WESTERN AUSTRALIAN MARINE TURTLE REVIEW

Turtle Bay, Dirk Hartog Island

Jurabi Point, Northwest Cape National Park

Thevenard Island

Beach 6, Rosemary Island, Dampier Archipelago

By

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REVIEW PROCESS

The Western Australian Department of Conservation and Land Management (DCLM) invited the Queensland Environmental Protection Agency to provide the services of Dr Colin Limpus to visit Western Australia during 2-16 October 2002 and review the current turtle conservation and management programs in Western Australia in order to advise DCLM on future directions

The Terms of Reference for the review visit are summarised in Appendix 1. Persons from a range of Divisions within DCLM, Department of Fisheries, the petroleum industry, tourist industry, academics and volunteer participants were interviewed (Appendix 2). During this review process, no formal discussions were held with representatives of indigenous communities who also have an interest in marine turtle conservation.

In addition, a broad spectrum of published literature, unpublished reports and internal departmental management related documents relevant to marine turtles in Western Australia were examined (References).

INTRODUCTION

Marine turtles have a complex life history (Appendix 3) relative to other reptiles and most terrestrial vertebrates. They are characterised by several features that contribute to their susceptibility to serious detrimental impacts from human activities.

- Delayed maturity with first breeding occurring when they are several decades old.
- Non-annual breeding with individuals skipping years between breeding seasons.
- These two attributes require a correspondingly high annual survivorship throughout the life cycle for maintenance of population stability.
- Temperature dependant sex determination with female hatchlings produced from warm beaches and male hatchlings produced from cool beaches.
- Oceanic dispersal of post-hatchlings.
- Immature turtles recruit back to coastal foraging areas dispersed over tens, hundreds or thousands of kilometres from the nesting beaches.
- Large immature and adult turtles occupy these coastal foraging areas with high fidelity to their individual foraging sites over decades.
- Migration from foraging areas to traditional nesting beaches.
- Imprinting of hatchlings to the earth's magnetic field of the nesting area, is presumed to be a significant factor enabling adults to return to breed within the region of their birth.

Marine turtle conservation requires the successful functioning of the species across most of its habitats and life history phases rather than conservation management at a few representative sites such as individual nesting beaches or foraging sites. The focus in marine turtle conservation today is primarily on the management of the genetically recognised stock (management unit) throughout its total life history and full range of habitats.

Using population modelling it is possible to investigate the potential performance of a turtle population in response to various management options (Chaloupka, 1998, 2002;

Chaloupka and Limpus, 1998). These desktop studies based on a well-quantified demography of eastern Australian green turtles and loggerhead turtles indicate that even small long-term increases in annual mortality from anthropogenic sources above natural mortality levels will cause population declines. Marine turtle populations are resilient to occasional short-duration major losses at localised phases in their life history. In contrast, long-duration increases of more than a few percent in annual mortality at any stage in the life history are not sustainable. For severely depleted populations, full recovery after removal of the mortality factors can be expected to require several generations (up to 100 or more years).

In the absence of comparable detailed demographic data from Western Australian stocks, the following "rules of thumb" are offered as indicators for identifying management issues that need to be examined in detail.

- Mortality from anthropogenic sources needs to be summed from all sources and from throughout the foraging and breeding range for a management unit.
- Mortalities that are elevated for decades can be expected to have a negative impact on the population.
- The loss of an adult turtle from the population will have a very much greater negative impact on population dynamics than the loss of an immature turtle.
- Adult losses from anthropogenic sources are unlikely to be sustainable if they pool to more than 10% of the annual recruitment to the breeding population. Annual recruitment to the adult nesting population is likely to be of the order of 30%, based on long-term monitoring of eastern Australian populations. It is therefore recommended that adult female loss should be kept to <3% of the annual nesting population. For a nesting population of 20000 females annually, this would translate to <600 adult females annually. Allowing for a sex ratio of about 2 females to 1 male for most populations, an additional loss of ~300 adult males should also be sustainable.
- On the collective nesting beaches for a genetic stock, at least 70% of clutches should be successfully producing hatchlings annually to maintain population stability.

WESTERN AUSTRALIAN MARINE TURTLE SPECIES

There are six species of marine turtles within Western Australia and it is one of the few places in the world that still has large nesting populations. Four species breed within Western Australia in large numbers.

Green turtle, *Chelonia mydas*: Western Australia supports 1 genetic stock of green turtles nesting from the Ningaloo Coast to the Lacepede Islands (FitzSimmons *et. al.* 1997, Moritz *et. al.* 2002). This is one of the largest green turtle populations remaining in the world and appears to be the largest for the eastern Indian Ocean (Figure 1a).

