	5.0 (1.5)	-	0.7 (0.3)	3.3 (0.9)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Notes: N/A indicates not included in original list of benthic macroinvertebrate categories; - indicates nil recorded.

Table A1.29 Differences in the Abundance of Benthic Macroinvertebrates (mean abundance per transect ± SE) between Chevron Australia (2012a) and this Report at sites located in the Zones of Influence

Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
		Other soft corals	Sponges (branching)	Ascidians combined	Sponges (barrel)	Crinoids	Sponges (cup)	Sponges (digitate)	Sponges (fan)	Sponges (globular)	Gorgonians	Hydroids	Sea whips	Sponges (tubular)	*Turbinaria* spp.	Sponges (variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
DSS1	Revised	-	2.3 (1.5)	-	-	-	1.0 (0.6)	-	3.3 (0.9)	-	-	1.3 (1.3)	10.0 (2.5)	-	1.0 (0.6)	4.3 (2.0))	0.3 (0.3)	-	-	-	2.6 (0.3)	-	-	-	-	0.0 (0.0)
	Chevron Australia (2012a)	-	7.3 (2.2)	0.3 (0.3)	-	0.3 (0.3)	2.7 (0.9)	3.3 (0.9)	5.0 (0.6)	1.7 (0.9)	-	2.0 (1.5)	13.7 (4.2)	1.0 (0.6)	1.7 (0.3)	3.7 (1.2)	N/A	N/A	N/A	N/ A	N/A	N/A	N/ A	N/A	N/A	N/A
LC1	Revised	0.3 (0.3)	1.0 (0.6)	-	-	1.3 (0.9)	-	-	-	-	-	0.7 (0.3)	8.3 (2.2)	-	1.0 (0.6)	2.0 (1.5)	-	-	-	-	1.0 (1.0)	-	-	-	-	1.0 (0.6)
	Chevron Australia (2012a)	-	4.0 (0.6)	-	0.3 (0.3)	1.0 (0.6)	-	0.3 (0.3)	1.0 (1.0)	2.7 (1.2)	1.0 (0.6)	1.0 (1.0)	21.3 (4.1)	0.3 (0.3)	1.3 (0.7)	4.3 (2.6)	N/A	N/A	N/A	N/ A	N/A	N/A	N/ A	N/A	N/A	N/A
LC2	Revised	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3 (0.3)	-	-	-	-	-	-	-	-	-	-
	Chevron Australia (2012a)	-	-	0.3 (0.3)	-	-	-	-	-	-	-	-	-	-	-	-	N/A	N/A	N/A	N/ A	N/A	N/A	N/ A	N/A	N/A	N/A
LC3	Revised	-	-	-	-	-	-	-	-	-	-	-	11 (2.0)	-	0.3 (0.3)	0.3 (0.3)	-	-	0.3 (0.3)	-	-	-	-	-	0.3 (0.3)	-
	Chevron Australia (2012a)	-	0.7 (0.3)	-	-	0.7 (0.3)	-	1.0 (1.0)	-	0.3 (0.3)	-	-	14.0 (3.8)	-	-	-	N/A	N/A	N/A	N/ A	N/A	N/A	N/ A	N/A	N/A	N/A
LC4	Revised	1.3 (0.7)	1.0 (0.6	-	-	2.0 (1.0)	-	-	-	-	1.3 (0.3)	-	3.3 (1.9)	0.3 (0.3)	0.3 (0.3)	3.0 (1.5)	0.3 (0.3)	-	0.3 (0.3)	-	1.3 (0.8)	-	-	-	6.0 (3.2)	0.7 (0.3)

Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
		Other soft corals	Sponges (branching)	Ascidians combined	Sponges (barrel)	Crinoids	Sponges (cup)	Sponges (digitate)	Sponges (fan)	Sponges (globular)	Gorgonians	Hydroids	Sea whips	Sponges (tubular)	*Turbinaria* spp.	Sponges (variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
	Chevron Australia (2012a)	1.0 (0.6)	3.0 (2.5)	0.3 (0.3)	-	5.0 (4.0)	-	0.7 (0.3)	-	2.0 (1.1)	2.0 (0.6)	-	2.7 (0.9)	3.0 (2.1)	2.0 (1.5)	2.0 (0.6)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LNGR1	Revised	-	0.3 (0.3)	-	-	0.7 (0.7)	-	-	0.3 (0.3)	-	-	-	2.3 (1.9)	-	1.3 (0.3)	1.7 (0.7)	0.3 (0.3)	-	-	-	2.6 (1.7)	0.3 (0.3)	-	-	0.3 (0.3)	0.3 (0.3)
	Chevron Australia (2012a)	0.3 (0.3)	0.7 (0.3)	-	-	0.7 (0.7)	-	-	-	2.3 (1.2)	-	-	3.7 (2.7)	0.3 (0.3)	0.7 (0.3)	2.0 (0.6)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LNGR2	Revised	-	1.3 (0.7)	-	-	-	0.3 (0.3)	0.3 (0.3)	1.0 (1.0)	0.3 (0.3)	0.3 (0.3)	-	3.7 (1.9)	-	3.7 (2.0)	1.7 (1.2)	-	0.3 (0.3)	-	-	3.66 (2.3)	-	-	-	-	0.3 (0.3)
	Chevron Australia (2012a)l	1.0 (0.6)	1.7 (1.2)	-	-	-	0.7 (0.3)	2.0 (2.0)	2.3 (1.3)	0.7 (0.7)	-	-	-	4.7 (1.9)	4.0 (1.1)	1.0 (0.6)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LNGR3	Revised	0.3 (0.3)	-	-	-	-	-	0.3 (0.3)	0.6 (0.6)	-	-	-	2.6 (0.6)	-	1 (0.0)	2.0 (1.0)	4 (1.0)	0.3 (0.3)	-	-	3.6 (0.8)	0.7 (0.7)	-	-	-	0.7 (0.7)
	Chevron Australia (2012a)	-	-	9.7 (0.7)	-	-	0.3 (0.3)	-	-	0.3 (0.3)	-	0.3 (0.3)	3.3 (0.9)	-	1.0 (0.6)	1.0 (0.6)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NEBWI2	Revised	-	0.3 (0.3)	-	-	1.0 (1.0)	0.3 (0.3)	-	2.0 (0.6)	0.3 (0.3)	0.3 (0.3)	-	0.7 (0.3)	0.3 (0.3)	3.3 (2.3)	3.3 (1.2)	-	0.3 (0.3)	-	-	1.6 (1.6)	-	-	0.3 (0.3)	-	-
	Chevron Australia (2012a)	-	0.7 (0.7)	0.7 (0.7)	-	2.0 (2.0)	1.0 (1.0)	0.3 (0.3)	3.7 (1.9)	-	1.7 (0.7)	-	1.3 (1.3)	-	0.7 (0.7)	2.0 (0.6)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
		Other soft corals	Sponges (branching)	Ascidians combined	Sponges (barrel)	Crinoids	Sponges (cup)	Sponges (digitate)	Sponges (fan)	Sponges (globular)	Gorgonians	Hydroids	Sea whips	Sponges (tubular)	*Turbinaria* spp.	Sponges (variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
TP1	Revised	0.3 (0.3)	-	-	0.3 (0.3)	0.3 (0.3)	-	-	-	-	-	0.3 (0.3)	-	-	0.3 (0.3)	1.0 (0.6)	0.3 (0.3)	-	-	-	0.3 (0.3)	-	-	-	-	-
	Chevron Australia (2012a)	-	-	0.3 (0.3)	0.3 (0.3)	-	-	0.3 (0.3)	0.3 (0.3)	-	-	0.3 (0.3)	0.7 (0.7)	-	0.3 (0.3)	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TP10	Revised	4.0 (0.6)	1.3 (0.9)	-	0.3 (0.3)	-	0.3 (0.3)	0.7 (0.7)	1.0 (1.0)	-	-	0.3 (0.3)	3.0 (1.5)	-	0.3 (0.3)	8.7 (5.2)	3.3 (0.3)	1.7 (1.2)	-	-	5.3 (3.9)	0.3 (0.3)	-	-	-	0.7 (0.3)
	Chevron Australia (2012a)	3.3 (0.9)	0.7 (0.3)	6.3 (1.9)	1.0 (0.6)	-	1.3 (0.9)	-	-	0.7 (0.3)	-	0.7 (0.3)	1.3 (0.3)	-	-	0.7 (0.7)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TP9	Revised	1.0 (1.0)	1.0 (0.6)	-	1.7 (0.7)	-	-	-	-	-	-	1.0 (1.0)	1.0 (0.6)	-	1.7 (1.2)	0.3 (0.3)	7.3 (2.3)	0.7 (0.7)	-	-	1.3 (0.3)	-	-	-	-	0.3 (0.3)
	Chevron Australia (2012a)	-	0.3 (0.3)	15.7 (1.2)	1.7 (0.3)	-	0.7 (0.3)	0.3 (0.3)	-	-	-	10.7 (3.8)	1.3 (0.3)	-	1.0 (1.0)	1.7 (0.7)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TPC1	Revised	-	2.7 (1.5)	-	0.3 (0.3)	0.7 (0.3)	-	0.7 (0.3)	1.3 (1.3)	-	0.3 (0.3)	-	3.0 (1.5)	0.3 (0.3)	1.3 (0.9)	4.0 (1.2)	0.7 (0.3)	-	-	-	2.3 (1.3)	-	-	0.3 (0.3)	-	-
	Chevron Australia (2012a)	0.3 (0.3)	0.7 (0.7)	-	-	0.7 (0.3)	0.3 (0.3)	1.7 (0.9)	2.3 (1.9)	-	0.3 (0.3)	-	6.3 (2.3)	0.7 (0.3)	2.0 (0.6)	4.0 (2.1)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Site	Estimate	Taxonomic Groups in Chevron Australia 2012a															New Taxonomic Groups used in this Report									
		Other soft corals	Sponges (branching)	Ascidians combined	Sponges (barrel)	Crinoids	Sponges (cup)	Sponges (digitate)	Sponges (fan)	Sponges (globular)	Gorgonians	Hydroids	Sea whips	Sponges (tubular)	*Turbinaria* spp.	Sponges (variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
TPC3	Revised	1.0 (1.0)	2.3 (0.9)	-	0.3 (0.3)	1.7 (1.2)	-	0.7 (0.3)	3.0 (0.6)	1.0 (1.0)	-	-	2.3 (0.3)	-	0.7 (0.3)	4.3 (0.3)	0.3 (0.3)	-	-	-	7.3 (4.9)	0.7 (0.3)	-	-	-	-
	Chevron Australia (2012a)	0.7 (0.3)	2.0 (0.6)	-	0.3 (0.3)	2.0 (1.2)	-	0.7 (0.3)	1.7 (0.7)	0.3 (0.3)	-	0.3 (0.3)	3.0 (1.5)	1.7 (0.9)	1.7 (1.2)	4.3 (0.7)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes: N/A indicates not included in original list of benthic macroinvertebrate categories; – indicates nil recorded.

Table A1.30 Differences in the Abundance of Benthic Macroinvertebrates (mean abundance per transect ± SE) between Chevron Australia (2012a) and this Report at Reference Sites

Site	Estimate	Taxonomic Groups in Chevron Australia 2011a															New Taxonomic Groups used in this Report									
		Other soft corals	Sponges (branching)	Ascidians combined	Sponges (barrel)	Crinoids	Sponges (cup)	Sponges (digitate)	Sponges (fan)	Sponges (globular)	Gorgonians	Hydroids	Sea whips	Sponges (tubular)	*Turbinaria* spp.	Sponges (variable)	Ascidians (colonial)	Ascidians (solitary)	Gastropods	Nudibranchs	Other hard corals	Sea cucumbers	Sea pens	Sea stars	Sea urchins	Unidentified
DGI0	Revised	1.3 (0.9)	4.3 (1.2)	-	-	0.3 (0.3)	-	2.7 (1.8)	-	-	-	0.3 (0.3)	0.7 (0.3)	-	1.0 (0.6)	4.7 (0.3)	-	-	-	-	1.6 (0.8)	0.7 (0.7)	-	-	-	1.3 (0.3)
	Original	1.7 (0.9)	5.0 (1.5)	-	1.0 (0.6)	0.3 (0.3)	0.7 (0.7)	4.3 (1.8)	-	0.3 (0.3)	-	0.3 (0.3)	0.7 (0.3)	0.3 (0.3)	1.3 (1.3)	3.0 (2.0)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DSR3	Revised	-	0.3 (0.3)	-	-	0.7 (0.3)	-	-	0.3 (0.3)	-	-	-	1.0 (1.0)	-	-	-	-	-	-	-	-	-	-	-	-	0.3 (0.3)
	Original	-	0.3 (0.3)	-	-	1.0 (0.6)	-	0.7 (0.3)	-	-	-	-	4.7 (0.3)	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DSR5	Revised	-	1.3 (0.9)	-	-	-	-	-	0.3 (0.3)	-	-	0.3 (0.3)	3.0 (1.0)	-	1.3 (0.3)	3.0 (1.2)	-	-	-	-	2.0 (0.0)	1.0 (0.6)	-	-	0.7 (0.7)	0.7 (0.3)
	Original	-	1.3 (0.9)	-	-	-	0.3 (0.3)	0.3 (0.3)	-	0.7 (0.3)	-	-	2.3 (0.9)	-	1.0 (0.6)	1.3 (0.7)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DSR6	Revised	2.3 (1.5)	-	-	0.3 (0.3)	-	-	-	0.7 (0.7)	0.3 (0.3)	-	2.3 (0.9)	-	-	4.7 (1.3)	1.0 (1.0)	1.7 (1.2)	-	-	-	43.0 (19.8)	0.3 (0.3)	-	-	-	0.3 (0.3)
	Original	-	-	-	0.7 (0.3)	-	-	-	-	0.3 (0.3)	-	1.3 (0.9)	-	0.3 (0.3)	0.3 (0.3)	0.7 (0.3)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes: N/A indicates not included in original list of benthic macroinvertebrate categories; – indicates nil recorded.

Table A1.31 Differences in Percentage Contribution of Benthic Macroinvertebrates (total number) to the Total Number of Benthic Macroinvertebrate Individuals found on Limestone and Soft Sediment, between the original Marine Baseline Data (Chevron Australia 2012a) and this Report

		Limestone		Soft Sediment	
		Chevron Australia 2012a	**Revised Data used in this Report**	**Chevron Australia 2012a**	**Revised Data used in this Report**
Taxonomic groups included in Chevron Australia (2012a)	Other soft corals	4.1	4.9	2.3	3.1
	Sponges (branching)	4	1.4	10.3	8.0
	Ascidians combined	25.2	10.0	1.1	6.9
	Sponges (barrel)	1.9	0.3	0.9	1.1
	Crinoids	2.3	1.4	5.1	3.3
	Sponges (cup)	1.6	0.9	2.7	0.4
	Sponges (digitate)	2.7	1.4	5.8	1.8
	Sponges (fan)	3.5	4.3	8.5	4.0
	Sponges (globular)	2.5	0.6	4.9	1.1
	Gorgonians	0.9	0.3	1.8	1.2
	Hydroids	17.4	1.4	2.1	1.8
	Sea whips	17.5	10.3	34.5	26.2
	Sponges (tubular)	1.1	0.3	2.4	1.3
	Turbinaria spp.	7.8	6.0	5.3	7.5
	Sponges (variable)	7.7	22.9	11.0	13.4
New taxonomic groups (this Report)	Ascidians (colonial)	N/A	6.6	N/A	6.5
	Ascidians (solitary)	N/A	3.4	N/A	0.4
	Gastropods	N/A	0.0	N/A	0.2
	Nudibranchs	N/A	0.6	N/A	0.0
	Other hard corals	N/A	25.5	N/A	11.6
	Sea cucumbers	N/A	2.9	N/A	1.3
	Sea pens	N/A	0.0	N/A	0.0
	Sea stars	N/A	0.3	N/A	0.2
	Sea urchins	N/A	1.1	N/A	3.1
	Unidentified	N/A	3.2	N/A	2.5

Note: N/A indicates not included in original list of benthic macroinvertebrate categories. Counts of macroinvertebrate species from site DSR6 were excluded from the Revised columns in this table, as DSR6 was classified as a coral site for the revised analysis

Table A1.32 Difference in Classification of Surficial Sediments between Chevron Australia (2012a) and this Report

Area	Description of Surficial Sediment Characteristics	
	Chevron Australia (2012a)	**Revised Data used in this Report**
General Description	The sediments in the waters surrounding Barrow Island were characterised by six sediment types (Sand, gravelly Sand, sandy Gravel, muddy Sand, gravelly muddy Sand, muddy sandy Gravel). Total organic carbon varied between <0.05% and 0.8% and total inorganic carbon between 9.3% and 11.4%. Sediments on the east coast of Barrow Island were generally more variable than on the west coast, including higher proportions of mud and gravel	The sediments in the waters surrounding Barrow Island were characterised by six sediment types (Sand, gravelly Sand, sandy Gravel, muddy Sand, gravelly muddy Sand, muddy sandy Gravel). Total organic carbon varied between <0.05% and 0.8% and total inorganic carbon between 5.4 % and 11.4%. Sediments on the east coast of Barrow Island were generally more variable than on the west coast, including higher proportions of mud and gravel.
Surficial Sediment Characteristics within the Zones of High Impact and Zones of Moderate Impact Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal		
Sites in the Vicinity of the MOF and Causeway and the LNG Jetty Access Channel		
General Description	Sediments in the shallow inshore area on the east coast predominantly comprised of a thin veneer of gravelly Sand overlying a solid limestone pavement. The sediments were fine-to-coarse grained sands, with gravel fractions accounting for up to 20% of the volume of particles. The total organic carbon in the sediment varied across the MOF and LNG Jetty area, with no clear trends in the distribution of organic carbon content.	Sediments in the shallow inshore area on the east coast predominantly comprised of a thin veneer of gravelly Sand overlying a solid limestone pavement. Surficial sediments at the majority (approximately 85%) of sites within the vicinity of the MOF and LNG Jetty had >70% sand and <10% and <20% mud and gravel respectively. Sediments collected in the vicinity of the MOF were dominated by gravelly Sand, with Sand, gravelly muddy Sand, muddy Sand, and sandy Gravel also occurring at four sites. Sediments collected near the LNG Jetty were characterised by Sand and gravelly Sand, with approximately 30% of samples a variety of sandy Gravel, muddy Sand, and gravelly muddy Sand. The total organic carbon in the sediment varied across the MOF and LNG Jetty area, with no clear trends in the distribution of organic carbon content.
Dredge Channel	The sediments within the channel to the south-east were varied, although fine-to-coarse grained sand fractions were most common, with <5% of particles classified as mud or gravel in the middle of the channel where tidal currents were the greatest. On the eastern boundary of the channel, the sediments were characterised by higher mud fractions, with muddy Sand the dominant sediment type. Clay and silt fractions accounted for >10% of the volume of particles, indicating that water	Sediments in the channel were varied, although fine-to-coarse grained sand fractions were most common, with <10% of particles classified as mud or gravel at the majority (approximately 85%) of sites.

