

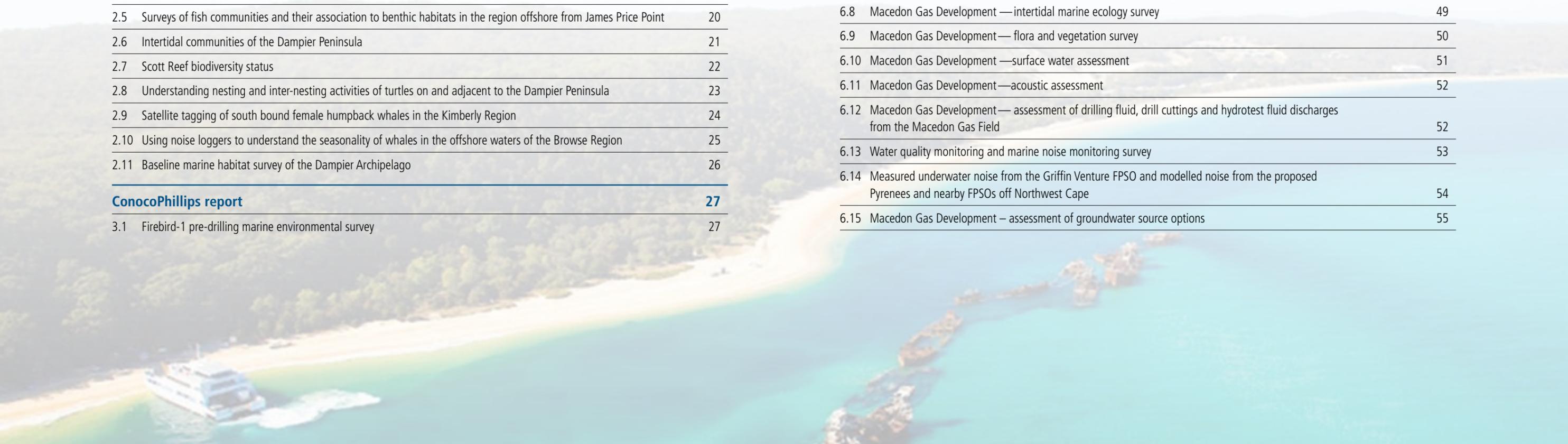


APPEA
ENVIRONMENTAL
RESEARCH COMPENDIUM

1 Contents



Foreword	iv
Chevron reports	1
1.1 Gorgon dredging simulation studies	1
1.2 Quantification of suspended sediment concentrations and sedimentation associated with pipeline installation directional drilling from the west coast of Barrow Island	2
1.3 Barrow Island flora and vegetation surveys	4
1.4 Barrow Island protected marine species	6
1.5 Sea turtle track census monitoring program	7
1.6 Sea turtle hatchling arena experiments	8
1.7 Barrow Island light survey	9
1.8 Marine benthic habitats	10
1.9 Barrow Island intertidal habitats	11
1.10 Barrow Island marine surveys	12
1.11 Plant pathogen threats to Barrow Island	13
1.12 Measurement and model prediction of ocean currents and tides at Barrow Island, North Western Australia	14
1.13 Bioremediation of oil contaminated soil on Barrow Island	15
Woodside Energy reports	16
2.1 Long-term monitoring of marine turtles of Scott Reef	16
2.2 Surveys of humpback whale migration patterns and behaviours in the Kimberley region	17
2.3 Distribution and abundance of dugongs in the shallow waters of the Dampier Peninsula	18
2.4 Distribution and abundance of sea snakes, sharks and seabirds along the Dampier Peninsula	19
2.5 Surveys of fish communities and their association to benthic habitats in the region offshore from James Price Point	20
2.6 Intertidal communities of the Dampier Peninsula	21
2.7 Scott Reef biodiversity status	22
2.8 Understanding nesting and inter-nesting activities of turtles on and adjacent to the Dampier Peninsula	23
2.9 Satellite tagging of south bound female humpback whales in the Kimberly Region	24
2.10 Using noise loggers to understand the seasonality of whales in the offshore waters of the Browse Region	25
2.11 Baseline marine habitat survey of the Dampier Archipelago	26
ConocoPhillips report	27
3.1 Firebird-1 pre-drilling marine environmental survey	27
Nexus Energy report	28
4.1 Review of cyclone data (1986 to 2006) in the Timor Sea specifically within the vicinity of the Crux Field Development	28
Apache reports	29
5.1 Estimating demographic parameters of breeding populations of Hawksbill Turtles—a critically endangered marine species	29
5.2 Collaborative whale shark data collection—Ningaloo Reef 2009–2013	31
5.3 Monitoring of annual variation in seabird breeding colonies throughout the Lowendal Group of Islands	32
5.4 The integrated Shearwater Monitoring Project	33
5.5 Marine monitoring—corals	35
5.6 Varanus and Bridled Islands vegetation monitoring	37
5.7 Chemical and biological assessment of produced formation water discharge from Harriet A Platform with a tropical reef species, stripey seaperch (<i>Lutjanus carponotatus</i>)	38
5.8 Marine monitoring program for persistence and impacts of synthetic-based muds	40
BHP Billiton reports	42
6.1 Macedon Gas Development — air quality screening assessment	42
6.2 Macedon Gas Development — fauna assessment at plant site and linear infrastructure corridor	43
6.3 Macedon Gas Development—sea turtle survey	44
6.4 Whale population parameters near the Ravensworth Development Area (boat-based survey)	45
6.5 Macedon Gas Development—subtidal marine ecology survey	46
6.6 Seabed biodiversity survey at the Stybarrow 3, Harrison 1 and Crosby 2 locations	47
6.7 Ursula coastline marine turtle habitat usage	48
6.8 Macedon Gas Development — intertidal marine ecology survey	49
6.9 Macedon Gas Development — flora and vegetation survey	50
6.10 Macedon Gas Development —surface water assessment	51
6.11 Macedon Gas Development —acoustic assessment	52
6.12 Macedon Gas Development — assessment of drilling fluid, drill cuttings and hydrotest fluid discharges from the Macedon Gas Field	52
6.13 Water quality monitoring and marine noise monitoring survey	53
6.14 Measured underwater noise from the Griffin Venture FPSO and modelled noise from the proposed Pyrenees and nearby FPSOs off Northwest Cape	54
6.15 Macedon Gas Development — assessment of groundwater source options	55



Foreword

The Australian oil and gas industry has a long history of supporting and investing in environmental research. Over the past decades Australia's petroleum industry has taken a strategic view towards understanding and managing the effects it has on the environment.

This compendium brings together 49 research projects undertaken by Australian petroleum companies in recent years and provides simple summaries of these studies.

The summaries explain why and how a project was undertaken, the outcomes and findings, and the implications for the industry.

Studies in this document include, among other subjects, research on:

- fauna, including whales, sharks, turtles, seabirds, dugongs, sea-snakes and fish
- vegetation and threats to vegetation
- currents and tides
- marine and terrestrial habitats
- water-quality monitoring and marine noise monitoring
- dredging simulation studies.

Targeted research efforts fill knowledge gaps while also reducing the duplication of research efforts. Compiling these studies into one volume provides ready access to the most current environmental data.

These projects show the industry's determination to build a better understanding of the environment in which it operates and minimise their environmental impacts.

In providing these research findings in an easily understood format, the industry is demonstrating its ongoing commitment to sharing that information and each company is more than willing to provide further information on any of these projects on request.

1 Chevron reports

1.1 Gorgon Dredging Simulation Studies

What was done

An environmental modelling and mapping consulting firm was contracted to carry out simulations for the dredging of the Materials Offload Facility (MOF) and the LNG shipping access channel for the Chevron Gorgon Development at Barrow Island, Western Australia.

To achieve this two sophisticated numerical computer models were used:

- A 3D coastal ocean model used to simulate the complex 3D ocean currents surrounding Barrow Island.
- A 3D dredge simulation model used to determine the fate of particles released into the water column during the dredging operations.

Modelling the movement of dredged materials was carried out in two steps. Firstly the 3D ocean circulation of the region south of Barrow Island and north of the Montebello Islands was predicted for 15 months. Then the total dredge program was simulated over 464 days, which simulates the daily behaviour and movement of the dredged material based on an estimated dredge log.

The model predicted the hourly distribution of Total Suspended Solids (TSS) and area of seabed coverage to be developed over the entire dredge program. The daily output and movement of material was analysed to derive periods of continuous exposure to turbidity and/or sedimentation. Impact criteria were used to produce exposure zones showing regions affected by turbidity and sedimentation that result in areas of high impact, moderate impact or influence (but no impact).

Why it was done

Dredging simulation studies for the proposed dredging activities at Barrow Island were undertaken to determine the fate of particles released into the water column during dredging operations for the Gorgon Development. This information was used to assess potential environmental implications of the dredging activities and develop approaches to minimise the impacts associated with the proposed development.

Findings

Four simulations were carried out, using an outlined set of assumptions, to predict the behaviour of particles released into the water column during the dredging program.

Simulation 1 (The 'Base' Case) predicted a build up of deposited sediments in the immediate vicinity of the dredging area and spoil disposal site from the settlement of larger sediments (> 75 µm). Finer sediments remained suspended for longer periods of time leading to increased turbidity, which varied significantly in space and time. Model analysis indicated that the dredging of the MOF contributed very little to the defined impact zones. The turbidity and sedimentation generated during dredging remained localised in the region surrounding the dredge and bund overflow. An area of moderate impact extending northward over the Lowendal shelf was attributed to materials released into the water column by the propeller wash of the Trailing Hopper Suction Dredger (THSD). This material is subject to strong tidal currents and southerly winds allowing it to move, deposit and resuspend during several tidal cycles, and reach the Lowendal shelf.

Simulation 2 (The 'Base' Case with UKC Controlled) applied the same assumptions as Simulation 1 but with under-keel clearance (UKC) controlled to 4 metres. This model predicted a significant reduction in the moderate impact zone, particularly in the region extending towards the Lowendal shelf.

Simulation 3 (The 'Base' Case with more easterly winds) applied the same assumptions as Simulation 1 but modelled the dredging from 1 October 1999 to 8 January 2001 to cover a period of higher than average easterly wind events. The simulation produced similar results to the 'base' case, but with slightly increased flushing of sediments during the winter months.

Simulation 4 (The 'Base' Case with more westerly winds) applied the same assumptions as Simulation 1 but modelled the dredging from 1 October 2001 to 8 January 2003 to cover a period of higher than average easterly wind events. The simulation minimal change to the impact zones however indicated that increased westerly winds could result in higher occurrences of turbidity across the Lowendal shelf.

Implications for the industry

This study establishes computer modelling programs as accurate and reliable approaches to simulate ocean currents and tides and predict movements of material released into the water column during dredging activities. This can provide valuable information for conducting risk assessments for project related infrastructure and activities.





1.2 Quantification of suspended sediment concentrations and sedimentation associated with pipeline installation directional drilling from the west coast of Barrow Island

What was done

On behalf of Chevron, a private consulting firm carried out a study investigating the outcomes of a proposed directional drilling program for the Gorgon development at Barrow Island, Western Australia. Sedimentation patterns generated from directional drilling were modelled and compared for different drilling fluids (bentonite clay or a water soluble polymer) and for alternative pipeline routes (Flacourt Bay or North White's Beach). The drilling program was to be carried out over the period from June to December and involved 10 separate drilling operations, each lasting approximately one week with a break of 7 to 10 days between each drilling phase. Thus, there were 10 separate periods of continuous discharge separated by 7 to 10 days of nil discharge over a period of approximately 6 months.

Modelling of the hydrodynamic circulation in the Barrow Island region was conducted using a 3D hydrodynamic model. The model was applied to predict circulation from wind and tidal effects.

Sediment discharges associated with the alternative drilling fluids and pipeline routes were also simulated using a 3D sedimentation model. This model was used to estimate the transport, sinking and settlement of mixed particle sized sediments; and to calculate the concentrations of suspended solids within the water column and rates of sedimentation to the seabed.

Using a set of assumed discharge rate, the model was able to estimate hourly suspended sediment concentrations at defined depth layers in the region, identify locations where sediment concentrations were expected to exceed defined thresholds and estimate the cumulative sedimentation from the full drilling program.

Why was it done

Modelling of the suspended sediment concentrations and sedimentation associated with the directional drilling program at Barrow Island was conducted to identify potential environmental implications associated with the drilling program. The model simulations provided Chevron with advice on which drilling fluid to use, and the most appropriate pipeline route, to minimise environmental impacts from the proposed directional drilling program.

Findings

Simulations of suspended sediment concentrations suggested that discharged sediments would tend to travel southwards from the Flacourt Bay site and northwards from the North White's Beach site, reflecting the strong influence of tidal currents on local hydrodynamic flows.

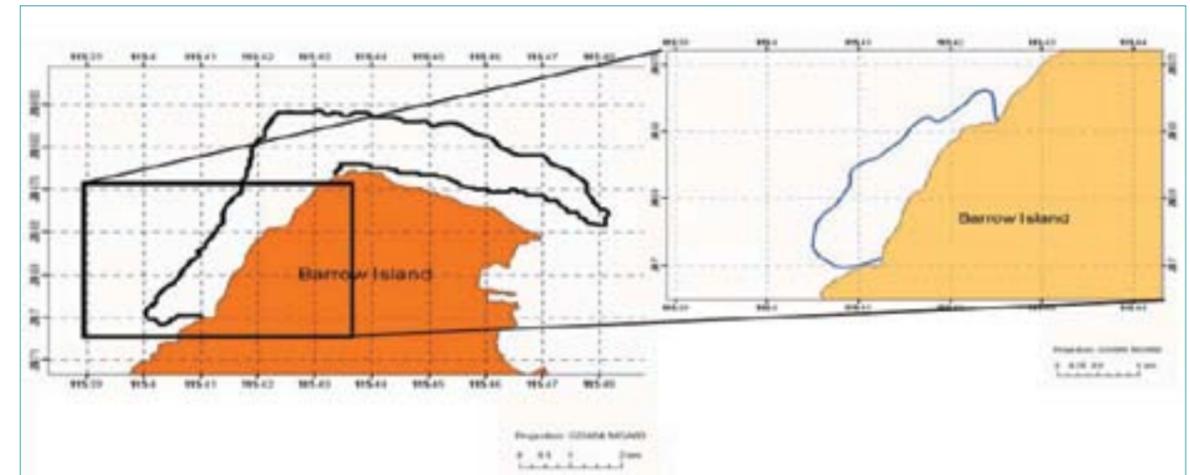
Simulations of bentonite discharge from Flacourt Bay suggest that elevated suspended sediments may potentially extent southward beyond Boodie Island on occasions. Simulations of bentonite discharge from North White's Beach indicated that elevated concentrations of bentonite would consistently occur around the North end of Barrow Island. Criteria used to indicate the significance of impacts of sedimentation and suspended sediment on corals suggest that the discharge of bentonite at North White's Beach could be expected to cause total mortality only to corals in the immediate vicinity of the discharge. Partial mortality could be expected over a 3 km long area south of the discharge and a zone of influence would extend from approximately 4 km south of the discharge to the northeast corner of Barrow Island.

Discharge simulations assuming that cuttings are released with a water-based polymer indicated a much reduced zone of potential influence from suspended sediments when compared to the bentonite discharges. Based on the impact criteria, no coral mortality (total or partial) beyond the immediate discharge location would be expected to result from the water-based polymer discharges.

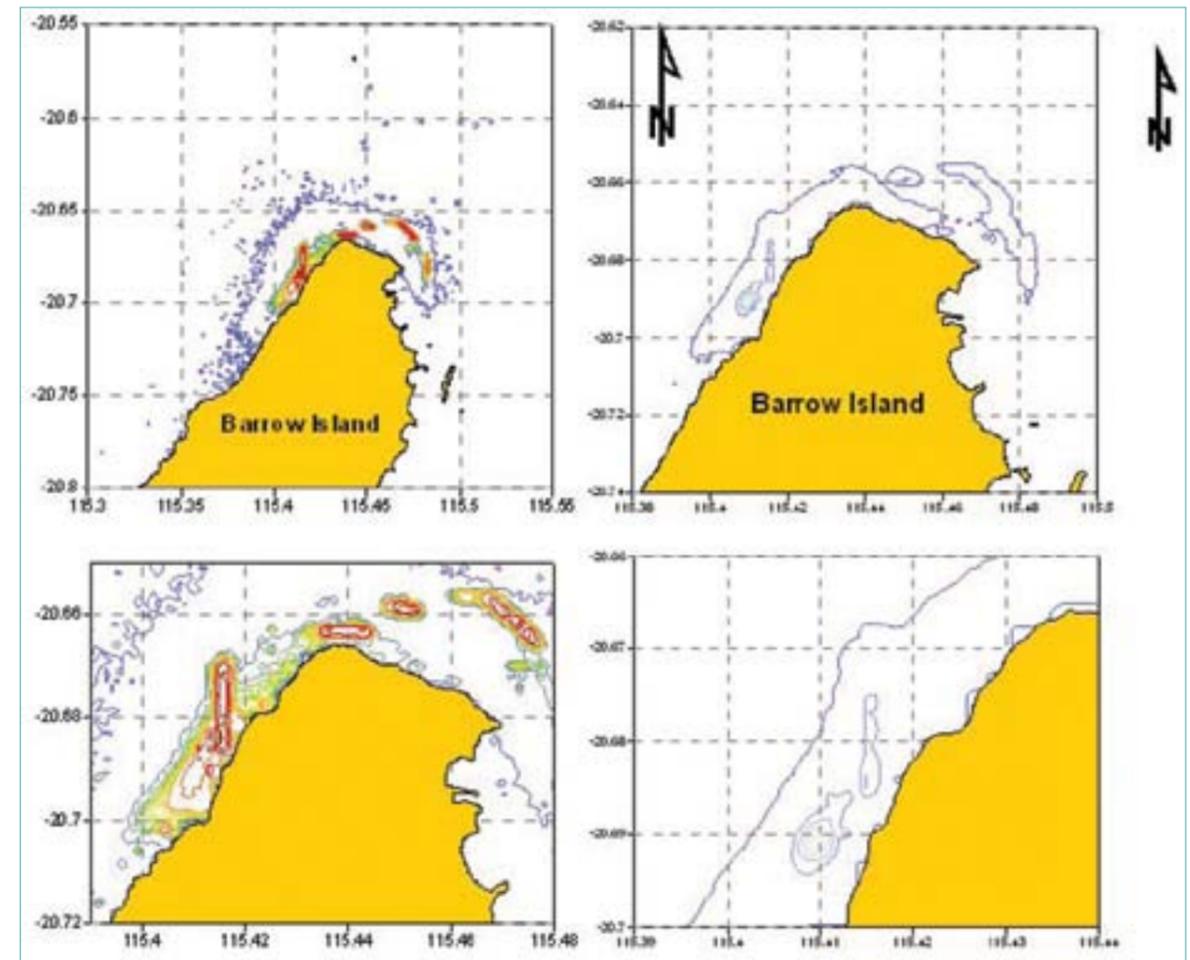
Modelling of cumulative sedimentation indicated that a significantly larger area of seabed would be impacted if bentonite was used as the drilling fluid, compared to discharge using the water-based polymer. Bentonite discharge at Flacourt Bay was predicted to settle along the full extent of the western Barrow Island coast. In contrast, a much reduced sediment pile was predicted for discharge of cuttings with the water-based polymer.

Implications for the industry

The results of this study provide a valuable comparison of sediment discharges generated from bentonite and water-based polymer drilling fluids. It would appear that sediment discharged using a water-based polymer for directional drilling generally affects a smaller area than that impacted from bentonite sediment discharges.



ABOVE Locations where suspended solid concentrations are expected to exceed 25 mg/l due to bentonite discharge at North Whites Beach. The main image shows locations where >25 mg/l are expected for at least 1 hour per day for 5 consecutive days. The inset shows locations where >25 mg/l are expected for 6+ hours during daylight hours for at least 2 consecutive days.



