MARINE TURTLE CONSERVATION AND GORGON GAS DEVELOPMENT, BARROW ISLAND, WESTERN AUSTRALIA

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REPORT

TO

ENVIRONMENTAL PROTECTION AUTHORITY, WESTERN AUSTRALIA
&
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT, WESTERN AUSTRALIA

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1. Introduction

This report is in response to a request from the Environmental Protection Authority and Department of Conservation and Land Management, Western Australian on 9 May 2006 to provide advice on:

- Likely impacts on marine turtle populations of the Gorgon proposal to construct and operate a liquefied natural gas processing and export facility on Barrow Island.
- Action to protect the flatback turtle population in the future, and
- Action for future monitoring of these turtle populations.

2. Summary of turtle biology relevant to the Gorgon Proposal

2.1. Turtle species

Barrow Island supports internationally significant nesting populations for two species of threatened species of marine turtles (green turtle, *Chelonia mydas*, and flatback turtle, *Natator depressus*), and minor nesting by a third (hawksbill turtle, *Eretmochelys imbricata*). The biology of these species has been reviewed recently for Western Australia (Limpus, 2002) and for Australia (Limpus, in press a,b,c,d)

The marine turtle populations that aggregate for breeding in Western Australia (WA) are all genetically discrete from other populations of the respective species that breed in other Australian states and neighbouring countries (Broderick et al. 1994; Dutton et al. 2002; Moritz et al. 2002). The biological consequences of this are:

- For each species, groups of rookeries on adjacent islands and mainland beaches form the interbreeding population of the stock for each species within WA.
- Because of temperature dependent sex determination, it can be expected that beaches with different temperature profiles will produce hatchlings with different sex ratios. Complementary rookeries producing both male and female hatchlings are critical for the viability of each population.
- The large breeding groups (major rookeries) have the greatest potential for providing the large-scale hatchling recruitment necessary for maintenance of population viability for large stocks of each species in WA.
- If any stock of WA turtles is seriously depleted or lost, turtles of the same species from outside of WA will not recruit to replace the WA nesting turtles within human management time frames. Such replacement can only be expected over a timeframe of thousands of years.

Flatback turtles: The nesting population on the eastern beaches of Barrow Island is a major part of the Pilbara Coast genetic stock management unit. (Dutton et al. 2002). This summer breeding Pilbara Coast (Northwest Shelf) stock effectively will not interbreed with the neighbouring winter (mid year) breeding flatback stock that aggregates to breed in western Arnhem Land and Bonepart Gulf (Limpus, in press d).

The Pilbara Coast nesting population could account for 30% or more of the total breeding population for this species that is endemic to the Australian continental shelf (Limpus, 2002, 2004). Although the size of the annual nesting population has been incompletely quantified, the sampled nesting is consistent with 500 to 1000 flatback turtles nesting annually on Barrow Island (ERMP TAC6 Attachment 1; K. Pendoley, pers. comm. May 2006). This Barrow Island population is not only significant for Western Australia, it is one of the few documented large nesting aggregation for the species. This makes it an internationally significant rookery for the species. In order of magnitude, about 70% (~500 females annually) of Barrow Island flatback turtle nesting occurs on the mid east coast beaches (Mushroom, Tank, Terminal, Bivalve, Inga and Yacht Club Beaches. ERMP TAC7 Appendix 1). These beaches lie immediately to the north and south of Town Point where most of the infrastructure for the Gorgon Project will be located (ERMP Ch08).

Green turtle: The very large nesting population on the western beaches of Barrow Island is a major part of the Northwest Shelf genetic stock (management unit) (Moritz et al. 2002). This Northwest Shelf genetic stock is internationally significant, being one of the few remaining very large green turtle breeding populations remaining globally (Hirth, 1997; IUCN, 2004). North White's Beach, the beach identified for the Barrow Island shore crossing of the feed gas pipeline on the western side of the island supports only a trivial amount of nesting (ERMP TAC7 Attachment 1).

Both these Western Australia turtle stocks have been, and continue to be subjected to a range of negative impacts from human activities within their nesting, migratory and foraging ranges that give concern for the long term viability of each species as a whole in WA (Limpus, 2002). Any reduction in population dynamics performance for these species at Barrow Island resulting from the Gorgon Development will further reduce the long term survival prospects for these species in WA. Similarly any enhancement of population performance that can be achieved through this Gorgon Development will increase their survival prospects.

2.2. Marine turtle sensory ability

Marine turtles have an acute sense of **smell** that depends on water being drawn into the mouth and flushed out through the nostrils rather than water being inhaled via the nostrils. They appear to have no sense of **taste** (Manton et al. 1972). Their **vision** is good with them seeing a similar visible spectrum to the human eye as well as seeing in the ultraviolet range. Their eyes may not form as clear an image when out of water. Their **hearing** is limited because they do not have external ears but they can hear low frequency sounds (vibrations) outside the range of the human ear. They do not hear the frequencies that can be heard by the human ear.