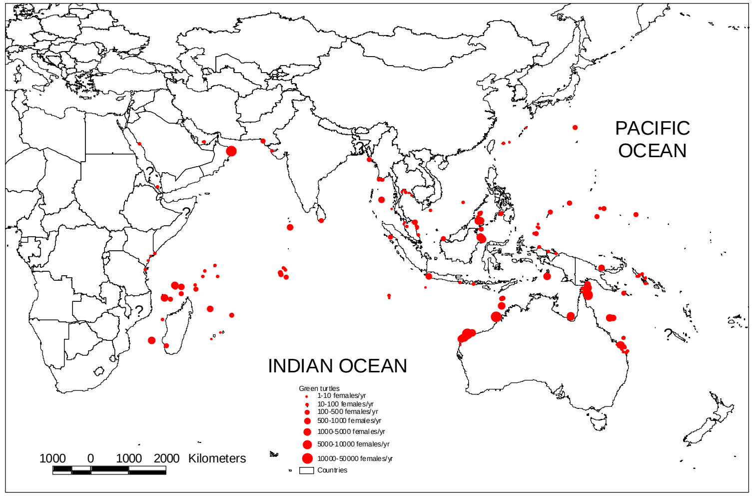
Hawksbill turtle, *Eretmochelys imbricata*: Western Australia supports 1 genetic stock of hawksbill turtles with nesting centred on the Dampier Archipelago (Broderick *et. al.* 1994; Broderick and Moritz, 1996). This is one of the largest hawksbill turtle populations remaining in the world and is the largest in the Indian Ocean (Figure 1b).

Loggerhead turtle, *Caretta caretta*: Western Australia supports 1 genetic stock of loggerhead turtles with nesting encompassing the Dirk Hartog Island to

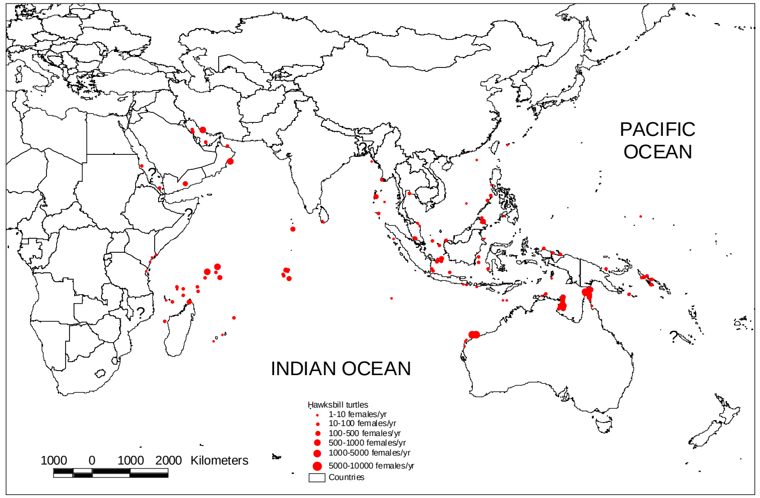
Varanus Island region (FitzSimmons *et. al*. 1996; Dutton *et. al.* 2002). This is the third largest loggerhead turtle population remaining in the world and is one of only four stocks in the Indian Ocean (Figure 1c).

Flatback turtle, *Natator depressus*: The flatback turtle is endemic to the Australian continental shelf and all nesting occurs in Australia with approximately one-third of the total breeding for the species occurring in Western Australia. Western Australia supports 2 genetic stocks of flatback turtles. The southern stock nests throughout the Northwest Shelf from Exmouth to about the Lacepede Islands and is characterised by summer nesting; the northern stock breeds mainly in winter and nests at Cape Domett and presumably adjacent areas in western Arnhem Land (FitzSimmons *et. al*. 1996; Dutton *et. al.* 2002) (Figure 1d).

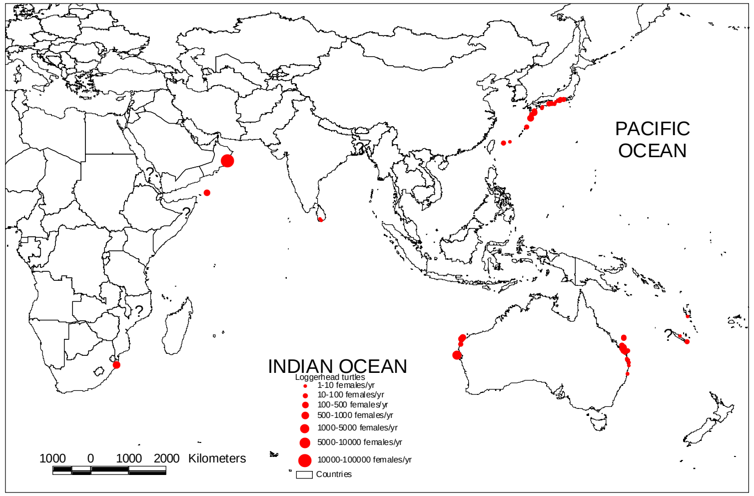
Figure 1. Distribution of marine turtle rookeries within the Indian Ocean, South East Asia and western Pacific Ocean region. These data were collated by the author from published records and correspondence with representatives of countries and states that participated in meetings that led to the development of the MEMORANDUM OF UNDERSTANDING ON THE CONSERVATION AND MANAGEMENT OF MARINE TURTLES AND THEIR HABITATS OF THE INDIAN OCEAN AND SOUTH-EAST ASIA. Australia is a signatory to this MOU.