Area	Description of Surficial Sediment Characteristics	
	Chevron Australia (2012a)	Revised Data used in this Report
	circulation patterns on the eastern edge of the channel may be conducive to deposition of finer particles.	
East Barrow Ridge	Sediments on the East Barrow Ridge mainly comprised of Gravel (>40%) and sand fractions of varying depths overlying the limestone pavement ridge. The high gravel content was likely due to the presence of shell grit and coral rubble generated by the bombora fields and scattered coral colonies that occur along the ridge.	Sediments within the ZoHI and ZoMI on the East Barrow Ridge mainly comprised sand (66–81%) and gravel (14–32%) fractions of varying depths overlying the limestone pavement ridge. The high gravel content was likely due to the presence of shell grit and coral rubble generated by the bombora fields and scattered coral colonies that occur along the ridge.
Sites in the Vicinity of the Dredge Spoil Disposal Ground		
Dredge Spoil Disposal Ground	Four sediment types occurred within the Dredge Spoil Disposal Ground: Sand, gravelly Sand, muddy Sand and sandy Gravel. Fine-to-coarse grained sand fractions characterised these sediment types with sediments comprised of >80% sand, while the mud and gravel fractions were more variable among sites. The variation observed in sediment characteristics across the Dredge Spoil Disposal Ground indicates that localised hydrodynamic effects may lead to deposition of finer sediments in some areas. The level of organic carbon in the sediments also varied across the Dredge Spoil Disposal Ground.	Four sediment types occurred within the Dredge Spoil Disposal Ground: Sand, gravelly Sand, muddy Sand and sandy Gravel. Fine-to-coarse grained sand fractions characterised these sediment types with the majority (approximately 90%) of samples comprising >75% sand, while the mud and gravel fractions were more variable among sites. The variation observed in sediment characteristics across the Dredge Spoil Disposal Ground indicates that localised hydrodynamic effects may lead to deposition of finer sediments in some areas. The level of organic carbon in the sediments also varied across the Dredge Spoil Disposal Ground.
Area at Risk of Material or Serious Environmental Harm due to the Marine Upgrade of the Existing WAPET Landing		
	South of WAPET Landing, the sediment was made up of fine sands overlain with coarser material made up of shells, shell grit and scattered rubble. The sediments adjacent to the groyne were predominantly fine sands with occasional shells and rubble. Adjacent to the WAPET Landing Barge Berth the sediments comprised a thin veneer of fine-to-coarse grained sand with shell grit, while adjacent to the Barge Landing Ramp the sediments were predominantly fine-to-medium grained sands with some shells.	South of WAPET Landing, the sediment was made up of fine sands overlain with coarser material made up of shells, shell grit and scattered rubble. Within the vicinity of WAPET Landing, sediments were classified as gravelly Sand and contained more than 80% sand (the majority medium to coarse), 7–16% gravel, and only traces of mud (<2%).

Area	Description of Surficial Sediment Characteristics	
	Chevron Australia (2012a)	Revised Data used in this Report
Zones of Influence Associated with the Generation of Turbidity and Sediment Deposition from Dredging and Dredge Spoil Disposal, and Reference Sites not at Risk of Material or Serious Environmental Harm due to the Construction or Operation of the Marine Upgrade of the Existing WAPET Landing, MOF, LNG Jetty, or Dredge Spoil Disposal Ground and in Regionally Significant Areas		
Coral Monitoring Sites	Five sediment types characterised the sediments at the coral monitoring sites: Sand, gravelly Sand, sandy Gravel, gravelly muddy Sand, muddy sandy Gravel. The sediments at Ant Point Reef, Southern Lowendal Shelf, Ah Chong, Biggada Reef, Dugong Reef, Batman Reef, and Southern Barrow Shoals were typically characterised by high proportions of coarse sand (32–72%) and gravel (5–53%) fractions, reflecting the coral rubble and shell grit generated from the reef areas. The sediments at Dugong Reef had the highest percentage by volume of gravel; the lowest gravel content was recorded at Ah Chong and Southern Lowendal Shelf. Sediments at Batman Reef and Biggada Reef had the highest content of silts (10% and 13% respectively) and fine sands (14% and 12% respectively). Higher proportions of finer particles in the sediments at these sites may be a reflection of the reef structure causing localised hydrodynamic conditions favourable to deposition. The total organic carbon content varied among the sites.	Five sediment types characterised the sediments at the coral monitoring sites: Sand, gravelly Sand, sandy Gravel, gravelly muddy Sand, muddy sandy Gravel. The sediments at Ant Point Reef, Southern Lowendal Shelf, Ah Chong, Biggada Reef, Dugong Reef, Batman Reef, LNG3, and Southern Barrow Shoals were typically characterised by high proportions of coarse sand (32–72%) and gravel (5–53%) fractions, reflecting the coral rubble and shell grit generated from the reef areas. The sediments at Dugong Reef had the highest percentage by volume of gravel and the lowest gravel content was recorded at Ah Chong. Sediments at Batman Reef and Biggada Reef had the highest content of silts (10% and 13% respectively) as did LNG3 fine sands (14%, 12%, and 13% respectively). Higher proportions of finer particles in the sediments at these sites may be a reflection of the reef structure causing localised hydrodynamic conditions favourable to deposition. The total organic carbon content varied between 0.25% and 0.36% among the sites.
Other Sites	The sediments in the deeper water areas east of the East Barrow Ridge were mostly sands of varying thickness. The sediments generally comprised only fine-to-coarse grained sand fractions, with <5% of particles classified as mud or gravel. Further inshore, at sites with a shallow underlying limestone pavement, higher gravel fractions were present. Sites on the north-eastern and south-western boundaries of the East Barrow Ridge had higher mud content where the sediments accumulated in deeper layers above the hard pavement. Mud deposits were also recorded at the shallow inshore sites between Double Island and the MOF and at the southern end of the channel adjacent to the East Barrow Ridge. The total organic carbon content varied among the sites.	The sediments in the deeper water areas south-east of the East Barrow Ridge were mostly sands of varying thickness (approximately 90% of samples were >70% sand). The sediments generally comprised fine-to-coarse grained sand fractions, with <10% of particles classified as mud (approximately 90% of samples) and <20% as gravel (approximately 85% of samples). Further inshore along the east coast shelf at sites with a shallow underlying limestone C36pavement, higher gravel fractions were present. Mud deposits were also recorded at some shallow inshore sites between Double Island and the MOF and at the southern end of the channel adjacent to the East Barrow Ridge. The total organic carbon content varied among the sites.

Note: Results presented in full as per Marine Baseline Report (Chevron Australia 2012a) so as not to change the meaning or context of data.

Appendix 2 Statistical Analysis Process for Indicator Species in Coral Habitats

Table A2.1 Multivariate PERMANOVA Results for Relative Abundance of *Acanthurus grammoptilus* for Coral Habitat (Four-factor Design with Year Pooled) for MOF and Ref Only

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	0.20	0.10	0.66	0.539	9952
IvR	1	0.14	0.14	0.08	0.783	9814
Zone(IvR)	2	2.06	1.03	0.61	0.586	9954
Survey×IvR	*2*	*0.26*	*0.13*	*0.83*	*0.447*	*9954*
Site(Zone(IvR))	7	11.64	1.66	4.08	<0.001	9947
Survey×Zone(IvR)	*4*	*2.60*	*0.65*	*4.30*	***0.020***	*9954*
Survey×Site(Zone(IvR))	14	2.08	0.15	0.37	0.983	9930
Res	170	69.32	0.41			
Total	202	89.18				

Notes: Bold font in P-value column = significant difference for term of interest; The term 'MOF' is representative of the combined development at the Materials Offloading Facility, Causeway and LNG Jetty Access Channel.

Table A2.2 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × Zone(IvR) for Relative Abundance of *Acanthurus grammoptilus* for MOF and Ref Only for Coral Habitat

Zone	t	P-value	Permutations	P(MC)
ZoHI				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.92	0.520	6	0.385
Post-Development Survey Year 2, Marine Baseline Program	0.72	0.494	156	0.476
Post-Development Survey Year 1, Marine Baseline Program	1.55	0.177	89	0.141
ZoMI				
Post-Development Survey Year 2, Post-Development Survey Year 1	2.78	0.250	3	0.224
Post-Development Survey Year 2, Marine Baseline Program	1.08	0.503	6	0.479
Post-Development Survey Year 1, Marine Baseline Program	0.10	1.000	6	0.941
ZoI				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.12	0.867	425	0.906
Post-Development Survey Year 2, Marine Baseline Program	2.35	0.114	6279	0.102
Post-Development Survey Year 1, Marine Baseline Program	5.67	**0.028**	6031	0.010

Zone	t	P-value	Permutations	P(MC)
Reference				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.02	0.911	416	0.982
Post-Development Survey Year 2, Marine Baseline Program	0.68	0.510	6222	0.535
Post-Development Survey Year 1, Marine Baseline Program	0.31	0.780	6314	0.779

Notes: Bold font in P-value column = significant difference for term of interest; The term 'MOF' is representative of the combined development at the Materials Offloading Facility, Causeway and LNG Jetty Access Channel.

Table A2.3 Multivariate PERMANOVA Results for Relative Abundance of *Choerodon cauteroma* for Coral Habitat (Two-factor Design with Year, Site and Zone Pooled)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	0.66	0.33	1.11	0.332	9954
IvR	1	1.15	1.15	3.86	0.053	9817
Survey×IvR	*2*	*1.96*	*0.98*	*3.29*	***0.039***	*9962*
Res	205	61.16	0.30			
Total	210	66.71				

Notes: Bold font in P-value column = significant difference for term of interest

Table A2.4 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × IvR for Relative Abundance of *Choerodon cauteroma* for Coral Habitat

Zone	t	P-value	Permutations	P(MC)
Impact				
Post-Development Survey Year 2, Post-Development Survey Year 1	2.14	**0.038**	942	0.040
Post-Development Survey Year 2, Marine Baseline Program	0.85	0.401	2487	0.398
Post-Development Survey Year 1, Marine Baseline Program	3.31	**0.002**	2986	0.002
Reference				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.06	1.000	22	0.955
Post-Development Survey Year 2, Marine Baseline Program	0.86	0.407	179	0.393
Post-Development Survey Year 1, Marine Baseline Program	0.80	0.424	151	0.426

Notes: Bold font in P-value column = significant difference for term of interest

Table A2.5 Multivariate PERMANOVA Results for Relative Abundance of *Choerodon schoenleinii* for Coral Habitat (Three-factor Design with Year and Site Pooled)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	1.26	0.63	3.98	0.021	9947
IvR	1	0.09	0.09	0.59	0.444	9802
Zone(IvR)	2	0.23	0.12	0.74	0.478	9955
Survey×IvR	*2*	*1.13*	*0.56*	*3.57*	***0.029***	*9952*
Survey×Zone(IvR)	*4*	*0.91*	*0.23*	*1.44*	*0.224*	*9952*
Res	199	31.42	0.16			
Total						

Notes: Bold font in P-value column = significant difference for term of interest

Table A2.6 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × IvR for Relative Abundance of *Choerodon schoenleinii* for Coral Habitat

Zone	t	P-value	Permutations	P(MC)
Impact				
Post-Development Survey Year 2, Post-Development Survey Year 1	3.26	**0.001**	9835	0.002
Post-Development Survey Year 2, Marine Baseline Program	0.54	0.594	9842	0.594
Post-Development Survey Year 1, Marine Baseline Program	3.19	**0.002**	9840	0.002
Reference				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.58	0.555	152	0.565
Post-Development Survey Year 2, Marine Baseline Program	1.51	0.137	772	0.138
Post-Development Survey Year 1, Marine Baseline Program	1.00	0.340	324	0.321

Table A2.7 Multivariate PERMANOVA Results for Relative Abundance of *Pentapodus emeryii* for Coral Habitat (Five-factor Design)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	0.31	0.15	2.02	0.238	9959
IvR	1	0.58	0.58	0.44	0.807	9964
Year(Survey)	1	0.04	0.04	0.20	0.680	9877
Zone(IvR)	2	0.19	0.09	0.21	0.970	9953
Survey×IvR	*2*	*0.45*	*0.23*	*1.00*	*0.544*	*9965*
Site(Zone(IvR))	8	12.70	1.59	6.57	0.015	9957
Survey×Zone(IvR)	*4*	*5.07*	*1.27*	*5.72*	***0.005***	*9963*
Year(Survey)×IvR	1	0.28	0.28	1.22	0.316	9840
Survey×Site(Zone(IvR))	16	2.61	0.16	0.73	0.711	9957

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Year(Survey)×Zone(IvR)	2	0.16	0.08	0.39	0.655	9940
Year(Survey)×Site(Zone(IvR))**	6	1.38	0.23	0.84	0.541	9948
Res	165	45.23	0.27			
Total	210	71.86				

*Notes: Bold font in P-value column = significant difference for term of interest; ** = Term has one or more empty cells*

Table A2.8 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × Zone (IvR) for Relative Abundance of *Pentapodus emeryii* for Coral Habitat

Zone	t	P-value	Permutations	P(MC)
ZoHI				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.66	0.607	9	0.521
Post-Development Survey Year 2, Marine Baseline Program	50.28	0.335	3	**0.012**
Post-Development Survey Year 1, Marine Baseline Program	72.32	0.326	3	**0.008**
ZoMI				
Post-Development Survey Year 2, Post-Development Survey Year 1	5.09	0.240	3	0.126
Post-Development Survey Year 2, Marine Baseline Program	1.70	0.271	16	0.378
Post-Development Survey Year 1, Marine Baseline Program	3.75	0.135	16	0.165
ZoI				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.52	0.622	8339	0.629
Post-Development Survey Year 2, Marine Baseline Program	1.64	0.197	9963	0.331
Post-Development Survey Year 1, Marine Baseline Program	1.15	0.414	9958	0.411
Reference				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.33	0.740	425	0.756
Post-Development Survey Year 2, Marine Baseline Program	0.68	0.721	9936	0.689
Post-Development Survey Year 1, Marine Baseline Program	0.69	0.718	9942	0.663

Table A2.9 Multivariate PERMANOVA Results for Relative Abundance of *Plectropomus* spp. for Coral Habitat (Three-factor Design with Year and Site Pooled)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	3.13	1.57	8.88	<0.001	9952
IvR	1	0.01	0.01	0.05	0.824	9829

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Zone(IvR)	2	3.32	1.66	9.41	<0.001	9943
SurveyxIvR	2	1.06	0.53	3.01	**0.055**	9942
SurveyxZone(IvR)	4	1.87	0.47	2.65	**0.039**	9952
Res	199	35.08	0.18			
Total	210	43.62				

Notes: Bold font in P-value column = significant difference for term of interest

Table A2.10 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × Zone (IvR) for Relative Abundance of *Plectropomus* spp. for Coral Habitat

Zone	t	P-value	Permutations	P(MC)
ZoHI				
Post-Development Survey Year 2, Post-Development Survey Year 1	1.33	0.406	4	0.224
Post-Development Survey Year 2, Marine Baseline Program	1.86	0.054	71	0.086
Post-Development Survey Year 1, Marine Baseline Program	3.92	**0.005**	56	**0.002**
ZoMI				
Post-Development Survey Year 2, Post-Development Survey Year 1	0.17	0.970	79	0.869
Post-Development Survey Year 2, Marine Baseline Program	1.03	0.376	295	0.307
Post-Development Survey Year 1, Marine Baseline Program	1.83	0.094	141	0.080
ZoI				
Post-Development Survey Year 2, Post-Development Survey Year 1	1.89	0.067	2209	0.068
Post-Development Survey Year 2, Marine Baseline Program	0.17	0.872	4343	0.867
Post-Development Survey Year 1, Marine Baseline Program	2.57	**0.013**	2922	**0.013**
Reference				
Post-Development Survey Year 2, Post-Development Survey Year 1	2.51	**0.017**	723	**0.017**
Post-Development Survey Year 2, Marine Baseline Program	1.33	0.190	2924	0.188
Post-Development Survey Year 1, Marine Baseline Program	1.27	0.215	2605	0.216