ABOVE Comparison of cumulative sedimentation predicted for discharge of bentonite and cuttings (left) and polymer and cuttings (right) off North Whites Beach, assuming no re-distribution of sediments after initial settlement.





1.3 Barrow Island flora and vegetation surveys

What was done

Chevron engaged a private consulting firm to prepare a report describing the flora and vegetation occurring in areas proposed for development as part of the Gorgon Gas Development on Barrow Island. The report details the findings of a series of botanical surveys conducted within the proposed gas processing facility and surrounding area, and along extended easements for three proposed pipeline routes.

Botanical surveys were completed during September and October 2003, and repeated again using identical methods in January 2004. Two post-cyclone surveys at the proposed Development areas were also undertaken in April and May 2004, approximately 6 to 8 weeks after Cyclone Monty passed over Barrow Island. The plots for assessment were selected to represent undisturbed vegetation within the proposed Development areas.

Vegetation types within the proposed gas processing facility development and along the proposed pipeline routes were also mapped using detailed site observations and records, aerial photography and plant specimen collection.

Why it was done

The flora and vegetation study on Barrow Island was conducted to identify and locate any rare, restricted and/or introduced flora species, and significant vegetation types occurring within the proposed Gorgon Gas Development areas. The information gathered for this report was used to assess the environmental implications associated with the Gorgon Project and assist with the development of suitable mitigation measures to manage these impacts.

Findings

These botanical surveys identified 68 families, 180 genera and 406 vascular plant taxa on Barrow Island. The 406 vascular plant species, subspecies and varieties constitute approximately 23% of the flora recorded for the Pilbara region. Fourteen vascular plant species were found to be non-indigenous species to the Island, the majority of which have been recorded in the vicinity of previously disturbed sites.

The flora of Barrow Island is regionally significant because there are species or taxa that:

- Represent the southern limit of plants of the Kimberly region.
- Represent the western limit of plants of the Pilbara region.
- Represent the northern limit of the plants of Cape Range and southwards.

No protected plant taxa listed under Section 179 of the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act); no Declared Rare Flora species, as listed under subsection (2) of Section 23F of the *Western Australian Wildlife Conservation Act 1950* and no species as listed under Schedule 1 by the Department of Environment and Conservation (previously CALM), were located on Barrow Island.

Two priority species have been collected on Barrow Island:

- *Helichrysum oligochaetum* (Priority 1)
- *Corchorus interstans* ms (Priority 3).

Neither species distributions are restricted to Barrow Island. The Priority 1 species *Helichrysum oligochaetum* was recorded on the flats south of the proposed gas processing facility, and was not identified during any of the surveys within the proposed Development areas. *Corchorus interstans* ms (Priority 3) was recorded within the proposed gas processing plant site and the proposed North White's Beach pipeline corridor. *Corchorus interstans* ms is widespread on Barrow Island and known to extend into the Pilbara region. The species has also been observed to regenerate successfully on rehabilitated sites' (Astron Environmental, 2002).

Generally, vegetation of the near-coastal environments is relatively consistent within the Pilbara region. The typical pattern of vegetation comprises mangroves in tidal areas, *Spinifex longifolius* assemblages on the foredunes, halophytic communities on the saline flats, stunted vegetation on the near-coastal rocky headlands, and hummock grasslands of *Triodia* on the inland areas. The grass species and emergent shrubs and trees in these hummock grasslands reflect local patterns in landforms, soils and moisture availability.

The surveys found no vegetation communities listed under the EPBC Act on Barrow Island. Furthermore, no threatened ecological community listed in CALM's Threatened Ecological Database have been recorded or are known to occur on Barrow Island.

Most of the vegetation in the proposed Gorgon Gas Development area is in excellent to pristine condition, with little apparent disturbance. Importantly, the majority of the vegetation communities mapped within the proposed development locations extend well beyond the Development areas.



Hakea lorea, subspecies *lorea* specimen.

Implications for the industry

The flora and vegetation study of proposed Gorgon Gas Development areas provides additional information on the botanical configuration of Barrow Island. The study provides additional botanical specimens and data for the Western Australia Herbarium, and helps further describe the vegetation and floral taxa of the island.

References

Astron Environmental. 2002. Preliminary Vegetation and Flora Survey of Proposed Gorgon Development, Barrow Island, October 2002. Prepared for Chevron Texaco/Gorgon Joint Venture Australia Pty Ltd.





1.4 Barrow Island protected marine species

What was done

Chevron engaged a private environmental consulting firm to conduct a literature review of the protected marine species occurring within the proposed Gorgon Gas Development on Barrow Island, Western Australia. The report sourced information from a desktop review of the available literature on marine species in the area, liaisons with Government Departments, APPEA and research personnel, and opportunistic observations collected during field surveys for the Gorgon Development.

Field surveys investigating intertidal and marine ecology and assessing the conservation significance of areas pertaining to the Gorgon Gas Development were undertaken during August 2002, January 2003 and January 2004. The surveys examined the supratidal, intertidal and marine areas on the east and west coasts of Barrow Island, at locations likely to be affected by the development and operation of the proposed marine facilities.

Why it was done

The review of protected marine species occurring on and around Barrow Island was completed to assist with the assessment of environmental implications associated with the Gorgon Gas Development. The information attained was used in the environmental risk assessment for the proposed gas processing facility and related developments.

Findings

The report identified more than 100 protected marine species occurring, or likely to occur, in the waters surrounding Barrow Island. These included:

- 37 fish species
- 45 mammalian species (e.g. cetaceans, dugong)
- 20 reptilian species.

Protected fish and invertebrate species known or likely to occur in the waters surrounding Barrow Island include fish from the family Syngnathidae (e.g., seahorses, pipefish, pipehorses and seadragons) and sharks (e.g., grey nurse, great white and whale sharks). The habitats which these protected species occupy are generally widespread throughout the Pilbara region, and there are no known features in the proposed Gorgon Gas Development area to suggest that significant concentrations of protected fish and/or shark would occur in the region.

The waters surrounding Barrow Island contain diverse and abundant populations of sea turtles and sea snakes. Six of the world's seven species of marine turtle frequent the Pilbara region (green, flatback, hawksbill, loggerhead, leatherback and olive ridley). Barrow Island is an important feeding and nesting area for sea turtles. Three species (green, flatback and hawksbill) primarily nest on the Island, flatback turtle on the east coast and green turtle on the west coast. A diverse and abundant assemblage of sea snakes appears to occur in the proposed Gorgon Development area, with an estimated 22 species of sea snake occurring in Western Australian waters.

Australia has a diverse array of cetacean fauna, with 43 of the 79 species recognised worldwide (54%) having been recorded in Australian Commonwealth waters. Two threatened species of whale, the blue whale (*Balaenoptera musculus*) and humpback whale (*Megaptera novaengliae*) are listed as occurring in the Barrow Island region. A number of other whale species occur off the north Western Australian coast that may occur in the Development area on occasions, such as the sei (*Balaenoptera borealis*), fin (*B. physalus*), minke (*B. acutorostrata*), and Brydes (*B. edeni*) whale. Encounters with sperm (*Physeter macrocephalus*) and melon headed (*Peponocephala electra*) whales are also possible, given their distribution range.

The bottle-nosed dolphin (*Tursiops truncatus*) and the Indo-Pacific humpbacked dolphin (*Sousa chinensis*) inhabit the shallow waters of the inner Rowley Shelf, including Barrow Island. A number of deep water dolphins also occur off the north Western Australian coast, such as the spinner (*Stenella longirostris*), striped (*Stenella coeruleoalba*), common (*Delphinus delphis*), Risso's (*Grampus griseus*), spotted (*Stella attenuata*) and rough-toothed (*Steno bredanensis*) dolphin, some of which may occur in the proposed Gorgon Gas Development area. Killer (*Orcinus orca*) and false killer whales (*Pseudorca crassidens*) have also been sighted in the waters surrounding Barrow Island. Dugongs (*Dugong dugong*) may also pass through and possibly feed on seagrass around Barrow Island.

Implications for industry

This review provides important information on the marine protected species occurring in the waters surrounding Barrow Island, and the wider Pilbara shelf region of the north Western Australian coast. This information is a valuable resource when assessing the environmental implications of proposed industry related activities occurring off the north Western Australian coast.



1.5 Sea turtle track census monitoring program

What was done

A sea turtle monitoring program was conducted by Pendoley Environmental biologists on behalf of Chevron on Barrow Island, Western Australia. Beaches were surveyed during spring tides, over periods of three to five consecutive days, from November 2003 to January 2004, and November 2004 to February 2005. Monitoring periods were selected to coincide with peak sea turtle nesting activity on the island; and the beaches surveyed were those identified as potential infrastructure locations for the proposed Gorgon Project (i.e. the proposed feed gas pipeline on the west coast, and the proposed development at Town Point on the east coast).

Selected beaches were surveyed routinely for sea turtle nesting activity and tracks. Nesting activity was quantified by counting the number of overnight tracks (that terminated in a successful nest) that crossed a line dug into the sand at the commencement of each monitoring period. Nest emergences were quantified from the number of hatchling tracks crossing the line each night.

Why it was done

The sea turtle track census monitoring program was conducted to gather information on the geographical distribution and timing of nesting and hatchling emergences on Barrow Island beaches. The sea turtle monitoring program investigated:

- beach use preferences for east and west coast census beaches
- daily fluctuations in turtles beach visits relative to the tides
- yearly variations in turtles visiting Barrow Island
- peak nesting months on Barrow Island
- peak nest emergence months on Barrow Island.

This information was used to identify potential environmental implications associated with the Gorgon development and advise Chevron on the potential locations of infrastructure associated with the project.

Findings

Nesting flatback turtles were found to favour the east coast beaches of Barrow Island. Flatback turtle nesting densities were highest on the central east coast and decreased towards the north and south ends. The flatback turtle nesting period peaked during December and January. Internesting habitat for east coast flatback turtles was not identified; however, their preference for soft bottom habitat indicates that their internesting grounds are likely to be located off the edge of the intertidal platform, stretching into the navigation channel running the length of the east coast.

Nesting green turtles were found to favour the west coast beaches of Barrow Island. Green turtle nesting density was consistently high along the west coast beaches. Green turtle nesting spread over a longer period when compared to flatback turtles, peaking in January and February. Superior nesting habitat for green turtles was found to be in deep sand (greater than 1 m deep). Internesting habitat for green turtle was found to be the rocky intertidal and subtidal platforms of the west coast. Barrow Island was also identified as an important feeding ground for green turtles and appears to be a feeding ground and juvenile habitat for flatback turtles.

Hawksbill turtles nested in very low numbers (<10 per week) around most of Barrow Island (east and west beaches). Hawksbill turtles were able to nest in shallower sands (30–40 cm deep).

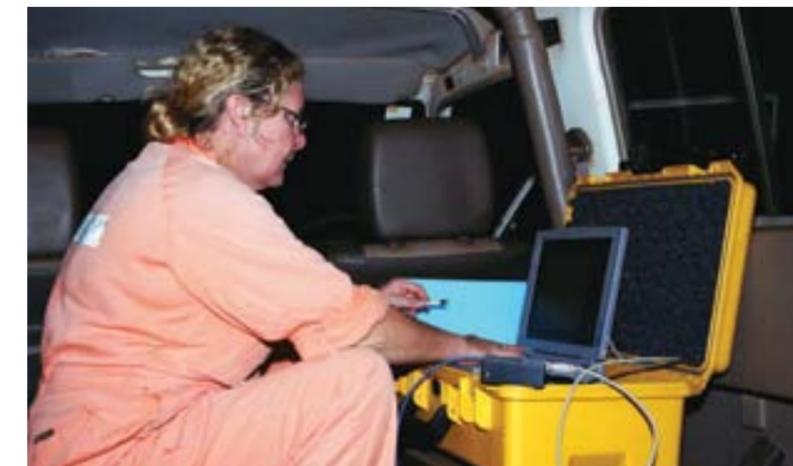
The monitoring program also found that the total number of turtle tracks on a beach per night does not necessarily accurately represent the nesting effort occurring on a beach. The survey found that 47% of flatback turtle tracks and 52% of green turtle tracks recorded represented unsuccessful nesting crawls, which did conclude with the deposition of eggs.

Implications for the industry

This study provides valuable information on the geographical distribution and timing of sea turtle nesting activities on Barrow Island, and the wider Pilbara shelf region of the north Western Australian coast. It outlines a successful method for monitoring turtle nesting activity and hatchling emergence on beaches utilised by sea turtles.

References

Pendoley K. 2005. *Sea Turtles and the Environmental Management of Industrial Activities in North West Western Australia*. PhD Thesis, Murdoch University. Perth Western Australia.





1.6 Sea Turtle Hatchling Arena Experiments

What was done

Sea turtle hatchling arena experiments were carried out by Pendoley Environmental on Barrow Island on 16–22 April 2004, and 1–6 February 2005. The experiments used a circular pitfall arena design, where each arena was 10 m in diameter with a 40 cm deep trench around its circumference. An array of lights consisting of 250 W high pressure sodium vapour lights (x 2), 250 W metal halide lights (x 2), and 36 W fluorescent lights (x 14) were mounted on a 3 m tall stand. The light types were selected to represent the lighting typically used in industrial settings. The light array emitted light intensities at 250 and 500 W, and was powered by a 5 kVA 'silent' running diesel generator positioned 25 m from the array.

Experimental arenas were installed at distances of 100m, 200m, 500m and 800m from the light array, along North Yacht Club Beach of Barrow Island. Hatchlings were released at the centre of each arena using a remote release mechanism, and allowed 5 minutes to reach the trench at the edge of the arena. Hatchlings were then collected and the number in each segment of the arena, as well as those remaining in the centre of the arena was scored.

Why was it done

The objectives of the sea turtle hatchling area study were to:

- Collect qualitative (spectra) and quantitative (Lux) data from the different light sources at different intensities and set distances
- investigate the impacts (behavioural response) of three light types and two light intensities at four distances (100m, 200m, 500m and 800m) on green and flatback turtle hatchlings.

The information obtained from this study was used to advise Chevron on the potential impacts of infrastructure lighting on turtle hatchling behaviour, orientation and sea-finding ability. This information was used to both inform engineering design for the proposed Gorgon development and to develop lighting management guidelines for all aspects of the construction and operational phases of the project.

Findings

The pilot study in April 2004 established that flatback and green turtle hatchlings are attracted to artificial lights. The experiment in February 2005 demonstrated conclusively that artificial lights impact hatchling orientation and can reduce their sea-finding success over hundreds of metres from the light source. Hatchling behaviour differed significantly with distance (and consequently light intensity) from the light source.



Flatback hatchlings appeared to be influenced by all three light types at 100m distance from the array. Fluorescent and metal halide lights attracted flatback hatchlings at 200m, while sodium vapour lights also appeared to influence the hatchlings at 200m (as indicated by increased scattering). Flatback hatchlings did not appear to be affected by any light source at distances greater than 500m.

Green turtle hatchlings were attracted to all three light types at 100m and 200m. The light array may have also influenced their seaward orientation at 500m and at 800m, represented as increased scattering at these distances.

Recognising that the measurement of light by commercial instruments (e.g., Lux) is not representative of the light most strongly detected by turtles, hatchlings were found to respond to sodium light at estimated intensities ≥ 0.19 Lux, while metal and fluorescent light sources influenced hatchling behaviour at intensities an order of magnitude lower at ≥ 0.05 Lux. This supports recommendations made to the Gorgon development to use sodium vapour light sources, over metal halide or fluorescent light sources, in the vicinity of sea turtle rookeries.

Implications for the industry

The findings of this study suggest that any artificial light sources used for infrastructure developed in the vicinity of turtle rookeries should use sodium vapour lights, over metal halide or fluorescent light sources. This should minimise the impacts on hatchling behaviour and sea-finding ability generated by artificial lighting positioned nearby sea turtle nesting sites. This information builds on previous research and the industries current understanding of sea turtle hatchlings response to artificial light.



1.7 Barrow Island Light Survey

What was done

A field light monitoring program was conducted by Pendoley Environmental, on behalf of Chevron, on Barrow Island. The survey was carried out over two nights from 9–11 March, 2004. Measurable light levels and spectral characteristics were gathered from point source lights around Barrow Island. Light was measured using an Ocean Optics USB2000 miniature spectroradiometer and GPS positions were taken to allow sites to be revisited over time.

Why was it done

The primary aim of this study was to measure the intensity and spectral signature of electric lights and flares typically found on Barrow Island. The existing light sources on east coast Barrow Island beaches were also measured to provide a baseline measure of the existing light field at two turtle nesting beaches prior to Gorgon development activities. This information may become beneficial when later assessing the potential impacts of the development on sea turtle nesting activities and hatchling events.

Findings

The Barrow Island light survey found that high and low pressure sodium vapour lights were the most common light sources on the island. Some existing sodium vapour lights are visible from turtle nesting beaches.

The study found that the lights most likely to be disruptive to sea turtle hatchlings on Barrow Island are likely to be bright white lights that emit low wavelength light, such as fluorescent, metal halide and mercury vapour lights. The low wavelength emissions from these lights are strongly detected by dark adapted eyes and are therefore likely to be highly disruptive to sea turtle hatchlings at night.

The lights likely to be least disruptive to sea turtle hatchlings on Barrow Island are the flares and the high pressure sodium vapour lights, which are currently used on the coastal locations on Barrow Island. These lights emit at longer wavelengths than moonlight and are less attractive to hatchlings than short wavelength light. The yellow light also causes less atmospheric scatter than white lights, reducing glow in the sky.

Implications for the industry

This study suggests that in order to minimise impacts on sea turtle hatchlings and their sea-finding ability, infrastructure developed in the vicinity of sea turtle rookeries should utilise high wavelength sodium vapour lights, as opposed to lights rich in short wavelength light such as fluorescent, metal halide and mercury vapour lights. This information builds on previous research and the industries current understanding of sea turtle hatchlings response to artificial light.





1.8 Marine benthic habitats

What was done

Chevron, on behalf of the Gorgon Venture participants, engaged a private environmental contracting firm to survey the marine benthic habitats in potential Development areas for the proposed Gorgon gas processing facility on Barrow Island, Western Australia. The study comprised a review of the information available describing the marine environment of the area and field surveys at the locations of proposed infrastructure.

Field surveys were undertaken during August 2002, January 2003 and January 2004. Subtidal, benthic marine habitats were surveyed using a combination of video transects and snorkel diver surveys.

Broad-scale habitat maps for the east and west coast Development areas were generated from aerial photography taken in October 2001. Ground-truth data collected during the field surveys was used to confirm habitat descriptions in potential impact areas and to assist in characterising the distribution of benthic habitats in the broader region.

Why it was done

The study investigating marine benthic habitats in the Barrow Island region was used to identify any areas of high conservation significance within the proposed Development area and assess the environmental implications associated with the Gorgon project. Assessment of potential impacts was based on the results of field observations, general knowledge of the area from previous surveys and literature on the region.

Findings

Five main subtidal habitats dominate the wider Barrow Island region:

- coral reefs and bomboras
- seagrass and macroalgae meadows
- invertebrate filter feeder assemblages on pavement
- deeper high profile reefs
- soft sediments.

A majority of the high conservation areas occurring within the proposed Development area are related to coral habitats. Coral communities may be considered to be of conservation significance because they may contain a high level of species diversity, or have a restricted distribution in the Barrow-Montebello Complex. Coral communities of regional significance include:

- fringing reef communities to the west of the Montebello Islands
- patch reefs and bomboras stretching along the southeastern Montebello Islands

- Biggada Reef on the west coast of Barrow Island
- An extensive *Acropora coral reef* on the eastern side of the Lowendal Shelf.
- Coral patch reef and bomboras fields on the southern end of the Lowendal Shelf
- Dugong Reef
- Batman Reef
- Barrow Island Shoals.

Locally significant coral communities surrounding Barrow and Lowendal Island include:

- coral assemblages that fringe parts of the northeast and east coasts of Barrow Island
- coral assemblages on the eastern side of Double Island
- a series of bomboras along a raised limestone ridge offshore of Shark Point on the eastern side of the Barrow Island.