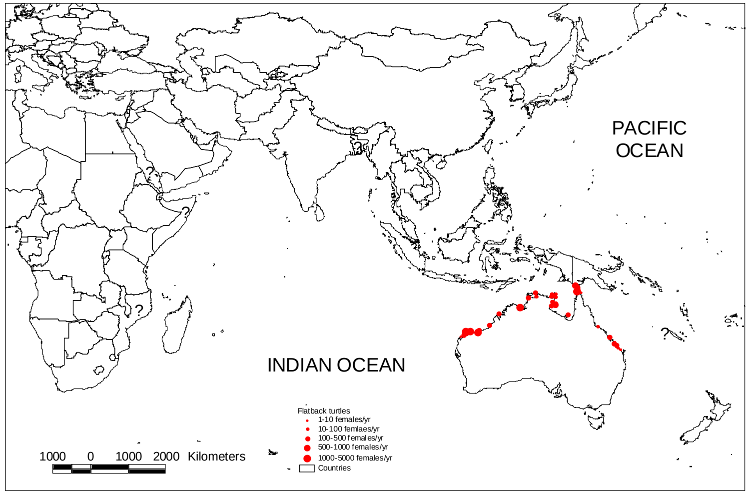
a. Green turtle rookeries, *Chelonia mydas*



b. Hawksbill turtle rookeries, *Eretmochelys imbricata*



c. Loggerhead turtle rookeries, *Caretta caretta*



d. Flatback turtle rookeries, *Natator depressus*

An additional two species of marine turtle occur in Western Australia as foraging turtles only.

Leatherback turtle, *Dermochelys coriacea*: Within the Indo-Pacific region, leatherback turtle populations are in significant decline. There has been no confirmed breeding in Western Australia. Foraging leatherback turtles from foreign rookeries, including those in Indonesia, pass through Western Australian waters. There is regular mortality of these migrating turtles in the south-west of the state caused by entanglement in float-lines to crayfish pots (Anon, 1982, 1985, 1987; Limpus and McLachlan, 1978).

Olive ridley turtle, *Lepidochelys olivacea*: There has been no olive ridley turtle breeding recorded in Western Australia but it may occur within the islands of the Kimberley Region given that low density nesting is known to occur on nearby Northern Territory beaches. Foraging olive ridley turtles have been recorded in Western Australian waters on isolated occasions (L. Baird, pers. comm.).

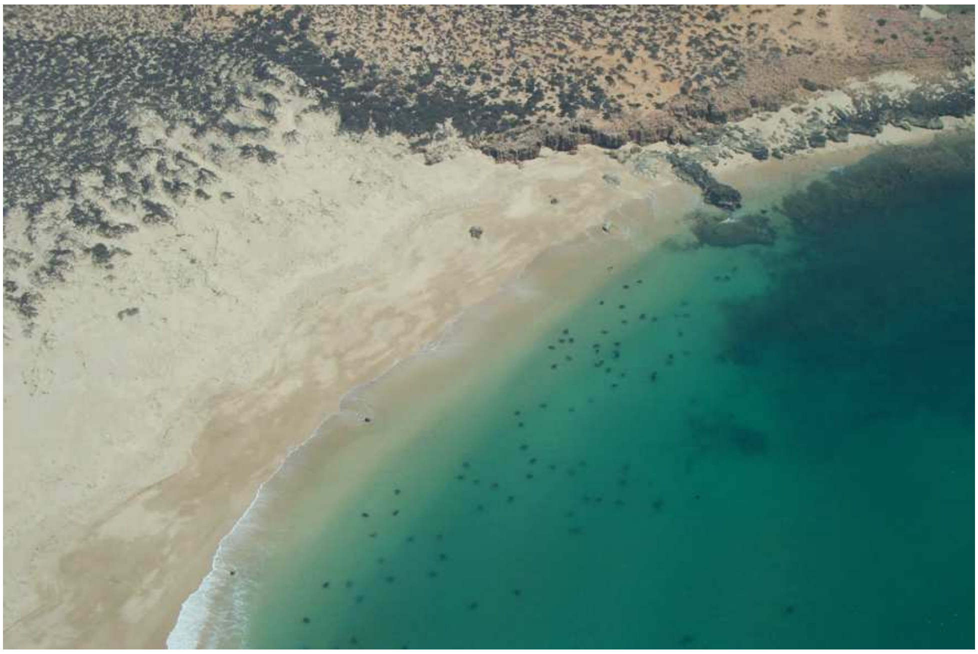
BASKING TURTLES

Large aggregations of basking marine turtles are rare in present times on the global scale. Western Australia is an exception to this. Basking green and to a lesser extent loggerhead turtles have been abundant on islands between North West Cape and the Dampier Archipelago (Figure 2a) and on the Ningaloo Coast (Figure 2b). Basking green turtles were observed in small numbers during the current review period on Barrow Island, Monte Bello Islands (Figure 2c) and Rosemary Island.