Marine turtles can detect **magnetic fields**. Hatchlings are imprinted to the earth's magnetic field in the region of their birth while older turtles appear to be imprinted to other locations including foraging area(s) and courtship areas (Lohmann and Lohmann, 1994,1996). Using a mental "map" and the earth's magnetic field, marine turtles are able to repeatedly travel to the same locations along approximately direct migratory pathways between the feeding, courtship and nesting areas. At a local scale, other cues may also be used to assist in navigation between resting, foraging and basking areas (Avens and Lohmann, 2003).

2.3. Habitats

Barrow Island and adjacent marine areas provides essential habitat for a wide range of the life history stages for marine turtles, including courtship areas, internesting habitat, nesting beaches and foraging habitats. Barrow Island provides terrestrial habitat for breeding turtles including their eggs and hatchlings. The adjacent marine habitats provide courtship and internesting habitat for breeding turtles and pelagic and benthic foraging habitat for non-breeding turtles.

Courtship area(s): a tidal or sub-tidal marine area where courtship between the migrating adult males and females occurs.

Mating turtles do not feed or only feed to a limited extent. Courting turtles may also bask by day or night on beaches. This occurs extensively with green turtles on Barrow Island’s western beaches (Limpus, 2002, in press b). This should not be confused with low tide stranding of females as they return to sea from the nesting beach (ERMP TAC7).

The courtship habitat used by flatback turtles that breed on Barrow Island has not been identified. There is no evidence that flatback turtles come ashore to bask at any phase of their life history. It is presumed that most flatback courtship will occur in deeper coastal waters not necessarily adjacent to the nesting beach.

Internesting habitat: the marine habitat occupied by breeding adult females while they ovulate and prepare eggs for laying.

This habitat will occur offshore but at variable distances from the nesting beaches, depending on the species and coastal topography. Females, as they prepare for the next laying event, return repeatedly to the internesting habitat following the laying of each clutch of eggs. Preparation of a clutch for laying takes about two weeks. Therefore a green turtle laying an average of 5 clutches for the season will spend about 10 weeks in the internesting habitat. A flatback turtle that averages 3 clutches of eggs per season will spend about 6 weeks in the internesting habitat. Turtles in the internesting habitat do not feed or only feed to a limited extent while they are producing eggs. They live off stored fat reserves at these times.

Results of recent satellite telemetry of four internesting flatback turtles from the mid eastern beaches of Barrow Island have yet to be fully analysed. However, preliminary assessment (K. Pendoley, pers. comm.) indicates that:

- These females spent most of their internesting periods well offshore and outside the area likely to be impacted by dredging.
- Each female remained within the immediate inshore area of her nesting beach for a few days immediately following each nesting event.

Each nesting turtle will transit through the immediate inshore area as they approach and leave the beaches. With approximately 500 nesting females nesting on these beaches and each, on average, laying three clutches per season, these nesting turtles should spend from 1,500 to 4,500 “turtle-days” within the vicinity of the dredging operations during the course of a nesting season. This should approximate to a daily presence of 35-75 internesting females swimming in the vicinity of the dredging operations during the breeding season.

Green turtle internesting habitat for Barrow Island is expected to be spread throughout inshore waters in less than 18m depth along the entire northwestern and northern coast (ERMP TAC7).

Nesting beach(s): the terrestrial habitat where adult females come ashore to lay eggs above the high tide level.

The adult female does not necessarily return to breed at the beach of her birth but can be expected to breed within its general region (Limpus, unpublished data). She chooses her nesting beach while she is within the internesting habitat and travels to the beach when she is ready to lay a clutch of eggs. Nesting mostly occurs at night. Having chosen a nesting beach, the nesting female can be expected to return for repeated nesting to the same beach both within a breeding season and across successive breeding seasons, unless there are disturbance factors which may cause her to change nesting beaches. Long-lived individuals can be expected to breed for more than ten seasons spanning about 30 years of breeding life (EPA Turtle Research database). Because of this behaviour, we can hypothesise that the choice of nesting beach made by the female as she commences her breeding life will influence her choice of nesting beaches in subsequent breeding seasons. The adult female responds to light horizons when choosing her nesting beach (Salmon, 2003) and when returning to the sea from the beach.

Eggs incubate in the beach sands without parental care to produce hatchlings that dig their way unaided to the beach surface. Incubation period, incubation success and hatchling sex ratio are a function of beach sand temperatures within the nest. Incubation success / hatchling production depends on egg survival which is strongly influenced by beach stability. Erosion and flooding by rising water tables cause death of eggs. Hatchlings do not use the beach or immediately adjacent waters for feeding or resting. Hatchlings are imprinted to the earth’s magnetic field as they leave the nest and are probably imprinted to the smell of the first water that they contact. They orient towards light horizons at low angles of elevation to find their way to the sea and swim perpendicular to wave fronts as they disperse from the beach.

The pivotal temperature for each of the turtle stocks, the temperature profiles for the WA nesting beaches, and the sex ratio of hatchlings produced at the major nesting beaches have yet to be recorded or published. These data are unknown at this time.