Notes: Bold font in P-value column = significant difference for term of interest

Table A2.11 Multivariate PERMANOVA Results for Relative Abundance of *Symphorus nematophorus* for Coral Habitat (Four-factor Design with Year Pooled)

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
Survey	2	0.31	0.15	0.72	0.498	9958
IvR	1	0.58	0.58	0.53	0.486	9813
Zone(IvR)	2	0.60	0.30	0.28	0.726	9946
SurveyxIvR	*2*	*1.80*	*0.90*	*4.09*	***0.039***	*9942*
Site(Zone(IvR))	8	8.43	1.05	4.47	<0.001	9945

Source	df	SS	MS	Pseudo-F	P(perm)	Permutations
SurveyxZone(IvR)	*4*	*0.99*	*0.25*	*1.15*	*0.368*	*9953*
SurveyxSite(Zone(IvR))	16	3.44	0.21	0.91	0.561	9924
Res	175	41.23	0.24			
Total	210	58.25				

Notes: Bold font in P-value column = significant difference for term of interest

Table A2.12 Pair-wise Comparisons in PERMANOVA for the Significant Interaction Term Survey × (IvR) for Relative Abundance of *Symphorus nematophorus* for Coral Habitat

Zone	t	P(perm)
Impact		
Post-Development Survey Year 2, Post-Development Survey Year 1	2.47	0.085
Post-Development Survey Year 2, Marine Baseline Program	0.38	0.726
Post-Development Survey Year 1, Marine Baseline Program	2.00	0.099
Reference		
Post-Development Survey Year 2, Post-Development Survey Year 1	1.53	0.218
Post-Development Survey Year 2, Marine Baseline Program	3.83	**0.010**
Post-Development Survey Year 1, Marine Baseline Program	2.47	0.179

Notes: Bold font in P-value column = significant difference for term of interest

Appendix 3 Demersal Fish Species

Table A3.1 Fish Species (listed alphabetically by genus) Recorded from a Total of 761 stereo-BRUV Deployments conducted off Barrow Island from the 2008 and 2009 Marine Baseline Program and the 2011 and 2012 Post-Development Surveys

Family	Species	Common Name	Authority	2008		2009		2011		2012		Habitat				
				Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Coral	Macroalgae	Sand	Seagrass	Sessile Invertebrates
Balistidae	*Abalistes stellatus*	Starry Triggerfish*	(Anonymous, 1798)	29	14.7	23	9.6	25	10.8	25	8.5	x	x	x	x	x
Pomacentridae	*Abudefduf bengalensis*	Bengal Sergeant	(Bloch, 1787)	109	24.7	94	17.4	170	18.8	112	17.4	x	x	x	x	x
Pomacentridae	*Abudefduf sexfasciatus*	Scissortail Sergeant	(Lacépède, 1801)	49	2.0	58	5.1	1	0.5	1	0.5	x				
Pomacentridae	*Acanthochromis polyacanthus*	Spiny Puller	(Bleeker, 1855)	3	1.3	3	1.7					x				x
Acanthuridae	*Acanthurus dussumieri*	Pencil Surgeonfish	Valenciennes, 1835	10	4.0	1	0.6			7	2.3	x				
Acanthuridae	*Acanthurus grammoptilus*	Inshore Surgeonfish	Richardson, 1843	88	23.3	149	22.5	143	22.1	200	23.0	x	x	x		x
Acanthuridae	*Acanthurus maculiceps*	Spotted-Face Surgeonfish	(Ahl, 1923)	1	0.7	3	0.6					x				
Acanthuridae	*Acanthurus nigricans*	Velvet Surgeonfish	(Linnaeus, 1758)	0		2	0.6						x			
Acanthuridae	*Acanthurus triostegus*	Convict Surgeonfish	(Linnaeus, 1758)	1	0.7					11	0.5	x				
Monacanthidae	*Acreichthys tomentosus*	Bristle-Tail Leatherjacket	(Linnaeus, 1758)	0		2	0.6			2	0.5		x	x		
Centriscidae	*Aeoliscus strigatus*	Razorfish	(Günther, 1860)	0				19	0.5					x		
Myliobatidae	*Aetobatus ocellatus*	Whitespotted Eagle Ray	(Kuhl, 1823)	0				1	0.5	3	0.9	x				
Carangidae	*Alectis ciliaris*	Pennantfish	(Bloch, 1787)	1	0.7			1	0.5	1	0.5	x				
Carangidae	*Alepes* spp	Small Mouthed Scad		0				1	0.5	37	2.8	x	x	x	x	
Monacanthidae	*Aluterus scriptus*	Scrawled Leatherjacket	(Osbeck, 1765)	1	0.7			3	1.4	1	0.5	x		x		
Pomacentridae	*Amblyglyphidodon batunai*	Batuna Damsel	Allen, 1995	1	0.7							x				
Pomacentridae	*Amblyglyphidodon curacao*	Staghorn Damsel	(Bloch, 1787)	1	0.7			1	0.5	6	0.5	x				
Pomacentridae	*Amphiprion clarkii*	Clark's Anemonefish	(Bennett, 1830)	1	0.7			3	0.5	8	1.9		x	x		x
Monacanthidae	*Anacanthus barbatus*	Bearded Leatherjacket	Gray, 1831	1	0.7	1	0.6	2	0.5	1	0.5			x		x
Labridae	*Anampses geographicus*	Scribbled Wrasse	Valenciennes, 1840	1	0.7							x				

Family	Species	Common Name	Authority	2008		2009		2011		2012		Habitat				
				Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Coral	Macroalgae	Sand	Seagrass	Sessile Invertebrates
Labridae	*Anampses lennardi*	Blue-And-Yellow Wrasse	Scott, 1959	48	13.3	36	9.0	20	6.6	13	3.8	x	x	x		x
Labridae	*Anampses meleagrides*	Speckled Wrasse	Valenciennes, 1840	8	4.0			12	4.7	23	7.5	x	x			
Serranidae	*Anyperodon leucogrammicus*	Whitelined Rockcod*	(Valenciennes, 1828)	0				1	0.5			x				
Apogonidae	*Apogon* spp	Cardinalfish Species		40	0.7	52	1.7	72	2.3			x	x			
Ariidae	*Arius thalassinus*	Giant Sea Catfish	(Rüppell, 1837)	0				1	0.5			x				
Tetraodontidae	*Arothron caeruleopunctatus*	Bluespotted Puffer	Matsuura, 1994	0				2	0.9	2	0.9	x		x		
Tetraodontidae	*Arothron hispidus*	Stars And Stripes Puffer	(Linnaeus, 1758)	0				2	0.9			x	x			
Tetraodontidae	*Arothron nigropunctatus*	Blackspotted Puffer	(Bloch & Schneider, 1801)	0						1	0.5		x			
Tetraodontidae	*Arothron stellatus*	Starry Puffer	(Bloch & Schneider, 1801)	0		1	0.6	2	0.9			x	x	x		
Blenniidae	*Aspidontus dussumieri*	Lance Blenny	(Valenciennes, 1836)	0		1	0.6					x				
Blenniidae	*Aspidontus taeniatus*	False Cleanerfish	Quoy & Gaimard, 1834	1	0.7	16	5.1	12	2.3			x	x			
Carangidae	*Atule mate*	Barred Yellowtail Scad	(Cuvier, 1833)	116	11.3	195	6.7	317	11.7	187	9.9	x	x	x	x	x
Balistidae	*Balistoides viridescens*	Titan Triggerfish	(Bloch & Schneider, 1801)	0				1	0.5			x				
Blenniidae	*Blenniidae* spp	Blenny Species		0		2	1.1	16	3.3	1	0.5	x	x			x
Labridae	*Bodianus bilunulatus*	Saddleback Pigfish*	(Lacépède, 1801)	0		1	0.6					x				
Labridae	*Bodianus diana*	Diana's Pigfish*	(Lacépède, 1801)	1	0.7							x				
Caesionidae	*Caesio caerulaurea*	Goldband Fusilier	Lacépède, 1801	100	0.7	72	2.8	20	0.9			x				
Caesionidae	*Caesio cuning*	Yellowtail Fusilier	(Bloch, 1791)	422	14.0	588	11.2	397	6.1	213	4.7	x		x		x
Caesionidae	*Caesio teres*	Blue Fusilier	Seale, 1906	78	4.7			151	4.2	133	2.3	x	x	x		
Tetraodontidae	*Canthigaster coronata*	Crowned Toby	(Vaillant & Sauvage, 1875)	1	0.7	1	0.6						x			x
Carangidae	*Carangoides chrysophrys*	Longnose Trevally*	(Cuvier, 1833)	1	0.7	1	0.6	2	0.5			x		x		x
Carangidae	*Carangoides ferdau*	Blue Trevally*	(Forsskål, 1775)					5	0.5	4	1.4	x	x			
Carangidae	*Carangoides fulvoguttatus*	Gold-Spotted Trevally*	(Forsskål, 1775)	172	24.7	214	42.1	294	43.7	410	41.3	x	x	x	x	x
Carangidae	*Carangoides gymnostethus*	Bludger Trevally*	(Cuvier, 1833)	4	1.3	9	1.7	215	13.1	312	11.7	x	x	x	x	x
Carangidae	*Carangoides hedlandensis*	Bumpnose Trevally*	(Whitley, 1934)			8	1.1	26	7.0	10	1.9	x		x		x
Carangidae	*Carangoides orthogrammus*	Thicklip Trevally*	(Jordan & Gilbert, 1882)	4	0.7	4	1.1							x		x

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Carangidae	*Carangoides uii*	Japanese Trevally*	Wakiya, 1924			3	0.6							x		
Carangidae	*Caranx ignobilis*	Giant Trevally*	(Forsskål, 1775)	5	2.0	1	0.6	129	13.1	52	7.5	x		x	x	x
Carangidae	*Caranx melampygus*	Bluefin Trevally	Cuvier, 1833							1	0.5	x				
Carangidae	*Caranx sexfasciatus*	Bigeye Trevally*	Quoy & Gaimard, 1825			1	0.6			8	0.9			x	x	
Carangidae	*Caranx tille*	Tille Trevally*	Cuvier, 1833	1	0.7									x		
Carcharhinidae	*Carcharhinus amblyrhynchoides*	Graceful Shark*	(Whitley, 1934)					4	1.4			x		x		x
Carcharhinidae	*Carcharhinus amblyrhynchos*	Grey Reef Shark*	(Bleeker, 1856)	1	0.7	1	0.6	7	1.9	4	1.9	x	x			
Carcharhinidae	*Carcharhinus cautus*	Nervous Shark*	(Whitley, 1945)							1	0.5				x	
Carcharhinidae	*Carcharhinus falciformis*	Silky Shark*	(Bibron, 1839)			1	0.6							x		
Carcharhinidae	*Carcharhinus leucas*	Bull Shark*	(Valenciennes, 1839)	1	0.7											x
Carcharhinidae	*Carcharhinus limbatus*	Common Blacktip Shark*	(Valenciennes, 1839)	1	0.7			25	8.5	19	8.0	x	x	x		x
Carcharhinidae	*Carcharhinus melanopterus*	Blacktip Reef Shark*	(Quoy & Gaimard, 1824)	10	6.7	5	2.8	12	5.2	7	2.3	x	x			x
Carcharhinidae	*Carcharhinus plumbeus*	Sandbar Shark*	(Nardo, 1827)	2	1.3					1	0.5	x	x			x
Carcharhinidae	*Carcharhinus sorrah*	Spot-Tail Shark*	(Valenciennes, 1839)	1	0.7					1	0.5			x		
Serranidae	*Cephalopholis argus*	Peacock Rockcod*	Bloch & Schneider, 1801	1	0.7	1	0.6	4	1.4			x				
Serranidae	*Cephalopholis boenak*	Brownbarred Rockcod*	(Bloch, 1790)	10	4.7	7	2.2	13	4.7	14	5.2	x		x	x	
Serranidae	*Cephalopholis miniata*	Coral Rockcod*	(Forsskål, 1775)	13	6.0	13	5.1	1	0.5	17	6.1	x		x		
Scaridae	*Cetoscarus bicolor*	Bicolour Parrotfish	(Rüppell, 1829)	1	0.7							x				
Monacanthidae	*Chaetodermis penicilligera*	Tasselled Leatherjacket	(Cuvier, 1817)	1	0.7					1	0.5			x	x	
Chaetodontidae	*Chaetodon adiergastos*	Philippine Butterflyfish	Seale, 1910	1	0.7	2	1.1			3	1.4	x				
Chaetodontidae	*Chaetodon aureofasciatus*	Goldstripe Butterflyfish	Macleay, 1878	38	14.0	52	13.5	44	12.7	38	10.3	x	x			x
Chaetodontidae	*Chaetodon auriga*	Threadfin Butterflyfish	Forsskål, 1775	11	4.0	4	1.7	1	0.5	10	3.3	x	x			
Chaetodontidae	*Chaetodon bennetti*	Eclipse Butterflyfish	Cuvier, 1831							1	0.5	x				
Chaetodontidae	*Chaetodon citrinellus*	Citron Butterflyfish	Cuvier, 1831							1	0.5	x				
Chaetodontidae	*Chaetodon lineolatus*	Lined Butterflyfish	Cuvier, 1831	18	7.3	22	6.2	17	5.2	27	7.5	x				
Chaetodontidae	*Chaetodon lunula*	Racoon Butterflyfish	(Lacépède, 1803)	2	0.7	3	1.1	2	0.5	6	1.9	x				

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Chaetodontidae	*Chaetodon lunulatus*	Pinstripe Butterflyfish	Quoy & Gaimard, 1824	10	2.7	1	0.6	3	0.9	7	1.4	x				
Chaetodontidae	*Chaetodon marginalis*	Margined Coralfish	Richardson1842			1	0.6					x				
Chaetodontidae	*Chaetodon oxycephalus*	Spotnape Butterflyfish	Bleeker, 1853							1	0.5	x				
Chaetodontidae	*Chaetodon plebeius*	Bluespot Butterflyfish	Cuvier, 1831	3	2.0	7	2.8	7	2.3	3	1.4	x				
Chaetodontidae	*Chaetodon speculum*	Ovalspot Butterflyfish	Cuvier, 1831	1	0.7	1	0.6	7	1.9	4	0.9	x				
Chaetodontidae	*Chaetodon trifascialis*	Chevron Butterflyfish	Quoy & Gaimard, 1825					1	0.5			x				
Chaetodontidae	*Chaetodon vagabundus*	Vagabond Butterflyfish	Linnaeus, 1758							1	0.5	x				
Pomacanthidae	*Chaetodontoplus duboulayi*	Scribbled Angelfish	(Günther, 1867)	63	32.0	56	20.2	54	18.8	51	19.2	x	x	x	x	x
Pomacanthidae	*Chaetodontoplus personifer*	Yellowtail Angelfish	(McCulloch, 1914)	6	2.0	7	2.2	2	0.9	3	1.4	x	x	x		x
Labridae	*Cheilinus chlorourus*	Floral Maori Wrasse*	(Bloch, 1791)	1	0.7	2	1.1	14	5.2	2	0.9	x	x			
Labridae	*Cheilinus fasciatus*	Redbreast Maori Wrasse*	(Bloch, 1791)	2	0.7								x			
Labridae	*Cheilinus trilobatus*	Tripletail Maori Wrasse*	Lacépède, 1801	11	7.3	1	0.6	5	2.3	2	0.9	x	x			
Labridae	*Cheilio inermis*	Sharpnose Wrasse	(Forsskål, 1775)	9	5.3	18	8.4	10	4.2	12	3.8	x	x			
Apogonidae	*Cheilodipterus artus*	Wolf Cardinalfish	Smith, 1961			4	0.6					x				
Chaetodontidae	*Chelmon marginalis*	Margined Coralfish	Richardson, 1842	42	18.7	37	13.5	41	13.6	41	13.1	x	x	x	x	x
Diodontidae	*Chilomycterus reticulatus*	Spotfin Porcupinefish	(Linnaeus, 1758)							1	0.5		x			
Hemiscylliidae	*Chiloscyllium punctatum*	Grey Carpetshark	Müller & Henle, 1838	11	7.3	2	1.1	15	7.0	8	3.8	x	x	x		x
Scaridae	*Chlorurus bleekeri*	Bleeker's Parrotfish	(de Beaufort, 1940)	1	0.7			1	0.5			x				
Scaridae	*Chlorurus microrhinos*	Steephead Parrotfish	(Bleeker, 1854)	4	2.7	14	5.6	15	5.2	25	3.8	x	x			
Scaridae	*Chlorurus sordidus*	Greenfin Parrotfish	(Forsskål, 1775)	7	3.3	75	6.7	39	6.1	24	3.3	x	x			
Labridae	*Choerodon cauteroma*	Bluespotted Tuskfish*	Gomon & Allen, 1987	117	44.0	195	43.3	153	31.9	159	38.0	x	x	x	x	x
Labridae	*Choerodon cephalotes*	Purple Tuskfish*	(Castelnau, 1875)	5	3.3	14	7.9	11	3.8	14	4.7	x	x	x		x
Labridae	*Choerodon cyanodus*	Blue Tuskfish*	(Richardson, 1843)	182	58.0	240	51.7	271	52.6	245	52.6	x	x	x	x	x
Labridae	*Choerodon schoenleinii*	Blackspot Tuskfish*	(Valenciennes, 1839)	122	51.3	128	45.5	155	46.5	176	48.4	x	x	x	x	x
Labridae	*Choerodon vitta*	Redstripe Tuskfish	Ogilby, 1910	2	1.3	43	3.9	10	1.9	1	0.5		x	x		x
Pomacentridae	*Chromis atripectoralis*	Blackaxil Puller	Welander & Schultz, 1951			35	1.7					x				