Seagrass communities/habitats in the local Barrow Island area are typically of lower conservation significance. The seagrass genera comprised within the community are widespread throughout the region and the meadows are of low density/sparse, meaning the habitat is unlikely to be of importance to local dugong or sea turtle populations. Macroalgae beds on the east and west coasts of Barrow Island are also of low conservation significance as they are widely distributed in the region. The macroalgae beds undergo large seasonal fluctuations in biomass and are known to recover rapidly from disturbance, meaning impacts from the proposed Gorgon development are unlikely to result in long-term implications.

Some high profile reef habitats located within the proposed development area were found to be of local conservation significance to marine communities in the Barrow Island region. The rocky reefs and platform provide structural diversity to an otherwise planar seabed in the proposed feed gas pipeline corridor. The undercut caves and ledges provide an important refuge for fauna and attachment point for filter feeding organisms.

Despite containing some well developed infauna assemblages, soft sediment habitat located in the proposed development area were typically of low conservation significance. This is because soft sediment habitats are very widespread in the region.

Implications for the industry

This study provides additional information on the marine benthic habitats of the Barrow Island area and wider region.

1.9 Barrow Island intertidal habitats

What was done

Chevron engaged a private environmental consulting firm to prepare a report describing the intertidal habitats existing in the Barrow Island region and detail the local intertidal communities occurring at proposed marine infrastructure sites for the proposed Gorgon development.

Intertidal habitats in proximity of the proposed causeway at Town Point and the mainland shore crossing of the domestic gas pipeline were surveyed during 26–28 January 2004. The surveys examined the immediate intertidal habitats expected to be affected along with the habitats adjacent to the proposed infrastructure locations. Surveys were conducted as close as possible to spring low tide to maximise the time for surveying and the area of exposed habitat. Marine biologists examined and characterised the area extending from the very low intertidal to supra-tidal zones.

Why it was done

Marine infrastructure for the proposed Gorgon development includes elements in intertidal habitats on the east and west coasts of Barrow Island, comprising:

- a shore crossing a North White's Beach or Flacourt Bay on the west coast of Barrow Island
- a causeway at Town Point on the east coast incorporating shore crossings for export pipelines
- a shore crossing near Robe River on the mainland for the domestic gas pipeline.

Intertidal studies of these areas expected to be affected by the proposed Gorgon development were undertaken to identify intertidal areas of conservation significance and assist the formal environmental assessment for the proposal. The report was developed to describe the results of the field surveys and relates the findings to existing information on similar intertidal areas within the region.

Findings

Intertidal habitats of the Barrow Island region consist of:

- limestone platform reefs
- rocky shores
- sandy beaches
- sand/mud flats
- coral reefs
- mangals.

Extensive intertidal rock platforms occur on both the west and east coasts of Barrow Island. The different energy regimes that prevail on the east (low energy) and west (high energy) coasts maintain different covers of sediments which influence the macroalgal and fauna assemblages that inhabit the intertidal zones. Generally species richness tends to be higher in the lower intertidal zone of rock platforms. Where beach rock is exposed for extended periods, it is generally colonised by a range of molluscs and barnacles that generally inhabit intertidal notch habitats. East coast rock platforms often have a relatively wide

zone of sediments on the inner flat with associated infaunal and epifaunal communities.

Rocky shores are typically double-notched in the upper intertidal zone in the West Pilbara region. The double notches are created by erosion of the limestone cliff face above and below the protective or accretionary band of oysters in the central zone. The oyster zone is composed of clusters of the rock oyster, *Saccostrea cucullata*, and cemented barnacles also form an important component of intertidal notch communities. Generally, intertidal notches on the wave exposed west coast shores of Barrow Island tend to be more species-rich than the comparable habitats of the more sheltered east coast shores.

Sandy beaches around Barrow Island generally lack invertebrate species, other than ghost crabs and burrowing bivalves. The importance of sandy beaches is primarily related to their significance for turtle and seabird nesting, roosting and foraging.

Large intertidal sand flats are relatively uncommon on the offshore Rowley Shelf. Observations of the northern sand sheets suggest they support a limited faunal community. Intertidal sand flats in Bandicoot Bay support a diverse array of benthic and burrowing fauna and extensive areas of seagrasses and macroalgae. Areas with seagrass contain increased invertebrate fauna, usually dominated by gastropods.

The intertidal coral reef at Biggada Reef in Turtle Bay is a Marine Park. The reef crest and lagoon areas support an extensive of corals that are exposed on very low tides. Survey revealed that intertidal coral habitats support a range of fauna including at least 64 species of scleractinian (hard) coral, 32 species of echinoderm and 75 species of shelled mollusc.

Local intertidal habitat surveys of the shore crossing at North White's Beach or Flacourt Bay found that intertidal habitats were typical of those occurring along the west coast of Barrow Island and were of low conservation significance. Intertidal assemblages in the North White's Beach area were dominated by rock oyster zones and associated mollusc and cirripede (barnacle) fauna. Intertidal areas of the steep sandy beaches at Flacourt Bay were found to support limited assemblages of bivalves and crustaceans.

Intertidal habitat surveys at Town Point Causeway and Landing area on the east coast of Barrow Island found that the intertidal habitats and associated assemblages were widespread along the east coast and were of low conservation significance. Invertebrate assemblages of the upper intertidal boulder zone and limestone pavement supported a relatively low diversity biotic assemblage.

Implications for the industry

Project baseline studies of intertidal areas provide starting-point marine and coastal monitoring information to enable the development of monitoring programs in sensitive locations in preparation for project installation.





1.10 Barrow Island marine surveys

What was done

The Western Australian Museum conducted marine surveys for Chevron to determine whether any introduced pest species listed by the National Introduced Marine Pest Information System (NIMPIS) were present in the waters surrounding Barrow Island, Western Australia. Surveying was divided into two components:

- a preliminary investigation of subtidal habitats of the islands conducted by diving and snorkelling during August 2004
- a subsequent survey of intertidal habitats during September 2004 was conducted, with an emphasis on barnacle species present in the waters.

Specimens collected were reported and housed in the Western Australian crustacean museum.

Why it was done

The surveys were conducted to gather baseline information on the presence of introduced marine pest species in the waters of Barrow Island. This information provides an important baseline comparison for future surveys of the region monitoring the introduction of marine pest species following activities associated with the Gorgon development. The risk of marine introductions and the establishment of potential marine pests in the region will increase dramatically as marine traffic increases with the development of the Gorgon gas processing facility.

Findings

The preliminary survey did not identify any marine pest species present in the waters of Barrow Island.

The subsequent survey identified 10 barnacle species present in the intertidal habitats of Barrow Island. Four barnacle species (*Balanus reticulatus*, *Megabalanus ajax*, *M. tintinnabulum* and *M. rosa*) may be regarded as marine introductions into the area, and three of the species, *B. reticulatus*, *M. tintinnabulum* and *M. rosa*, are well known, widely distributed fouling species. The mechanism via which most of these introduced barnacle species became introduced to the waters of Barrow Island and Western Australia is most likely through distribution by ship transport and vessel fouling.

Although four potentially introduced barnacle species were found during the survey, none of these are considered to be pest species included on the NIMPIS marine pest species list. No data are available as to whether the presence of introduced species in Western Australia (or Australia) has caused any ecological consequences, or whether they have had any adverse impacts on native species and Australia's marine biodiversity.

Implications for the industry

These surveys provide important background information and baseline data on introduced marine pest species in the Barrow Island area, to which future monitoring programs can compare. This information can be used to manage and mitigate the introduction of marine pests to Western Australian waters and assist in the protection of Australia's native marine species and biodiversity.



1.11 Plant pathogen threats to Barrow Island

What was done

A 'desktop study' and report investigating plant pathogen threats to Barrow Island was prepared by the Queensland Department of Primary Industries and Fisheries (2005), for Chevron in relation to the proposed Gorgon gas plant development on Barrow Island. Three specimen-based plant pathology herbarium databases, the Australian Plant Pest Database (APPD), Australian Plant Disease Database (APDD) and Queensland Department of Primary Industries Plant Pathology Herbarium Database (BRIP) were examined for the presence of records detailing plant pathogens on host plants from Barrow Island and neighbouring islands. Scientific literature was also analysed to identify reports of plant pathogens of Barrow Island hosts. Plant pathogens that were identified were assessed to determine the level of risk that they posed to the resident flora of Barrow Island.

Why it was done

The report was conducted to assess the threat that plant pathogens from the mainland pose to the resident flora of Barrow Island. This information can be used to assess biosecurity risks associated with the Gorgon development, and ensure that adequate safeguards are in place to prevent the movement of pathogens to Barrow Island.

Findings

An investigation of plant pathogen databases and the scientific literature revealed that only two plant pathogens have been recorded from Barrow Island or neighbouring islands. These pathogens, *Aecidium species* and *Uredo species*, both occur on *Acanthocarpus verticillata* and represent different stages of the same undescribed rust fungus.

There are at least 126 plant pathogenic fungi that have been reported from the mainland on hosts that also occur on Barrow Island. There are several pathways by which plant pathogens may enter Barrow Island (e.g. soil, food, wind and insects). The movement of soil and food poses the greatest threat for introducing new plant pathogens, due to the absence of quarantine measures to reduce the risk of establishment. It is estimated that there could be over 4000 indigenous plant pathogens already occurring on Barrow Island.

Implications for the industry

This study provides important information on plant pathogen threats to the flora of Barrow Island. Knowledge of potential threats assists with the development of management approaches and procedures to reduce the risk of introducing new pathogens, protecting the diversity of native plant species on Barrow Island. These management measures can be applied to safeguard against plant pathogen introductions for other industry projects, particularly with an increased reliance on world-wide trade to support new development.



1.12 Measurement and model prediction of ocean currents and tides at Barrow Island, North Western Australia

What was done

A private consulting firm was contracted by Chevron to carry out dredging simulations for the Materials Offload Facility (MOF) and the LNG shipping access channel for the Gorgon Development at Barrow Island, Western Australia.

To achieve this two sophisticated numerical computer models were used:

- a model to simulate the complex 3D ocean currents surrounding Barrow Island
- a model to determine the fate of particles released into the water column during the dredging operations.

Field measurements were also carried out on the eastern side of the island to gain an understanding of ocean circulation around the island. These field measurements involved:

- the deployment of two Acoustic Doppler Current Profilers (ADCP) for approximately 18 days to cover a full spring to neap tidal cycle
- the deployment of a third ADCP
- the deployment of several drifting buoys that were tracked by boat.

Why it was done

Measurements and model predictions of ocean currents and tides at Barrow Island were undertaken to determine the fate of particles released into the water column during dredging operations for the Gorgon Development. This information was used to assess the potential environmental implications of the dredging activities.

Findings

The dominant influences on the circulation in the waters surrounding Barrow Island are the local winds and tides. Examination of the circulation models shows that the shallow bathymetry to the north and south of Barrow Island restricts the flow of the flood tide from the open ocean to the coast. Consequently, a mass transport of water to the coast, east of Barrow Island, occurs during the build up of a high tide. The build up is derived from flows around the northern and southern ends of Barrow Island, and from water flowing southeast (varies) in the gap between the Montebello Islands and the Barrup Peninsular. This later flow is induced because of the limited mass transport possible across the shallow areas to the north and south of Barrow Island.

In the vicinity of Barrow Island the flood tide flows around the north and south ends of the island and generally meets anywhere between Dugong Reef and the Lowendal Shelf, which then combines to flow towards the coast. The meeting of the two components of the flood tide is dependent on the spring-neap tidal cycle and the strength of southerly winds.

Implications for the industry

This work is valuable because prior to this study the manner in which the flood and ebb tide circulated on the eastern side of Barrow Island was not well understood. This study also confirms complex 3D ocean current modelling as a reliable method to simulate ocean currents and tides and predict other oceanic processes, such as the fate of dredge plumes or other marine discharges.



1.13 Bioremediation of oil contaminated soil on Barrow Island

What was done

Research investigating the bioremediation of oil contaminated soil using indigenous soil microbes was conducted by the University of Western Australia for Chevron. A two-phase microcosm experiment was performed using soils from Barrow Island that contained indigenous microbes capable of biodegrading hydrocarbons.

Phase 1 of the incubation study encouraged the development of a hydrocarbon responsive microbial consortium through the addition of crude oil, while controlling soil moisture and nutrients. Phase 1 involved the addition of crude oil and the regulation of soil moisture and nutrient levels based on predetermined values for optimal biodegradation. Control experiments consisted of soil not exposed to oil and sterilised soil and oil.

Phase 2 commenced with addition of fresh oil to the soil. The extent to which the oil contaminant of both experimental phases is degraded was determined by periodical hydrocarbon analysis. Dynamics of the soil microfauna community including changes to soil microbial biomass, microbial activity, soil microbial function and soil microbial structure were observed using microbial biomass carbon, community level physiological profiling (CLPP) and phospholipids fatty acid (PLFA) methodologies.

The treatments were:

- soil mixed with crude oil
- soil without crude oil
- sterilised soil with sterilised oil

Phase 2 experiment involved the addition of crude oil to each of the three soils incubated in phase 1. Two soils were assessed for variation in the hydrocarbon biodegradation of hydrocarbon primed and non-primed soils.

The two-phase incubation study was performed over a 111 day period (61 days for phase 1 and 60 days for phase 2).

Why it was done

The study aimed to establish whether optimisation of an indigenous soil microbial community through controlled exposure to oil hydrocarbons can accelerate the bioremediation of subsequent oil spill events. The study endeavoured to adapt the soil microbial community to enhance hydrocarbon degradation.



Findings

At the completion of phase 1 exposure of Barrow Island soil to crude oil there was adaptation of the soil microbial community, structural change identified by varied PLFA compositions and functional change identified by CLPP with a selection of substrates.

Hydrocarbon analysis showed n-alkanes were significantly reduced in the oil contaminated soil by the end of phase 1 through microbial degradation

Microbial communities of Barrow Island soils were adapted structurally and functionally following exposure to crude oil hydrocarbons, resulting in quantitatively significant enhancement in the rate of biodegradation of aliphatic constituents of crude oil added to represent a second contamination.

Biodegradation of aromatic constituents of the subsequently added crude oil was slower. This suggests the initial phase one exposure of the soil to oil hydrocarbons inhibited the activity of aromatic degrading microbes whilst at the same time promoting microbes favouring aliphatic hydrocarbons.

The PLFA composition of the soil was altered following exposure to crude oil hydrocarbons and changed further after phase 2. The final PLFA composition was largely dependent on time since most recent oil exposure.

Soil microbial activity (indicated by carbon evolution) did change following contamination with crude oil hydrocarbons. The extent of this community level physiological profile (CLPP) change was also dependant on the number of exposures, and time since first exposure. Biodegradation proceeded at a significantly faster rate in phase 1 than phase 2.

Implications for the industry

This study displayed enhanced degradation of aliphatic oil components following the inoculation of the indigenous soil microbial community by an aliphatic rich substrate. Enhanced biodegradation of hydrocarbons is important for reduced exposure time of toxic hydrocarbons to ecosystems and individual organisms. By maintaining an adapted indigenous soil microbial community at sites prone to oil spills (e.g. bioventing piles) and applying these adapted microbial communities in situ to the spill site, the rate of aliphatic hydrocarbon biodegradation can be increased, reducing exposure time and subsequent adverse environmental effects

Adaptation of soil microbial communities to preferentially degrade aliphatic hydrocarbons through inoculation with aliphatic rich substrate suggests incubation by substrates rich in other hydrocarbon oil constituents may also promote preferential degradation. This work may be useful for bioremediation strategies for oil spill sites.



2 Woodside Energy reports

2.1 Long-term monitoring of marine turtles of Scott Reef

What was done

On behalf of the Browse Joint Venture, Woodside engaged a private consulting firm, along with Charles Darwin University, to establish baseline marine turtle nesting activity at Sandy Islet, Scott Reef. This information was collected during seven surveys in 2006, 2008, and 2009.

The studies describe the species and abundance of marine turtles present at Sandy Islet, with a focus on collecting information about nesting location, nesting success and hatching success. Morphometric information (carapace length and width) for the marine turtle species was assembled, and skin tissue samples were taken for DNA analysis. In addition, opportunistic random surveys were undertaken to identify interesting habitat.

Why it was done

Woodside, on behalf of the Browse Joint Venture, is proposing to develop the Torosa, Brecknock, and Calliance gas fields located approximately 290 km off the Kimberley coast in the Browse Basin. The Torosa field lies in the vicinity of Scott Reef, which has an ecological value detailed as providing a 'breeding habit for the nationally vulnerable green turtle', as well as being recognised as an area of 'reserved land'.

To date, marine turtle surveys at Scott Reef have been infrequent and limited in duration, due in part to its remote location and logistical constraints, which has resulted in the assumption that few turtles nested within the area. Surveys undertaken by in 2006 and 2007 observed increased nesting activity during the summer months. This led to the current studies of 2006, 2008, and 2009 being conducted in order to collect baseline data on turtle nesting activity and describe species richness and abundance at Scott Reef. This information will be used as a reference point against which to assess any potential impact that the proposed Browse LNG Development may have on marine turtles. It will also assist the development of any future environmental management plans.

Findings

The results from the seven surveys indicate that the summer months from late November to February are the preferred breeding season of the green turtle. It is estimated that the nesting population of the 2008–09 breeding season is 779 females, with a standard error greater than 50% of this value.

Scott Reef female green turtles are on average slightly smaller than other breeding green turtles in northern Australia. They have smaller clutches but the hatchlings are the same size and mass as green turtle hatchlings in other rookeries in northern Australia.

The Scott Reef and Browse Island green turtle management unit comprises two presumably fragmented nesting rookeries that are 190km apart. Summer is the peak of nesting activity. Due to the remote location of Scott Reef, implementing a long term marine turtle monitoring program has been difficult, but necessary in order to measure population stability in the long term. The five factors which provide the basis of this monitoring program has included: nesting population size, nesting success of females, density dependent mortality of nests and eggs, hatching success and emergence success. It is important to note that the green turtles nesting at Scott Reef and Browse Island form a discreet management unit or mate population from the world's green turtle populations, which highlights their fidelity to their nesting region and the lack of movement between neighbouring regions.

In order to measure the population dynamics, it is necessary to identify the number of individuals that nest within a given period at about the peak of nesting. As long as the timing of the survey remains constant, annual fluctuation in nesting populations may be recorded over a long time span (five to fifteen years), and will result in a lesser risk of errors in population estimates. The timing of surveys at Sandy Islet should include a new moon spring tide in order to minimise disturbance from researchers.

Implication for the Industry

An important factor in determining the outcome of the approvals process for Browse Island is the discovery that green turtles nesting at Scott Reef and Browse Island form a discreet management unit from the world's green turtle populations.



2.2 Surveys of humpback whale migration patterns and behaviours in the Kimberley region

What was done

Woodside commissioned the Centre for Whale Research (CWR) in 2008 and a private consulting firm in 2009 to conduct a marine megafauna baseline survey in order to support the assessment and management of any potential impacts to humpback whale migration from the proposed James Price Point LNG development. Aerial and vessel-based surveys were undertaken during the humpback migration season in 2008 and 2009, with a focus on Dampier Peninsula. In addition, the survey was extended out to Scott Reef, to include the proposed pipeline route and potential offshore installations. The survey was designed with an emphasis on sampling humpback whales (in particular) and dugongs, but also recorded most other visible marine megafauna such as turtles, sea snakes and sharks.

Aerial surveys were conducted on a fixed wing aircraft using three distinct flight patterns to quantify the distribution and abundance of humpback whales adjacent to the James Price Point coastal area, offshore to Scott Reef, and at two reference sites (Pender Bay and Gourdon Bay).

Marine vessel based surveys were undertaken to establish fine scale humpback whale distribution and density across the James Price Point coastal area, as well as behavioural data and residence time for this location, and a reference site at Pender Bay. Data was also acquired on dive rates and velocities to support the derivation of a population estimate from data acquired during aerial surveys.