Offshore currents for pelagic dispersal of post-hatchlings: After an initial swimming frenzy which takes the hatchlings some 10s of kilometres offshore, they change behaviour to commence feeding as they drift in pelagic waters.

While green turtles are dispersed by currents into oceanic pelagic waters, flatback post-hatchlings remain in neritic (near shore) pelagic waters.

Foraging habitat for non breeding turtles: The marine habitats surrounding Barrow Island support year-round foraging populations of marine turtles (Prince, 2001).

The coral reef, rocky reef, algal turfs and seagrass beds adjacent to Barrow Islands (ERMP Ch.8) will support foraging green turtles. The dense beds of seapens off the east coast of Barrow Island (ERMP, TA C8) will support foraging flatback turtles. Hawksbill turtles will be foraging on selected algae, sponges, soft corals and other invertebrates on the coral and rocky reefs. Loggerhead turtles will be foraging primarily on molluscs and crabs across a wide range of hard and soft-bottomed habitats. For each species, the population can be expected to include the full size range of turtles from young immature turtles recently recruited from the pelagic post-hatchling life history phase to large adults. For each species, these foraging turtles may be a mix of genetic stocks and should include representatives from all stocks with breeding areas within ~2000km of the foraging area. While some of the foraging turtles may be part of the Barrow Island breeding population, most will not. However, for each species, the vast majority will be part of the same genetic stock as breeds on Barrow and nearby islands.

3. Hazards to marine turtle survivorship and successful population dynamics associated with the Gorgon Project at Barrow Island

3.1. Photopollution

In 1985, Verheijen introduced the term “Photopollution” which he defined as “degradation of the photic habitat by artificial light”. Modern society’s modification of light horizons at turtle nesting beaches through the use of night lighting and other artificial light sources creates a habitat that “repels female [turtle]s from nesting beaches and causes the death of many of their hatchlings” (Salmon, 2003).

The disorientation behaviour of adult and hatchling marine turtles in response to altered light horizons is similar for all species (Limpus, 1971; Limpus and Reed, 1985; Limpus et al. 2003; Lohmann et al. 1997; Salmon, 2005; ERMP TAC7 Attachment 2). Limpus (2002) and Salmon (2003) describe the avoidance of nesting beaches with bright light horizons by nesting females and associated population declines. On the Woongarra Coast in eastern Australia, there has been a progressive decline in loggerhead turtle nesting on Kellys Beach (The 2nd best nesting beach in the district prior to the mid 1970s.) that has paralleled the proliferation of street, housing and motel lighting illuminating the horizon of the nesting beach since the 1970s (Queensland EPA Turtle database; C. Limpus, unpublished observations). Some 30yr later, Kellys Beach now supports a trivial level of nesting with none occurring on most nights of the nesting season. Paralleling this decline at Kellys Beach there has been an increase in nesting at Oaks Beach about 10km to the north within the remaining “dark horizon” coastline. However, Oaks Beach is not a suitable incubator for turtle eggs, having the poorest nesting success for all beaches in the district and being one of the most erosion prone beaches in the district with associated higher risk of erosion of nests during storms.

Individual lights as point sources can disorient hatchlings turtles in close proximity (up to hundreds of metres). The scale of the impact zone being a function of type of light and light intensity (ERMP TAC7 Attachment 3). However, the diffuse glow of many lights of a township or large industrial facility shining at and reflected into the night sky can cause the disorientation of hatchlings on beaches up to 4.8km from the light sources (C. Limpus, unpublished observation at US Virgin Islands). Similarly, the diffuse glow over modestly illuminated tourist resort buildings behind a forested dune margin attracted hatchlings from up to 0.5km out to sea back onto the beach (C. Limpus, unpublished observation at Heron Island). Vessels with deck lights on and at anchor off turtle nesting beaches in the Great Barrier Reef in the absence of a moon at night attract and trap hatchling turtles dispersing from the beaches (C. Limpus, unpublished observations). Predatory fish, dolphins and birds such as silver gulls will target the trapped hatchlings swimming in the light pool around a vessel. Any impact that increases the time that hatchling turtles spend in crossing through the shallow waters off the nesting beach can be expected to increase hatchling mortality because of the associated increased fish and bird predation on these turtles (Gyuris, 1994).

The Gorgon Project infrastructure including the gas processing facility (GPF), flare system, materials offloading facility (MOF), administration and maintenance facilities, roads, airport, construction village (including recreational facilities) associated with Town Point and other locations close to the east coast have the potential to drastically alter the light horizons behind and over the most important flatback turtle nesting beaches in Western Australia. The MOF, LNG jetty and associated navigation lighting have the potential to extend these altered light horizons for some 4.4km out to sea from Town Point. The LNG jetty extends diagonally across the approaches to the beach to the south of Town Point.