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Pomacentridae	*Chromis cinerascens*	Green Puller	(Cuvier, 1830)			10	2.2	1	0.5			x				
Pomacentridae	*Chromis fumea*	Smoky Puller	(Tanaka, 1917)	31	4.7	35	2.8	143	3.8	30	1.9	x	x	x	x	x
Pomacentridae	*Chromis viridis*	Blue-Green Puller	(Cuvier, 1830)	59	2.7	13	1.1	70	3.3	3	0.9	x	x			
Pomacentridae	*Chrysiptera glauca*	Grey Demoiselle	(Cuvier, 1830)	1	0.7					1	0.5	x				
Pomacentridae	*Chrysiptera hemicyanea*	Azure Demoiselle	(Weber, 1913)	1	0.7							x				
Labridae	*Cirrhilabrus cyanopleura*	Blueside Wrasse	(Bleeker, 1851)	7	0.7											x
Cirrhitidae	*Cirrhitichthys oxycephalus*	Spotted Hawkfish	(Bleeker, 1855)			1	0.6							x		
Blenniidae	*Cirripectes filamentosus*	Filamentous Blenny	(Alleyne & Macleay, 1877)	1	0.7							x				
Chaetodontidae	*Coradion chrysozonus*	Orangebanded Coralfish	(Cuvier, 1831)	4	2.0	11	3.4	6	2.3	2	0.9	x	x	x		x
Labridae	*Coris aygula*	Redblotched Wrasse	Lacépède, 1801	5	3.3	11	3.9	4	1.4	7	2.8	x				
Labridae	*Coris caudimacula*	Spot-Tail Wrasse	(Quoy & Gaimard, 1834)	6	4.0	18	6.2	5	1.4	16	3.3	x	x	x		x
Labridae	*Coris dorsomacula*	Pinklined Wrasse	Fowler, 1908					8	0.9							x
Labridae	*Coris gaimard*	Clown Wrasse	(Quoy & Gaimard, 1824)							1	0.5	x				
Labridae	*Coris pictoides*	Pixy Wrasse	Randall & Kuiter, 1982	5	2.7	16	3.4	6	1.9	9	1.4	x	x			x
Serranidae	*Cromileptes altivelis*	Barramundi Cod*	(Valenciennes, 1828)	9	5.3	13	6.2	6	2.8	14	5.6	x				
Acanthuridae	*Ctenochaetus striatus*	Lined Bristletooth	(Quoy & Gaimard, 1825)	3	2.0	20	7.9	1	0.5			x	x			
Scombridae	*Cybiosarda elegans*	Leaping Bonito*	(Whitley, 1935)			38	1.1	4	1.4	1	0.5		x	x		
Pomacentridae	*Dascyllus aruanus*	Banded Humbug	(Linnaeus, 1758)					5	0.5				x			
Pomacentridae	*Dascyllus reticulatus*	Headband Humbug	(Richardson, 1846)	10	0.7	10	1.7	5	1.4	1	0.5	x				
Pomacentridae	*Dascyllus trimaculatus*	Threespot Humbug	(Rüppell, 1829)					2	0.5			x				
Dasyatidae	*Dasyatis kuhlii*	Bluespotted Maskray	(Müller & Henle, 1841)	13	8.7	3	1.7	12	5.6	5	2.3	x	x	x	x	x
Dasyatidae	*Dasyatis thetidis*	Black Stingray	Ogilby, 1899							1	0.5			x		
Carangidae	*Decapterus russelli*	Indian Scad	(Rüppell, 1830)			1	0.6								x	
Haemulidae	*Diagramma labiosum*	Painted Sweetlips*	Macleay, 1883	33	16.7	80	19.7	54	16.0	89	18.3	x	x	x	x	x
Diodontidae	*Diodon liturosus*	Blackblotched Porcupinefish	(Soviet Fishery Data, 1998)					1	0.5			x				
Grammistidae	*Diploprion bifasciatum*	Barred Soapfish	Cuvier, 1828	13	3.3	4	1.7	12	3.8	15	5.6	x			x	

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Pomacentridae	*Dischistodus prosopotaenia*	Honeyhead Damsel	(Bleeker, 1852)			1	0.6					x				
Echeneidae	*Echeneis naucrates*	Sharksucker	Linnaeus, 1758	58	22.7	71	27.0	127	33.8	121	29.1	x	x	x	x	x
Elopidae	*Elops hawaiensis*	Hawaiian Giant Herring*	Regan, 1909	14	4.7	2	0.6	12	4.7	13	5.6	x	x	x	x	x
Labridae	*Epibulus insidiator*	Slingjaw Wrasse	(Pallas, 1770)	7	4.7	4	2.2	4	1.9	3	1.4	x				
Serranidae	*Epinephelus areolatus*	Yellowspotted Rockcod*	(Forsskål, 1775)	1	0.7	1	0.6	1	0.5	1	0.5	x		x		
Serranidae	*Epinephelus bilobatus*	Frostback Rockcod*	Randall & Allen, 1987	46	20.0	40	12.9	98	23.5	114	27.7	x	x	x		x
Serranidae	*Epinephelus coioides*	Goldspotted Rockcod*	(Hamilton, 1822)	19	10.0	9	5.1	14	6.6	8	3.8	x	x	x	x	x
Serranidae	*Epinephelus fasciatus*	Blacktip Rockcod*	(Forsskål, 1775)	23	12.0	21	10.1	24	8.0	44	14.6	x	x	x		x
Serranidae	*Epinephelus malabaricus*	Blackspotted Rockcod*	(Bloch & Schneider, 1801)	3	2.0	1	0.6	6	2.3	8	3.3	x			x	
Serranidae	*Epinephelus merra*	Birdwire Rockcod*	Bloch, 1793			1	0.6					x				
Serranidae	*Epinephelus multinotatus*	Rankin Cod*	(Peters, 1877)	15	6.0	6	3.4	12	4.2	18	7.0	x	x	x	x	x
Serranidae	*Epinephelus polyphekadion*	Camouflage Grouper*	(Bleeker, 1849)	9	5.3	25	11.8	30	8.0	34	10.8	x				
Serranidae	*Epinephelus quoyanus*	Longfin Rockcod*	(Valenciennes, 1830)	4	1.3	1	0.6	2	0.9	1	0.5	x	x			
Serranidae	*Epinephelus rivulatus*	Chinaman Rockcod*	(Valenciennes, 1830)	26	10.0	42	14.6	36	13.1	14	5.2	x	x	x		x
Serranidae	*Epinephelus sexfasciatus*	Sixbar Grouper*	(Valenciennes, 1828)							1	0.5			x		
Serranidae	*Epinephelus tukula*	Potato Rockcod*	Morgans, 1959			1	0.6					x				
Orectolobidae	*Eucrossorhinus dasypogon*	Tasselled Wobbegong*	(Bleeker, 1867)	1	0.7							x				
Tetraodontidae	*Feroxodon multistriatus*	Ferocious Puffer	(Richardson, 1854)			4	2.2	3	1.4	11	5.2			x	x	x
Fistulariidae	*Fistularia commersonii*	Smooth Flutemouth	Rüppell, 1838	1	0.7	4	1.1	10	0.9			x	x			
Carcharhinidae	*Galeocerdo cuvier*	Tiger Shark*	(Péron & Lesueur, 1822)	6	4.0	4	2.2	4	1.9	7	3.3	x	x	x	x	x
Glaucosomatidae	*Glaucosoma magnificum*	Threadfin Pearl Perch*	(Ogilby, 1915)	4	1.3	275	2.2	3	0.9	3	0.5	x				
Carangidae	*Gnathanodon speciosus*	Golden Trevally*	(Forsskål, 1775)	110	23.3	385	18.0	225	24.4	731	37.1	x	x	x	x	x
Gobiidae	*Gobiidae* spp	Goby Species				3	1.1	3	1.4	2	0.5	x	x		x	
Labridae	*Gomphosus varius*	Birdnose Wrasse	Lacépède, 1801	1	0.7					1	0.5	x				
Scombridae	*Grammatorcynus bicarinatus*	Shark Mackerel*	(Quoy & Gaimard, 1825)			2	0.6									x
Microdesmidae	*Gunnellichthys pleurotaenia*	Blacklined Wormfish	Bleeker, 1858					2	0.9			x				x

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Lethrinidae	*Gymnocranius grandoculis*	Robinson's Seabream*	(Valenciennes, 1830)					2	0.9	4	0.5	x				
Lethrinidae	*Gymnocranius* spp	Seabream Species*		1	0.7	1	0.6					x	x			
Muraenidae	*Gymnothorax eurostus*	Stout Moray	(Abborr, 1860)					2	0.9			x	x			
Muraenidae	*Gymnothorax flavimarginatus*	Yellowmargin Moray	(Rüppell, 1830)	8	4.7			5	2.3	4	1.4	x	x			
Muraenidae	*Gymnothorax javanicus*	Giant Moray	(Bleeker, 1859)					5	2.3	1	0.5	x				
Muraenidae	*Gymnothorax thrysoideus*	Greyface Moray	(Richardson, 1845)	3	0.7			1	0.5	1	0.5	x	x			
Muraenidae	*Gymnothorax undulatus*	Undulate Moray	(Lacépède, 1803)	4	2.7	4	2.2	3	1.4	24	9.9	x	x			x
Labridae	*Halichoeres chrysus*	Golden Wrasse	Randall, 1981					1	0.5	3	1.4	x				x
Labridae	*Halichoeres hortulanus*	Checkerboard Wrasse	(Lacépède, 1801)					2	0.9			x				
Labridae	*Halichoeres margaritaceus*	Pearly Wrasse	(Valenciennes, 1839)	1	0.7			1	0.5			x	x			
Labridae	*Halichoeres marginatus*	Dusky Wrasse	Rüppell, 1835			1	0.6					x				
Labridae	*Halichoeres melanochir*	Orangefin Wrasse	Fowler & Bean, 1928	2	1.3	27	10.1					x	x			
Labridae	*Halichoeres nebulosus*	Cloud Wrasse	(Valenciennes, 1839)	9	4.7	21	7.3	38	9.4	62	9.4	x	x			x
Labridae	*Halichoeres nigrescens*	Bubblefin Wrasse	Bloch & Schneider, 1801					1	0.5				x			
Hemigaleidae	*Hemigaleus australiensis*	Weasel Shark*	White, Last & Compagno, 2005	1	0.7											x
Labridae	*Hemigymnus fasciatus*	Fiveband Wrasse	(Bloch, 1792)	1	0.7	3	1.7	1	0.5			x				
Labridae	*Hemigymnus melapterus*	Thicklip Wrasse	(Bloch, 1791)	45	20.7	32	11.8	15	6.6	17	7.0	x	x			
Hemigaleidae	*Hemipristis elongata*	Fossil Shark*	(Klunzinger, 1871)	4	2.7			3	1.4	1	0.5	x		x		x
Hemiscylliidae	*Hemiscyllium trispeculare*	Speckled Carpetshark	Richardson, 1843	1	0.7			1	0.5	1	0.5	x				
Chaetodontidae	*Heniochus acuminatus*	Longfin Bannerfish	(Linnaeus, 1758)	40	14.7	47	13.5	29	6.1	40	10.8	x	x	x		x
Chaetodontidae	*Heniochus monoceros*	Masked Bannerfish	Cuvier, 1831			2	0.6					x				
Chaetodontidae	*Heniochus singularius*	Singular Bannerfish	Smith & Radcliffe, 1911	3	1.3	3	1.7	4	0.9	2	0.9	x				x
Clupeidae	*Herklotsichthys* spp	Herring Species		101 6	5.3			337 4	8.9	378	1.4	x	x	x		
Dasyatidae	*Himantura fai*	Pink Whipray	Jordan & Seale, 1906			11	2.2	6	1.9	13	5.2	x		x	x	x
Dasyatidae	*Himantura jenkinsii*	Jenkins' Whipray	(Annandale, 1909)	1	0.7											x

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Dasyatidae	*Himantura toshi*	Brown Whipray	Whitley, 1939	3	2.0					1	0.5	x				x
Dasyatidae	*Himantura uarnak*	Reticulate Whipray	(Forsskål, 1775)	1	0.7			4	1.4	3	1.4		x	x		x
Dasyatidae	*Himantura undulata*	Leopard Whipray	Manjaji-Matsumoto & Last, 2008	1	0.7									x		
Scaridae	*Hipposcarus longiceps*	Longnose Parrotfish	(Valenciennes, 1840)	13	6.0			1	0.5			x	x			x
Labridae	*Hologymnosus annulatus*	Ringed Slender Wrasse	(Lacépède, 1801)	1	0.7	1	0.6					x				
Labridae	*Hologymnosus doliatus*	Pastel Slender Wrasse	(Lacépède, 1801)	1	0.7								x			
Labridae	*Iniistius* spp	Razorfish Species		4	2.0	4	2.2	1	0.5	11	3.8			x		
Pseudochromidae	*Labracinus lineatus*	Lined Dottyback	(Castelnau, 1875)	7	4.7	17	7.9	12	5.6	5	2.3	x	x			
Labridae	*Labroides dimidiatus*	Common Cleanerfish	(Valenciennes, 1839)	49	18.7	49	15.2	58	16.4	76	20.7	x	x	x	x	x
Labridae	*Lactoria cornuta*	Longhorn Cowfish	(Linnaeus, 1758)	1	0.7								x			
Tetraodontidae	*Lagocephalus lunaris*	Rough Golden Toadfish	(Bloch & Schneider, 1801)	6	4.0	2	1.1	14	4.2	27	10.3			x	x	x
Tetraodontidae	*Lagocephalus sceleratus*	Silver Toadfish	(Gmelin, 1789)			31	7.3	15	4.7	14	4.7			x	x	x
Labridae	*Leptojulis cyanopleura*	Shoulderspot Wrasse	(Bleeker, 1853)	3	0.7	55	2.8	15	3.3	31	1.4	x	x			
Lethrinidae	*Lethrinus atkinsoni*	Yellowtail Emperor*	Seale, 1910	108	24.7	150	18.0	185	18.3	205	19.7	x	x	x		
Lethrinidae	*Lethrinus genivittatus*	Threadfin Emperor*	Valenciennes, 1830	112	15.3	238	16.3	18	4.7	198	20.7	x	x	x	x	x
Lethrinidae	*Lethrinus laticaudis*	Grass Emperor*	Alleyne & Macleay, 1877	95	32.7	91	30.3	117	26.3	95	25.8	x		x		
Lethrinidae	*Lethrinus lentjan*	Redspot Emperor*	(Lacépède, 1802)			15	2.2	16	2.3	15	3.8	x	x	x	x	x
Lethrinidae	*Lethrinus microdon*	Smalltooth Emperor*	(Valenciennes, 1830)			6	1.1	2	0.9	4	0.9	x				
Lethrinidae	*Lethrinus miniatus*	Redthroat Emperor*	(Forster, 1801)	2	1.3							x				
Lethrinidae	*Lethrinus nebulosus*	Spangled Emperor*	(Forsskål, 1775)	93	22.0	61	18.5	216	32.4	262	36.6	x	x	x	x	x
Lethrinidae	*Lethrinus olivaceus*	Longnose Emperor*	Valenciennes, 1830	5	3.3	2	1.1	6	2.8	7	1.4	x				
Lethrinidae	*Lethrinus punctulatus*	Blue-Lined Emperor*	(Carpenter, pers comm)	810	29.3	316	21.3	808	24.4	514	21.1	x	x	x	x	x
Lethrinidae	*Lethrinus ravus*	Drab Emperor*	Carpenter & Randall, 2003							3	0.5	x				
Lethrinidae	*Lethrinus variegatus*	Variegated Emperor*	Valenciennes, 1830	20	4.7	23	6.7	13	0.9	4	1.9	x	x	x	x	x
Carcharhinidae	*Loxodon macrorhinus*	Sliteye Shark*	Müller & Henle, 1839	20	8.7			46	13.6	7	2.8			x	x	x
Lutjanidae	*Lutjanus argentimaculatus*	Mangrove Jack*	(Forsskål, 1775)			2	1.1	10	1.4	3	1.4	x				