Figure 2. Basking turtles in Western Australia.

a. Basking green turtles, Barrow Island in 1980s. Photo by Keith Morris.

b. Basking adult sized loggerhead turtle with a basking elephant seal, Ningaloo Coast, late 1990s. Photo courtesy of C. Williams, email 6 Oct 2000.



c. Courtship aggregation of green turtles in the shallows of Northwest Island, Monte Bello Group, 11 October 2002. This was one of many courtship aggregations observed from the air within the Monte Bello Islands on that day. Small numbers of basking turtles were observed associated with each courtship aggregation.

The significance of this basking behaviour is poorly understood. Our experience in eastern Australia is that these basking aggregations include adult male and female turtles, breeding and non-breeding adults and immature turtles. In Western Australia, at least some of the basking appears to coincide with courtship time.

Basking turtles are of interest to tourists when encountered. At Heron Island in the southern Great Barrier Reef where this type of behaviour was once common, it has now all but ceased since the establishment of the tourist resort on the island. Presumably this change has been in response to regular human approach to turtles in the shallows and on the beach. On Fraser Island in Queensland, it has been necessary to introduce education material to discourage tourists from “rescuing” the basking turtles back into the water.

WESTERN AUSTRALIAN MARINE TURTLE CONSERVATION ACTIONS

Turtles were initially listed among Native Wildlife but harvested under license during 1950s to 1973. The Fisheries and Wildlife Department ceased issuing licences for commercial turtle harvest in Western Australia as of 30 June 1973 (Minister for Fisheries and Fauna press release, 30 May 1973). Currently in Western Australia, all marine turtles are protected species and have been afforded the same threatened species status as has applied under the federal EPBC Act.

Habitat protection:

The WA government conservation agency under its various titles has examined the State on a system-by-system basis, starting in the 1960s and extending to the present, and has developed a comprehensive system of National Parks and Nature Reserves. As a result of these actions, a major proportion of marine turtle nesting on islands occurs within these protected habitats. Exceptions include:

- The major *Caretta caretta* rookery on Dirk Hartog Island.
- Islands off the Kimberley Coast.

Marine turtle nesting on the mainland beaches is not as well represented in the conservation reserve system. Almost the entire nesting habitat of the Ningaloo coast is contained within the 40m wide strip of land above high tide that is contained within the Ningaloo Marine Park. However, outside of the Cape Range National Park, the management of the nesting habitat is largely driven by the management of the adjacent pastoral leases. The other mainland turtle rookeries such as the coast to the south-east of Cape Thouin (Mundabullangana Station), Eighty-mile beach and the coast south of the Ningaloo Marine Park are mostly within pastoral leases.

The Ningaloo and Shark Bay Marine Parks provide two large and significant areas of in-water habitat protection for marine turtles. These encompass a broad spectrum of foraging areas for adult and immature turtles, courtship habitat and internesting habitat. Other planned marine parks in the Dampier Archipelago and Montebello / Barrow Islands area will also provide similar significant conservation management of a wide spectrum of marine habitat for turtles.

Removal of introduced predators from areas of conservation significance:

The policy of DCLM to remove introduced animals from island Nature Reserves has been beneficial for marine turtles. Examples include the eradication of feral cats and black rats from the Montebello Islands and black rats from several other northwest islands. The broad-scale baiting of foxes in areas adjacent to mainland turtle nesting beaches (Figure 3) will substantially reduce egg loss to foxes in these areas.

Figure 3. Fox baiting warning sign at the entry gate to the coastal paddock containing Cowie Beach and other significant flatback turtle nesting beaches, Mundabullangana Station, Pilbara Coast, October 2002.

Research and monitoring:

- Mapping the distribution of marine turtle nesting and feeding populations
  DCLM Marine Conservation Branch maintains a GIS database that summarises the recorded distribution of marine turtle nesting beaches by species in Western Australia. These data have been mostly gathered during field studies by Dr Prince and K. Morris. This database is:
  - comprehensive for distribution for each species from the State's southern limit of turtle nesting northward to the Lacepede Islands;
  - not quantitative with respect to the abundance of nesting that occurs at each rookery.

  Foraging ground distribution data are available for a very limited number of sites and have been derived primarily from aerial survey observation during dugong surveys and some flights dedicated to turtle surveys. These surveys typically do not provide species identification for turtles sighted (Preen *et al.* 1997).

- Stock identification
  Dr Prince has developed a highly successful collaborative project with one of the leading marine turtle population genetics research teams globally. This collaboration has resulted in the recognition of the biological management units for effectively all species of marine turtles breeding in Australia (Broderick *et. al.* 1994; Broderick and Moritz, 1996); Dutton *et. al.* 2002; FitzSimmons *et. al.* 1996; FitzSimmons *et. al.* 1997; Moritz *et. al.* 2002). See the species summaries above for the Western Australian results.

  Within Western Australia, the only obviously ambiguous nesting populations that remain to be genetically assessed are those at
  - Browse Island (green turtles) and
  - Kimberley Coast (all species).