Why it was done

The purpose of this survey was to acquire information on humpback whale occurrence, distribution and activities in the James Price Point area, to support the assessment and management of potential impacts from the proposed developments. Previous studies have indicated that the region, including waters surrounding the proposed development site, is frequented by humpback whales during their northward and southward migration, with 21–63% of the sightings comprised of calf-cow pairs.

Findings

Flights for the humpback and nearshore regional surveys were conducted throughout the 2008 and 2009 seasons. Both annual surveys were extensive e.g. the 2009 surveys totalled 85 hours. During this time approximately 18,000 linear kilometres of transect were sampled. A total of 2707 groups of medium and large whales were recorded during aerial surveys, comprising 3799 adults and 342 calves (including recaptures).

The 2009 vessel transect surveys were conducted three times during the season with a total of 25 survey days, and sampled a total of 30 randomly selected transects at James Price Point and 17 at Pender Bay. This effort amounted to over 1000 km surveyed at James Price Point and over 600km at Pender Bay. A total of 1174 adult whales and 88 calves in 879 groups were recorded. During these vessel surveys over the 2009 season over 1100 humpback adults, and 85 calves locations and behaviours were recorded.

Implications for the Industry

Understanding humpback whale migration is important when determining any potential impacts of oil and gas development in the region. These studies have shown less than 5% of humpback whales were recorded within 8km of the shoreline and therefore are found in low numbers in the James Price coastal area.

During the annual humpback whale migration, aerial surveys are a cost-effective way to determine the distribution and abundance of whales in a region. Alternatively, the spatial extent of data acquired from vessel based surveys is limited these vessel-based surveys provide important data on local whale behaviour.



2.3 Distribution and abundance of dugongs in the shallow waters of the Dampier Peninsula

What was done

Nearshore regional surveys were undertaken in July and September 2009, over the same survey area and using similar sampling methodology as a survey undertaken in March 2009. A fixed wing aircraft and the standard strip width sampling method were utilised. Data from the nearshore regional surveys, and the March 2009 survey were analysed to determine the distribution and abundance of dugongs in inshore waters off the west coast of the Dampier Peninsula (La Grange Bay to Cape Leveque).

Why it was done

The purpose of this project was to quantify the distribution and abundance of dugongs in inshore waters off the west coast of the Dampier Peninsula. Surveys were conducted in March, July and September, in order to provide enough information to establish a baseline for dugongs at this location, and adequately inform the environmental approvals for the proposed James Price Point LNG development.

The surveys provide the first systematic assessment of west Kimberly coastal dugong populations, with standardised survey methodology applied across three survey periods, encompassing both dry and wet seasons. Twenty hours were spent on-transect during each of the nearshore regional surveys, which sampled an area of approximately 1600km² from a survey area of approximately 9400km².

Findings

Dugongs in the region are primarily found in shallow coastal waters, mainly in water less than 20m deep and often below 10m deep. The areas inshore of the Lacepede Islands (off Beagle Bay) around Carnot Bay and in Roebuck Bay appear to be areas important for dugongs, based on relative densities.

The southern portions of the survey area had the highest population estimate and supported the highest number of calves in all survey periods; Roebuck Bay appeared to consistently have the highest population of dugongs, including calves, within the survey area. The population of dugongs of the Dampier Peninsula coastline between Cape Leveque and Cape Bossut is estimated to be between 930 and 1700 individuals, which is comparable to the Exmouth Gulf but considerable smaller than Shark Bay.

The dugong population was substantially higher in both July and September, in comparison to March. The dugong population during the dry season appeared to increase from that during the wet, suggesting movement from other areas.

Implications for the Industry

The dugong is the only marine mammal in its family, Dugongidae, and is recognized internationally as threatened. It is listed by the International Union for Conservation of Nature (IUCN) as Vulnerable on its Red List of Threatened Species. The species is listed as a threatened (Vulnerable) and migratory Species under the EPBC Act and as Specially Protected under the *Western Australian Wildlife Conservation Act 1950*. It is generally accepted that Australia supports the most abundant dugong population in the world.

The habitat feature of greatest importance to dugongs (a largely herbivorous marine mammal) is seagrass beds. CSIRO and AIMS undertook a benthic habitat survey of various locations in the Kimberley Region on behalf of the Northern Development Taskforce in 2008. It was found that the James Price Point coastal area, being within the Quondong Point to Coulomb Point location has not been found to support any significant seagrass beds. Unlike the highly productive, sheltered embayment's of Roebuck, Carnot, Pender and Beagle Bay, James Price Point is exposed to wave energy and winds which can be adverse conditions for the establishment of seagrass.

2.4 Distribution and abundance of sea snakes, sharks and seabirds along the Dampier Peninsula

What was done

A private consulting firm was engaged by Woodside to undertake a series of marine fauna baseline surveys to support the assessment and management of potential impacts from the proposed James Price Point LNG development. Aerial and marine vessel based surveys were undertaken during the period July to October 2009 with a focus on James Price Point and extending along the Kimberley coast for regional context.

Why it was done

This survey was part of a series of marine fauna baseline surveys that are being undertaken to support the assessment of potential impact for the proposed James Price Point LNG development. The Kimberley region supports a number of threatened species listed under the *Western Australian Wildlife Conservation Act 1950* (Wildlife Act) and the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), including marine reptiles, dugongs, whales, dolphins, and certain shark species. However, very few systematic surveys have occurred in the region to quantify the distribution and abundance of its marine fauna, with no known long-term studies of population status, and very few dedicated ecological studies of habitat usage.

Findings

Aerial surveys were conducted across a total of thirty days between 1 July and 14 October 2009, and comprised 85 hours of survey effort on transect. Approximately 18,000 linear kilometres of transect were sampled. A total of 11,505 sightings of marine fauna (other than humpbacks and dugongs) were recorded during the aerial surveys, including sharks, rays, fish, birds, sea snakes and cetaceans. Approximately 39% (4503) of sightings were confirmed to genus or species, including sixteen species from five faunal groups: sharks, rays, fish, birds, and cetaceans. In addition, 923 surface craft (vessels) were recorded during the survey.

Vessel surveys for the regions off James Price Point and Pender Bay were completed over three survey periods: 25 July–9 August, 24 August–7 September and 29 September–9 October 2009. A total of 115 hours of survey effort on transect were successfully completed, sampling a total of 1689km of linear transects at James Price Point (1042km) and Pender Bay (647km). A total of 437 fauna sightings were recorded during the vessel surveys at James Price Point, of which 124 were identified to species. Sightings at Pender Bay totalled 239 animals of which 40 were identified to species. Sea snakes were the most commonly sighted faunal group both at James Price Point and at Pender Bay.

Implications for the Industry

Of the marine fauna species afforded specific conservation (threatened or migratory) status by the EPBC Act and Wildlife Act, only seven were confirmed to be present in the James Price Point area from the surveys: green turtle, flatback turtle, loggerhead turtle, spotted bottlenose dolphin, Indo-Pacific humpback dolphin, killer whale and Bryde's whale. The 2009 surveys confirmed a diversity of marine fauna species in and surrounding proposed development areas. However, no fauna group or species was restricted to the James Price Point area and, based on observations recorded, the area does not appear to have particular importance for any of the marine fauna that can be sampled by the survey techniques employed. The James Price Point area had generally fewer associated sightings than other locations, such as Carnot Bay, the Lacepede Islands or Roebuck Bay. Moderate densities of dolphins, turtles and sea snakes may occur periodically off James Price Point, but the data indicate use of the area is sporadic.





2.5 Surveys of fish communities and their association to benthic habitats in the region offshore from James Price Point

What was done

Australian Institute of Marine Science (AIMS) was contracted by Woodside to survey the associations between demersal vertebrates (fishes, sharks, rays, and seasnakes) with benthos in each of the major habitat types represented in the Quondong Point to Coulomb Point study area.

Why it was done

The goal of the study was to provide baseline estimates of fish diversity and relative abundance in the James Price Point coastal area in direct relation to habitat and depth.

Of the 197 Baited Remote Underwater Video Stations (BRUVS) deployed during the field campaign, 154 produced imagery of sufficient quality to classify the benthic substratum and epibenthic cover, and to identify and count vertebrates. This report presented the results of univariate and multivariate analyses of the responses of the vertebrates at each BRUVS site, in terms of relative abundance and presence/absence, to the depth, position and epibenthic cover of key groups of marine plants and filter feeders.

Findings

All sets of BRUVS produced fish sightings, with a median of 10 species, a mean of 10 and a maximum of 22 species per set. A total of 7108 individuals from 116 species of fishes, sharks, rays and seasnakes were recorded from the 154 sites. Only two species were endemic to Western Australia, the frostback cod (*Epinephelus bilobatus*) and western butterfish (*Pentapodus vita*). About 45% of the species sighted were of economic importance to fisheries, but they contributed less than 25% numerically. Smaller species were most numerous, and the numbers of fish sighted had a median of 38, a mean of 46 and maximum of 167 individuals of all species. Multivariate analysis showed that species responded to the amount of epibenthic cover in the study area and that there was an interaction between depth and sediment composition, and depth and epibenthic cover, in defining four fish assemblages to the north and south of James Price Point.

Implications for the Industry

The benthic habitats at the northern and southern ends of the survey area were clearly important to many species, but in general there appeared to be little association of particular vertebrate species or biotic habitat types with the James Price Point area itself. The study area was notable for the diversity and abundance of small pelagic species (e.g. *Atule* and *Selaroides trevallies*) and large pelagic and semi-demersal predators, when compared with other studies in the Kimberley and Pilbara bioregions.



2.6 Intertidal communities of the Dampier Peninsula

What was done

The Browse LNG Development is proposed to be located at James Price Point, on the Dampier Peninsula, with development related activities to be undertaken in the adjacent coastal area. The progression of the nearshore marine facilities and shore pipeline crossings may require extensive construction activities, including dredging, excavating, blasting and trenching. As such, benthic habitats in close proximity to these facilities, including intertidal habitats, may potentially be impacted.

Three intertidal study sites were surveyed: two in the precinct area and one for reference. Video and digital photography were taken at each site and were analysed to determine species composition, relative abundance and percentage cover. The benthic characteristics identified were mapped and classified using a combination of littoral zone, biota and substrate attributes. Data from all sites were statistically analysed to determine differences in taxa between sites, between areas within sites and at different heights on the shore.

Why it was done

The primary objectives of the intertidal study were to:

- identify and map the distribution and abundance of intertidal flora and fauna within the defined study sites of James Price Point coastal area, with particular emphasis on benthic primary producer habitat to meet the requirements of the EPA Environmental Assessment Guideline No. 3, Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment.
- identify the physical features and zones (e.g. sand, rubble, mud) of the intertidal area and their approximate locations within each defined study site
- identify the distribution and abundance of invertebrate fauna within the defined study sites of the intertidal zone of the James Price Point coastal area.

The results obtained from this study was used to compile a report that describes the intertidal community (flora and fauna) of the James Price Point study areas, including species composition of the defined study areas; relative density of species within the defined study areas; habitat maps showing community composition within the defined study areas; and the regional significance of the intertidal habitats

Findings

Large tidal regimes are likely to be the defining environmental factor influencing the distribution of intertidal benthic primary producers and associated benthic taxa in the James Price Point coastal area. This is largely because the difference in tidal height between successive tides determines the periods of emersion and inundation and consequently the likelihood of desiccation. Similar studies in other macrotidal regions have found that sedimentation, turbidity and temperature were the driving factors of benthic cover. These factors are strongly influenced by tides and weather.

Implications for the Industry

The results of this study showed that the intertidal reef platforms in the James Price Point coastal area were spatially dynamic. The hard substrata were dominated by fine silt to coarse sand and turf algae. The distribution and abundance of benthic taxa recorded at all sites was variable among areas within sites and heights on the shore, predominantly due to differing periods of inundation. Notably, species composition was not statistically significant between the three survey areas. Similarly, no species of local, regional or conservation significance were recorded in this study.



2.7 Scott Reef biodiversity status

What was done

The Australian Institute of Marine Science (AIMS) entered into a contract with Woodside, for the Browse Joint Venture Partners (JVP) in February 2008, to undertake the three-year Scott Reef Research Project (SRRP). The sites which AIMS has been surveying at Scott Reef represent the longest-running monitoring program of its kind in Western Australia. Based on many years of successful collaboration, Woodside and AIMS worked together to identify gaps in knowledge about Scott Reef which could be researched and used for science, management and industry (including the proposed Browse Project). The research was undertaken to:

- highlight the current status and health of the biological communities at Scott Reef and describe any natural or anthropogenic impacts to its flora and fauna
- describe the current state of knowledge of Scott Reef based on historical and ongoing research
- update the outcomes of research at Scott Reef.

Why it was done

This work was commissioned with the goal of understanding the shallow-water coral and fish communities and included:

- long-term monitoring of coral and fish communities—the AIMS long-term monitoring program was established at Scott Reef in 1994 to quantify the natural variability of coral reef communities, particularly their responses to disturbances such as cyclones and coral bleaching
- coral demography and population models—a supplementary study was established to quantify rates of birth (recruitment), growth and survival of two common groups of corals at Scott Reef, to investigate the ultimate causes of changes in coral cover and community structure at the long-term monitoring sites
- genetic connectivity of coral and fish population—the genetic connectivity of populations of corals and fishes that have different reproductive modes are being compared between Scott Reef and its neighbouring reefs with the expectation that contrasting life histories will yield insights into dispersal and colonisation patterns.
- reproduction and recruitment of corals—reproduction and recruitment by corals involves the production of larvae and their subsequent settlement and metamorphosis into new coral colonies. This process underlies the maintenance of communities and facilitates their recovery from disturbances.

Findings

Despite the isolation of Scott Reef and the low number of neighbouring systems that can supply coral recruits, the recovery of Scott Reef coral communities across most depths has been relatively rapid. This may be due to the high water quality at Scott Reef, which provide an environment where corals have high rates of growth and survival, resulting in communities that are more resilient to disturbance. The coral communities at Scott Reef are expected to continue to return to their pre-bleaching state in the absence of major disturbances. The longer-term resilience of these communities will depend on maintaining good water quality, minimizing local stressors, and the magnitude of predicted increases in water temperatures and severity of cyclones.

Implications for the Industry

Over historical timeframes, coral reef systems have been resilient to major disturbances, however the increasing frequency and scale of disturbance has important implications for the resilience of coral reefs worldwide. The offshore nature of the Scott Reef system, combined with the absence of commercial fishing and many direct human stressors, means it is relatively unaffected by anthropogenic impacts that are common on other coral reefs. However, the most notable exception is traditional fishing of some prized stocks, which includes the overfishing of sea cucumbers, trochus, and reef sharks. Communities at Scott Reef, ten years after bleaching, showed resilience to a climate-driven disturbance.



2.8 Understanding nesting and inter-nesting activities of turtles on and adjacent to the Dampier Peninsula

What was done

Woodside, for the Browse JVPs, commissioned a range of investigations to characterise the environment in the region of the proposed gas plant development at James Price Point (JPP). One of the specific environmental concerns was potential impacts to marine turtles. Since only a few surveys have attempted to quantify the distribution, abundance and habitat use of these fauna, a private consulting firm was engaged by Woodside to undertake a series of surveys. Data collection occurred between July 2009 and March 2010, coinciding with the foraging period for post-nesting turtles in the region. This study included aerial, vessel, beach, and satellite tag surveys conducted off the Kimberley coast.

Why it was done

The specific objectives of the study was to:

- determine the distribution and relative abundance of turtles along the west coast of the Dampier Peninsula and the Lacepede Group
- determine the distribution density, population characteristics, clutch characteristics and seasonality of the nesting turtle population within and adjacent to the JPP area
- determine the spatial extent of the inter-nesting habitat, nesting beach fidelity and post-nesting migrations of flatback and green turtles found within and adjacent to the James Price Point area and the Lacepede Island Group.

Findings

In terms of distribution and relative abundance, green turtles were the predominant marine turtle species during the breeding period, with the highest densities occurring at the Lacepede Island Group. During the non-breeding period, a mix of green, loggerhead, hawksbill and flatback turtle were found along the Dampier Peninsula.

No mating was observed along the Dampier Peninsula, however relatively high densities of mating green turtles were sighted in the nearshore areas of the Lacepede Island Group.

Based on the March 2009 aerial survey, high densities of turtles were recorded in waters around the Lacepede Island Group and north of James Price Point. From December through to February, the predominate species observed nesting at the Lacepede Island Group was the green turtle.

The northern migratory pathway for green and flatback turtle nesting at southern rookeries generally runs northeast long the Kimberley coast adjacent to the James Price Point area.

Implications for the Industry

The 2009–10 surveys confirmed that the Lacepede Island Group supports a large green turtle rookery. The Dampier Peninsula area appears to support adult and juvenile turtles and migrating turtles from southern rookeries. It is unlikely that these turtles are restricted to this area and utilise surrounding areas of similar habitat. There were no regular concentrations or high densities of any species of turtle adjacent to the James Price Point area.



2.9 Satellite tagging of south bound female humpback whales in the Kimberley Region

What was done

This satellite-tagging survey on humpback whales was aimed at increasing knowledge about the specific migratory routes, habitat use, resting areas, calving areas and the individual behaviours of the males, females and mothers with calves. A greater understanding of the movement and migratory behaviours of these whales will better inform the management of proposed and existing industrial activities within or close to the calving and migratory areas and will consequently maximise conservation outcomes for whales. This information is of special interest to Woodside, who is undertaking a marine impact survey on the Browse LNG precinct, in order to assess the conservation significance of the area offshore at James Price Point.

Why it was done

The aim of this project was to deploy satellite tags on female humpback whales with calves in or near their known calving grounds in the Kimberley region of Western Australia. Females with calves were preferentially tagged because it is the behaviour of these animals that are likely to be the most sensitive to industrial activities and other anthropogenic disturbance and therefore are of most interest to conservation managers and other stakeholders.

Findings

The study involved the first large-scale (>20) deployment of satellite tags on Australian humpback whales. The tracks provided by these tags totalled over 23,000km (1250 locations) and revealed detailed migratory behaviour of several individual nursing female humpback whales. One individual was tracked from its breeding ground in northwestern Western Australia to its feeding ground at the edge of sea ice around Antarctic; a migration distance of over 7000km. Also two individuals deviated from the expected migratory route close to the coast of Western Australia and were tracked 1200km into the Indian Ocean. These two whales represent 50% of the whales that provided location data south of Exmouth Gulf so this may represent a relatively common behaviour. It is possible that

such whales divert from the most direct route to their Antarctic feeding grounds, to exploit temperate foraging areas. Such behaviour has shown many eastern Australian humpback whales visit productive waters off Fiordland, New Zealand before continuing their migration to Antarctic waters. In the regions close to the known calving areas the behaviour of the whales was also less predictable. Northwest of Pender Bay several of the tagged whales showed inconsistent direction in their migratory behaviour with some heading north before again turning south. Others looped out to sea before returning to shallower waters. Once south of Pender Bay the whales displayed more consistent migratory behaviour with little or no meandering.

Implication for the Industry

Generally, the tagged whales migrated close to the coastline of Western Australia, often within a few tens of kilometres of shore and the width of the migratory corridor revealed by the tagged whales was frequently less than 100km. In places, such as off Eighty Mile Beach, the migratory corridor was less than 30km wide. North of Exmouth Gulf the widest point of the migratory corridor revealed by the tagged whales was off the northwest point of the Dampier Peninsular where the distance between the inshore and offshore tracked whales was nearly 200km.

Although the tagged whales generally stayed close to the coast this may not reflect the behaviour of males or females without calves. It is thought that females with young calves tend to stay close to shore in order to reduce the possibility of attacks by sharks and killer whales. This behaviour was also revealed by the bathymetry data which showed that these migrating whales were usually in less than 30m of water.



2.10 Using noise loggers to understand the seasonality of whales in the offshore waters of the Browse Region

What was done

In 2006, Woodside commissioned the Centre of Marine Science and Technology to deploy sea loggers in and around Scott reef to assess the occurrence and activities of whales and other marine life in the area. These loggers have been exchanged annually ever since.