Maintenance of dark horizons behind and over the nesting beaches should be a primary strategy when planning for the long term survival of significant marine turtle populations. However, the ERMP (sections 6.2, 7.3) make it clear that the total Gorgon facility on shore and on the causeway and LNG jetty will not be dark and hence will not maintain the natural dark horizon that is part of the key parameters that cues turtles to nest on these beaches (Salmon, 2003).

While there will be more extensive night use of lighting during construction, there also will be extensive continuing use of night lighting during the 60+ years (approaching two generations for flatback turtles) of operational phase in addition to intermittent light from the flare(s), vehicle traffic on the causeway and jetty and from ship loading operations (x3 24hr periods per week) plus other shipping. The ERMP (Section 7.3) identifies a number of useful tactics for reducing light intensity and light spillage, including use of long wavelength lighting, shaded lights, reduced height bollards, facing lights away from beach, reducing lighting on reflective surfaces, ground-based flares, motion detector switching and maximising daylight hours where “lighting” is essential. While the ERMP implies dramatic reductions in lighting effects over a conventional lighting regime, it gives no assurance that the achieved reduction will keep changes to the light horizons at a level that is not disruptive to nesting turtles and a level that does not increase hatchling mortality.

The starting premise regarding the fate of the Barrow Island mid east coast flatback nesting population if this facility is constructed as currently proposed is that the shift away from a dark horizon behind and over the nesting beaches will have two significant negative impacts on population dynamics:

- The size of the nesting population on these beaches will decline substantially over the next few decades. It is presumed that this will be primarily the result of 1st time breeding females choosing to nest at darker beaches further along the coast and that conditions associated with these other beaches outside the currently preferred nesting sites will be less suitable for production/appropriate dispersal of vigorous healthy hatchlings of the appropriate sex ratio.
- During periods when the moon is not above the horizon and during overcast periods, there will be increased incidence of hatchling disorientation. This will lead to increased mortality of hatchlings through increased predation while on the beach and their being lost inland. Increased time spent crawling on the beach results in less active hatchlings with reduced stored fat reserves reaching the water. This will result in slower swimming hatchlings crossing inshore waters with increased risk of predation and a reduction in how far the hatchlings can swim out to sea before the swimming frenzy ceases.

Hatchlings swimming from the beach will swim approximately perpendicular to the beach but they also will move laterally under the influence of the long-shore tidal currents (ERMP AIP). These lateral currents will transport a portion of the nightly hatchling production from an extended area of adjacent beaches past the LNG jetty and moored vessels. This will enhance the likelihood of hatchlings being trapped within brightly illuminated areas adjacent to the jetty and moored vessels. This will further increase hatchling mortality.

While it has not been tested, it is highly likely that the convergence of tidal currents that occurs off Town Point with the associated off shore current may provide an important mechanism in efficient dispersal of hatchlings from these beaches. The causeway, MOF and LNG Jetty is being constructed within this potentially critical convergence zone.

3.2. Low frequency sound, vibrations and movement

Marine turtles hear low frequency sounds/vibrations. This aspect of their biology has been little studied. Preliminary studies at Barrow Island indicate that hatchlings will respond to some sounds/vibrations and move towards a small generator (ERMP TAC7 Attachment 2). Within the Great Barrier Reef, we have observed green turtles shifting their nesting distribution away from a vessel with no deck lights but generator running and moored about 0.5km from the beach (C. Limpus, unpublished observation). In contrast, green and loggerhead turtles that are long term residents on the reef adjacent to Heron Island Harbour have habituated to vessel activity around them with resulting minimal disturbance caused by the vessels.

Marine turtles coming ashore to nest respond negatively to large things (including large animals and upright people) moving near them. Their normal response is to abort that particular nesting attempt and to return to the sea and move to try nesting at some point further along the beach.

There will be considerable low frequency noise from generators, other machinery on the shore, docks and jetty and noise from engines and generators on moored and moving vessels. There will be moving vehicles with lights along the causeway and jetty. These noise sources and obvious large moving objects will be concentrated along the linear array of structures approximately in the middle of the preferred nesting beaches.

It is to be expected that this noise pollution and vehicle traffic will cause adult turtles approaching the beach for nesting to move away from the causeway/jetty area. This should result in a reduction in nesting attempts on the beaches immediately adjacent to the causeway at Town Point. It is unlikely that the internesting turtles will spend sufficient time in close proximity to the sources to allow for their habituation to these disturbance effects. Given the uncertainty regarding the intensity of the geographical range of the disturbance effect, the extent of displacement of nesting females cannot be estimated at this time.

In contrast, based on the preliminary studies at Barrow Island, the possibility exists that low frequency vibrations may attract hatchlings. If this occurs, then the nett impact of this attraction will be to further aggregate hatchlings towards the illuminated structures of the causeway, jetty and moored vessels.

Where possible, generators and other fixed machinery that produces low frequency sound should be mounted on vibration absorbing foundations.