  The next important phase of the population genetics research will be to analyse the distribution of these genetic "tags" within foraging populations to determine the relative contribution of the various stocks to the foraging areas within the state. Similarly, genetic “tags” can be used to quantify the contribution of the various stocks within turtle harvests or other sources of mortality.

- Tagging program

  Dr Prince has chosen the standard titanium turtle tag manufactured by Stockbrands Co. P/L, Perth for the WA tagging studies. This is the most reliable external tag for long-term tagging studies of the Cheloniid turtles (Limpus, 1992). The use of double tagging in the front flipper axillary tag application positions is well suited to high tag retention rates with most turtle species (Limpus, 1992). For flatback turtles, which have softer skin and are more prone to loss of the standard flipper tags, injected PIT tags have far more reliable tag retention rates (Parmenter, 1993). A combination of PIT tags and flipper tags are recommended for tagging projects with flatback turtles and the similarly soft skinned leatherback turtles.

  The tagging program coordinated by Dr Prince has been very effective in tagging a large number of nesting female green, loggerhead, hawksbill and flatback turtles across a range of rookeries in Western Australia (Prince, 1998, 2000).

  These tagged turtles have already yielded a large number of post-nesting migration tag recoveries for turtles en route to, or back at, their respective foraging areas (Prince, 1994, 1998, pers. comm.). From these data, there can be derived a good first approximation of the distribution of foraging areas supplying green and loggerhead turtles to the Western Australian rookeries. There is a high probability that additional recoveries of these tagged turtles will continue for years to come. These data warrant re-analysis every 3 to 5 years to take into account the accumulating tag recoveries. The number of tag recoveries and the quality of the tag recovery data can be enhanced by conducting dedicated in-water turtle tag-recapture studies in parallel with the tagging studies at the nesting beaches (Heithaus *et al*. 2002; Limpus *et al*. 1994). During the review, it was apparent that some DCLM staff had tag recovery data in their district offices that had not been forwarded to cental office for identification of the origin of the turtles. These tag recoveries represent lost data if they are not collated to the turtle database.

  Similarly, the subsequent recaptures back at their nesting beaches in later breeding seasons of turtles originally tagged on nesting beaches has yielded a large body of data on remigration interval (= interval between breeding seasons) (Prince, 1994). A detailed analysis of these data would produce a valuable contribution to understanding the demography of Western Australian marine turtles, given that remigration interval is variable between stocks. However, many green, loggerhead and hawksbill turtles skip many years between breeding seasons. Therefore, the loss of continuity of tagging census studies at a number of the Western Australian rookeries in recent years (Prince, 2000) will have compromised the quantification of the longer return intervals. This will lead to an under estimation of the remigration interval. This is a critical demographic parameter, one for which population function is very sensitive to variation. To be rigorous, tagging studies designed to measure remigration interval need to run for about two modal return intervals --- for green turtles this equates to about 10-12 years of tag-recapture studies at the same rookery.

Another valuable contribution from recaptures of tagged turtles has been the identification of a range of anthropogenic activities that impact foraging turtles from the Western Australian stocks (Prince, 1998, 2000). Given that hunting pressures can change, that fisheries can redeploy to new locations and change in their methods of operations, and that human usage of coastal waters in Shark Bay and the Ningaloo Coast is escalating, the distribution and demography of turtle mortality can not be expected to remain temporally or spatially constant. The maintenance of tagged populations of turtles on the nesting beaches with associated post-migration tag recoveries provides one effective tool for linking changing mortality factors to the impacted stocks.

- Database

  The turtle database is currently in Microsoft Access format. It has undergone several changes in structure since it was first established by Dr Prince. In its current format, it contains records of tagging and tag recovery events for individual turtles and is GIS compatible. It has a data dictionary that defines the majority of the fields and codings used. It should be possible to extract data by year, site, species, size and remigration interval. It appears as a very simplified summary of data collected in the field. I am sure that a researcher attempting to use it for summarising field data from a comprehensive field tagging study could do so with the introduction of new codes and possible new fields as required. The data contained can be easily transported to other softwares for more comprehensive analysis, e.g. to specialised statistical packages. With suitable training, a person could write programs for extracting derived data for further analysis, e.g. for growth analysis or mark-recapture analysis.

  One person who has tried to analyse some of the data expressed reservations concerning the accuracy of the data as it was originally collected. I am not able to judge the quality (accuracy, repeatability, precision) of the data within the database. However, it was apparent during discussion with some field volunteers and staff that items like tape measures were not being regularly checked for accuracy as tapes stretch or shrink. Most turtles appear to be only measured once in a season and I found little evidence among the field personnel that team members were checking measurements on the same turtle to ensure consistency and repeatability of measurements by the various team members.

  My overall impression of the database was that it would provide a vehicle for analysing the tagging data. However, the database appears to have been structured for simplistic summarising rather than ensuring that structured data is gathered that can be used to target the intent of the specific research or monitoring projects.