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Lutjanidae	*Lutjanus bohar*	Red Bass*	(Forsskål, 1775)	2	1.3	3	1.7	3	1.4	4	0.9	x				
Lutjanidae	*Lutjanus carponotatus*	Stripey Snapper*	(Richardson, 1842)	172	38.7	296	34.8	177	22.5	128	23.0	x	x	x	x	x
Lutjanidae	*Lutjanus fulviflamma*	Blackspot Snapper*	(Forsskål, 1775)			4	0.6					x				
Lutjanidae	*Lutjanus lemniscatus*	Darktail Snapper*	(Valenciennes, 1828)	25	12.7	28	9.6	35	9.9	40	12.2	x	x	x		
Lutjanidae	*Lutjanus malabaricus*	Saddletail Snapper*	(Bloch & Schneider, 1801)	8	0.7			6	0.9	5	2.3	x		x		x
Lutjanidae	*Lutjanus quinquelineatus*	Fiveline Snapper*	(Bloch, 1790)	7	1.3	23	2.2	104	1.9	11	1.4	x				
Lutjanidae	*Lutjanus russellii*	Moses' Snapper*	(Bleeker, 1849)	6	2.7	8	1.1			2	0.9	x				
Lutjanidae	*Lutjanus sebae*	Red Emperor*	(Cuvier, 1828)			1	0.6	2	0.9	7	2.8	x			x	
Lutjanidae	*Lutjanus vitta*	Brownstripe Snapper*	(Quoy & Gaimard, 1824)	21	1.3	2	1.1	7	0.9	21	1.9	x	x	x		x
Mobulidae	*Manta birostris*	Manta Ray	(Donndorff, 1798)	2	0.7			1	0.5			x				
Blenniidae	*Meiacanthus grammistes*	Linespot Fangblenny	(Valenciennes, 1836)	1	0.7	13	6.7	4	1.4	2	0.9	x	x			
Monacanthidae	*Monacanthus chinensis*	Fanbelly Leatherjacket	(Osbeck, 1765)	1	0.7	11	5.1	2	0.9	2	0.9		x	x		x
Holocentridae	*Myripristis violacea*	Violet Soldierfish	Bleeker, 1851			1	0.6	1	0.5			x				
Acanthuridae	*Naso brevirostris*	Spotted Unicornfish	(Valenciennes, 1835)	2	1.3	8	3.4	6	1.9	8	0.9	x				
Acanthuridae	*Naso fageni*	Horseface Unicornfish	Morrow, 1954	13	4.0	16	3.9	20	3.3	62	4.7	x	x			
Acanthuridae	*Naso lituratus*	Clown Unicornfish	(Forster, 1801)	3	1.3			2	0.5	2	0.9	x				
Acanthuridae	*Naso unicornis*	Bluespine Unicornfish	(Forsskål, 1775)	43	11.3	16	6.7	21	5.6	3	1.4	x	x			
Ginglymostomatidae	*Nebrius ferrugineus*	Tawny Shark	(Lesson, 1830)			5	2.8	2	0.9	7	3.3	x	x	x		x
Carcharhinidae	*Negaprion acutidens*	Lemon Shark*	(Rüppell, 1837)	3	2.0	6	3.4	5	2.3	9	4.2	x	x	x		x
Nemipteridae	*Nemipterus* spp	Threadfin Bream Species*		194	24.0	104	25.3	172	23.5	211	17.8	x		x	x	x
Pomacentridae	*Neoglyphidodon melas*	Black Damsel	(Cuvier, 1830)	4	2.7	3	1.1	5	1.9	3	0.9	x				
Pomacentridae	*Neoglyphidodon nigroris*	Scarface Damsel	(Cuvier, 1830)			11	3.4	9	1.9	4	0.9	x				
Pomacentridae	*Neopomacentrus azysron*	Yellowtail Demoiselle	(Bleeker, 1877)			56	2.2	18	0.9	16	0.5	x				
Pomacentridae	*Neopomacentrus cyanomos*	Regal Demoiselle	(Bleeker, 1856)	1	0.7					25	1.4	x	x			
Pomacentridae	*Neopomacentrus filamentosus*	Brown Demoiselle	(Macleay, 1883)	351	19.3	516	14.6	302	13.1	274	11.3	x	x	x		x

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Orectolobidae	*Orectolobus ornatus*	Banded Wobbegong*	(De Vis, 1883)	2	1.3							x				
Orectolobidae	*Orectolobus reticulatus*	Network Wobbegong	Last, Pogonoski & White, 2008					1	0.5				x			
Ostraciidae	*Ostracion cubicus*	Yellow Boxfish	Linnaeus, 1758	5	3.3	5	2.8	3	1.4			x	x	x		
Ostraciidae	*Ostracion meleagris*	Spotted Boxfish	(Shaw, 1796)					1	0.5	1	0.5		x			
Monacanthidae	*Oxymonacanthus longirostris*	Harlequin Filefish	(Bloch & Schneider, 1801)					2	0.9			x	x			
Carangidae	*Pantolabus radiatus*	Fringefin Trevally*	(Macleay, 1881)			7	1.1					x				x
Chaetodontidae	*Parachaetodon ocellatus*	Ocellate Butterflyfish	(Cuvier, 1831)	28	6.0	30	7.3	31	4.2	62	6.1	x	x	x		x
Monacanthidae	*Paramonacanthus choirocephalus*	Pigface Leatherjacket	(Bleeker, 1852)	60	16.7	157	25.8	131	18.3	105	17.4		x	x	x	x
Pinguipedidae	*Parapercis nebulosa*	Pinkbanded Grubfish	(Quoy & Gaimard, 1825)	37	16.0	59	22.5	37	11.7	25	7.5	x	x	x	x	x
Plotosidae	*Paraplotosus butleri*	Sailfin Catfish	Allen, 1998	3	1.3	2	1.1					x				
Mullidae	*Parupeneus barberinoides*	Bicolour Goatfish*	(Bleeker, 1852)	46	14.0	38	12.9	42	9.9	35	11.3	x	x	x		x
Mullidae	*Parupeneus cyclostomus*	Goldsaddle Goatfish*	(Lacépède, 1801)	1	0.7			7	1.4	2	0.5	x				
Mullidae	*Parupeneus heptacanthus*	Opalescent Goatfish*	(Lacépède, 1802)	14	2.7			9	2.3	6	1.9	x		x		x
Mullidae	*Parupeneus indicus*	Yellowspot Goatfish*	(Shaw, 1803)	100	30.7	125	27.5	131	27.2	66	21.1	x	x	x	x	x
Mullidae	*Parupeneus multifasciatus*	Banded Goatfish	(Quoy & Gaimard, 1825)	1	0.7							x				
Mullidae	*Parupeneus spilurus*	Blacksaddle Goatfish*	(Bleeker, 1854)	6	3.3	33	5.6	18	2.8	16	2.8	x	x			
Dasyatidae	*Pastinachus sephen*	Cowtail Stingray	(Forsskål, 1775)	1	0.7	2	1.1					x		x		
Nemipteridae	*Pentapodus emeryii*	Purple Threadfin Bream	(Richardson, 1843)	162	44.7	250	41.0	240	40.4	221	37.1	x	x	x	x	x
Nemipteridae	*Pentapodus nagasakiensis*	Japanese Threadfin Bream	(Tanaka, 1915)					3	0.5	7	1.9	x	x	x	x	x
Nemipteridae	*Pentapodus porosus*	Northwest Threadfin Bream	(Valenciennes, 1830)	939	48.0	1037	49.4	1180	47.4	951	41.3	x	x	x	x	x
Nemipteridae	*Pentapodus vitta*	Western Butterfish	Quoy & Gaimard, 1824	579	26.0	570	39.3	597	19.7	649	27.7		x			
Blenniidae	*Plagiotremus rhinorhynchos*	Bluestriped Fangblenny	(Bleeker, 1852)			1	0.6	1	0.5			x	x	x		x
Ephippidae	*Platax batavianus*	Humphead Batfish	Cuvier, 1831	7	4.0	12	6.2	3	1.4	4	1.9	x	x			
Ephippidae	*Platax orbicularis*	Round Batfish	(Forsskål, 1775)			1	0.6			2	0.5			x		

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Ephippidae	*Platax pinnatus*	Longfin Batfish	(Linnaeus, 1758)			1	0.6					x	x	x		x
Ephippidae	*Platax teira*	Roundface Batfish	(Forsskål, 1775)	1	0.7	12	4.5	11	4.2	5	1.9		x			
Belonidae	*Platybelone argalus*	Flat-Tail Longtom	(Lesueur, 1821)	1	0.7							x				
Platycephalidae	*Platycephalidae* spp	Flathead Species*		5	3.3	2	0.6	7	2.3	5	1.9	x		x		x
Haemulidae	*Plectorhinchus albovittatus*	Giant Sweetlips*	(Rüppell, 1838)	1	0.7							x				
Haemulidae	*Plectorhinchus chaetodonoides*	Spotted Sweetlips	Lacépède, 1801	2	1.3	10	5.1	1	0.5			x				
Haemulidae	*Plectorhinchus gibbosus*	Brown Sweetlips*	(Lacépède, 1802)	5	3.3	2	1.1	5	2.3	5	2.3	x	x			x
Haemulidae	*Plectorhinchus multivittatus*	Manyline Sweetlips	(Macleay, 1878)	2	1.3	5	2.2	2	0.9			x				
Haemulidae	*Plectorhinchus picus*	Dotted Sweetlips	(Cuvier, 1830)	6	0.7											x
Haemulidae	*Plectorhinchus polytaenia*	Ribbon Sweetlips*	(Bleeker, 1852)			2	1.1	3	0.5	3	1.4	x				
Haemulidae	*Plectorhinchus vittatus*	Oriental Sweetlips	(Linnaeus, 1758)	2	1.3							x				
Serranidae	*Plectropomus* spp	Coral Trout*		128	43.3	170	44.4	119	29.6	158	33.8	x	x	x	x	x
Plotosidae	*Plotosus lineatus*	Striped Catfish	(Thunberg, 1791)					288	0.5				x			
Pomacanthidae	*Pomacanthus semicirculatus*	Blue Angelfish	(Cuvier, 1831)	5	3.3	10	5.1	3	1.4	3	1.4	x				
Pomacanthidae	*Pomacanthus sexstriatus*	Sixband Angelfish	(Cuvier, 1831)	53	24.7	54	23.0	45	16.9	52	20.2	x	x	x		x
Pomacentridae	*Pomacentrus amboinensis*	Ambon Damsel	Bleeker, 1868	2	0.7	5	0.6					x				
Pomacentridae	*Pomacentrus bankanensis*	Speckled Damsel	Bleeker, 1853			12	2.8					x	x			
Pomacentridae	*Pomacentrus coelestis*	Neon Damsel	Jordan & Starks, 1901	47	1.3	13	1.1	139	6.6	34	4.2	x	x	x		
Pomacentridae	*Pomacentrus limosus*	Muddy Damsel	Allen, 1992	95	17.3	32	5.1	136	12.7	126	10.3	x	x		x	x
Pomacentridae	*Pomacentrus milleri*	Miller's Damsel	Taylor, 1964	8	4.7	32	7.3	223	24.4	136	21.6	x	x			x
Pomacentridae	*Pomacentrus moluccensis*	Lemon Damsel	Bleeker, 1853	11	2.0	33	5.6	39	4.7	15	3.3	x				x
Pomacentridae	*Pomacentrus nagasakiensis*	Blue Scribbled Damsel	(Tanaka, 1917)					94	4.7	145	9.4	x	x			x
Pomacentridae	*Pomacentrus nigromanus*	Goldback Damsel	Weber, 1913	77	10.7	86	6.7	45	5.2	73	6.1	x				
Pomacentridae	*Pomacentrus philippinus*	Philippine Damsel	Evermann & Seale, 1907	4	0.7	9	2.8					x				
Pomacentridae	*Pomacentrus vaiuli*	Princess Damsel	Jordon & Seale, 1906					4	0.9	12	2.3	x	x			
Priacanthidae	*Priacanthus hamrur*	Lunartail Bigeye	(Forsskål, 1775)	1	0.7	1	0.6			1	0.5			x		x

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Pomacentridae	*Pristotis obtusirostris*	Gulf Damsel	(Günther, 1862)	1	0.7	57	2.8	50	0.9	198	6.6			x	x	x
Latidae	*Psammoperca waigiensis*	Sand Bass*	(Cuvier, 1828)			1	0.6	1	0.5	2	0.5	x				
Balistidae	*Pseudobalistes fuscus*	Yellowspotted Triggerfish	(Bloch & Schneider, 1801)			1	0.6					x				
Callionymidae	*Pseudocalliurichthys goodladi*	Longspine Dragonet	(Whitley, 1944)			1	0.6							x		
Labridae	*Pseudocheilinus evanidus*	Pinstripe Wrasse	Jordan & Evermann, 1903							8	0.9		x			
Pseudochromidae	*Pseudochromis fuscus*	Dusky Dottyback	Müller & Troschel, 1849	13	7.3	9	5.1	9	4.2			x	x			
Pseudochromidae	*Pseudochromis quinquedentatus*	Spotted Dottyback	McCulloch, 1926			1	0.6					x				
Pseudochromidae	*Pseudochromis wilsoni*	Yellowfin Dottyback	(Whitley, 1929)	1	0.7							x				
Labridae	*Pseudodax moluccanus*	Chiseltooth Wrasse	(Valenciennes, 1840)			1	0.6			1	0.5	x	x			
Monacanthidae	*Pseudomonacanthus elongatus*	Fourband Leatherjacket	Fraser-Brunner, 1940					1	0.5					x		
Monacanthidae	*Pseudomonacanthus peroni*	Potbelly Leatherjacket	(Hollard, 1854)					1	0.5	2	0.9			x	x	
Undefined	*Pseudorhombus* spp	Sand Flounder Species*		3	2.0	1	0.6	9	3.3	14	5.2			x		x
Labridae	*Pteragogus cryptus*	Cryptic Wrasse	Randall, 1981			3	1.7						x			
Labridae	*Pteragogus flagellifer*	Cocktail Wrasse	(Valenciennes, 1839)					1	0.5	1	0.5		x			
Caesionidae	*Pterocaesio* spp	Fusilier Species		799	13.3	845	9.6	2164	5.6	1049	8.9	x	x	x		x
Rachycentridae	*Rachycentron canadum*	Cobia*	(Linnaeus, 1766)	7	2.0	44	2.8	8	2.3	19	4.7	x	x	x	x	x
Rhinidae	*Rhina ancylostoma*	Shark Ray	Bloch & Schneider, 1801	1	0.7											x
Rhinobatidae	*Rhinobatos typus*	Giant Shovelnose Ray	Bennett, 1830			1	0.6	1	0.5					x		
Rhynchobatidae	*Rhynchobatus australiae*	Whitespotted Guitarfish	Whitely, 1939	10	6.7	8	4.5	9	4.2	22	9.4	x	x	x	x	x
Ostraciidae	*Rhynchostracion nasus*	Shortnose Boxfish	(Bloch, 1785)					5	1.9					x		
Holocentridae	*Sargocentron rubrum*	Red Squirrelfish	(Forsskål, 1775)			31	3.4			1	0.5	x				
Nemipteridae	*Scaevius milii*	Coral Monocle Bream	(Bory de Saint-Vincent, 1823)	3	1.3	37	2.8			1	0.5		x			x
Nemipteridae	*Scaevius vitta*	Coral Bream				14	3.9	1	0.5	161	11.7		x		x	x
Scaridae	*Scarus chameleon*	Chameleon Parrotfish	Choat & Randall, 1986	6	2.7	22	1.7			3	1.4	x	x			

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Scaridae	*Scarus flavipectoralis*	Yellowfin Parrotfish	Schultz, 1958	5	1.3							x				
Scaridae	*Scarus frenatus*	Sixband Parrotfish	Lacépède, 1802	2	1.3			1	0.5	1	0.5	x				
Scaridae	*Scarus ghobban*	Bluebarred Parrotfish*	Forsskål, 1775	13	8.0	70	16.3	77	16.0	191	34.3	x	x	x	x	x
Scaridae	*Scarus prasiognathos*	Greencheek Parrotfish	Valenciennes, 1840	1	0.7							x				
Scaridae	*Scarus psittacus*	Palenose Parrotfish	Forsskål, 1775	13	6.0	1	0.6					x	x			
Scaridae	*Scarus rivulatus*	Surf Parrotfish*	Valenciennes, 1840	20	8.0	54	15.2	31	8.0	12	3.8	x	x			
Scaridae	*Scarus rubroviolaceus*	Blackvein Parrotfish	Bleeker, 1847	8	4.7			2	0.9			x				
Scaridae	*Scarus schlegeli*	Schlegel's Parrotfish	(Bleeker, 1861)	72	26.0	108	28.1	114	23.5	7	2.8	x	x	x		x
Nemipteridae	*Scolopsis affinis*	Bridled Monocle Bream	Peters, 1877			1	0.6	13	3.8	1	0.5	x	x	x		x
Nemipteridae	*Scolopsis bilineata*	Two-Line Monocle Bream	(Bloch, 1793)	55	8.7	32	8.4	10	3.8	10	2.8	x		x		
Nemipteridae	*Scolopsis monogramma*	Rainbow Monocle Bream	(Kuhl & van Hasselt, 1830)	52	25.3	65	24.2	64	18.3	40	15.0	x	x	x	x	x
Nemipteridae	*Scolopsis trilineata*	Threeline Monocle Bream	Kner, 1868			51	1.1							x		
Carangidae	*Scomberoides commersonnianus*	Giant Queenfish*	Lacépède, 1801	9	6.0	3	1.7	57	17.4	28	10.8	x	x	x	x	x
Carangidae	*Scomberoides lysan*	Lesser Queenfish*	(Forsskål, 1775)					15	2.8	65	10.3	x	x		x	
Carangidae	*Scomberoides tol*	Needleskin Queenfish*	(Cuvier, 1832)	1	0.7							x				
Scombridae	*Scombridae* spp	Mackerel Species*		130	50.0	218	51.7	251	66.7	190	57.7	x	x	x	x	x
Carangidae	*Selar boops*	Oxeye Scad	(Cuvier, 1833)							4	0.5			x		
Carangidae	*Selaroides leptolepis*	Yellowstripe Scad	(Kuhl & van Hasselt, 1833)	577	20.7	904	22.5	2881	20.7	331	8.0	x		x		x
Carangidae	*Seriolina nigrofasciata*	Blackbanded Amberjack*	(Rüppell, 1829)	5	3.3	19	9.0	4	1.4	9	3.3			x		x
Siganidae	*Siganus argenteus*	Forktail Rabbitfish	(Quoy & Gaimard, 1825)	1	0.7					52	4.2	x	x	x	x	
Siganidae	*Siganus doliatus*	Bluelined Rabbitfish	Cuvier, 1830	154	18.0	101	12.9	59	8.0	125	12.2	x	x			
Siganidae	*Siganus fuscescens*	Dusky Rabbitfish	(Houttuyn, 1782)	196	22.0	592	20.2	458	19.7	92	4.7	x	x	x		x
Siganidae	*Siganus laqueus*	Stellate Rabbitfish	von Bonde, 1934					7	2.3	2	0.5	x	x			
Siganidae	*Siganus lineatus*	Goldlined Rabbitfish	(Valenciennes, 1835)					2	0.5			x				