3.3. Changing hatchling production with nesting beach selection

With any substantial shift of nesting distribution between nesting beaches, there are likely to be changes in hatchling sex ratio resulting from differences in beach sand temperatures. The direction and magnitude of such a sex ratio response to flatback turtles shifting away from nesting on any of the preferred mid east coast beaches of Barrow Island can not be determined with the available information.

Any shift of flatback nesting to the beaches that are not part of the preferred mid east coast beaches of Barrow Island is presumed to provide less than optimal conditions for hatchling production and dispersal. At this time data were not available that would allow my assessment of issues such as beach stability under storm conditions, nesting success, incubation success, hatchling sex ratio, hatchling survival and hatchling dispersal at representative beaches within the preferred mid east coast beaches and at other less preferred nesting beaches on the island.

3.4. Dredging (habitat modification)

Dredging of navigation channels and the turning basin will cause a direct reduction in available foraging grounds available for the locally foraging green, hawksbill, loggerhead and flatback turtles. Given the low density of turtles per hectare expected in these habitats, the long term impact of this direct foraging habitat loss should be a permanent population reduction in the order of magnitude of tens of turtles. The dredging and spoil dumping will cause an increase in turbidity and down current sedimentation over a considerably wider area on food resources. High turbidity and sedimentation can be expected to kill off seagrass and other food sources dependent on photosynthesis, lasting possibly for a few years after dredging (Preen and Marsh, 1995). There is likely to be a change in distribution of benthic invertebrate prey such as seapens in areas impacted by increased sedimentation. Overall, the dispersed sediment loads generated by dredging and spoil dumping can be expected to cause some additional population reduction beyond that cause by direct loss of habitat.

However, loss of potential turtle food resources through modification of benthic habitats that result from the dredging and other port construction operations will not have an impact on the internesting turtles nor will it impact on the dispersing hatchlings, given that these life history phases do not require food.

3.5. Dredging (direct turtle mortality)
Suction dredges kill turtles during dredging operations in other locations (Greenland et al. 2004). Death of turtles can be expected with dredging operations off the mid east coast beaches of Barrow Island because of the proximity to the large flatback nesting population and the presumed mixed foraging population of green, hawksbill, loggerhead and flatback turtles.

With 35-75 internesting flatback turtles daily within the inshore waters off the mid east coast nesting beaches, it is not unreasonable to anticipate that some of the internesting females as well as some of the resident foraging turtles will be killed during the dredging operations. However, no estimate of an expected annual mortality from dredging can be made at this time.

Dredging mortality could be reduced by ensuring that the year or so of planned dredging operations does not encompass more than one breeding season. Where possible, down time from dredging operations should be time tabled to coincide with peak nesting season.

The Brisbane Ports Corporation which is responsible for dredging for most ports in Queensland operates with a Code of Practice that addresses reducing turtle mortality. Within the USA, the US Army Corp of Engineers has considerable experience in the area of dredging with minimal impact on marine turtles.

3.6. Boatstrike
After dredging has established channels, it can be expected that foraging turtles will use the edges of dredged channels as resting areas. This is likely to cause an increase in density of foraging turtles in the vicinity of the channels designed for shipping traffic.

Within the confines of channels, especially at low tide, large propellers have the capacity to suck objects not attached to the substrate through the propeller. For turtles this will result in injury or death. In Queensland, a high proportion of turtles killed through boat-strike/propeller damage are associated with dredged shipping channels (Queensland EPA StrandNET database). Where injuries are not fatal, it is not uncommon for the injured turtle to take years for recovery and to be removed from the breeding population during those years.

Turtle deaths and injuries can be expected from turtle interactions with operating vessels in the dredged channels and turning basin. However, no estimate of an expected annual mortality from vessel interactions can be made at this time.

Apart from having the vessel travel at low speed, no suggestions are made for tactics for reducing this source of mortality.

Additionally it can be noted that in eastern Australia, in marina developments with walls composed of irregular shaped boulders, marine turtles will aggregate to feed on the benthic fauna and flora of the "artificial reef" and to rest/sleep in the crevices of the walls (C. Limpus, unpublished observations). With approximately 3km of wall surface (= new "rocky reef") proposed for the causeway and MOF off Town Point, it can be expected that turtles, especially juvenile green and hawksbill turtles, will aggregate around this new habitat. These turtles will also be susceptible to collision.

3.7. Vehicle traffic on nesting beaches

Vehicle traffic at beach crossing sites on nesting beaches by day or night can cause death of turtle eggs through compression or erosion of the nest. Any tyre ruts remaining after vehicles exit the beach become significant obstacles to hatchling turtles and can trap the hatchlings and seriously delay their entry to the sea.

In general, vehicle damage to turtles, their eggs and hatchlings are easily managed through strict management of vehicle use:

- Strictly minimise vehicle access to beaches.
- Move vehicles to points along the beach by utilising access from behind the dunes.
- Do not use vehicles on the beach or within sight of the beach at night during the nesting season;
- Where vehicles must access beaches,
    - Restrict dune crossing to as narrow a strip as possible;
    - Where a vehicle must move along the beach, wherever possible restrict travel to below the high tide mark. This allows the tide to remove tyre ruts.
    - When turtles lay eggs within "road" ways and work areas used during construction of beach crossings, the eggs should be removed within a few hours of being laid and with no vertical rotation to a safe incubation site within the normal nesting habitat of a preferred nesting beach.