Why it was done

The purpose of the surveys was to:

- gain an understanding of the presence and movements of great whales in the region
- measure and describe ambient sea noise including analysis of fish choruses and vessel activity over the recording period.

The sea noise loggers collected samples of ocean noise at frequent intervals over extended time periods. The data collected and logged on board was post-processed to describe vocalisation patterns of biological sources and the noise produced by human activities during the deployment time frame. The loggers are typically deployed to collect data on vocalising great whales such as minke, humpback and blue whales, plus fish sounds. Longer term deployments spanning many years allows a much clearer view of trends in animal movements to be identified and allows more accurate definition of any anomalous events identified.

Findings

There is a clear seasonality in the presence of all whales with May to October having humpbacks, the two minke subspecies and pygmy blue whales present in the broad region. During this time the humpbacks are believed to linger in the area. Comparison of humpback whale singing periods along the northern Western Australian coast suggested that many humpbacks do not reach the Kimberley area but rather spend their time further south.

The humpback season in the Exmouth area stretches approximately 136 days whereas in the Scott Reef region, some 1200km further north, it was only 80 days outside the reef and 34–62 days inside the reef.

On some, but not all years, pygmy blue whales may return south through October to January. Bryde's whales appear to be present all year round in low numbers within the Browse region with as of yet no clear trends in migratory behaviour or links to local productivity. There is seasonality in the fish choruses with winter lulls in calling behaviour of all choruses. The chorus believed due to nocturnal planktivorous fishes inside Scott Reef reached highest levels over late summer into Autumn. It is possible that this chorus reflects feeding activity thus indicating greatest productivity in the Scott Reef area over this period.

Implications for the Industry

New knowledge on Scott Reef whale presence has been obtained from the noise logger monitoring program and has been provided important data for the impact assessment process and current, and future management plans.



2.11 Baseline marine habitat survey of the Dampier Archipelago

What was done

A baseline marine habitat survey report has been prepared to show the location and spatial extent of different marine habitats within Mermaid Sound. This was supplemented by monitoring to determine the composition, condition and degree of cover of the biota present within habitat types. Surveying the type of fish assemblages present was also undertaken. Given the limited existing data of the area, additional surveys were required to provide the necessary detail as part of the Pluto project approval.

Why it was done

This comprehensive survey was undertaken to produce spatially accurate maps of Mermaid Sound, showing the location and spatial extent of different marine habitats. Detailed analyses of the taxonomic composition and baseline condition of biota within these areas were determined at representative locations. An extensive baseline of data on fish species assemblages and associations with substrate and biota has also been documented. These surveys were provide both qualitative and quantitative data to support future assessments of the condition of benthic habitats and associated biota in the project area.

Findings

In total 315km² of Mermaid Sound has been mapped in high resolution to distinguish habitat location and extent, using a combination of multibeam sonar, hyper-spectral sensors and 389km of towed video that identified the biota present in detail. The mapping process identified reef features that had not previously been detected in the area, as well as the distribution of primary biota, soft coral and sponge communities.

The majority of areas are a mixed mosaic of biota types, forming one single habitat type, rather than a range of dominant habitat types, aside from areas largely dominated by macroalgae. Areas of medium to dense coverage biota are primarily associated with hard reef substrates, whereas low density regions are typically found on obscured reef, regularly inundated by sand.

Hyper-spectral classification categorised mixed shallow water habitats, predominantly on the density of biota present. Classification of multibeam data was able to identify deeper substrate and biota classes, mapping the distribution of the individual types and cover with high accuracy. Final maps identify areas where primary biota co-occurs across the study area and where mixes of biota are classified as a single 'mosaic' habitat type.

Implications for the Industry

Habitat mapping was able to determine areas of mixed biota of sufficient density to identify suitable monitoring locations. The condition and pre-development health of key biota types present has now been determined, providing a baseline from which changes can be assessed. Of the monitoring undertaken, sufficient replication and power was obtained to detect possible changes in community composition. Diver and drop camera surveys identified sites both inside and outside the potential zone of influence from future Pluto dredging.

3 ConocoPhillips report

3.1 Firebird-1 pre-drilling marine environmental survey

What was done

In late 2005 the single well Firebird-1 exploration-drilling program was conducted in the Timor Sea Joint Petroleum Development area (JPDA) by ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips). This site is approximately 250km south of Suai in Timor-Leste and approximately 500km northwest of Darwin.

ConocoPhillips engaged a private consulting firm to undertake a pre-drill baseline environmental survey at the proposed well site. This survey consisted of a sediment quality study which aimed to categorise the sediments at and around the proposed well site. In addition, benthic infauna composition and abundance were assessed in relation to sediment chemistry.

Why it was done

The aim of the study was to undertake a pre-drilling marine environmental survey of the proposed Firebird-1 well site providing ConocoPhillips with a baseline seabed sediment chemistry profile, sediment particle size and an understanding of the benthic infauna communities at the site prior to drilling.

In order to make an assessment of the potential impacts from any routine or accidental overboard discharges during the drilling process it is important to have an understanding of the existing physical condition and chemistry of sediments on the sea floor at the exploration well site prior to commencement of activities. Monitoring of the benthic communities around the proposed site is informative as the organisms can integrate the effects of any pollutants over time.

Findings

There were a total of 19 sample sites; sediment was collected from each site with a total of 29 sample sets being taken with multiple samples for quality control. At each site a Van Veen grab sampler was lowered to the seabed to collect the sediment samples. The sediment samples consisted of a thin veneer of grey brown silt sands over grey silty coarse sands with shell fragments; there was little variation between samples.

The recorded metal levels in the sediment were low at all collection sites, with mercury being detected at five sites at a concentrations marginally above guideline levels. Hydrocarbons were not detected at any site in the pre-drill survey. Generally the metal concentrations at the collection sites were well below ANZECC and ARMCANZ guideline levels. Annelids were the most abundant and species rich of the benthic infauna phyla sampled.

Implications for the industry

This report is of value to ConocoPhillips as the findings conclude that the control sites are appropriate for the assessment of any changes in contaminate levels. Due to infauna abundance and diversity differences between the control and impact sites, infauna may vary independently in response to natural changes.



Arthropod specimen *Brachyuran*





4 Nexus Energy report

4.1 Review of cyclone data (1986 to 2006) in the Timor Sea specifically within the vicinity of the Crux Field Development

What was done

Nexus Energy produced a report detailing cyclone data tracking for a period of 20 years, from 1986 to 2006, specifically relating to cyclone proximity to the Crux Field Operations. The aim of the study was to gain a greater understanding of cyclone movements around the Timor Sea and surrounding areas in order for Nexus Energy to assess and manage potential impacts.

To assess the impacts cyclone movements could have on the Crux Field operations the severity and speed of the cyclone tracks were assessed. Historical data for the 20-year window was obtained from the Australian Bureau of Meteorology (BoM) that included cyclone track, speed of movement, wind severity and speed.

Why it was done

The report was undertaken for the purpose of assessing potential impacts and enhancing Nexus' ability to manage potential impacts on the Crux Field operations in AC/P23. The data was summarised and mapped to address the following:

- frequency of cyclones that approach within 200 and 450nm of Crux
- origin (genesis area) and direction of movement of cyclones and the likelihood of passing within 200nm of Crux
- the likelihood that a cyclone that originated between Crux and the Torres Strait would pass within 200nm, 450nm and 750nm of Crux
- speed of movement from source
- severity of cyclones approaching within 200nm of Crux
- potential effects of climate change.

Findings

The findings are categorised into frequency, origin and direction of movement in cyclones, speed of cyclone movement, severity and climate change.

In terms of frequency the data showed that 215 cyclones were recorded in the data set, 17 originated within 200nm of Crux with 48 cyclones coming within 200nm of Crux and 77 cyclones coming within 450nm of Crux.

The origin and direction of movement findings showed overall that the cyclones that passed within 200nm of Crux originated to the east moving towards the west, this being the common trend in movement over the 20-year period.

There were 26 cyclones which originated beyond 750nm to the east of Crux, 65% passed within the 450nm to 750 nm radius of Crux, 53% passed within the 200nm to 450nm radius and 34% passed within 200nm of Crux. Generally cyclones that originate within 750nm of Crux 75% pass within the 450nm radius.

Of the cyclones that originated within the 450–750nm radius two thirds of these passed within 450nm of Crux and continued to pass within 200nm. Eighty-one per cent of cyclones that originated within the 200–450nm radius of Crux passed within 200nm.

Generally speaking all of the cyclones moved in an east to west direction with one exception in 2004, cyclone Raymond that moved west to east. Most cyclones pass by Crux and keep heading in a westerly direction to the Indian Ocean or head south to make landfall.

The average speed of the cyclones tracked in the Timor Sea is between 4 and 20 knots. In general cyclones tended to move faster as they approached Crux and the fastest moving cyclone was recorded with a range between 13 to 20 knots. Interestingly as cyclones move past Crux the speed is increased slightly anywhere between 2 to 10 knots which over a 24-hour period can be between 50 to 240nm.

The severity of the cyclones is increased with the speed as they move from east to west. Outside the 200nm radius the cyclones tended to be category 1 or 2, within 200nm the category is increased to 2 or 3 and as they move further west and south they intensity can reach category 5.

There have been assumptions surrounding issue that climate change will lead to an increase in frequency and severity of cyclones; the BoM released findings that suggests this is unlikely.

Implications for the industry

This report suggests that consideration should be given to adjusting the cyclone alert phase or the 200nm, 450nm and 750nm radius around Crux. The Crux Field operations is positioned within a cyclone pathway in the Timor Sea with Indonesia to the north and the north coast of Australia to the south. The BoM should further develop their cyclone prediction analysis models and for enhanced accuracy.



5 Apache reports

5.1 Estimating demographic parameters of breeding populations of Hawksbill Turtles—a critically endangered marine species

What was done

Apache's offshore production facility on Varanus Island (commissioned in 1986) is subject to an environmental monitoring program to assess the impact of facility operations on the local terrestrial and marine environment. As part of this monitoring program a long term and ongoing capture-mark-recapture (CMR) study has been undertaken to estimate the demographic parameters of nesting populations of the Indo-Pacific hawksbill and flatback marine turtle. The hawksbill turtle species is listed on the IUCN Red List as critically endangered, however little is known to support robust diagnosis of population trends.

Field data collection is undertaken during October–November to coincide with the peak hawksbill turtle (*Eretmochelys imbricata*) nesting period and in January to capture the peak flatback turtle (*Natator depressus*) nesting period. The monitoring undertaken includes:

- a tagging program (CMR) to investigate turtle remigration intervals, adult morphology, nesting success and clutch size
- a track census program to investigate the distribution of marine turtle species on the main nesting beaches of Varanus Island and the surrounding Lowendal Islands
- a hatchling orientation (nest fan) program and hatchling dispersal study to investigate hatchling dispersion patterns immediately following emergence from the nest
- a hatchling and emergence success study to investigate hatchling survivorship in the immediate offshore zone
- a lighting assessment of visible light sources from the nesting beaches on Varanus Island.

All tagging data are maintained in the Western Australian Department of Environment and Conservation 'Database for WA Marine Turtle Conservation'.

Flipper tagging of nesting hawksbill and flatback turtles has been carried out each year at various times between October and January for over 20 years since October 1987 to the present. Tagging occurs during the main peak of the austral summer nesting season for these species at nesting beaches on Varanus Island and opportunistically on the surrounding Lowendal Islands. Turtles are double tagged at first encounter to a nesting beach using uniquely numbered titanium tags or this information is recorded for re-emerging turtles.

Since 2010, turtles were also implanted with a Passive Integrated Transponder (PIT) tag in the left shoulder. PIT tags were used to overcome problems caused by high rates of flipper tag loss that is experienced in flatback turtles as it is considered a more permanent 'life time' tag.

Why it was done

The primary objective of the Varanus Island Marine Turtle Tagging Program is to tag and record biometric information of all observed nesting marine turtles on the beaches of Varanus Island. The long term dataset on turtle nesting and hatching activity provides a better understanding of the demographic parameters of breeding populations of hawksbill and flatback turtles using Varanus Island and assists with the ongoing environmental management of Apache's operations on Varanus Island.

This programme also contributes to the datasets used by the WA Department of Environment and Conservation for the management of sea turtles off the coast of Western Australia.

Findings

Annual reports provide information on the findings for each year. Information on the remigration intervals, adult curved carapace length and clutch size has been compared to other nesting sites in Australia and indicated that the turtles nesting on Varanus Island are within the range for these parameters. Since 2005–06 season, the parameters measured and the methodologies used have been standardised to allow meaningful temporal comparisons for the number of new and remigrant turtles using the nesting beaches on Varanus Island. So far, the numbers have been fluctuating with no obvious temporal trends indicating a longer term increase or decrease.

Work has been undertaken by researchers at the DEC to assess Apache's long term data using statistical modelling which takes into consideration seasonal breeding omissions to determine the hawksbill turtle's survival probability. Adult female hawksbills do not nest each year due to physiological constraints such as high energy demands required for breeding migration and a fluctuating food supply. Adult female turtles are far more likely to rest for at least one season after nesting than to nest again the following year. This skipped breeding behaviour presents a challenge to accurately estimate demographic parameters.

Assessment of this long term sampling database has indicated the annual survival probability for nesting hawksbills was constant over the last 20 years, which was encouragingly high and indicative of a healthy stock indicating that oil and gas activities on Varanus Island have not impacted the hawksbill population. The data confirmed that adult female hawksbills nesting on Varanus Island are far more likely to rest for at least one season after nesting than to nest again in the following year.



5.1 Estimating demographic parameters of breeding populations of Hawksbill Turtles—a critically endangered marine species *continued*



Implications for the industry

The results of the assessment of this database contribute to the long-term monitoring and understanding of turtle nesting and activity on Varanus Island, in Western Australia. The Varanus Island Marine Turtle Tagging Program provides useful census information on turtle nesting locations, adult morphology, nesting behaviour, nesting success and reproductive effort (i.e. clutch size). It also provides important data on hatchling survivorship and dispersion. Ongoing monitoring allows for the identification of significant trends in turtle nesting and activity on the island, and subsequently provides an important management tool to assess whether oil and gas activities are having any detrimental long term effects on the turtle population utilising Varanus Island as a nesting location.



5.2 Collaborative whale shark data collection—Ningaloo Reef 2009–13

What was done

This research project has four major ongoing programs:

1. whale shark migration derived by tagging studies
2. photo identification
3. genetic sampling
4. small-scale movement and diving analysis.

Field work to date has occurred over a three year period of what is a planned 5-year project (2009–13). Between late April and June of each year researchers collect data on whale sharks (*Rhincodon typus*) within the coastal waters off Ningaloo Station (between Black Rock and Norwegian Bay). Once a shark is sighted using spotter planes, a charter vessel is directed to position drivers ahead of the approaching shark for tag deployment. Some sharks are also tagged with satellite tracking and video recorder tags. Still photographs and stereo video recordings are taken of sharks encountered for identification purposes. Additionally, skin biopsy samples are taken for genetic studies, lengths of the sharks are estimated and gender is identified and recorded.

Tag deployment consists of Temperature-Depth-Recorder archival logger tags and video and data acquisition platform (VDAP) tags. The latter provides a high resolution 3-D swimming path of whale sharks. All tags are deployed using a dart and tether technique.

This ongoing research programme is supported by funding from Apache Energy Ltd, the Australian Institute of Marine Science, the U.S. NOAA Ocean Exploration Program, Charles Darwin University, Sea World Research and Rescue Foundation and CSIRO Marine and Atmospheric Research.

Why it was done

The research work will provide important information on the migratory path and behaviour of this species and determine if there is a relationship with other known aggregations of whale sharks in other parts of the world.

This project consists of two main components:

- an ongoing study on whale shark migration by Mark G. Meekan (Australian Institute of Marine Science), Jeffrey J. Polovina (NOAA Fisheries), Steven G. Wilson and John D. Stevens (CSIRO Marine and Atmospheric Research)
- ongoing photo identification and genetic sampling projects conducted by Mark G. Meekan, Corey J. A. Bradshaw (University of Adelaide) and Conrad W. Speed (AIMS/CDU).

Findings

The photograph and stereo video identification data are now being analysed and compared with data bases obtained from tourist operators at Ningaloo and collaborators in the Maldives, Seychelles, Mozambique and Djibouti.

Analyses of earlier VDAP deployments have been completed and show whale shark use four tactics to save energy and improve foraging efficiency: fixed, low power swimming; constant low speed swimming; gliding; and asymmetrical diving. These tactics increase foraging efficiency by 22–32% relative to swimming horizontally. Further deployments will be used to extend these results and to explore the bio-mechanics of whale shark movement patterns.

VDAPs secured to sharks of varying sizes and age exhibit strikingly similar locomotor habits despite a nearly two-fold difference in body length, estimated five-fold difference in body mass, and likely several years of difference in age. Sharks tended to swim away from the reef during the morning and afternoon and toward the reef in the evening, covering roughly 40km (in three dimensions) during the deployments. They spent part of the time within 5m of the sea surface. The rest of the time they performed 'dives' (descent from near the sea surface toward the bottom followed by immediate ascent) or swam horizontally at depth, usually close to the sea floor.

The dives of whale sharks are generally similar to the dives of air-breathing marine mammals and this pattern of descent from and ascent to the surface is thought to be used for food searching. Whale sharks take advantage of their negative buoyancy to incorporate periods of gliding into their dive descents, an energy-conservation tactic previously documented in marine mammals.

During all activities away from the surface, speeds of the sharks while actively swimming (i.e. excluding gliding) were very low (mean + s.d.: 0.67 + 0.16 m/s and 0.56 + 0.10 m/s) and relatively stable.

Implications for the industry

This collaborative whale shark research project will provide valuable information on whale shark demographics and migration patterns. Such information will be useful for offshore oil and gas companies operating within the Exmouth Sub-basin.





5.3 Monitoring of annual variation in seabird breeding colonies throughout the Lowendal Group of Islands

What was done

Apache Energy conducts ongoing monitoring of avifauna present at the Lowendal Group of Islands, located on the North West Shelf (NWS) of Western Australia. The survey records the numbers and breeding stages of seabirds. Forty four islands and rocks are visited on three occasions in late January, early March and late May of each year.

Seabird nesting habitat is mapped for each island and populations of each breeding species are calculated. Notes on the stage of breeding are also recorded, and where applicable, eggs are measured and weighed for some species, to define accurately breeding dates.

Why it was done

The populations of seabirds breeding on the Lowendal Island Group are considered significant in a regional and national context. Knowledge of the breeding location, population size and timing of breeding for seabirds is essential for the development of effective management plans for the region, which encompass oil spill mitigation and silver gull control. This study is in its sixth year, forming a basis for comparisons between seasons over time, which can assist with the identification of short and long term effects upon the breeding seabirds of the island group.

The specific objectives of this survey were:

- to obtain data for the whole island group so that seasonal variation in species richness and abundance of island avifauna could be assessed
- to monitor changes in the presence and populations of seabirds in the areas, with particular interest in the silver gull population.

Findings

Avifauna surveys undertaken to date have recorded a total of 35 bird species throughout the Lowendal Island Group. These comprised 12 species of seabirds, 9 species of waders, 4 species of shorebirds, 4 species of raptors and 5 species of landbirds.

The seasonal variations in population density of seabird assemblages of site-faithful migratory seabirds, such as bridled terns and wedge-tailed shearwaters on the Lowendal Island Group, are potentially explained by a number of factors. Variations in the 'quality' of the environment, in terms of resource availability, climatic factors and oceanographic influences can result in fluctuating breeding populations on a year to year basis, as well as through over-riding longer term trends, via a process known as 'ecological drift', where population dynamics differ from location to location within a metacommunity.



The reduction in silver gull breeding populations observed is likely a desired outcome of a management strategy (egg shaking as per approved permit conditions by the Department of Environment and Conservation) to reduce the predation of sea turtle hatchlings by this species.