Family	Species	Common Name	Authority	2008		2009		2011		2012		Habitat				
				Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Coral	Macroalgae	Sand	Seagrass	Sessile Invertebrates
Siganidae	*Siganus punctatissimus*	Finespotted Rabbitfish	Fowler & Bean, 1929	6	2.0	10	2.8	13	3.3	6	1.4	x	x			
Siganidae	*Siganus punctatus*	Spotted Rabbitfish	(Schneider, 1801)	18	6.7	17	6.2	21	3.3	9	1.9	x	x			
Siganidae	*Siganus trispilos*	Threespot Rabbitfish	Woodland & Allen, 1977			2	0.6					x				
Siganidae	*Siganus virgatus*	Doublebar Rabbitfish	(Valenciennes, 1835)	22	3.3	26	5.6	137	8.5	55	6.6	x	x			
Sillaginidae	*Sillago* spp	Whiting Species*	Whitley, 1943	38	7.3			35	6.6	18	5.6			x	x	x
Sphyraenidae	*Sphyraena barracuda*	Great Barracuda*	(Walbaum, 1792)			1	0.6	4	1.9	3	1.4	x	x	x		
Sphyraenidae	*Sphyraena jello*	Pickhandle Barracuda*	Cuvier, 1829	29	10.0	10	2.2	63	6.6	10	4.2	x	x	x	x	x
Sphyraenidae	*Sphyraena obtusata*	Striped Barracuda*	Cuvier, 1829	3	1.3	40	0.6			1	0.5	x	x			x
Sphyrnidae	*Sphyrna lewini*	Scalloped Hammerhead*	(Griffith & Smith, 1834)	1	0.7	1	0.6					x		x		
Sphyrnidae	*Sphyrna mokarran*	Great Hammerhead*	(Rüppell, 1837)	7	4.7	5	2.8	9	4.2	8	3.3	x	x	x		x
Pomacentridae	*Stegastes fasciolatus*	Pacific Gregory	(Ogilby, 1889)	4	2.0							x				
Pomacentridae	*Stegastes nigricans*	Dusky Gregory	(Lacépède, 1801)	1	0.7					4	0.5	x				
Pomacentridae	*Stegastes obreptus*	Western Gregory	(Whitley, 1948)	5	2.7	8	2.8	3	0.9			x				
Stegostomatidae	*Stegostoma fasciatum*	Zebra Shark	(Hermann, 1783)	2	1.3	5	2.8	8	3.8	1	0.5	x	x	x		x
Labridae	*Stethojulis strigiventer*	Silverstreak Wrasse	(Bennett, 1833)					11	2.3	17	1.9	x	x			
Balistidae	*Sufflamen chrysopterum*	Eye-Stripe Triggerfish	(Bloch & Schneider, 1801)					1	0.5			x				
Balistidae	*Sufflamen fraenatum*	Bridled Triggerfish	(Latreille, 1804)	1	0.7	1	0.6					x				
Lutjanidae	*Symphorus nematophorus*	Chinamanfish*	(Bleeker, 1860)	51	27.3	72	29.2	77	32.4	65	26.8	x	x	x	x	x
Synodontidae	*Synodontidae* spp	Lizardfish Species		4	2.0	42	16.9	13	6.1	13	6.1			x	x	x
Dasyatidae	*Taeniura lymma*	Bluespotted Fantail Ray	(Forsskål, 1775)	1	0.7	1	0.6			2	0.9	x			x	
Dasyatidae	*Taeniura meyeni*	Blotched Fantail Ray	Müller & Henle, 1841	1	0.7			2	0.9	1	0.5	x	x		x	
Terapontidae	*Terapon theraps*	Largescale Grunter	(Cuvier, 1829)			9	0.6							x		
Labridae	*Thalassoma lunare*	Moon Wrasse	(Linnaeus, 1758)	283	30.7	209	24.7	248	23.9	149	16.9	x	x			x
Labridae	*Thalassoma lutescens*	Green Moon Wrasse	(Lay & Bennett, 1839)	2	1.3	1	0.6			6	1.4	x				

Family	Species	Common Name	Authority	2008		2009		2011		2012		Habitat				
				Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Total #	% of deployments	Coral	Macroalgae	Sand	Seagrass	Sessile Invertebrates
Tetraodontidae	*Torquigener pallimaculatus*	Rusty-Spotted Toadfish	Hardy, 1983	164	5.3	128	16.3	303	6.1	117	10.8			x	x	x
Carcharhinidae	*Triaenodon obesus*	Whitetip Reef Shark*	(Rüppell, 1837)	6	4.0	11	6.2	7	2.8	2	0.9	x	x			
Belonidae	*Tylosurus crocodilus*	Crocodile Longtom	(Péron & Lesueur, 1821)	1	0.7							x				
Belonidae	*Tylosurus gavialoides*	Stout Longtom	(Castelnau, 1873)					3	1.4				x			
Mullidae	*Upeneus moluccensis*	Goldband Goatfish	(Bleeker, 1855)	17	3.3									x		x
Mullidae	*Upeneus tragula*	Bartail Goatfish*	Richardson, 1846	199	21.3	213	22.5	302	22.1	191	15.5	x	x	x	x	x
Mugilidae	*Valamugil seheli*	Bluespot Mullet*	(Forsskål, 1775)					4	0.5					x		
Ephippidae	*Zabidius novemaculeatus*	Shortfin Batfish	(McCulloch, 1916)			5	0.6	13	0.9			x		x		
Zanclidae	*Zanclus cornutus*	Moorish Idol	(Linnaeus, 1758)	9	4.7	7	3.9	7	2.8	6	2.3	x	x			
Acanthuridae	*Zebrasoma scopas*	Brown Tang	(Cuvier, 1829)					2	0.5			x				

Appendix 4 Demersal Fish Length

Table A4.1 Mean Length of the 20 Most Common Fish Species Viewed by Stereo-BRUV for Post-Development Survey Year 2 at each Site

Site	Species	Number (n)	Mean Length (mm)	Standard Error
CFR1	*Pentapodus porosus*	2	119.3	13.0
	Pterocaesio spp	11	108.8	9.5
	Gnathanodon speciosus	86	321.4	65.9
	Pentapodus vitta	2	65.4	1.9
	Carangoides fulvoguttatus	65	362.5	43.3
	Lethrinus nebulosus	3	390.5	65.2
	Pentapodus emeryii	2	186.8	23.0
	Choerodon cyanodus	8	301.2	40.8
	Lethrinus atkinsoni	14	244.8	32.2
	Acanthurus grammoptilus	11	236.7	29.3
	Scombridae spp	2	649.6	62.4
	Scarus ghobban	2	311.1	78.2
	Choerodon schoenleinii	4	318.0	74.3
CFR2	*Gnathanodon speciosus*	9	292.1	123.7
	Carangoides fulvoguttatus	50	260.5	59.1
	Lethrinus nebulosus	38	367.4	52.4
	Carangoides gymnostethus	18	240.2	9.1
	Pentapodus emeryii	1	229.3	
	Choerodon cyanodus	5	293.3	107.2
	Lethrinus atkinsoni	6	267.5	50.2
	Acanthurus grammoptilus	5	334.4	32.0
	Scombridae spp	3	481.4	64.1
	Atule mate	43	242.0	26.7
	Scarus ghobban	8	250.2	134.3
	Choerodon schoenleinii	6	307.0	182.0
CFR3	*Gnathanodon speciosus*	7	203.4	17.1
	Carangoides fulvoguttatus	1	262.0	
	Lethrinus nebulosus	18	352.5	43.0
	Pentapodus emeryii	3	218.9	30.5
	Choerodon cyanodus	11	264.1	56.7
	Lethrinus atkinsoni	6	249.2	30.1
	Acanthurus grammoptilus	18	209.4	50.6
	Scombridae spp	2	515.8	6.3
	Scarus ghobban	17	284.4	83.6
	Choerodon schoenleinii	4	323.4	144.5
CFR4	*Lethrinus punctulatus*	4	266.5	11.1
	Carangoides fulvoguttatus	2	486.6	291.7
	Lethrinus nebulosus	6	442.8	63.9
	Carangoides gymnostethus	36	223.4	15.9

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Pentapodus emeryii	8	217.0	53.9
	Choerodon cyanodus	8	284.1	64.4
	Lethrinus atkinsoni	36	282.5	36.1
	Acanthurus grammoptilus	8	195.1	51.6
	Scombridae spp	3	573.7	24.2
	Atule mate	3	232.1	28.3
	Scarus ghobban	8	246.8	107.3
	Choerodon schoenleinii	1	498.4	
CI1	*Pentapodus porosus*	1	123.4	
	Gnathanodon speciosus	1	274.6	
	Lethrinus punctulatus	14	213.7	15.9
	Carangoides fulvoguttatus	12	527.2	170.7
	Lethrinus nebulosus	18	376.8	89.7
	Pentapodus emeryii	6	207.0	20.5
	Choerodon cyanodus	12	249.6	52.3
	Acanthurus grammoptilus	4	221.6	38.1
	Scombridae spp	1	490.9	
	Scarus ghobban	7	288.5	74.1
	Choerodon schoenleinii	5	251.0	70.2
CI2	*Pentapodus porosus*	6	56.8	13.5
	Pterocaesio spp	77	114.6	16.0
	Gnathanodon speciosus	18	322.5	98.0
	Lethrinus punctulatus	1	226.0	
	Carangoides fulvoguttatus	10	367.0	81.9
	Lethrinus nebulosus	34	351.3	95.2
	Pentapodus emeryii	13	227.1	30.5
	Choerodon cyanodus	7	266.7	49.5
	Lethrinus atkinsoni	1	271.7	
	Acanthurus grammoptilus	9	231.9	51.9
	Scombridae spp	1	504.0	
	Scarus ghobban	11	264.9	110.4
	Choerodon schoenleinii	9	411.6	119.4
CI3	*Pterocaesio* spp	141	114.8	16.4
	Gnathanodon speciosus	5	46.9	7.9
	Carangoides fulvoguttatus	6	383.1	44.7
	Lethrinus nebulosus	5	436.3	69.0
	Pentapodus emeryii	6	189.8	40.4
	Choerodon cyanodus	10	225.8	63.2
	Lethrinus atkinsoni	10	287.4	13.7
	Acanthurus grammoptilus	27	209.7	35.0
	Scombridae spp	8	600.0	294.4
	Scarus ghobban	10	215.9	57.7

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Choerodon schoenleinii	6	322.0	139.1
CN1	*Gnathanodon speciosus*	2	673.8	13.4
	Carangoides fulvoguttatus	9	533.8	78.1
	Lethrinus nebulosus	4	360.9	51.8
	Carangoides gymnostethus	8	587.3	77.8
	Pentapodus emeryii	4	186.8	62.6
	Choerodon cyanodus	5	256.8	29.8
	Lethrinus atkinsoni	66	272.8	29.9
	Acanthurus grammoptilus	40	222.8	25.6
	Scombridae spp	1	421.6	
	Scarus ghobban	9	353.8	84.9
	Choerodon schoenleinii	8	260.5	46.4
CN2	*Pterocaesio* spp	154	110.9	16.0
	Gnathanodon speciosus	2	595.3	212.0
	Lethrinus punctulatus	6	240.7	10.8
	Carangoides fulvoguttatus	3	541.6	8.0
	Lethrinus nebulosus	2	325.7	1.3
	Carangoides gymnostethus	1	696.3	
	Pentapodus emeryii	4	229.5	31.6
	Choerodon cyanodus	3	258.8	44.6
	Lethrinus atkinsoni	13	286.7	22.8
	Acanthurus grammoptilus	8	217.8	26.0
	Scombridae spp	4	499.1	40.6
	Atule mate	1	227.6	
	Scarus ghobban	8	256.1	64.8
	Choerodon schoenleinii	4	359.8	74.7
CN3	*Pterocaesio* spp	92	122.3	31.2
	Gnathanodon speciosus	1	760.6	
	Carangoides fulvoguttatus	13	440.2	80.6
	Lethrinus nebulosus	12	355.6	61.5
	Pentapodus emeryii	5	224.8	37.5
	Choerodon cyanodus	11	271.0	89.8
	Lethrinus atkinsoni	14	229.4	40.7
	Acanthurus grammoptilus	4	234.4	9.9
	Scombridae spp	5	514.9	75.9
	Scarus ghobban	6	327.1	111.6
	Choerodon schoenleinii	7	373.8	127.6
CN4	*Pterocaesio* spp	11	185.4	19.9
	Gnathanodon speciosus	1	689.4	
	Carangoides fulvoguttatus	8	611.5	62.0
	Lethrinus nebulosus	4	415.8	46.9
	Carangoides gymnostethus	4	305.8	25.1

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Pentapodus emeryii	6	219.4	37.9
	Choerodon cyanodus	3	328.7	17.1
	Lethrinus atkinsoni	3	340.6	21.4
	Scarus ghobban	3	227.2	78.9
	Choerodon schoenleinii	4	376.8	102.9
CN5	*Pterocaesio* spp	14	113.0	8.9
	Lethrinus punctulatus	12	270.9	22.8
	Carangoides fulvoguttatus	7	307.9	81.7
	Lethrinus nebulosus	4	341.2	84.8
	Carangoides gymnostethus	20	570.8	141.4
	Pentapodus emeryii	12	213.6	36.5
	Choerodon cyanodus	10	257.1	58.6
	Lethrinus atkinsoni	6	302.7	24.5
	Acanthurus grammoptilus	9	195.2	24.4
	Scarus ghobban	8	255.3	70.5
	Choerodon schoenleinii	7	235.6	37.4
DGI3	*Pentapodus porosus*	16	174.4	17.3
	Gnathanodon speciosus	22	56.2	9.3
	Pentapodus vitta	34	136.9	22.0
	Selaroides leptolepis	116	146.3	18.2
	Nemipterus spp	18	180.1	28.1
	Scombridae spp	6	528.2	70.2
	Atule mate	61	204.8	12.7
	Pristotis obtusirostris	6	49.9	17.6
DSI1	*Pentapodus porosus*	6	101.2	17.9
	Gnathanodon speciosus	63	342.7	82.9
	Lethrinus punctulatus	1	274.6	
	Carangoides fulvoguttatus	17	522.5	109.4
	Lethrinus nebulosus	1	431.0	
	Carangoides gymnostethus	49	286.2	30.3
	Pentapodus emeryii	3	234.0	17.1
	Choerodon cyanodus	3	183.7	22.4
	Nemipterus spp	2	170.4	148.4
	Lethrinus genivittatus	1	37.1	
	Scombridae spp	6	559.0	93.5
	Scarus ghobban	7	206.6	44.2
	Pristotis obtusirostris	25	34.8	7.9
	Choerodon schoenleinii	3	547.8	112.4
DSI2	*Pentapodus porosus*	158	165.9	37.7
	Gnathanodon speciosus	13	446.1	80.3
	Carangoides fulvoguttatus	8	336.8	59.0
	Carangoides gymnostethus	14	237.7	11.4

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Nemipterus spp	1	261.6	
	Scombridae spp	7	513.0	46.5
	Pristotis obtusirostris	87	45.2	12.9
DSN1	*Pentapodus porosus*	55	162.3	23.1
	Pentapodus vitta	8	127.5	22.0
	Lethrinus punctulatus	14	209.6	28.8
	Carangoides fulvoguttatus	1	217.8	
	Selaroides leptolepis	43	148.5	12.9
	Carangoides gymnostethus	3	220.5	7.2
	Nemipterus spp	26	186.9	13.5
	Scombridae spp	5	627.3	55.9
	Atule mate	7	213.6	5.3
DSN3	*Pentapodus porosus*	37	161.5	28.9
	Lethrinus punctulatus	1	355.7	
	Carangoides fulvoguttatus	7	352.6	17.7
	Carangoides gymnostethus	57	503.5	23.3
	Nemipterus spp	3	129.8	28.1
	Lethrinus genivittatus	1	71.1	
	Scombridae spp	2	670.7	143.1
	Pristotis obtusirostris	8	55.7	7.3
MFR1	*Pentapodus porosus*	16	137.7	15.1
	Gnathanodon speciosus	4	345.5	350.1
	Pentapodus vitta	3	94.0	47.3
	Lethrinus punctulatus	19	200.8	54.4
	Carangoides fulvoguttatus	3	394.6	236.5
	Lethrinus nebulosus	10	352.8	68.3
	Pentapodus emeryii	18	229.0	48.3
	Choerodon cyanodus	20	205.3	79.3
	Acanthurus grammoptilus	2	281.9	57.9
	Lethrinus genivittatus	8	50.4	9.7
	Scombridae spp	1	714.8	
	Atule mate	5	219.9	8.9
	Scarus ghobban	11	195.5	92.3
	Choerodon schoenleinii	10	394.3	141.3
MFR3	*Pentapodus porosus*	4	58.5	15.3
	Lethrinus punctulatus	8	152.2	6.4
	Carangoides fulvoguttatus	2	533.6	0.4
	Lethrinus nebulosus	7	496.8	65.0
	Pentapodus emeryii	12	144.9	52.9
	Choerodon cyanodus	7	278.9	56.4
	Lethrinus atkinsoni	2	269.8	179.5
	Acanthurus grammoptilus	1	194.1	