If managed appropriately, vehicle usage on beaches should have no negative impacts on the viability of the turtle populations.

3.8. Staff use of beaches

I am starting with the assumption that the construction and operations staff for the facility and crews from visiting vessels will not be permitted to bring pets such as dogs and cats to the island. This needs to be strictly enforced.

Use of beaches by day for recreational activities such as swimming, sailing, board riding and fishing should have no detrimental impact on the nesting turtles or on egg incubation. However, such activities by night can be detrimental to the turtles. It is recommended that the turtle nesting beaches be closed to general access from dusk to about 6.ooam during the turtle nesting and hatchling season.

Staff, out side of their employed duties, may wish to assist with turtle conservation activities. With appropriate training, persons resident on the island have the potential to make a significant contribution by assisting the management agencies and research/monitoring consultants in turtle monitoring, research and management. This option should be considered.

3.9. Laying the Feed gas pipeline and associated shore crossing

The laying of the feed gas pipeline across the inshore habitats and the associated shore crossing for the pipeline at North White's Beach will cause short term, localised disturbance to courting turtles in the area. It is unlikely that this will cause any reduction in population function for the courting green turtles. Similarly, the shore-based work at North White's Beach will have an impact on a trivial proportion of the island's green turtle nesting population.

4. Maintaining sustainable populations

Not all species of marine turtles in Australia are equally well understood with respect to their biology (Limpus, in press a,b,c,d). The green and loggerhead turtle populations of eastern Australia are among the best understood for their population dynamics. This has permitted comprehensive modelling of their biology and development of rigorous heuristic modelling of their population dynamics (*C. mydas*: Limpus and Chaloupka, 1997; Chaloupka and Limpus, 1998; Chaloupka, 2001, 2002; Chaloupka et al. 2004; Chaloupka, 2004. *C. caretta*: Chaloupka, 1998; Slater et al. 1998; Chaloupka and Limpus, 1998, 2001, 2002; Chaloupka, 2003; Chaloupka et al. 2004).

This approach to modelling marine turtle populations when applied to other species/populations is also proving to be informative (Chaloupka and Limpus, 1997; Chaloupka, 1998, 2001; Balazs and Chaloupka, 2004; Bjorndal et al. 2005).

There are insufficient demographic data for key life history parameters such as age at maturity and age/sex based survivorship data for flatback turtles to enable a comparable reliable model to be developed for this species. Until such models are available to test the population performance of flatback turtles under the impact of different multiple threats, we can apply some of the general lessons being learned from the green turtle and loggerhead turtle models. Analysis with these models produces some common outcomes:

- When mortality increases by as little as only a few percent above natural mortality levels at any life history stage and continues over the time frame of a turtle generation (a few decades), a marine turtle population will decline significantly.
- Consistent annual losses from a population of the order of 5-10% of a life history stage above natural mortality levels can be expected to cause serious population declines within one generation and reduce populations towards extinction within about 100yr (several generations). Under these conditions, IUCN threatened species criteria would indicate that the population should be considered to be under significant threat.
- When anthropogenic mortality factors impacting a population are removed, recovery of the population will be slow. For example, the decline caused by loss of a few percent of the adult green turtles from a population over 50yr can be expected to require ~150yr for the population to recover after the mortality factor is removed (assuming that no other mortality factors are operating on the population).

- When absolute numbers of turtles killed are considered, the loss of a few hundred adult females can have a similar population impact as the loss of thousands of immature turtles. Indeed, the loss of a single breeding adult could be equivalent to the loss of many thousands of hatchlings in terms of the population dynamics for the species.

There is a reasonable probability that the combined continuing impact over the ~60yr life of the Gorgon project of changed light horizons at the beach and noise transmission into inshore waters will contribute to a significant reduction in the flatback nesting population at the preferred nesting beaches of mid east coast of Barrow Island within 20 to 30 years.

There is a reasonable probability that there will be an increase in hatchling mortality on the beaches and in the adjacent waters as a result of the altered light horizons of the Gorgon project. There is a reasonable probability that, through standard management of light, this mortality increase can be kept at a modest level. However, with even an increase in hatchling mortality of only a few percent per year over and above natural mortality rates but extending over the decades of the project, this population can be expected to decline in the long term. Such decline will only be in evidence when that next generation of turtles return as first time breeding turtles in several decades time.

There is a reasonable probability that a small number of internesting flatback turtles will be killed by the dredging. This mortality will add to the more significant hatchling mortality and the consequences of scaring of the nesting females from the beaches.

Collectively, these impacts imply that there is a reasonable probability that the Gorgon Project as it is currently planned threatens the viability of the most important flatback turtle rookery in Western Australia. The principal problems are linked to changing from dark horizons over the nesting beaches to illuminated horizons.