However, there is a considerable body of data that has been gathered during WA marine turtle research that has not been recorded in the current database. In addition to the tagging database there would be value in having some additional databases structured to summarise:

- Census data gathered on visits to the various rookeries across the year – these aggregated data would not contain the individual tagging data.
- Migration data summarising the original tagging data at the nesting beach and the recapture data from the foraging area.
- Summary of the numbers of turtles tagged by species, year, site and turtle life history stage (sex, maturity and activity).

Some of these summary type databases may be produced as derived data using analysis of the "tagging data" if very comprehensive field data recording has been collated in the tagging database.

Communication with DCLM and between agencies:

DCLM internal communications:

- There has been a break down in communication between the turtle research and monitoring staff and the DCLM management
- Tag recovery data in regional offices is not being communicated to the turtle database coordinator.
- Turtle stranding/mortality data is being recorded in some regions but the data is not being analysed and not being integrated statewide. There is no consistent recording of turtle stranding and mortality.
- The results of the annual monitoring and research projects have not been fully written up with attention to rigorous methodology and statistical analyses of data. Periodic reports reviewing data across the years for the major study sites would be warranted. These review reports would seem suited to publication in peer-reviewed journals.
- There needs to be a reconciliation of state wide issues and local management issues when planning for turtle conservation.

DCLM communications with other agencies:

It was apparent that there was regular discussion between individual DCLM staff and staff in other agencies such as Department of Fisheries (DOF). However, there appeared to be a limited flow of information to the managerial levels in both agencies. Both agencies need to work in unison to ensure a whole of government delivery of the conservation program within fisheries activities. Fisheries bycatch data for threatened species needs to be equally available to both DCLM and DOF.

The Draft Bycatch Action Plan (DOF, 2002) was data deficient with respect to turtle bycatch. It appears not to have brought available data to the fore to support actions. DCLM management should ensure that conservation issues are given appropriate recognition and analysis in planning document such as this.

Community participation:

The turtle conservation project that Dr Prince established in 1985 encouraged broad community participation in the field activities (Prince, 1994). A wide range of community members participated as volunteers. The exemplary collaboration between the James Scheerer Research Charter (C. & J. Shankland, publicity brochure) and DCLM to support volunteer participation in monitoring the loggerhead turtle nesting at Dirk Hartog Island is a credit to all those involved in its development and implementation. Some groups of volunteers such as the Rosemary Island team and some individuals like Peter Mack at Bateman Bay obviously have a deep personal commitment to making a positive contribution to marine turtle conservation. Partnerships between DCLM and volunteers such as these can be extremely beneficial for conservation. At the same time, maintaining a clear direction for the projects and effective reporting of results requires the participation of supportive DCLM staff in an ongoing capacity.

Some indigenous folks have been active collaborators in the turtle conservation project, especially the One Arm Point Community with the tagging program at Lacepede Islands. The Aboriginal communities on Dampier Peninsula have also been actively involved in an assessment of the indigenous hunting of turtles in this area.

Volunteers who have participated in the tagging programs spoke enthusiastically about their learning experience in the project. Some were unaware of the outcomes from the results that followed on from their participation. Much of the continuity of the community participation appears to have diminished as the range of field projects have been scaled back in recent years.

Public education:
There is a range of informative and accurate brochures produced by DCLM and available to the public, including:

- Marine Turtles
- Park Notes. Cape Range National Park and Ningaloo Marine Park: A guide to turtle watching on the northwest coast.
- Shark Bay World Heritage Notes. Marine turtles.

Volunteer newsletters with the intent of keeping project participants informed of results from the turtle conservation projects have been produced by various DCLM officers:

- Western Australian Turtle Research Newsletter, numbers 1-6.
- Marine Turtle Research Project Rosemary Island, Volunteers Newsletter, numbers 1-6.

Along the Ningaloo Coast the turtle nesting beaches were well sign-posted with management information and educational information (Figure 4).

Figure 4. Signage at turtle nesting beaches within the Cape Range National Park.

a. Turtle watching guidance.

b. Restricted vehicle access.

DCLM staff at Exmouth are collaboratively planning with the local Government for improved visitor control and education of tourists wishing to view nesting turtles within the Cape Range National Park.

It is suggested that DCLM establish a training / education program for its own staff and volunteers so that information on turtle biology, threatening processes and research and/or management techniques can be provided. If the course were run in December, Exmouth would be a suitable location as course participants could receive hands on training with nesting turtles.

COASTAL DEVELOPMENT AND TURTLE CONSERVATION

Coastal Western Australia, from Shark Bay, through the Ningaloo Coast and northward to the Pilbara Coast with the associated islands from Northwest Cape to Dampier Archipelago, is a region that can be expected to have continued extensive industrial and tourism development in the decades to come. This same region supports extremely significant marine turtle breeding and foraging populations. It will be a challenge to manage the changes that the increased coastal development will bring so as to retain these spectacularly large marine turtle populations.

Given the complexities of marine turtle life history and failures in their management in other countries for a great diversity of reasons, we can start with the premise that without a concerted effort towards their conservation, there is a high probability that their populations will dwindle as a result of habitat alteration. I would expect some of the effects to operate via reduced population performance while other effects should be manifest via increased mortality.