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Lethrinus genivittatus	3	56.0	7.7
	Scombridae spp	1	624.2	
	Scarus ghobban	15	181.1	63.4
	Choerodon schoenleinii	5	500.7	83.4
MFR4	*Pentapodus porosus*	36	119.6	38.4
	Gnathanodon speciosus	6	737.3	83.9
	Lethrinus punctulatus	3	131.1	27.5
	Carangoides fulvoguttatus	34	476.1	95.9
	Lethrinus nebulosus	2	456.4	71.0
	Pentapodus emeryii	1	150.8	
	Choerodon cyanodus	3	244.8	123.7
	Lethrinus genivittatus	4	60.8	21.9
	Scombridae spp	3	492.9	87.0
	Choerodon schoenleinii	4	303.6	185.5
MFR5	*Pentapodus porosus*	3	100.3	59.8
	Pterocaesio spp	43	204.5	19.6
	Gnathanodon speciosus	13	207.2	29.8
	Lethrinus punctulatus	3	160.7	7.1
	Carangoides fulvoguttatus	5	492.9	57.3
	Lethrinus nebulosus	16	465.0	78.2
	Pentapodus emeryii	34	210.9	33.5
	Choerodon cyanodus	13	289.0	43.7
	Lethrinus atkinsoni	5	263.2	21.8
	Acanthurus grammoptilus	3	192.9	38.0
	Lethrinus genivittatus	3	48.8	7.3
	Scarus ghobban	7	255.3	105.8
	Choerodon schoenleinii	4	419.3	146.6
MI1	*Pentapodus porosus*	14	43.4	6.7
	Gnathanodon speciosus	10	792.1	105.7
	Pentapodus vitta	4	95.4	29.0
	Lethrinus punctulatus	24	207.2	12.5
	Carangoides fulvoguttatus	2	320.0	116.8
	Lethrinus nebulosus	1	191.3	
	Pentapodus emeryii	6	224.9	31.0
	Choerodon cyanodus	4	235.1	58.1
	Lethrinus genivittatus	2	49.2	3.2
	Scombridae spp	1	418.7	
	Choerodon schoenleinii	6	206.4	29.9
MI2	*Pentapodus porosus*	27	150.4	25.1
	Gnathanodon speciosus	3	243.6	7.0
	Pentapodus vitta	42	62.4	17.1
	Lethrinus punctulatus	43	173.5	35.9

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Carangoides fulvoguttatus	1	234.5	
	Lethrinus nebulosus	2	505.1	27.1
	Pentapodus emeryii	16	184.8	29.0
	Choerodon cyanodus	5	169.6	98.8
	Acanthurus grammoptilus	1	297.5	
	Lethrinus genivittatus	13	52.4	6.5
	Scombridae spp	3	461.1	72.0
	Choerodon schoenleinii	5	184.4	38.4
MN1	*Pentapodus porosus*	16	104.5	28.0
	Pentapodus vitta	27	66.5	6.1
	Lethrinus punctulatus	1	138.3	
	Carangoides fulvoguttatus	5	276.4	55.0
	Lethrinus nebulosus	5	294.6	29.5
	Pentapodus emeryii	12	185.6	37.5
	Choerodon cyanodus	5	240.9	68.7
	Acanthurus grammoptilus	1	158.5	
	Lethrinus genivittatus	24	53.7	8.5
	Scombridae spp	4	677.1	193.5
	Scarus ghobban	3	203.9	42.2
	Choerodon schoenleinii	8	281.3	84.7
MN2	*Pentapodus porosus*	7	110.6	50.5
	Pterocaesio spp	17	132.0	16.7
	Gnathanodon speciosus	25	259.0	29.3
	Pentapodus vitta	19	86.7	25.2
	Lethrinus punctulatus	161	169.0	34.7
	Carangoides fulvoguttatus	11	256.0	45.3
	Lethrinus nebulosus	1	220.4	
	Pentapodus emeryii	8	177.6	29.2
	Choerodon cyanodus	7	208.7	26.6
	Lethrinus genivittatus	25	129.6	35.7
	Scombridae spp	5	519.9	19.0
	Scarus ghobban	2	272.3	109.4
	Choerodon schoenleinii	4	203.2	78.0
MN3	*Pentapodus porosus*	5	32.5	3.0
	Gnathanodon speciosus	8	217.3	5.8
	Pentapodus vitta	6	38.4	6.2
	Lethrinus punctulatus	6	235.6	25.6
	Carangoides fulvoguttatus	6	277.6	41.6
	Lethrinus nebulosus	9	268.8	29.6
	Pentapodus emeryii	11	244.6	26.3
	Choerodon cyanodus	4	173.8	40.8
	Acanthurus grammoptilus	1	250.2	

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Lethrinus genivittatus	2	54.4	23.2
	Scombridae spp	1	554.0	
	Scarus ghobban	1	263.1	
	Choerodon schoenleinii	2	344.5	196.0
MN4	*Pentapodus porosus*	5	113.3	61.2
	Gnathanodon speciosus	3	291.9	12.4
	Pentapodus vitta	8	59.2	6.9
	Lethrinus punctulatus	13	227.0	16.7
	Carangoides fulvoguttatus	19	260.9	22.6
	Lethrinus nebulosus	2	448.0	134.7
	Pentapodus emeryii	9	211.8	31.9
	Choerodon cyanodus	6	156.7	92.1
	Lethrinus genivittatus	7	66.7	15.3
	Scombridae spp	1	514.7	
	Atule mate	1	262.1	
	Choerodon schoenleinii	4	244.4	28.3
SAFR1	*Pentapodus porosus*	8	181.6	24.8
	Gnathanodon speciosus	10	47.4	8.2
	Pentapodus vitta	98	143.2	20.7
	Selaroides leptolepis	95	131.4	17.9
	Nemipterus spp	3	173.3	6.3
	Lethrinus genivittatus	1	164.3	
	Scombridae spp	1	539.4	
	Atule mate	1	199.0	
SAFR2	*Gnathanodon speciosus*	24	56.2	11.4
	Pentapodus vitta	50	135.8	14.0
	Scombridae spp	3	540.0	25.6
SAFR3	*Pentapodus porosus*	12	168.7	16.2
	Gnathanodon speciosus	4	33.1	7.2
	Pentapodus vitta	47	137.4	14.0
	Selaroides leptolepis	6	140.6	6.0
	Nemipterus spp	23	164.0	19.1
	Lethrinus genivittatus	2	126.3	6.0
	Scombridae spp	6	653.8	108.4
SAN1	*Pentapodus porosus*	8	173.4	12.2
	Gnathanodon speciosus	29	195.7	199.4
	Pentapodus vitta	32	145.7	14.9
	Carangoides fulvoguttatus	2	256.8	1.6
	Selaroides leptolepis	8	153.4	8.7
	Nemipterus spp	30	175.5	13.3
	Scombridae spp	2	638.0	183.0
	Atule mate	1	252.8	

Site	Species	Number (n)	Mean Length (mm)	Standard Error
	Choerodon schoenleinii	1	318.9	
SI1	*Pentapodus porosus*	16	144.0	24.0
	Gnathanodon speciosus	1	194.3	
	Pentapodus vitta	44	125.0	14.2
	Nemipterus spp	3	188.1	14.2
	Scombridae spp	17	492.1	69.9
	Pristotis obtusirostris	1	42.9	
SI2	*Pentapodus porosus*	3	150.4	90.0
	Gnathanodon speciosus	6	631.3	185.1
	Lethrinus punctulatus	23	219.9	19.5
	Lethrinus nebulosus	1	269.1	
	Choerodon cyanodus	4	210.9	70.3
	Nemipterus spp	1	83.2	
	Scombridae spp	2	427.4	57.4
	Atule mate	3	157.4	44.4
	Scarus ghobban	1	245.2	
	Choerodon schoenleinii	1	309.1	
SIFR2	*Pentapodus porosus*	73	167.4	26.9
	Pterocaesio spp	23	127.6	13.4
	Lethrinus punctulatus	1	213.7	
	Carangoides gymnostethus	1	227.4	
	Choerodon cyanodus	1	134.0	
	Nemipterus spp	5	206.6	19.9
	Lethrinus genivittatus	18	130.0	18.3
	Scombridae spp	3	594.1	33.0
	Pristotis obtusirostris	6	91.0	14.5
SIFR3	*Pentapodus porosus*	3	189.1	31.6
	Gnathanodon speciosus	21	44.0	13.0
	Pentapodus vitta	17	150.4	20.3
	Carangoides gymnostethus	1	227.6	
	Nemipterus spp	6	196.6	19.6
	Scombridae spp	8	485.4	73.4
	Atule mate	15	230.2	15.5
SIFR5	*Pentapodus vitta*	1	42.5	
	Carangoides fulvoguttatus	1	519.6	
	Lethrinus nebulosus	3	377.7	59.2
	Pentapodus emeryii	1	208.5	
	Choerodon cyanodus	12	272.2	41.3
	Acanthurus grammoptilus	6	244.1	63.3
	Lethrinus genivittatus	2	37.7	0.0
	Scarus ghobban	1	233.6	
	Choerodon schoenleinii	12	270.4	57.7

Site	Species	Number (n)	Mean Length (mm)	Standard Error
SIN1	*Pentapodus porosus*	1	134.2	
	Pentapodus vitta	11	118.9	18.0
	Lethrinus genivittatus	42	67.0	14.7
	Scombridae spp	12	521.8	78.7
	Pristotis obtusirostris	6	39.2	4.9
SIN2	*Pentapodus porosus*	3	174.2	21.6
	Gnathanodon speciosus	13	252.1	344.0
	Carangoides fulvoguttatus	1	237.3	
	Selaroides leptolepis	1	110.9	
	Nemipterus spp	4	160.8	28.9
	Scombridae spp	3	579.2	58.9
	Atule mate	1	118.8	
SIN3	*Pentapodus porosus*	12	51.8	6.5
	Pentapodus vitta	16	54.9	10.3
	Carangoides fulvoguttatus	8	355.2	107.9
	Lethrinus nebulosus	12	405.4	48.8
	Choerodon cyanodus	3	296.0	11.2
	Acanthurus grammoptilus	1	259.6	
	Scombridae spp	5	604.0	102.2
	Scarus ghobban	2	285.9	32.3
	Choerodon schoenleinii	3	330.5	35.5
SIN4	*Pentapodus porosus*	59	181.7	22.0
	Gnathanodon speciosus	16	354.9	218.2
	Lethrinus punctulatus	16	200.9	13.4
	Carangoides fulvoguttatus	1	537.2	
	Nemipterus spp	1	153.7	
	Scombridae spp	5	489.3	78.0
	Atule mate	3	154.6	21.8
SIN5	*Pentapodus porosus*	71	172.8	28.8
	Gnathanodon speciosus	4	553.1	351.4
	Carangoides fulvoguttatus	4	313.3	147.6
	Carangoides gymnostethus	5	364.6	178.4
	Nemipterus spp	12	137.0	37.7
	Scombridae spp	9	535.2	119.7
	Atule mate	2	286.2	0.9
SIN6	*Pentapodus porosus*	36	157.1	18.5
	Selaroides leptolepis	4	146.8	13.0
	Choerodon cyanodus	1	169.7	
	Nemipterus spp	13	175.4	35.4
	Lethrinus genivittatus	1	51.5	
	Scombridae spp	3	503.4	42.5
	Pristotis obtusirostris	3	74.4	4.8

Site	Species	Number (n)	Mean Length (mm)	Standard Error
SIN7	*Pentapodus porosus*	25	155.6	25.3
	Gnathanodon speciosus	13	656.2	86.9
	Pentapodus vitta	5	45.4	10.9
	Lethrinus punctulatus	1	205.8	
	Carangoides fulvoguttatus	2	419.5	64.0
	Lethrinus nebulosus	2	426.8	29.2
	Carangoides gymnostethus	4	223.3	9.4
	Nemipterus spp	31	207.8	46.2
	Scombridae spp	2	487.8	104.9
	Atule mate	5	225.8	9.0
	Pristotis obtusirostris	4	32.8	2.3

Table A4.2 Mean Length of the 20 Indicator Demersal Fish Species for Coral Habitats at Barrow Island for the Marine Baseline Program, Post-Development Survey Year 1, and Post-Development Survey Year 2 for each of the Coral Survey Sites

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
CFR1	*Abudefduf bengalensis*				1	75		2	62.0	1.9
	Acanthurus grammoptilus	2	296.4	52.6	2	201	35.2	11	236.7	8.8
	Chaetodon aureofasciatus	3	52.2	2.7						
	Chelmon marginalis	1	75.2							
	Choerodon cauteroma	10	209.4	16.6						
	Choerodon cyanodus	13	251.0	24.5	6	278	18.4	8	301.2	14.4
	Choerodon schoenleinii	17	342.7	33.5	3	329	80.0	4	318.0	37.1
	Cromileptes altivelis	2	419.5	58.9						
	Epinephelus bilobatus				2	242	57.1	3	252.5	24.3
	Epinephelus polyphekadion	2	435.7	90.9						
	Lethrinus atkinsoni	21	261.5	8.2	19	268	5.8	14	244.8	8.6
	Lethrinus nebulosus	3	385.1	15.8	3	353	40.7	3	390.5	37.6
	Lutjanus carponotatus	16	243.7	19.6	1	152		1	351.9	
	Neopomacentrus filamentosus	8	49.4	2.6						
	Pentapodus emeryii	7	154.6	12.9				2	186.8	16.2
	Plectropomus spp	14	384.9	28.4	2	339	7.0	2	482.1	61.0
	Pomacanthus sexstriatus	8	220.1	7.8	3	248	24.7	3	260.3	16.0
	Siganus doliatus	9	208.8	18.5				1	211.2	
	Symphorus nematophorus	2	566.6	35.9	2	389	90.3	1	540.1	
	Thalassoma lunare	35	85.4	2.8	22	113	6.2	7	95.1	5.4
CFR2	*Abudefduf bengalensis*	4	101.8	9.5	4	129	3.0	3	168.8	31.4
	Acanthurus grammoptilus	5	263.1	14.3	3	224	8.8	5	334.4	14.3
	Chaetodon aureofasciatus	11	67.2	4.3	1	74		3	130.8	85.3
	Chelmon marginalis	2	84.5	4.7	1	128		1	74.7	
	Choerodon cauteroma				1	230		4	251.1	16.5
	Choerodon cyanodus	16	237.4	25.9	10	262	27.9	5	293.3	47.9
	Choerodon schoenleinii	11	392.1	55.4	5	372	48.0	6	307.0	74.3
	Cromileptes altivelis	1	519.8							
	Epinephelus bilobatus	1	256.4		1	305		3	280.8	15.5

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
	Epinephelus polyphekadion				1	354		2	530.8	89.8
	Lethrinus atkinsoni	29	236.2	8.4	6	247	10.9	6	267.5	20.5
	Lethrinus nebulosus	2	420.5	39.5	8	387	18.8	38	367.4	8.5
	Lutjanus carponotatus	19	164.2	6.3	4	249	63.4	9	214.5	28.8
	Neopomacentrus filamentosus	1	73.0							
	Plectropomus spp	14	258.4	21.8	2	209	97.4	1	229.3	
	Pomacanthus sexstriatus	3	245.9	30.1	2	283	40.8	10	358.4	19.1
	Siganus doliatus	3	165.7	0.9				2	169.7	13.1
	Symphorus nematophorus	2	628.2	10.9	1	752		4	200.4	39.7
	Thalassoma lunare	17	161.2	8.1	8	143	11.6	1	447.5	
CFR3	*Abudefduf bengalensis*	23	128.7	3.8	4	103	9.9	2	109.1	24.3
	Acanthurus grammoptilus	16	238.6	15.9	6	179	13.0	18	209.4	11.9
	Chaetodon aureofasciatus	4	93.6	7.7	2	68	2.5			
	Chelmon marginalis	8	121.4	6.9	2	91	11.4			
	Choerodon cauteroma	6	240.1	16.1	1	153		3	220.2	17.4
	Choerodon cyanodus	14	286.3	21.4	16	229	19.7	11	264.1	17.1
	Choerodon schoenleinii	18	356.9	30.8	6	380	52.6	4	323.4	72.2
	Epinephelus bilobatus	3	286.1	20.6	2	179	32.1			
	Lethrinus atkinsoni	3	265.8	73.1	4	249	25.0	2	241.4	5.3
	Lethrinus nebulosus	8	355.0	31.6	22	425	15.7			
	Lutjanus carponotatus	47	258.8	7.4	5	264	41.2	6	249.2	12.3
	Neopomacentrus filamentosus	4	51.1	4.2	3	47	5.1	18	352.5	10.1
	Pentapodus emeryii	10	157.6	9.7				8	313.8	13.7
	Plectropomus spp	8	357.0	30.7	7	321	51.1	9	40.5	1.2
	Pomacanthus sexstriatus	3	196.0	43.3	2	193	67.5	3	218.9	17.6
	Siganus doliatus	16	204.4	20.0	4	107	5.9	5	334.7	79.7
	Symphorus nematophorus	9	515.7	42.7	2	637	112.0			
	Thalassoma lunare	8	121.3	13.4	3	161	3.1	8	188.4	13.0
CFR4	*Abudefduf bengalensis*	1	133.2		3	119	1.1	3	150.1	7.5
	Acanthurus grammoptilus	6	207.9	18.4	5	154	22.2	8	195.1	18.2
	Chaetodon aureofasciatus	2	92.3	3.2	7	66	6.0	3	98.9	17.8