If the project cannot be relocated to some less sensitive site off Barrow Island or to a site within the interior of Barrow Island from where dark light horizons over the beach will not be impacted, and if there is a serious desire to retain a robust flatback nesting population on the eastern beaches of Barrow Island as an integral part of this iconic island, then the lighting strategies underlying the planning for the Gorgon facilities at Town Point need to be rethought and refocussed towards maintaining dark horizons.

Darkness is the preferred management option when it comes to secure management of marine turtle rookeries. Where darkness cannot be achieved by containing necessary light within enclosed opaque areas, the principals being promoted for management of elevated dark horizons by Salmon (2003) and Tuxbury and Salmon (2005) need to be incorporated into design of the facilities.

Design the landscape and architecture of the facilities to create a high-elevation opaque/dark horizon from the viewpoint of the nesting beaches that separates all facilities from the beaches. Consider the following:

- Create a high-elevation dark horizon on the seaward aspects of all facilities with external lighting and hence light spillage.

- Construct a high solid “multi-story” height wall around the perimeter of facilities to create an artificial elevated dark horizon inland of the beaches.
- The height of the above horizon-wall could be enhanced if it was built on top of a large/high bund wall of “soil” surrounding the land-based facilities. This bund wall could be constructed using the dredge spoils from the channels and mooring area. This latter action would have the added benefit of reducing broad scale marine habitat loss from spoil dumping at sea and the associated turbidity and siltation.
- Large structures equivalent to “multi-story buildings” that do not require external lighting can be built on the seaward side of facilities and be part of the surrounding “wall”. This may be a potential use of tall gas storage tanks.
- Office buildings can be built with no windows/doors opening through walls on the seaward side.
- A wall like this may need passageways for wildlife at ground level. If so, then light baffles can be constructed. The same would apply for vehicle and pedestrian movement through gates.
- Light baffles should be installed on all door opening from brightly illuminated areas to the outside of buildings.
- A wall like this may have some value in containing invasive species.

All lighting that is not essential for “external use” where it would cause light spillage should be contained within light proof containers. A container may be on the scale of a building or down to the scale of a box. For example,

- Consider placing instrument areas and valves that need extensive lighting inside ventilated rooms rather out in open areas.
- Can the seaward side of gas processing facilities be closed off to create opaque walls?
- Instead of outdoor floodlit recreation areas such as tennis courts, use indoor areas.

For lights that must be used in the open environment, the recommended starting point for planning such lighting should be with the question of “How can dark horizons be maintained?” Consider the possibilities:

- Investigate new lighting designs beyond those in current use, including “monochromatic” LED lights, low pressure sodium vapour lights in a search for more turtle friendly lighting while recognising that no light source that can cause any disorientation of the turtles is desirable for use.
- Use proximity relays switches and time switches to have lights turned on only when required.
- Re-examine why lighting is required at each specific location and design lighting to provide illumination for that specific purpose. For example, when contrasted with the level of lighting used to mark aircraft runways and for illuminating navigation lanes for shipping, road ways do not need to be illuminated by numerous bright overhead lights on elevated bollards. This is usually argued from a safe operations perspective. Bright lights may be needed for high speed vehicle use but safe operations can be achieved with less light fixtures and lowered lighting levels of the carriage way with vehicles travelling at lower speeds.

- Remove high beam capacity from all vehicles and adjust vehicle speed limits to maintain safe operations.
- Intermittent flashing lights with a very short on-pulse and long off-interval are non disruptive to marine turtle behaviour, irrespective of the colour. Flashing marine navigation lights do not cause disorientation of turtles. Consider increasing use of this type of lighting for marking carriage ways, walk ways, entrances, exits and key work areas.
- Equipping staff with head lamps, as is done in the mining industry, and reduce fixed lighting of the work area and design tasks/work areas to maximise use and efficiency of this type of lighting rather than illuminating the entire work area.
- When using head spots, increase use of reflective signage and demarcation of areas from a work place health and safety perspective.
- With recreation facilities such as outdoor barbeque areas, have the lighting on time switches set to turn off at 7.30pm.

Vessels moored at the jetty for loading have the potential to cause significant increases in hatchling mortality. Lighting on these vessels should be managed in the same way as for the rest of the facilities. All unnecessary lighting should be contained within the vessel and no light spillage occurring from portholes. The lighting of the vessel should be designed and/or modified before it is commissioned to enter this area of operations. Navigation/anchor lights on top of masts can be accepted. Bright deck lights need to be addressed to find ways to shield them.

Significantly reduce impacts on turtle populations by ensuring that the year or so of planned construction (island based facilities, causeway and jetty) and dredging operations does not encompass more than one breeding season. Where possible, down time from drilling and construction at beach crossing sites and from dredging operations should be time tabled to coincide with peak turtle breeding season.

The rare, short term emergency use of extensive bright lights, while disruptive to turtles for the duration of their use, will have minimal long term impacts on the population function. However, design this emergency lighting from the perspective of maintaining a dark horizon where ever possible.