Implications for the industry

The results of this ongoing seabird monitoring survey contributes to the knowledge of the location of seabird colonies in the Lowendal Islands, how these colonies fluctuate in size from season to season, and to some extent the factors which may be affecting the breeding participation and success of some of these species. This information provides a powerful management tool in terms of identifying conditions that favour breeding participation and success, associated with 'naturally' occurring condition fluctuations (climate, food source etc.). This study provides valuable information which can be used to protect the Lowendal Island Group avifauna breeding colonies, contribute to mitigation measures and management plans for potential 'pest' species, such as silver gulls, and can be integrated into oil spill contingency plans.



5.4 The integrated Shearwater Monitoring Project

What was done

Apache Energy, as part of its annual environmental monitoring programme, undertakes ongoing surveys of wedge-tailed shearwater (*Ardeanna pacifica*) colonies, on four islands on the northwest shelf of Western Australia. Monitoring is undertaken at Varanus and Airlie Islands (islands with oil and gas infrastructure) and Bridled and Serrurier Islands (control islands without oil and gas infrastructure), during November and March–April of each breeding year. Transects and quadrats are surveyed on each island, where shearwater burrows are counted and inspected, to determine breeding participation (i.e., number of eggs laid) and breeding success (i.e., number of chicks raised to fledging).

Wedge-tailed Shearwater colonies have been monitored in relation to oil and gas activities on the NWS since 1985 providing a long term database of 26 years of monitoring data. In 1994, three independent monitoring studies were combined into the Integrated Shearwater Monitoring Programme (ISMP), in its current form. In 1999, Apache undertook responsibility for the entire ISMP.

The ISMP monitors plots on each island by estimating occupancy of burrows either through direct counts of active burrows or using the more invasive technique involving entering the burrow with a video camera (the 'burrow-scope') and noting the burrow's contents. A 'pre-season' visit in November is timed to identify breeding birds, the presence of an egg and or an adult being recorded. A 'post-season' visit in March/April is timed to identify chicks just before fledging.

Thus the field programme provides estimates of:

- breeding population for any particular year
- proportion of the breeding population attempting to breed (the participation rate)
- hatching success
- fledging success.



Why it was done

The aims of the study and ongoing ISMP are:

- to compare breeding effort of the wedge-tailed shearwater with later breeding success between each of the islands monitored
- to monitor any differences between breeding effort and breeding success at those islands which do not have oil and gas infrastructure and at those that do
- to investigate the relationship between breeding participation and breeding success with fluctuations in oceanographic (El Nino Southern Oscillation Index) and climatic factors, and where possible provide a regional context for this.

Findings

On islands of the NWS, Wedge-tailed Shearwaters usually return to their colony areas to resume courtship and re-excavate burrows in August each year. Prior to egg laying there is an exodus of 2–3 weeks where the birds go out to sea to feed and build up body weight and condition. On returning, only one egg is laid per pair of birds. Egg laying starts at the end of October or beginning of November. There is an incubation period of 55 days whereupon the newly hatched chicks are brooded for only several days, but are fed nightly by both parents. The young chicks are tended by the parents until late March–early April and are then abandoned. The chicks must then lose weight before they are able to fly. Shearwaters then spend the non-breeding season feeding in open waters between May and August, travelling close to the Equator.

The March (end of breeding season) visit is conducted prior to fledging of nestlings and serves to ascertain the number of fledglings produced. This gives an index of reproductive success, or the number of eggs converted to fledglings. The beginning of breeding season visit is conducted during the incubation period, when the number of breeding attempts are estimated by counting the number of birds with eggs, eggs alone and predated eggs. The total number of eggs counted is used to estimate the breeding participation, defined as the number of breeding attempts in intact, presumably used burrows.

Within each of the monitoring transects and quadrats, there are two types of sampling areas:

- burrow census ('count') strips, where intact burrows with and without recent surface evidence of occupation are counted in 10m segments along each strip
- burrow scope ('video') strips, where a video camera and light source are directed down the burrow sending the image back up to a video monitor on the surface.



5.4 The integrated Shearwater Monitoring Project *continued*



The long-term trend in the number of breeding attempts is related to the Southern Oscillation Index (SOI). Years of low SOI values result in a lower proportion of breeding attempts on all islands, however, since 2006 there has been an increase in the proportion of breeding attempts in line with a return to a positive SOI.

The long term trend in the number of chicks raised is also related to the SOI. The correlation is not as strong as for breeding attempts as regional (e.g. cyclones) and local (e.g. predation) conditions during the chick rearing phase act independently of the SOI.

During years of negative SOI poor feeding conditions at sea results in increasing numbers of dead chicks at the very end of the breeding season, resulting in an earlier abandonment of breeding by the adult shearwaters.

The SOI returned to a neutral state in 2009–10, however, on some islands there was a decline in breeding attempts and breeding success (Serrurier Island and Airlie Island) while on others there was an increase in either breeding attempts or success or both (as was the case for Varanus Island).

Implications for the Industry

The results of this ongoing survey work contributes to the long-term monitoring of wedge-tailed shearwaters at colonies on the NWS of Western Australia. The monitoring program provides a useful measure of variability in reproductive effort (number of eggs laid) and breeding success (number of chicks surviving to fledging) over time. Monitoring of several colonies provides a robust measure of regional variability in environmental conditions, and variation in breeding parameters from one year to the next. Comparing colonies on undisturbed islands to those islands with oil and gas infrastructure/activities, provides an ongoing assessment of the success of the environmental management practices at these facilities and assists with understanding the ecology of an important seabird species for oil spill contingency planning and response. Location of the monitoring sites on Varanus Island (A), Bridled Island (B), Airlie Island (C) and Serrurier Island (D).

5.5 Marine monitoring—corals

What was done

Apache Energy Limited operates several oil and gas fields and associated infrastructure through its Hub on Varanus Island on the North West Shelf of Western Australia. Apache's main infrastructure in the region includes several gas plant on Varanus Island, a crude oil export terminal, the various offshore production platforms and pipelines connecting to them.

The surrounding waters to Varanus Island are a declared Marine Conservation Reserve (MCR). On a regional scale, coral distribution within the MCR is patchy. Coral reef communities are most developed in the relatively clear water and high energy conditions of the Montebello Island's western barrier reefs. Bommies and patch reefs occur on the more turbid, lower energy water along the Montebello/Lowendal and Barrow Islands chain eastern edge.

Apache has monitored corals in the region since 1985 using various sampling designs and techniques. In 2000, a baseline survey was carried out and permanent coral monitoring transects at 11 sites were established. Power analyses indicated that the design was capable of detecting change of 20–25% at an impacted site relative to control sites at 80% power. Since 2000, the same sampling design and methods have been used and surveys carried out annually from 2000 to 2002 and thereafter biannually.

The coral monitoring programme has the following objectives:

- describe coral assemblages
- quantify spatial and temporal variability of coral assemblages
- determine whether Apache's activities and operations are having a detectable effect on the coral assemblages surveyed.

Fieldwork for the coral monitoring programme is carried out for a 10-day period usually in September. Sites are located within the Lowendal Island group and Airlie Island with some sites more distant within the Montebello group. At each site, there are four, 50m long transects with permanent markers at the start and end points (star pickets) and at the 10, 20, 30 and 40m marks (steel rods) along each transect. Transects are generally parallel to each other and perpendicular to the depth contours.

Prior to 2010, all analyses of survey data used the AIMS Video Transect Analysis System (AVTAS), which relied on stills extracted from video of permanent transects. In 2011 the AVTAS method was superseded by a digital still photography method, which has improved the quality of frames for data analysis. As per the video method, photography is done on the right hand sides of transects, ~1m from a flexible fibreglass tape laid along the transect. A digital camera held in an underwater housing is used, and a 35cm aluminium rod attached to the housing ensures that a constant height above seabed is maintained, thereby standardising the size of photo-quadrats among all surveys

(25cm x 34cm). Photos are taken by divers at 1m intervals along the tape, with 50 photos collected at each site.

Video data are also collected at each site for back-up and archival purposes. Photographs and notes are also taken at each site to record the presence of bleaching, disease or coral predators (i.e. *Acanthaster planci* or *Drupella* spp.).

To determine whether Apache's activities are having an impact, coral and other biota and substrata were identified and classified at five points shown on each of 40 randomly selected photographs from the total of 50 for each transect taken along each of the four transects for each site. Using the Coral Point Count (CPCe) program, data were extracted from the photographs and multivariate and univariate analyses were used to assess differences in coral cover and composition by family from 2000 to 2011.

Corals were identified to family level and form (branching, massive, sub-massive, plating, corymbose, encrusting, foliose and columnar). Commonly occurring macroalgae (such as *Sargassum* spp. and *Padina* spp.) were identified to genus and unidentified alga to phyla. Other biota (e.g. sponges, ascidians, echinoderms) were identified to phyla where possible. Other category included sand (particle size less than 0.5mm), sediment (very fine sediments overlying live coral) and rubble (unconsolidated fragments of hard dead coral that were not colonised by turfing algae).

Why was it done

The study is done to determine whether Apache's activities are having an impact on the corals inhabiting the marine environment surrounding its operations. Corals are significant benthic primary producers which play a key role in many reef ecosystems and have an iconic status in all areas they occur and are protected under state law.

The coral monitoring program has the following objectives:

- describe the coral assemblages
- quantify spatial and temporal variability of coral assemblages
- determine whether Apache's activities and operations on Varanus Island are having a detectable effect on the coral assemblages surveyed.





Findings

Over the seven surveys undertaken to date, most sites supported a high diversity of corals (8–11 families), but three sites had consistently fewer (5–7 families). Total coral cover ranged from 8% to 41% and comprised mainly hard coral.

Acroporidae, Faviidae and Poritidae showed the greatest percent cover of the hard corals. At seven sites, Acroporidae or Faviidae, or both of these, had the greatest cover. Poritidae had the greatest cover at two sites, although jointly with Faviidae at one site. Soft corals (Alcyoniidae) had the greatest cover at one site and there was one site where Alcyoniidae and the non-scleractinian Milleporidae together had the most cover. Corals of the families Oculinidae and Siderasreidae had the least percent cover. The Oculinid genus *Galaxia* was observed at a few sites and has been recorded as a minor contributor to coral cover in the past. Siderastridae were recorded at only one site. Interestingly, the pattern for most sites has remained the same since 2000.

Branching corals dominated at four sites, whereas at most other sites massive corals were the dominant form. The presence of very large Porites bommies at some sites indicates a long history of coral presence. Visually dominant plate-like Acroporids were recorded at a five sites, while columnar and free-living colonies were least common. Macroalgae was present at all sites.

Although some sites surveyed were statistically different, many tended to cluster closely together over time, which indicated that coral cover and species composition was fairly consistent over time within most sites.

At some sites, small incremental changes between years were noted in total hard coral cover, or in the cover of many families of coral, that formed a trend over the study period. Some of the trends were cyclical with whole assemblages and/or families of coral returning to their original state as at the start of the monitoring period, which suggests that these assemblages are following a natural pattern. Similar trends to these have been recorded on the Great Barrier Reef.

Sites dominated by soft coral, non-scleractinian coral or by Acropora tended to remain distinct over time, while those characterised by more diverse assemblages formed a large cluster with considerable overlap between sites.

It appears that there are numerous natural processes including storm events, disease, bleaching and predation affecting coral assemblages and cover and these spatial and temporal trends are occurring independent of Apache's activities.

Implications for the industry

The data collected for these long term baseline coral surveys has assisted with quantifying natural spatial and temporal variability of the coral assemblages and cover in the waters surrounding Varanus Island. This will provide important information against which potential future impacts to the waters of the surrounding MCR from other activities external to Apache's activities can be measured.

5.6 Varanus and Bridled Islands vegetation monitoring

What was done

Vegetation monitoring is undertaken on Varanus Island and Bridled Island in the Lowendal Group. Bridled Island is remote from the operations on Varanus Island and is used as a reference location. Field work is undertaken each year in September–October.

Twenty nine established vegetation transects are monitored. These transects include:

- five control (undisturbed) transects on Bridled Island
- fifteen undisturbed transects on Varanus Island (3 within Apache's lease, 12 outside of the lease)
- seven disturbed transects within Apache's lease on Varanus Island.

Two transects established on areas that were accidentally burnt in 2007 on Varanus Island.

Each 20m long transect is divided into 20 x 1 m² quadrats and within each quadrat the following are recorded:

- total number of species present (must have roots within quadrat)
- total vegetation cover of the quadrat
- number of plants per species
- projected foliar cover (PFC) for each species.

In addition, general observations on habitat and species health are recorded and a photograph of each transect is taken. Data collected per transect are then statistically analysed using multivariate analyses allowing:

- an assessment of the impact of current operations on vegetation on Varanus Island by comparing undisturbed transects located on the lease on Varanus Island with 'control' transects, those outside of the lease and on Bridled Island
- the recovery of vegetation that has been disturbed within the lease on Varanus Island by comparing with undisturbed transects on Varanus Island
- the recovery of vegetation following a small fire in 2007 by comparing two disturbed by fire transects with two control transects.

The location, transect coordinates, habitat type, vegetation assemblage and disturbance type are all recorded for each transect.

Why was it done

Varanus and Bridled Islands are part of the Lowendal group of islands and are vested as nature reserves gazetted for the protection of their flora and fauna. Both islands are managed by the WA Department of Environment and Conservation.

The objectives of the vegetation monitoring program are to:

- detect and quantify any impacts on the vegetation communities on Varanus Island that may arise from Apache's operations
- for those sites that have been disturbed in the past, assess their recovery and provide information to initiate and improve rehabilitation of disturbed sites if necessary
- continue to contribute to Apache's long-term knowledge and understanding of Varanus and Bridled Island natural vegetation communities
- detect, monitor and control the spread of weeds on Varanus Island and rehabilitate affected sites to aid natural vegetation recovery.

Findings

A total of 122 flora species have been recorded on Varanus Island since 1999. Twelve of these are introduced weed species (some of which have since been eradicated) and four are introduced 'landscaping' plants.

A total of 82 taxa (including subspecies and varieties) from 27 families and 63 genera have been recorded from the annual vegetation monitoring program, including 59 taxa present within the transects and an additional 19 taxa opportunistically recorded. The most commonly represented families were Poaceae (11 taxa), Chenopodiaceae (10 taxa), Fabaceae (six taxa) and Malvaceae (six taxa).

Historically, the species present and their foliar cover in similar habitats on Varanus and Bridled Island are not significantly different. Perennial plants comprise proportionally more of total plant density on Varanus Island, while Bridled Island has more annual species than Varanus Island.

Analysis of the whole data set suggests that at an island scale the vegetation on both islands has not changed significantly over 8 years of monitoring. This suggests that Apache's operations on Varanus Island are not having a detrimental impact on the undisturbed vegetation on Varanus Island and the vegetation on Bridled Island.

Implications for the industry

Long term flora monitoring programs such as these provide important information and confirmation that impacts from oil and gas infrastructure and activities has minimal impact on the surrounding sensitive vegetation communities.





5.7 Chemical and biological assessment of produced formation water discharge from Harriet A Platform with a tropical reef species, stripey seaperch (*Lutjanus carponotatus*)

What was done

Since 1985, the production of oil from the Harriet offshore field (platforms Harriet Alpha, Bravo and Charlie) has resulted in produced formation water (PFW or fossilised seawater contained with an oil/gas reservoir) being separated from the hydrocarbons and discharged directly to the marine environment at the Harriet Alpha platform.

Recovered gas and crude oil from the Harriet Alpha, Harriet Bravo, Harriet Charlie production wells is received into separators on the Harriet Alpha platform. PFW recovered from each separator is normally directed to the Harriet Alpha PFW high pressure pumps that direct the majority of the PFW to Varanus Island for treatment and reinjection. The remaining PFW is treated on the Harriet Alpha produced water facilities to remove any entrained hydrocarbons and the resultant PFW then discharged to the marine environment.

In May 2003, the Australian Institute of Marine Sciences (AIMS) undertook a comprehensive biological and chemical assessment of the fate, effects and potential risks associated with produced formation water (PFW) discharge at Apache's Harriet Alpha Platform on the North West Shelf of Western Australia. The study included an *in situ* controlled fish caging study, field-based toxicity tests and laboratory-based toxicity tests. Fish, water samples and PFW samples were collected at T=0, T=3 days and T=10 days.

One hundred and thirty stripey seaperch (*Lutjanus carponotatus*), an ecological important reef species, were collected along the Dampier Harbour Liquefied Natural Gas (LNG) pipeline and translocated to the study area. Ninety fish were organised into cages, and two cages were deployed at three stations, totalling fifteen fish per cage. The stations represented near-field (Site A—within 200m NNW of Harriet Alpha), far-field (Site B—approximately 1000m NNW of Harriet Alpha) and outside the contact of the PFW discharge (Site C—approximately 20km NNW of Harriet Alpha). 14 individuals were sacrificed from the holding tank to represent day 0 exposure.

A suite of biomarkers aimed at measuring and detecting changes at the molecular, cellular, physiological and reproductive stages of the fish were used and included hepatic somatic index, cytochrome P450, EROD, CYP1A, CYP2M1, CYP2K1, GST activity, FACs, cholinesterase activity, histology, heat shock protein and vitellogenin.

Why was it done

The PFW discharge from the Harriet Alpha platform is, unarguably, the most studied discharge of this nature from a petroleum production facility anywhere in Australian waters. This discharge has been the focus of a considerable number of research and monitoring studies since the mid-1990s, including effluent characterisation studies, water quality monitoring in the vicinity of the platform and at more distant control sites, ecotoxicity studies, and field measurements and modelling studies to determine the fate and trajectory of the PFW plume.

Previous PFW studies at Harriet Alpha in 1998 found an initial horizontal dilution rate of 100–200 times within metres of the discharge point at Harriet Alpha. Beyond this zone, the plume of PFW tended to travel as a stream carried by the surface currents where it was subject to further horizontal diffusion at the rate of 0.1 m²s.

A pilot study by AIMS was conducted prior to the May 2003 study with the results confirming earlier findings that within <1000 m from the Harriet Alpha platform there was potential for biological effects in fish populations exposed to PFW effluent and that further investigations were necessary at the site.

This study was the next step in assessing exposure to, and potential effects of, PFW at Harriet Alpha. An assessment of exposure and effects would provide Apache with information on the spatial extent of impacts from PFW induced physiological and ecotoxicological changes detectable in fish and whether these known to be localised impacts were impacting on the waters and assemblages of the Montebello/Barrow Island Marine Conservation Reserve, with the closest border to Harriet Alpha approximately 4km to the northwest.

Findings

The results of the caging experiment indicated localized impacts to the health of the fish living in close proximity to Harriet Alpha (200m) but similar effects were not seen at 1000m from the platform or at the control location 20km away. Chemical analyses, combined with biomarkers of exposure and of effect at the molecular, cellular and whole organism level provide evidence for the existence of environmental impact out to a maximum distance of <300m, within proximity to the Harriet Alpha Platform point source discharge of PFW.



In addition to the field study, laboratory toxicity testing and the effects of PFW exposure on early life stages of development in bryozoans were examined. Most of the acute toxicity associated with the PFW was due to the organic compounds associated with particulate matter in the PFW rather than heavy metals or sulphides. The laboratory toxicity study concluded that it was likely that colonial biota residing on the platform may be impacted by the organics in the particulate phase of PFW.

Measured dilution of hydrocarbons at distances less than 1000m from the platform indicated that dispersion rates appear to be benzene>toluene>C1–C6, where typical dilution of total C1–C6 hydrocarbons was over 2500 times, and benzene and toluene, over 10,000 and 20,000 times respectively. Vertical profiles of PFW hydrocarbons showed that the PFW plume was primarily a surface to mid-depth feature with most hydrocarbons confined to the top 12m. Beyond 1000m, all hydrocarbons were well mixed vertically.

Implications for the industry

The Harriet Alpha offshore platform was Western Australia's first offshore oil producing platform. This research work along with the other 21 published research studies assessing PFW from this facility, demonstrate that the environmental impact from PFW disposal is localised (conservatively < 1000m from the platform) and limited to sublethal toxicity effects on attached biota to Harriet Alpha infrastructure and associated biota such as demersal fish within 200m of the platform. Assessing the exposure to and potential effects of PFW discharges to a range of organisms has provided important information to the wider community of the limited impact of discharging PFW to the marine environment from offshore oil and gas platforms.