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
	Chelmon marginalis	1	100.6		5	119	10.9	1	140.0	
	Choerodon cauteroma	2	197.7	36.3	3	232	11.7			
	Choerodon cyanodus	7	211.9	36.8	11	228	15.0	8	284.1	22.8
	Choerodon schoenleinii	3	381.2	111.7	4	526	60.5	1	498.4	
	Epinephelus bilobatus	7	299.1	16.9	6	262	13.5			
	Epinephelus polyphekadion	1	481.0		2	429	78.2	2	274.7	49.6
	Lethrinus atkinsoni	26	271.6	12.0	19	288	8.0	2	452.1	95.4
	Lethrinus nebulosus	2	476.4	60.9	4	423	41.1	36	282.5	6.0
	Lutjanus carponotatus	6	287.0	19.5	2	238	87.7	6	442.8	26.1
	Pentapodus emeryii	13	216.3	12.1				2	288.4	9.7
	Plectropomus spp	19	359.7	26.6	6	254	28.6			
	Pomacanthus sexstriatus	8	184.0	19.9	2	223	31.4	8	217.0	19.0
	Siganus doliatus				2	138	3.7	10	317.1	52.6
	Symphorus nematophorus	4	615.5	126.0	2	504	226.1	2	214.3	40.5
	Thalassoma lunare	39	88.2	3.9	26	109	5.2	12	157.8	10.5
CI1	*Abudefduf bengalensis*	16	143.3	5.2	3	118	8.2	4	151.7	14.8
	Acanthurus grammoptilus	34	222.6	8.5	4	192	16.6	4	221.6	19.0
	Chaetodon aureofasciatus	2	87.4	23.9						
	Chelmon marginalis	3	106.7	25.1	2	103	7.4	5	128.4	2.5
	Choerodon cauteroma	9	222.5	16.0	8	188	15.6	6	229.3	9.6
	Choerodon cyanodus	16	239.4	19.3	9	207	19.4	12	249.6	15.1
	Choerodon schoenleinii	14	381.4	35.7	4	143	11.7	5	251.0	31.4
	Cromileptes altivelis	2	403.1	38.9						
	Epinephelus bilobatus	6	316.6	14.1	2	208	3.0	4	266.9	14.4
	Epinephelus polyphekadion	1	444.5							
	Lethrinus atkinsoni	1	194.2		1	211				
	Lethrinus nebulosus	4	326.4	41.0	10	275	24.6	18	376.8	21.1
	Lutjanus carponotatus	21	263.5	18.0	1	277		10	164.5	15.9
	Neopomacentrus filamentosus	1	48.4					1	37.4	
	Pentapodus emeryii	25	207.6	8.8				6	207.0	8.4
	Pentapodus porosus				2	156	0.2	3	338.0	87.7

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
	Plectropomus spp	16	292.4	30.9	1	353		2	187.5	12.9
	Pomacanthus sexstriatus	7	216.9	27.0						
	Siganus doliatus	20	209.3	6.7				2	271.6	44.7
	Symphorus nematophorus	3	490.1	174.4	1	603		1	104.1	
	Thalassoma lunare	8	143.4	14.5				4	151.7	14.8
CI2	*Abudefduf bengalensis*	22	143.3	7.5	26	137	1.8	13	143.0	2.7
	Acanthurus grammoptilus	26	211.6	12.1	6	223	34.0	9	231.9	17.3
	Chaetodon aureofasciatus	1	92.6		2	64	23.5	1	60.7	
	Chelmon marginalis	9	138.7	6.1	3	129	19.3	2	127.2	1.7
	Choerodon cauteroma	11	235.9	8.7	8	218	7.3	9	215.0	8.0
	Choerodon cyanodus	14	284.0	14.4	8	237	27.0	7	266.7	18.7
	Choerodon schoenleinii	15	381.9	28.1	3	316	115.4	9	411.6	39.8
	Cromileptes altivelis	3	332.0	89.7				1	211.8	
	Epinephelus bilobatus	8	291.5	27.2	2	278	5.8	6	236.5	18.7
	Epinephelus polyphekadion	5	480.5	22.3	5	438	32.6	2	438.9	67.0
	Lethrinus atkinsoni	2	279.2	15.7	2	250	4.7	1	271.7	
	Lethrinus nebulosus	19	343.2	18.8	22	421	18.1	34	351.3	16.3
	Lutjanus carponotatus	19	275.0	15.2	26	210	10.5	10	270.6	19.1
	Neopomacentrus filamentosus	35	44.5	1.0	16	45	2.5	48	38.5	1.0
	Pentapodus emeryii	14	221.0	13.1				13	227.1	8.5
	Pentapodus porosus				6	107	34.7	11	392.5	39.0
	Plectropomus spp	16	400.8	45.9	7	354	68.6	4	302.7	10.9
	Pomacanthus sexstriatus	13	269.3	22.8	2	266	21.1	3	224.5	11.2
	Siganus doliatus	20	197.7	10.6	6	214	21.5	5	578.0	84.3
	Symphorus nematophorus	9	304.2	27.2	5	479	108.9	9	128.1	6.5
	Thalassoma lunare	11	129.4	11.1	9	130	9.9	13	143.0	2.7
CI3	*Abudefduf bengalensis*	27	132.4	5.2	16	127	2.5	13	128.0	2.4
	Acanthurus grammoptilus	7	172.3	22.1	9	213	10.1	27	209.7	6.7
	Chaetodon aureofasciatus	8	94.6	14.6	9	74	5.6	1	105.0	
	Chelmon marginalis	4	126.9	3.8	3	151	14.6	1	148.5	
	Choerodon cauteroma	2	192.2	57.8	1	248		2	227.2	50.2

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
	Choerodon cyanodus	13	285.0	12.0	12	212	17.6	10	225.8	20.0
	Choerodon schoenleinii	9	324.7	33.0	8	285	41.1	6	322.0	56.8
	Cromileptes altivelis	2	412.8	131.7				1	390.8	
	Epinephelus bilobatus	3	299.2	34.0	4	297	28.5	5	285.3	14.5
	Epinephelus polyphekadion	1	447.2		5	428	25.4	1	550.7	
	Lethrinus atkinsoni	10	303.9	11.0	7	278	15.8	10	287.4	4.3
	Lethrinus nebulosus				2	439	18.8	5	436.3	30.9
	Lutjanus carponotatus	30	244.6	14.0	10	293	9.3	17	248.0	13.8
	Neopomacentrus filamentosus	55	41.6	1.1	32	41	1.7	3	41.2	2.6
	Pentapodus emeryii	3	188.7	6.8				6	189.8	16.5
	Pentapodus porosus				1	58		10	343.9	22.7
	Plectropomus spp	12	404.1	42.2	6	300	54.7	4	208.8	21.9
	Pomacanthus sexstriatus	6	194.6	21.8	6	216	16.3	11	185.4	12.6
	Siganus doliatus	6	171.8	16.3	8	189	13.4	1	763.0	
	Symphorus nematophorus				1	266		15	140.0	6.0
	Thalassoma lunare	32	108.4	4.9	22	120	5.0	13	128.0	2.4
CN1	*Abudefduf bengalensis*	11	125.2	5.8	9	94	9.9	8	112.5	7.4
CN1	*Acanthurus grammoptilus*	35	237.8	5.6	25	226	9.3	40	222.8	4.0
CN1	*Chaetodon aureofasciatus*	4	83.0	7.0	3	101	7.2	1	68.2	
CN1	*Chelmon marginalis*	4	141.8	4.6	1	57		1	144.6	
CN1	*Choerodon cauteroma*	11	241.2	7.7	1	221		5	152.0	30.1
CN1	*Choerodon cyanodus*	16	246.8	12.9	15	247	8.0	5	256.8	13.3
CN1	*Choerodon schoenleinii*	18	375.8	32.5	7	312	66.0	8	260.5	16.4
CN1	*Cromileptes altivelis*	5	322.9	23.0	1	215				
CN1	*Epinephelus bilobatus*	8	288.1	12.9	6	310	16.9	11	301.4	9.3
CN1	*Epinephelus polyphekadion*	5	467.8	26.0	2	458	91.1	1	344.3	
CN1	*Lethrinus atkinsoni*	25	308.3	10.2	51	269	6.6	66	272.8	3.7
CN1	*Lethrinus nebulosus*	18	324.7	17.4	6	314	12.5	4	360.9	25.9
CN1	*Lutjanus carponotatus*	14	304.2	10.6	12	302	8.1	8	293.5	15.2
CN1	*Neopomacentrus filamentosus*	1	36.5		7	38	2.4	8	46.1	3.6
CN1	*Pentapodus emeryii*	13	255.4	14.4				4	186.8	31.3

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
	Pentapodus porosus				3	55	3.7	5	290.6	39.1
	Plectropomus spp	16	380.1	30.6	9	301	33.4	1	198.9	
	Pomacanthus sexstriatus	10	222.4	10.4	3	202	18.6	3	171.2	28.6
	Siganus doliatus	47	204.6	6.3	13	206	19.3	3	414.0	160.1
	Symphorus nematophorus	5	615.1	110.3				1	98.0	
	Thalassoma lunare	14	135.9	17.2	7	93	11.5	8	112.5	7.4
CN2	*Abudefduf bengalensis*	24	139.5	3.6	10	132	3.1	16	122.2	3.3
	Acanthurus grammoptilus	4	138.2	9.1	4	165	7.9	8	217.8	9.2
	Chaetodon aureofasciatus	7	76.1	6.2	2	83	4.2			
	Chelmon marginalis	1	146.9		1	87		2	141.9	9.8
	Choerodon cauteroma	3	262.0	23.2						
	Choerodon cyanodus	10	262.4	14.6	6	248	21.4	3	258.8	25.7
	Choerodon schoenleinii	7	398.9	49.3	4	245	25.9	4	359.8	37.3
	Cromileptes altivelis	1	320.1					2	373.5	55.4
	Epinephelus bilobatus	1	152.3		8	318	22.0	4	255.5	32.5
	Epinephelus polyphekadion	3	382.7	4.6	1	507		3	318.5	33.3
	Lethrinus atkinsoni	6	306.5	17.5	20	279	6.5	13	286.7	6.3
	Lethrinus nebulosus	1	347.2		4	462	27.6	2	325.7	0.9
	Lutjanus carponotatus	32	255.0	10.3	11	253	10.5	15	272.1	8.0
	Neopomacentrus filamentosus	28	45.3	1.8	4	41	3.3	18	38.8	1.7
	Pentapodus emeryii	6	258.9	10.3				4	229.5	15.8
	Plectropomus spp	8	376.0	45.9	8	337	40.6	11	325.6	14.2
	Pomacanthus sexstriatus	8	222.7	21.3	3	212	47.1	4	185.6	36.4
	Siganus doliatus	20	229.7	5.1	6	201	5.9			
	Symphorus nematophorus				1	410		1	292.6	
	Thalassoma lunare	30	113.5	5.9	17	115	7.3	10	133.2	8.9
CN3	*Abudefduf bengalensis*	11	142.6	2.9	62	125	3.0	13	129.9	5.6
	Acanthurus grammoptilus	9	243.3	13.2	8	200	18.9	4	234.4	5.0
	Chaetodon aureofasciatus	4	77.6	9.7	4	59	5.5	4	55.7	9.1
	Chelmon marginalis	6	131.9	8.8	1	116		1	135.6	
	Choerodon cauteroma	5	222.9	28.3	2	258	15.4	5	265.6	38.9

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
	Choerodon cyanodus	16	286.7	13.7	11	228	17.1	11	271.0	27.1
	Choerodon schoenleinii	9	485.0	42.6	2	373	192.8	7	373.8	48.2
	Cromileptes altivelis				2	324	28.6	2	331.1	6.6
	Epinephelus bilobatus	1	303.9		6	295	31.2	4	318.4	28.5
	Epinephelus polyphekadion				1	528		2	276.4	30.2
	Lethrinus atkinsoni	14	258.5	14.7	10	237	10.5	14	229.4	10.9
	Lethrinus nebulosus	15	306.3	19.9	6	372	33.1	12	355.6	17.8
	Lutjanus carponotatus	13	319.9	17.9	21	239	22.5	10	331.4	21.9
	Neopomacentrus filamentosus	12	46.5	4.3	2	37	11.1	3	42.5	3.5
	Pentapodus emeryii	22	228.5	9.1				5	224.8	16.8
	Plectropomus spp	10	325.7	30.8	7	401	32.4	14	377.2	22.2
	Pomacanthus sextriatus	8	178.8	16.8	2	145	36.8	4	153.8	28.2
	Siganus doliatus	5	212.0	20.4				4	216.2	22.6
	Symphorus nematophorus	10	703.1	43.9	1	911		4	668.0	9.9
	Thalassoma lunare	44	110.2	3.8	41	123	4.2	22	110.3	5.8
CN4	*Abudefduf bengalensis*	2	158.4	12.2	2	120	2.5	1	158.0	
	Acanthurus grammoptilus	4	255.2	7.6	5	253	16.0			
	Chaetodon aureofasciatus	2	84.1	15.5				1	93.1	
	Choerodon cauteroma	2	306.8	37.1	4	276	25.6			
	Choerodon cyanodus	3	315.5	9.4	5	291	17.1	2	257.6	34.9
	Choerodon schoenleinii	2	490.1	105.0	3	372	45.2	3	328.7	9.8
	Cromileptes altivelis	1	437.6		1	240		4	376.8	51.5
	Epinephelus bilobatus	6	336.5	17.9	5	265	36.5	3	282.9	13.1
	Epinephelus polyphekadion	1	652.4		4	506	63.5	1	318.8	
	Lethrinus atkinsoni	1	278.9		4	301	12.8	1	608.0	
	Lethrinus nebulosus	2	330.4	74.5	3	349	21.4	3	340.6	12.4
	Lutjanus carponotatus	15	236.2	3.8	8	230	32.0	4	415.8	23.5
	Neopomacentrus filamentosus	1	56.1		1	62		5	304.1	8.4
	Pentapodus emeryii	3	257.3	23.4				2	42.2	3.6
	Plectropomus spp	4	394.9	5.1	7	419	45.5	6	219.4	15.5
	Symphorus nematophorus	1	353.2		2	654	58.9	6	467.3	39.7

Site	Species	Marine Baseline Program			Post-Development Survey Year 1			Post-Development Survey Year 2		
		Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error	Number (n)	Mean Length (mm)	Standard Error
	Thalassoma lunare	4	116.2	12.9	13	113	7.5	3	237.1	11.4
CN5	*Abudefduf bengalensis*	7	137.9	4.0	2	135	14.2	2	118.7	5.9
	Acanthurus grammoptilus	6	244.5	26.7	14	195	14.5	9	195.2	8.1
	Chaetodon aureofasciatus	1	111.4		5	81	19.5	8	96.4	3.7
	Chelmon marginalis	1	131.1		2	154	6.7	5	140.4	10.8
	Choerodon cauteroma	4	205.1	14.3	3	221	20.7	4	250.3	10.1
	Choerodon cyanodus	6	199.9	23.7	4	208	35.7	10	257.1	18.5
	Choerodon schoenleinii	5	442.3	53.5	4	367	38.6	7	235.6	14.1
	Cromileptes altivelis				1	334				
	Epinephelus bilobatus				3	332	36.4	3	287.9	18.9
	Lethrinus atkinsoni	3	308.2	28.2	16	302	7.4	3	452.3	73.2
	Lethrinus nebulosus	13	505.0	25.7	8	384	35.0	6	302.7	10.0
	Lutjanus carponotatus	3	305.3	20.5	3	305	15.0	4	341.2	42.4
	Neopomacentrus filamentosus				6	35	1.4	8	326.8	15.4
	Pentapodus emeryii	7	222.0	18.6				3	42.6	4.4
	Pentapodus porosus				14	183	2.5	12	213.6	10.5
	Plectropomus spp	4	334.1	32.8	6	429	63.2	6	292.8	23.1
	Pomacanthus sexstriatus	2	232.3	24.8	3	243	40.3	3	195.5	25.9
	Siganus doliatus	4	169.9	9.9				3	232.1	4.9
	Symphorus nematophorus	5	705.6	93.9	2	344	158.0			
	Thalassoma lunare	10	134.6	13.0	7	130	12.1	10	138.4	11.1