Given that some lighting at existing facilities at Barrow Island is already altering the light horizons over the nesting beaches, re-design lighting at other existing facilities on Barrow Island to reduce their contribution to altering the light horizons over turtle nesting beaches.

5. Monitoring

Just as industrial plants have “work place health and safety” officers, the Gorgon Project should appoint staff with the role and authority to provide a safe environment for turtles, including particularly maintenance of the dark horizons.

A monitoring program should be in place prior to commencement of construction and maintained through out the life of the Barrow Island based project that is designed to:

- Detect long term changes in the distribution of turtle nesting, hatchling survivorship, orientation of adult and hatchling turtles within beaches adjacent to all facilities altering light horizons.

- Identify any shift of turtle nesting activity away from existing favoured beaches adjacent to facilities and towards less favourable beaches with respect to turtle population dynamics.
- Identify and quantify hatchling mortality relative to changed lighting horizons, including in the water in the vicinity of the causeway and jetty.
- Monitor the occurrence of sick, injured and dead turtles on Barrow Island, its surrounding inshore waters and the surrounding region. This stranding program should include identification of cause of injury and death of the turtles. While results of the stranding project should be reported annually, any significant change in the temporal or spatial change of strandings should be reported to the Government and Gorgon management immediately.

Because the Gorgon Project will impact the major breeding area for the Pilbara Coast flatback turtle stock, it has the capacity to impact on the entire stock. Therefore, the monitoring program should:
- Encompass not only the Barrow Island nesting beaches but also representative major nesting beaches for this stock.
- Address all life history phases including internesting and nesting females, eggs, hatchlings, pelagic foraging post-hatchlings and benthic foraging turtles of all sizes from immature to adult turtles.
- Quantify other threatening processes impacting on this stock of turtles throughout their range and which will have a cumulative impact on the stock over and above the direct impacts of the Gorgon project.

It would be appropriate for the Gorgon Project to be the focal point for a regional monitoring of the Western Australian flatback stock.

Given the significance of the impacts of this Gorgon Project on flatback turtles for Western Australia, all turtle research and monitoring associated with this project should be overseen and peer-reviewed by an independent expert panel. The roles of the panel should include the examination of:
- The key issues to be addressed by the research and monitoring projects;
- The appropriateness of the proposed research or monitoring projects to provide the information required;
- The rigour of the analysis and presentation of results.

This expert panel should have a role in providing advice to Government management, Gorgon Project management and technical staff involved in the research and monitoring.

Protocols need to be established where by the result of the monitoring program can be integrated with ongoing management planning of the project to facilitate its continued improvement in performance with respect to turtle conservation.

6. Off-set actions

Given that the Gorgon Project if constructed at the planned site on Barrow Island will have a negative impact on Western Australian flatback turtle stock, actions should be set in train to off-set the impacts of the Barrow Island facilities with projects that will contribute to enhancement of this turtle stock.

The Gorgon Project should contribute financially and in–kind as appropriate to support the following actions:

Increase production of vigorous, healthy, correctly imprinted hatchlings at nesting beaches by:

- Control feral predators on mainland nesting beaches. This should include a project to engage land owners along the mainland coast in protection of turtle nesting habitat and reduction of feral predation of eggs on their land.
- Rescue doomed eggs: Relocate doomed eggs from habitat with high natural egg mortality (such as below high tide level or on beaches that are erosion prone) to nearby areas within the natural nesting habitat that have high incubation success. All egg relocation to be completed within three hours of the eggs being laid and with the minimum of rotation of the eggs.

Support research to fill the gaps in our understanding of flatback turtle life history, particularly:

- Distribution, habitat use and diet of pelagic post-hatchling flatback turtles;
- Distribution, habitat use and diet of benthic foraging immature and adult flatback turtles;
- Quantify growth and age at maturity of flatback turtles;
- Quantify annual survivorship of flatback turtles by sex, maturity and age/size;
- Define the pivotal temperature for the Pilbara Coast flatback turtle stock and define the temperature profiles for the major nesting beaches for this stock.

Based on the results of the above research:

- Support a state wide community education project to enhance public participation in activities that reduce human induced mortality and that contribute to maintenance of good quality habitat for the species.
- Support the implementation of conservation actions to reduce human induced mortality of flatback turtle throughout their range in Western Australia.

It would be appropriate for the "independent expert panel" overseeing the Gorgon Project to be expanded to provide oversight of all research and monitoring projects associated with all Oil-Gas industry projects of the Pilbara Coast. A primary task of such an expert panel would be to address a major deficiency in current planning with respect to the Pilbara Coast Oil-Gas industry, namely the cumulative effects of multiple oil-gas production and processing facilities in the region.

Support a scholarship scheme targeted at the international market to attract collaboration by the academics with world leadership skills with respect to researching key turtle biology / conservation management issues, including improving our understanding of turtle vision and sea finding behaviour and the development of management to minimise impacts of altered horizons.

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