Dr Prince and Kelly Pendoley identified the issue of altered light horizons associated with brightly illuminated oil/gas facilities on islands (lighting and flares) such as at Barrow Island, Varanus Island (Figure 5a) and Thevenard Island (Figure 5b) and more recently with similar brightly illuminated structures at sea. The petroleum industry has been funding research to address some of the aspects of hatchling disorientation associated with altered night-time light horizons. At present the research appears to be focussed on experimental work to identify behavioural response of hatchlings with respect to light characteristics (wave length, intensity). I was presented with no studies directed at quantifying the magnitude of the problems with respect to hatchling disorientation for the region. How many sites are impacted? What is the size of the associated turtle nesting populations by species? What proportion of the hatchling production is being lost on the beaches due to disorientation?

Figure 5. Examples of coastal development on the Northwest Shelf.

a. Varanus Island, October 2002.

b. Thevenard Island, October 2002.

c. Pearl farm, Faraday Channel, Monte Bello Group, October 2002.

d. Gas export facilities at Dampier, October 2002.

Another consequence of changed night-time illumination over sizable areas of sea is that it is now possible for gulls and terns to forage extensively by night where previously they didn't (Dr Prince, pers. comm.; K. Pendoley, pers. comm.). These structures have the potential to trap hatchlings in these illuminated areas at sea and substantially increase hatchling predation by birds and fish. This is an issue that the petroleum industry should address.

A more difficult issue to address but one that may have far greater consequences in the long term is the potential for nesting turtles to respond negatively to the increased illumination over their nesting beaches. There is accumulating evidence that when the skyline of turtle nesting beaches become brightly illuminated, the associated adult nesting population will decline (Salmon *et al*. 2000), not because of mortality of the turtles but because the adult turtles choose not to use that beach. About two decades ago a large gas processing plant and its associated flares were constructed immediately behind the frontal dunes at Paka, Terengganu, Malaysia. This was then the most significant of green turtle rookeries on mainland Peninsula Malaysia. Since then the green turtle nesting population breeding at Paka beach has declined to almost zero (Ibrahim and Limpus, unpubl. Data). At the same time green turtle nesting numbers has been increasing at other less optimal nesting habitats to the south of Paka. If turtles shift from preferred nesting areas with their presumably good conditions for egg incubation, hatchling emergence success, hatchling imprinting and hatchling dispersal, then movement of nesting adults to breed on alternate beaches leaves them vulnerable to laying eggs in areas where the population may function suboptimally. No one appears to be addressing this issue in relation to the Western Australian rookeries.

Building these industrial facilities on islands also brings increased boating activity to the island with associated ongoing alteration to the benthic habits as well as increased potential for boat strike of turtles. The construction of pipelines to and from islands adds to this alteration of benthic habitat. The facilities on the islands have staff and they will use the beaches and adjacent waters for recreation. This can result in increased disturbance of nesting turtles and basking turtles on the beaches as well as increased boating activity adding to the above impacts of the industrial boating. People in these island communities expect to have similar amenities as those back on the mainland – with resulting potential for expansion of altered light horizons away from the industrial facilities to include street lights, illuminated recreational areas and housing lighting.

The more facilities that develop on an island and the more islands in the region that are developed, the greater the problem becomes. The recommended management option for major marine turtle nesting areas is "**lighting should be entirely excluded not only from the beach, but also from areas behind the beach in the form of a buffer (no development) zone**" (Salmon, Witherington and Elvidge, 2000).

I haven't addressed the issue of pollution from a future malfunction within the oil and gas industry, which many folks assured me, was not an issue. I would work on the premise that a major mishap will occur eventually. A pre-existing contingency plan would be useful.

Dampier/Karratha area supports an expanding export infrastructure for gas, iron ore and salt. When we flew into this area for the review meetings, there were 16 bulk ore carriers at anchor at sea from the port. Their anchors and their chains as they swung on their moorings would have been damaging the benthic habitat over many square kilometers. The ports with their shipping will have a negative impact locally on the environment from the accumulation of minor spillages and rubbish disposal, from the impact of their antifouling paints, from sediment disturbance by propeller wash from large vessels, from dredging of navigation channels, from boat strike, etc. These issues can be expected to expand as coastal development continues to expand in the northwest.

With an increasing human population at places like Denham, Exmouth and Karratha, given the hot dry nature of the surrounding countryside, there will be an increasing demand to use the regions islands, especially their beaches, for recreation. Beach shacks and tent camping on islands such as Rosemary and Malus Islands are examples of this. This takes with it the potential for increased disturbance of nesting and basking turtles on the beaches, altered light horizons as the building are fitted with lighting, increased boating activity in the vicinity of nesting beaches and associated turtle disturbance and boat strike.