5.8 Marine monitoring program for persistence and impacts of synthetic-based muds

What was done

Apache is the operator of a number of gas and oil fields in the shallow, tropical waters of the North West Shelf, Western Australia. It is also one of Australia's most active explorers historically drilling more offshore wells than any other company. Apache's main infrastructure in the region is its operating hub on Varanus Island, including several gas plants, a crude oil export terminal, the various offshore production platforms, and pipelines connecting to them

Apache has undertaken exploration drilling in the surrounding waters to Varanus Island. Spent drilling fluids (muds) and cuttings (ground up rock) are among the most significant waste streams from hydrocarbon exploration activities (drilling). During the drilling of a well drilling muds are separated from cuttings to meet statutory requirements regarding the volume of drill mud on cuttings (typically requiring less than 10%), however not all mud can be removed as some adheres to the cuttings. Consequently a coating of residual drilling mud is often discharged along with cuttings from the drill rig to the ocean.

Drill cuttings are generally inert and are expected to physical smother and alter sediment grain size of the seabed of a drilling location. Drill cuttings are a combination of fine and coarse soil and crushed rock material resulting from the drill bit cutting into the rock at the bottom of the well as the well is progressively deepened. During drilling, the drilling mud is continuously circulated to flush out cuttings.

In contrast, drilling muds can lead to sediment toxicity and/or increased organic loads, leading to anaerobic sediment conditions. Drilling mud can consist of water based muds (WBM) or synthetic based muds (SBM). The use of SBMs by the petroleum industry has increased in recent years relative to the use of oil-based muds (OBMs) and water-based muds (WBMs), as SBMs offer a better balance between high performance and low environmental impact.

The most recent survey in 2008 is a continuation of Apache's ongoing monitoring conducted since 2001 to investigate the persistence of sediment contamination and impacts on infauna resulting from SBM discharge in shallow, tropical marine habitats around the Lowendal Islands on the North West Shelf, Western Australia.

The current survey investigated sediment quality and the composition of infauna assemblages around four of Apache's well locations drilled with SBM: Agincourt, Gibson/South Plato, Victoria and Hector. The maximum periods between drilling at these locations and sampling for this monitoring program was 20 months at Victoria, 23 months at Gibson/South Plato, 24 months at Hector and 30 months at Agincourt. Control locations

previously sampled in 2002 and 2006 were also sampled in the current survey. This involved the collection of data on:

- the chemical composition, weathering and degradation of drill muds and cuttings around shallow water wells drilled with SBM
- infauna and grain size distributions around shallow water wells drilled with SBM
- infauna and grain size distributions at control sites situated away from potentially impacted sites.

At each well and control location, sites were sampled at distances of 20, 50, 100, 200 and 500m along transects both parallel and perpendicular to the axis of the predominant current flow, giving a total of 10 sites per location. At each site, samples were taken from the surface of the seabed and from approximately 20cm below the surface.

Why was it done

The study provides results of the chemical and biological monitoring of potential impacts from drilling operations around shallow well locations. Its objective was to determine the environmental impact of drilling operations that use SBMs and to determine how contamination and impacts change over time.

The results of this survey provided Apache with:

- information on the impacts of drilling with SBM in shallow water tropical environments on sediment quality and infauna assemblages in context with temporal patterns of change/recovery
- empirical data to validate environmental management of drilling muds to regulatory agencies.

Findings

A total of 41,056 organisms from 76 infaunal taxa were recorded during the 2008 survey from sediment sampling, taking the total number observed during the monitoring program to 111,668 organisms from 105 taxa. As in previous surveys, the most abundant taxa were polychaete worms. Other significant taxa observed included Nematodes, Gammarid Amphipods, Ostrocod crustaceans, unidentified threadlike polychaetes and polychaete worms.

There is some evidence that infauna community structures are returning to pre-disturbance patterns at Gibson/South Plato and Victoria. ANOSIM analyses using pooled data comparing these locations with control locations, excluding those sites which remain contaminated (the 20m along current sites at Gibson/South Plato and Victoria) and the 500m sites at Victoria (which displayed different community structures, based on other



factors), suggest that recovery is well underway. This suggests that in the absence of further drilling, these locations are likely to show full recovery (excluding the highly impacted 20m along current sites) by the time of the next survey in September 2011.

From the data it is clear that barium persists for longer in the sediments than hydrocarbons do. It has also indicated that horizontal migration of sediments, particularly the fine fraction from cuttings discharges, occurs at least to 100m along the current. In this study, elevated levels of both total recoverable hydrocarbon (TRH) and barium were found in samples taken from deeper in the sediments, indicating that vertical migration of contaminants is also occurring.

Implications for the industry

The ongoing study allowed an assessment of the effectiveness of the introduction of cuttings drying and centrifuging technology to Apache's drill rigs in 2005, which has resulted in less SBM coated cuttings being discharged to the seabed with a concomitant decrease in the localised hydrocarbon contamination around offshore well locations drilled with SBM.

These studies provide valuable information on the persistence of sediment contamination and recovery of infauna resulting from synthetic-based mud (SBM) discharged in shallow, tropical marine habitats.





6 BHP Billiton reports



6.1 Macedon Gas Development —air quality screening assessment

What was done

On behalf of BHP Billiton, a private consultancy firm was commissioned to conduct an air quality screening assessment as part of their proposal to build a gas processing and compression plant near Onslow, Western Australia. The plant, which will receive natural gas from the offshore Macedon gas field, will process and compress the gas for the delivery to the Dampier to Bunbury natural gas pipeline.

The air quality screening assessment was conducted for the client to identify potential impacts of the plant on the surrounding region and at specific sensitive receptor sites. The assessment considered the emissions of nitrogen oxides (NOx), nitrogen dioxide (NO₂) concentrations, potential ground level concentrations of carbon monoxide and VOC's (volatile organic carbons, concentrating on benzene and formaldehyde).

Ausplume (V 6.0), a Gaussian plume dispersion model developed by the Victorian EPA (where it is used as a regulatory model), was utilised to assess the potential emissions to air from the proposed plant. Emission rates were provided by BHP Billiton for processes involving six compression turbines and associated equipment. Using TAPM, a 3-dimensional prognostic model that predicts both meteorology and dispersion of air pollutants, including the chemical transformation involved in the production of ozone (EPA, 2004), metrological modelling was conducted to provide an Ausplume compatible metrological file for the site.

Why was it done

The air quality screening assessment was conducted to identify the potential impacts in the surrounding area of the proposed plant site, considering emissions of NO_x, CO and VOC's. It also helped predict the likely concentrations of pollutants to be experienced at ground level by local sensitive receptors. To ensure that predicted ground level concentrations are well below the acceptable criteria, dispersion modelling of emissions to atmosphere allows the prediction of indicative ground level concentrations.

Findings

Results of the dispersion modelling, from normal operation of the plant, indicated that the predicted ground level concentrations for NO₂, CO and VOC's (benzene and formaldehyde) within the model domain were well below the adopted assessment criteria. These results indicate that emissions from the BHP Billiton gas processing plant would be unlikely to impact on surrounding land use.

It must be noted that in the real world, emissions can be highly variable even when using identical equipment and fuel sources. Therefore, the results from any form of modelling can only provide an indicative order of magnitude prediction.

Implications for the industry

Whilst there are more complex models available, this study established that Ausplume has the advantage of many years of comparison against monitoring data. Major limitations of this model include not working well in complex terrains and in low wind conditions or where a coastal boundary layer is prevalent. Predictions of air quality concentrations can provide important information for potential future impacts and for conducting risk assessments for project related infrastructure and activities.

References

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6.2 Macedon Gas Development —fauna assessment at plant site and linear infrastructure corridor

What was done

BHP Billiton is proposing to construct a pipeline from the offshore Macedon gas field to transport gas to an onshore processing plant located to the southwest of Onslow. From there the pipeline will follow the gas plant infrastructure corridor to link with the Dampier to Bunbury Natural Gas Pipeline (DBNGP). An ecological consulting firm was commissioned to conduct an extended site inspection, with a focus on faunal assessments, along the proposed terrestrial pipeline route from the shore crossing to the DBNGP as part of the required environmental studies for the project.

The site lies within the Cape Range subregion of the Pilbara Bioregion, an area known for its high fauna biodiversity and endemism. The landscape and associated vegetation of the proposed site are typical of this region. The pipeline corridor passes through a range of habitats from the coastline to inland sites, with one major river crossing with distinct vegetation. The aims of the faunal assessment were to:

- review lists of fauna expected to occur on the study site in light of the fauna habitats present, with a particular focus on the likelihood of significant species being present
- identify significant or fragile fauna habitats within the study area
- recognise any ecological processes in the area upon which fauna may depend
- identify patterns of biodiversity within or adjacent to the study area
- identify potential impacts upon fauna and propose recommendations to minimise these impacts.

Why was it done

The purpose of the fauna assessment (both via desktop assessments and site inspections) was to identify a list of fauna species likely to occur within the project area and to determine if the assemblage of animals is likely to be unusual, with a particular focus on determining if there are any species of conservation significance present within the project area.

Findings

Site inspections and targeted surveys in combination with database and literature reviews provided an estimation of vertebrate species that could be present within the project site and surrounding areas. The assemblage identified potentially included 66 species of conservation significance occurring in the study area. Although there are ongoing studies, there was no available information regarding invertebrate fauna in the region in which the project area is located, and very little is known about short range endemic invertebrate species in the Pilbara generally.

Although some impacts upon fauna are unavoidable during a resource development project, of most concern are long term, deleterious impacts upon biodiversity, with a particular focus on habitats, significant species and ecological processes within the project area. So therefore, long term impacts of the proposed construction, rather than short term impacts were the main focus of this study.

The proposed development consists of a linear construction, with a narrow, largely temporary footprint, passing through widespread landscape lacking in unusual habitat features, and therefore the impacts are generally anticipated to be low. It was determined that the following impacts may need to be considered for management purposes:

- hydro-ecology — the pipeline route crosses minor and major watercourses and it is important that surface and sub-surface flows are not altered; this can adversely impact ecosystems both upstream and downstream
- mortality in trenches — trenches left open for days and not checked each morning can result in high rates of mortality or both rare and common species, which can attract feral predators. Appropriate management must be taken including limiting the amount of trench open at a given time and clearing any trapped fauna by mid-morning
- road kill — construction traffic can cause significant fauna to be vulnerable to road kill. Minimisation of night-time traffic and personnel education can reduce this risk
- loss of habitat effecting movement of gene flow — although the potential is low, if regeneration of vegetation over the pipeline and access tracks is slow, advice should be sought
- feral species — Foxes and feral cats abundance can increase as a result if the proposed activities. Educating personnel not to feed or unintentionally leave food out for these species will discourage these species to the area
- fire — fires should not be deliberately lit by personnel.
- light and noise — construction noise and light-spill should be avoided as much as practical.

As demonstrated by the gas pipeline that was constructed adjacent to the proposed route, post construction there should be little if any impact from a buried pipe, once revegetation occurs.

Implications for the industry

Fauna assessments using site inspections and targeted surveys in combination with database and literature reviews can provide important information for potential future impacts for project related infrastructure and activities. These studies provide additional information for both state and national faunal lists, and helps further describe the fauna taxa of the Pilbara area.



6.3 Macedon Gas Development—sea turtle survey

What was done

BHP Billiton is proposing to construct a pipeline from the offshore Macedon gas field to transport gas to an onshore processing plant located to the southwest of Onslow. From there the pipeline will follow the gas plant infrastructure corridor to link with the Dampier to Bunbury Natural Gas Pipeline (DBNGP).

A number of construction activities for the offshore component will be undertaken in the marine environment offshore in the area North West Cape and Onslow. These include a subsea development comprising production wells and subsea connections at the field and the installation of a wet gas pipeline and a well control umbilical between the field location and a shore crossing located adjacent to the existing Griffin Joint Venture (GJV) pipeline shore crossing.

A field survey was conducted in the vicinity of the proposed Macedon shore crossing location in January 2009. Morning low tides were selected to maximise the recordable beach area where any overnight turtle activity since the last high tide could be confirmed as having taken place. Information recorded included the date of survey, the geographical location of the start and finish of the transect, wind strength, a description of the beaches physical features above and below the high tide line, and the presence of turtle tracks and nesting pits. The information collected, used in conjunction with previous survey data collected during the environmental assessment phase of the project, will help assess the potential impacts of pipeline installation on sea turtle breeding and nesting.

Why was it done

It has been identified that the beach where the proposed shore crossing will occur supports a low/very low level of sea turtle breeding activity. Although BHP Billiton's preference is for construction of the shore crossing to occur outside of the core sea turtle breeding and nesting period, there lies a risk to sea turtles in the area should the time extend beyond this period. The location of the GJV pipeline was selected so to avoid known significant sea turtle nesting beaches, rocky shores and intertidal platforms, and subtidal features apparent on the regional habitat map, hence the grounds for the proposed location of the Macedon shore crossing.

Findings

No evidence of turtle tracks or nesting were found within the supra-tidal, intertidal and shallow marine zones during the two survey days. Throughout the investigation it was noted that the surface of the beach at the proposed shore crossing location was devoid of macro fauna and surface fauna during low tide with the only evidence of biological activity identified being crab diggings and mollusc trails.

These results were consistent with the previous surveys and observations which were conducted in the area. Combined with the previous surveys, the combined data indicate that at the most there is a very low level of turtle nesting activity in the proposed project area.

Implications for the industry

Fauna assessments such as these can provide important information on potential future impacts for project related infrastructure and activities. These studies provide additional data and confirmation to previous studies conducted in the area, and helps further describe the fauna taxa of the Pilbara area.



6.4 Whale population parameters near the Ravensworth Development Area (boat-based survey)

What was done

This boat based survey was intended to be used to provide detailed baseline whale population information prior to full scale development in the area. Thirteen 'experiment' and 13 'control' surveys were conducted between June and October 2004, in 10 day time blocks, although this was weather dependent. The surveys were boat based incorporating passing-mode line transects. Both the control and experimental surveys directly paralleled a path of transects flown during 2000–01 aerial surveys, to ensure comparisons between the two survey techniques were valid.

For each pod of whales identified, the data collected included sighting cue, pod composition, migratory direction, depth and behaviour. A record of other megafauna species sighted was also kept.

Why was it done

The study aimed to document humpback whale population parameters (migratory direction, preferred migratory depth, pod size and pod behaviour) in the immediate vicinity of the proposed Ravensworth oil field development well site.

Findings

The data collected in this study, combined with previous BHP data, and Woodside Energy survey data collected in the same year as this study, doubling the sample effort during the peak whale migration, increased the statistical power of any conclusions made regarding the movements of whale and other megafauna species throughout this region. Other species identified during the study period included dolphins, minke whales, Bottlenose whale, sunfish and manta rays.

Implications for the industry

The evaluation of successive annual datasheets against this detailed baseline information allowed accurate assessments of the impacts of the 2003–04 drilling operations. This study provided additional data to previous studies conducted in the area, and helps further describe the fauna taxa of the area.



6.5 Macedon Gas Development—subtidal marine ecology survey

What was done

BHP Billiton is proposing to construct a pipeline from the offshore Macedon gas field to transport gas to an onshore processing plant located to the southwest of Onslow. From there the pipeline will follow the gas plant infrastructure corridor to link with the Dampier to Bunbury Natural Gas Pipeline (DBNGP).

A number of construction activities for the offshore component will be undertaken in the marine environment offshore in the area North West Cape and Onslow. These include a subsea development comprising production wells and subsea connections at the field and the installation of a wet gas pipeline and a well control umbilical between the field location and a shore crossing located adjacent to the existing Griffin Joint Venture (GJV) pipeline shore crossing.

The preliminary pipeline routes were chosen by BHP Billiton to avoid the major physical features such as reefs and islands discernible on the navigational charts. This has the dual benefit of facilitating pipeline installation and also of protecting the sensitive habitats which are found on and around the identified features.

The survey consisted of a seafloor survey of the preliminary wet gas pipeline and umbilical routes to determine the present conditions and distribution of the shallow subtidal marine habitats that might be potentially impacted by the pipeline installation. Such adverse activities associated with the installation include trenching, jetting and/or rock covering.

Why was it done

The study aimed to describe the distribution and current condition of the marine habitats along the shallower (<30m) portion of the preliminary wet gas and umbilical routes. The data collected during these preliminary investigations will assist in optimising the pipeline routes, and subsequently during this assessment will assess the likely impacts of pipeline installation on the nearshore marine environment, focusing on sensitive marine habitats.

Key benthic primary producer which have been identified as being at potential risk from the installation are corals, macroalgae and seagrasses. The project area has been identified as containing regionally significant habitats as discovered from previous broad-scale habitat mapping of the region.

Findings

There were 47 transects studied during the survey period of four days in September 2008; surveys were conducted during a neap tide to maximise the potential for clear water conditions. Soft bottom communities were found to be present extensively along each of the proposed pipeline routes. The dominant substrate and benthic habitat type was sandy gravel. Marine macroalgae were present at most sites. As observed in previous studies, seagrasses were not observed at the majority of sites inspected. No reefs with high coral cover were encountered during the survey which was not unexpected given the effort made during the route selection to avoid these larger features.

The habitats and biota encountered during the course of the study are typical of those seen elsewhere on the Rowley Shelf with no areas of significantly high productivity recorded along the proposed pipeline routes. The predominant sand and sandy gravel habitat with its sparse cover of soft bottom communities is both widespread and of comparatively low productivity.

Implications for the industry

As this was considered an extension of previous studies conducted in the area, the collected data for this survey period has allowed the existing nearshore benthic habitat maps for the region to be extended and refined. As recorded previously during other studies in the area, the proposed project site consists of both widespread and low productive soft bottom communities with no significant habitats or biota encountered.



6.6 Seabed biodiversity survey at the Stybarrow 3, Harrison 1 and Crosby 2 locations

What was done

A marine fauna survey was conducted with the assistance of remotely operated underwater vehicles (ROV) at the Stybarrow 3, Harrison 1 and Crosby 2 locations—drilling locations off the Western Australian coast; survey time was allocated when the ROVs were not required for operations dedicated to drill support.

A baited video and digital stills camera was deployed by ROV at each of the locations and resultant snapshots of the dominant fauna were collected. Additionally, sediment samples were taken at two of the sites. Video transects of the seafloor were completed and the presence of organisms recorded. All transects were quantifiable in terms of percent cover of benthic organisms. The camera pods were deployed at least 50m from the drill station and left to take images every 5 minutes, with a maximum of 100 shots collected.

Why was it done

An opportunity to investigate some of northwestern Australia's deepwater slope animal communities was provided during BHP Billiton's recent drill program at the Stybarrow 3, Harrison 1 and Crosby 2 locations.

Findings

It was discovered that the Stybarrow 3, Harrison 1 and Crosby 2 locations supported a very low abundance of organisms that attach themselves to the seabed substrate. These seabed communities are typical of that expected at these depths and given the substrate composition.

The use of digital still cameras was able to capture detail of organisms present in the benthic community that would not be demonstrated with ROV surveys alone. Biota recorded in the surveys included crustaceans, deepwater fish and several types of invertebrates.

At each location the percent cover was very low at <1% live organisms. Significant findings included certain species behavioural patterns particularly in relation to their feeding behaviours and presence or absence of man-made structures and disturbance.

Implications for the industry

The use of ROVs, in combination with digital still cameras provides opportunities to study deepwater marine life, particularly around deep water drilling stations. This study helped further describe the marine fauna of the area.



6.7 Ursula coastline marine turtle habitat usage

What was done

The report collates the findings from three surveys of the mainland coastline at Urala station in January, March and December 2005. The surveys were carried out on behalf of BHP Petroleum. The three surveys documented evidence of turtle presence or absence using the tracks left by females crawling ashore to attempt to nest each night. Body pits, inferred nests and tracks left by hatchling fans were also used to identify nesting activity.

Aerial surveys were conducted in January 2005 covering the area from Coolgra Point to Tubridgi Point. Two observers conducted the track counts with one counting all visible tracks and the second counting only the tracks below the high tide line. The coastline around the Ursula Station homestead was inspected by vehicle in March and December 2005.

Why was it done

The surveys were conducted on behalf of BHP Petroleum to determine the amount of turtle activity on the mainland coastline at Urala station.

Findings

Over a 12-month period, the results of less than 2 weeks of surveys do not provide sufficient information to definitively describe the nesting dynamics of mainland populations. Therefore, putting the nesting effort along the Onslow coast into perspective is difficult in the absence of long term surveillance data.

The aerial survey results suggested there is substantially greater beach usage by nesting marine turtles on offshore islands than on the mainland beaches. Anecdotal evidence provided by the Cullen family at Urala Station indicated that turtle nesting was very high along their section of coastline in the mid 1990's, however few were observed from 2000–05. In the absence of systematic beach surveys by qualified biologist it is difficult to confirm these anecdotal reports.

Turtle tracks were recorded in four locations in the January 2005 survey, but no evidence of turtle nesting or hatching activities were recorded during the March and December 2005 surveys. It was concluded that due to the beach characteristics present along the surveyed coastline, that the most likely species to have nested on the Urala coast in the past is flatback turtles.

More recently, regional studies by marine biologists and ecologists have reported no evidence of turtle nesting activity (tracks or body pits) along the Urala coastline, suggesting this area is a marginal rookery supporting occasional very low nesting by flatback turtles.

Implications for the Industry

Although there is a lack of long term surveillance data on turtle nesting activity along the Urala Coastline, the current records suggest that turtle activity in the area surveyed only supports occasional very low nesting by flatback turtles.



6.8 Macedon Gas Development — intertidal marine ecology survey

What was done

BHP Billiton is proposing to construct a pipeline from the offshore Macedon gas field to transport gas to an onshore processing plant located to the southwest of Onslow, off the northwest coast of Western Australia. The intertidal component of the development will be the shore crossing for the wet gas pipeline and well control umbilical, which will be laid in a common trench.

The location of the proposed shore crossing was selected by BHP Billiton to take advantage of the known features of the previously constructed Griffin Joint Venture (GJV) shore crossing that lies adjacent to the proposed Macedon pipeline. Known features of the area include very low turtle nesting activity and a sandy beach with no mangrove fringe, combined with a disturbed seabed environment immediately offshore.

The field survey was conducted over two days in January 2009 on the morning low tide during a spring tide phase. This time of year was selected to maximise both the area of the intertidal zone being inspected and the area where any mobile faunal activity on the beach over the period of the last six to seven hours could be detected.

The data collected was used to describe and assess the impact of the pipeline installation on the intertidal environment, estimated to be approximately 2–3 months for this segment of the pipeline and umbilical construction period. This installation of the wet gas pipeline and umbilical will be the only project activity undertaken in the intertidal zone.

Why was it done

The survey was undertaken to describe the distribution and present condition of the intertidal habitats at the proposed shore crossing that might potentially be impacted by pipeline installation activities, including trenching, pipe-pull, sediment replacement and rock stabilisation.

Findings

The total length of beach covered on each survey day was 4 kilometres. The surface of the beach which the shore crossing is centrally located is devoid of attached living macro flora. Likewise fauna were also absent from the surface on the low tide with crab diggings and mollusc trails providing the only visible evidence of biological activity.

As expected from previous studies conducted in the area, seagrasses and macroalgae were not observed in the intertidal zone along the safety beach with the dominant fauna being mobile crabs and molluscs. The habitats and biota identified during the course of the survey are typical of high energy sandy beaches seen elsewhere on the mainland and island shorelines of North West Shelf. No areas of significantly high productivity were encountered.

There is no visible presence of the GJV pipeline through the intertidal zone which is completely covered in sand and the sandy beach has an uninterrupted profile across the pipeline. Likewise, the pipeline cannot be detected in the shallow water immediately offshore. The pipeline route can be detected through the landward parts of the dune system, only by the change of vegetation which resulted from the installation of sand trapping fences designed to aid rehabilitation of the vegetation along the pipeline route.

Implications for the industry

The example of the adjacently constructed GJV pipeline shows that rehabilitation of the shore crossing can be expected, with no ongoing impact on shore processes or intertidal flora and fauna. Rehabilitation of vegetation on the landward parts of the pipeline route is expected to occur with the installation of sand trapping fences.



6.9 Macedon Gas Development— flora and vegetation survey

What was done

The Macedon Gas Development is a gas pipeline project with a small onshore gas treatment facility, designed to commercialise previously undeveloped gas reserves in the offshore Macedon gas reserves in the offshore Macedon gas fields. The field is located off the northwest coast of Western Australia at a water depth of approximately 150m. The wet gas pipeline will take raw gas from the subsea manifold to shore, where it will be transported to the onshore plant for gas processing. Approximately 158 hectares will be cleared for the gas processing plant site, construction camp and internal roads.

A private consultancy firm conducted an assessment of flora and vegetation within the project area for the Macedon Development. In total, approximately 1200 hectares on land was surveyed. Phase 1 comprised a desktop study and dry season survey. Phase 2 comprised a wet season survey and the final report.

Surveys were conducted during three field trips, with botanist traversing the area by car and by foot. Areas known to be of high species richness and of special interest were surveyed in more detail. Each vegetation type was described in the field by assessing the dominant species in each stratum. A species list with all terrestrial flora encountered during the survey was compiled.

Why was it done

The information collected was used to identify the local and regional conservation significance of the habitat within the project area, identifying the potential impacts of the project and make recommendations regarding further studies and management requirements.

Findings

Most of the vegetation types recorded were typical for the region. In total, 39 vegetation sub-formations/associations were identified within the area surveyed. A total of 310 vascular plants representing 47 families and 125 genera were recorded within the project area. No flora species which have been declared as Rare Flora, pursuant to Subsection 2 of Section 23F of the *Western Australian Wildlife Conservation Act 1950* were located in the project area and no Priority Species were recorded.

Two species of flora of special interest were recorded as were ten introduced weed species. No threatened ecological communities were recorded in the project area, although a relict limestone dune at the proposed plant site was the only example of this kind of habitat in the project area and may warrant protection and further investigation will be necessary. Efforts should be made to minimise disturbance to sensitive habitats in the project area as the proposal goes ahead.

Implications for the industry

Flora assessments such as these can provide important information on potential future impacts for project related infrastructure and activities. These studies provide additional data and confirmation to previous studies conducted in the area, and helps further describe the flora of the project area.



6.10 Macedon Gas Development—surface water assessment

What was done

Located approximately 16km southwest of Onslow in the Pilbara region of Western Australia, the Macedon Gas Development is a pipeline and onshore processing plant that BHP Billiton is proposing to construct. The development comprising a processing plant will be situated in Ashburton North and will be connected via an access road from the existing Onslow Road. A private consultancy has undertaken a desk-top flood study to assess the potential impact of the development on the existing surface water regime.

In order to measure the impact of the development on the project site surface water regime, flood modelling was used to simulate the existing surface water environment during high magnitude rainfall events. A scenario representing the project site in its proposed developed state during the same rainfall events was generated to create a comparison.

The most significant impact predicted on the surface water environment of the project site, due to its nature and location, is the potential obstruction of flood flows during high flow events. In order to analyse the flooding characteristics of the project site, several sets of data were collected including rainfall records, stream flow gauged data and topographic data.

Why was it done

The aim of the assessment, with the use of modelling simulations, was to determine the impact of the development on surface water flow regimes at the onshore project site, in both its undeveloped and proposed developed state. The location and topography of the site indicates it may be regularly prone to inundation. The largest impact predicted at the site is the obstruction of the flow of flood waters during high flow events.

The purpose of the initial assessment using hydraulic modelling was to evaluate the flooding characteristics of the project site in its existing state, prior to the commencement of the Macedon Development. The hydraulic model was then used to simulate the development of the processing plant footprint and access road in order to determine their combined potential effects on local flooding characteristics.

Findings

Construction of the project will require alterations to the existing topography and development within the floodplain of the Ashburton River delta, which in turn may impact the surface water flow regime and surface water quality within the project site. Loss of floodplain storage, changes to rainfall runoff rates, impedance of surface flow, impacts on surface water quality and potential operational impacts have also been identified as potential impacts.

To mitigate the surface water impacts and risks identified in the report, water management measures have been identified to manage stormwater and flood risk in addition to potential surface water quality impacts. These include:

- the design of the access road may allow controlled overtopping of flood waters in high-magnitude events
- plant pad may be elevated above certain flood levels, protecting it from inundation during certain major rainfall events
- the plant pad could be designed to prevent damage caused by flood waters and waves during high flow events
- baseline and continuous monitoring of the site should be conducted to detect any changes in sediment loads and pollutant loads in surface water downstream of the project site
- a management plan should be formulated for the access road; this should include regular culvert inspections and maintenance.

Implications for the industry

Predictions of inundation impacts using hydraulic modelling can provide important information for future mitigation and for conducting risk assessments for project related infrastructure and activities. In this instance it has allowed for water management measures to be identified to manage stormwater and flood risk in addition to potential surface water quality impacts.



6.11 Macedon Gas Development—acoustic assessment

What was done

A preliminary assessment was undertaken to assess the likely noise impact of the proposed BHP Billiton Macedon Gas Development, to be located approximately 17 km southwest of the town of Onslow, Western Australia. The report provides an assessment based on acoustic data provided with regards to compliance with the *Western Australian Environmental Protection (Noise) Regulations 1997 Regulations*.

Modelling was carried out using SoundPlan 7.0. Individual calculations were carried out for both the plant and the flare, however additional assessments were undertaken for the flare during an emergency blowdown.

The input for the computer modelling included:

- source sound power levels
- ground topography
- atmospheric conditions.

Why was it done

It is a requirement that noise from the site be free of annoying characteristics (tonality, modulation and impulsiveness) at other premises. The *Environmental Protection (Noise) Regulations 1997* specifies the allowable noise levels that can be received at premises from other premises. Residential, commercial, industrial and recreational premises all have different measured allowable noise levels.

Findings

The results demonstrated that noise received at the surrounding receptors for normal operations would comply with the criteria and would be deemed to comply with the *Environmental Protection (Noise) Regulations 1997*. Noise emissions from an emergency blowdown also comply with the designated criteria and the requirements of the *Environmental Protection (Noise) Regulations 1997*.

Implications for the industry

Predictions of noise impacts using computer modelling can provide important information for future mitigation and for conducting risk assessments for project related infrastructure and activities. In this instance it will allow for noise management measures to be identified and to manage noise risks and impacts in the surrounding areas.

6.12 Macedon Gas Development— assessment of drilling fluid, drill cuttings and hydrotest fluid discharges from the Macedon Gas Field

What was done

BHP Billiton is proposing the construction of the Macedon gas field located off the northwest coast of Western Australia. Four production wells will be constructed, occurring in water depths of 120–180m. As part of the construction and commission phase there will be discrete discharges of drill cuttings and drilling fluid during the drilling of the production wells, and of hydrotest fluid during the commissioning of the wet gas/ export pipelines.

The dispersion rates of these discrete discharges were modelled by a private consultancy. The modelled discharges have been assessed in terms of their potential impact on the local marine environment and of the bordering Ningaloo Marine Park and Muiron Islands Marine Management Area.

The four proposed gas production wells will be drilled using seawater-based drilling fluid; oil-based or synthetic drill fluids will not be used. Each well will be drilled in two contiguous phases.

Why was it done

The purpose of the report is to describe the assessment of the potential impacts on the local environment of the discharge locations and the Ningaloo Marine Park occurring from the discharge of drilling fluid, drill cuttings and hydrotest fluid at the Macedon gas field.

Findings

Conservative discharge scenario modelling shows that the proposed discharges of drilling fluid, drill cuttings and hydrotest fluid from the four production wells, will be effectively dispersed within the lease area. Any short term impact that may occur will be confined to the immediate vicinity of the discharge point / well location and will not impact on either the Ningaloo Marine Park or Muiron Islands Marine Management Area located adjacent to the proposed site.

Implications for the industry

Predictions of dispersion using computer modelling can provide important information for mitigation and for conducting risk assessments for project related infrastructure and activities, particularly in areas of high conservation significance such as the adjacent Ningaloo Marine Park and Muiron Islands Marine Management Area.

6.13 Water quality monitoring and marine noise monitoring survey

What was done

Modern offshore developments such as Stybarrow Floating, Production, Storage and Offloading vessels (FPSO) and oil rigs have the potential to emit noise and vibrations into the surrounding aerial and marine environments during both the construction and operational phases.

It has been discovered that underwater acoustic noise can impact the marine fauna in the area by causing masking of communication, temporary or permanent threshold hearing loss of various marine species including fish, dolphins and whales, and adaptations in their behaviour and distribution. However, little research has been conducted into the direct impacts of FPSO noise in the marine environment.

Marine acoustic measurements were conducted over three days in November 2008 within the Stybarrow development area. The facility consists of five production wells, two gas lifts, one gas injector and two water injection wells. The objective was to record the level of noise propagated underwater by the FPSO facility during routine operations as part of long term monitoring of the effect of noise on the marine fauna in the area. Recordings using an acoustic profile recording system (APReS) were taken at a total of 32 locations within a 20km grid around the Stybarrow FPSO facility.

The main concerns arising from the FPSO operational noise include attraction of marine animals to the site, increased stress levels, disruption to underwater acoustic cues behaviour changes and localised avoidance. More research will have to be undertaken in this area to establish the actual impacts of the underwater noise produced by the FPSO.

Why was it done

The aim of the survey was to monitor water quality and marine noise around the Stybarrow FPSO. The Stybarrow facility, located 65km northeast of Exmouth, Western Australia, consisting of several drilling and production wells, lies in an area with a water depth of approximately 825m.

The area is considered to have low productivity due to the predominately warm tropical waters with low salinity and nutrient content. Regardless of the low overall productivity of the north Western Australian region, the area supports a high biodiversity of tropical marine species, with 149 species listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* within the northwest region of Australia.

Findings

The levels of noise produced by the normal operations of the FPSO when compared to the noise emitted from other shipping traffic were found to be approximately similar. At the minimum source levels, the FPSO produced noise less than a fast moving tanker, however during maximum noise production the Stybarrow FPSO produces sounds typical of a 25m tug vessel or just louder than a cargo ship.

Comparisons with other industrial activities including piling and seismic activity have found that the source levels recorded at the Stybarrow FPSO to be substantially lower, however it's important to note that both these activities are pulsed sounds and short lived compared to the continuous noise coming from operational FPSOs.

Implications for the industry

Marine acoustic measurements can provide important information for mitigation and for conducting risk assessments for project related infrastructure and activities, particularly in areas of high conservation significance. As there has been little research into the direct impacts of FPSO noise on the marine environment, this study is contributing towards the knowledge of this complex area.





6.14 Measured underwater noise from the Griffin Venture FPSO and modelled noise from the proposed Pyrenees and nearby FPSOs off Northwest Cape

What was done

In March 2005 Curtin University carried out underwater noise measurement of the Griffin Venture, a Floating Production Storage Offloading vessel (FPSO) used for the on-site processing of oil and gas at Exmouth Cape, Western Australia. The noise the Griffin Venture generated was reduced to source levels and used to model noise fields for the then proposed Pyrenees, Enfield, Vincent and Stybarrow FPSO vessels. There was the potential for five FPSO's to be operating in waters through the northwest to northeast of Exmouth Cape.

The report focused on the noise field of the Pyrenees site. Given the potential for numerous FPSO's to be located in close proximity, plus the existing Griffin Venture, all proposed and existing FPSOs were included to model the investigative cumulative noise impacts. The FPSO's proposed to be constructed for the Pyrenees, Stybarrow and Vincent fields; along with the Griffin Venture (the FPSO for the Enfield location) will all process gas and condensates (or oil).

Methods involved field measurements of underwater noise from the gas powered FPSO Griffin Venture using the Griffin Venture source levels to model the noise field about each proposed FPSO location. Noise measurements were carried out in March 2005 by drifting hydrophones.

Why was it done

The noise fields and the predicted exposures for marine animals moving through these regions were used to assess potential environmental impacts from the proposed FPSO's on marine fauna, with a particular focus on transiting great whales.

Findings

The rig-tender vessel that maintains a bulk carrier in line position with the FPSO was the event that produced the highest noise. These intense periods of noise produced during these offloading periods may typically occur over several hour periods. Individual FPSO offloading schedules will vary according to how quickly they fill their holding tanks.

The potential environmental effects of the FPSO to marine animals are:

- attraction to the source
- avoidance from the source at some range
- masking of whale signals
- possible increase in noise induced stress for animals which linger in the area.

Previous studies have shown that the most vigorous whale responses came from noise sources that changed suddenly, rapidly increased (such as an approaching vessel) or were unexpected. The noise produced by the FPSOs, rig tenders and ships are predicted to be reasonably constant in nature, namely there would normally be few sharp changes in noise level with time.

Therefore it is probable that under normal operating and offloading activities nearby megafauna will be aware of the FPSO operations / facility from a distance of 4–6 km and may approach it to approximately 1km. Given the continual and constant nature of the noise generated by individual FPSOs, it is probable that animals will in time habituate and the noise will not produce any startle or alarm type of responses.

Implications for the industry

Marine acoustic measurements can provide important information for mitigation and for conducting risk assessments for project related infrastructure and activities, particularly in areas where marine fauna are known to present. As there has been little research into the direct impacts of FPSO noise on marine fauna, particularly whale species, this study is contributing towards the knowledge of this complex area.



6.15 Macedon Gas Development – assessment of groundwater source options

What was done

A desktop study of available literature on water resources in the Ashburton River Basin was conducted for the construction phase of the proposed Macedon Gas Development project. The project, located approximately 50km north of Exmouth in the Pilbara region of Western Australia involves the development of a domestic gas plant and access road from the existing Onslow Road. The project site is located within the Northern Carnarvon Basin, a large, mainly offshore basin.

The Pilbara coast can be described as arid-tropical; it is an area of extremes with severe drought and major floods occurring at close intervals. The average annual rainfall ranges from 230 to 350mm and mainly occurs during the months of January through to April.

Why was it done

For the construction work, water will be needed for dust suppression and road building. The water supply has been estimated for both the construction and operational phases of the project, however there is uncertainty in the water supply demands estimates; actual demand may vary considerably from the original estimation. A sustainable water supply for both the construction phase and for the life of the project needs to be established for without environmental impacts on the watertable. Both surface water and groundwater sources were investigated.

Findings

The potential surface water sources that were identified and that could be developed for the Macedon Project water supplies include: divertible stream flow and seawater.

The known groundwater resources were comparatively ranked to identify the preferred option. The ranking assessment considered several key elements of the groundwater sources in the context of potential development, including:

- security of supply (sustainable yields)
- production bore numbers and depths
- potential environmental impacts of groundwater abstraction
- access
- groundwater quality
- treatment requirements
- estimated cost of development.

Based on the results it was evident that the Birdsong sandstone aquifer, a groundwater source, was a strong viable option. To demonstrate this source viability site investigations will be necessary, however even if the volume of water required was to double, the aquifer would still have sufficient supply. It is known that the groundwater in the area predominately has comparatively high salt content; therefore sourced water would need to be treated to obtain fresh / potable water. Seawater was also identified as being an option; this source would need to be piped to the site and also treated to obtain potable water quality.

The next stage of the study would be to further investigate the two preferred water options with more definitive studies concerning including feasibility and environmental impact assessment. Consultations with the Department of Water about specific requirements for license applications will support a sustainable water management throughout the stages of the project.

Implications for the Industry

This type of study will broaden the understandings of water resources, geology and hydrogeology of the Pilbara region of Western Australia. This type of study can provide important information for mitigation and for conducting risk assessments for project related infrastructure and activities, particularly in areas of meteorological extremes such as the project area.



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