Following in the wake of the growing oil, gas and iron ore export industry will come other entrepreneurial ventures for earning a living from the surrounding sea and islands. The pearl farms within the Montebello Archipelago would be an example of such a development. Proposals to develop aquaculture ventures in the region should proliferate along with their associated habitat alteration and increased boating activity. In parallel with increased accessibility to these areas and associated public accommodation that follows the industrial development will come the increased demand for tourist access to these attractive and interesting islands and waters. This will bring increased boating activity (habitat disturbance, boat strike) and tourism on the nesting beaches (potential disturbance of turtles). Developers will be eager to have their infrastructure looking out over the sea. This is incompatible with maintenance of long term, robust turtle nesting populations. **On turtle nesting beaches, the preferred management option needs to be darkness without alteration of the light horizons.** In Queensland we have been recommending a 1.5km darkness zone surrounding significant nesting beaches. Low pressure sodium vapour lights which are non attractive to loggerhead turtles are disruptive to green and flatback turtles. All other types of conventional lighting are very disruptive to all species.

When tourist visitation to an area becomes excessive and significant disruption of turtle nesting and hatchling dispersal is occurring, then the conservation agency should take control of the tourist access to the turtles. In Queensland, we have found that by selecting a few rookeries with ready access and reliable availability of turtles, tourists come to the areas we advertise. At these sites we then manage the upper limits to numbers of persons who can be present on the beach with the turtles and the behaviour of the persons around the turtles. We are encouraging tourism to selected sites to enhance conservation education. We do not manage these sites for zero disturbance. Rather, we manage to ensure that adult female nesting success is not significantly reduced, that nesting females are not scared away to other beaches, that there is a high incubation success for the eggs and that healthy, vigorous, correctly imprinted hatchlings emerge naturally from the nests to run undisrupted to the sea.

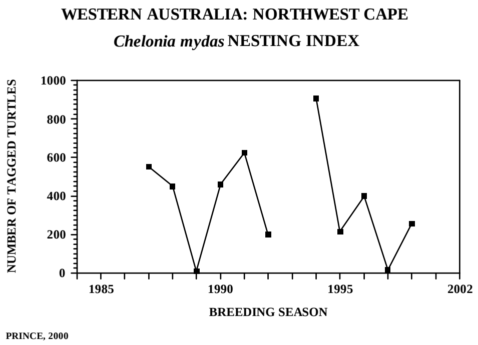
I am aware that I have painted a negative picture relative to coastal development. The development is inevitable. The challenge is to undertake strategic planning with respect to marine turtles to ensure that the development is kept as benign as possible in its impacts. Identify critical major nesting, internesting, courtship and foraging areas that can be included into planned minimal disturbance areas. Devise a scheme for satisfying the expectations and enjoyment of the tourists, aquaculture, etc outside or at the margins of major areas rather than having them operate in the middle of sensitive habitat. What is the potential for having some large areas of significant marine turtle habitat, that are not currently close to development, set aside as something approximating wilderness areas to counterbalance the large areas of major turtle nesting habitat that is already being impacted? The incremental negative impact of increased port facilities, boating activity and coastal run off on the coastal marine habitats, especially in bays will be the most difficult to contain. Of similar level of difficulty will be addressing the impact of altered light horizons in association with the oil and gas facilities already in existence and with new ones planned.

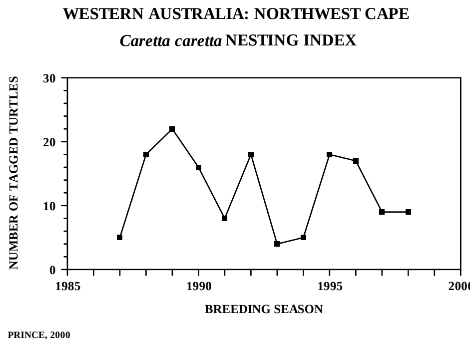
STATUS OF STOCKS

While some rookeries have been surveyed in part for some breeding seasons, for no marine turtle stock that breed in Western Australia is there a reliable quantified estimate of the size of the annual nesting population.

There is currently no readily available long-term quantified census statistics for any of the Western Australian marine turtle rookeries by which one can judge whether or not representative populations within the various stocks are stable or otherwise. The only long-term census data set that was brought to my attention during the review was for the green and loggerhead turtle nesting populations at Northwest Cape (Figure 6) based on tagging census data coordinated by Dr Prince (Prince, 2000) and the loggerhead turtle nesting population at Bateman Bay on the Ningaloo Coast based on clutch count data (Peter Mack, unpublished reports to DCLM). These data display no significant trend away from a stable population within the census time frames that encompass only a fraction of a generation for each species.

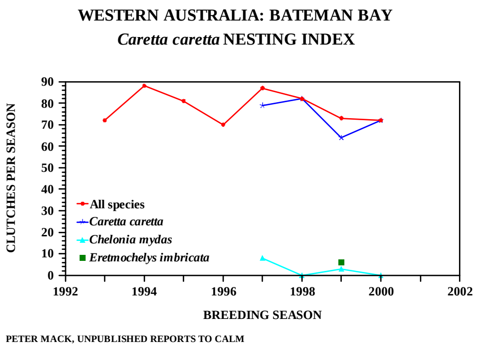
Figure 6. Available long-term census data from index beaches for green turtles and loggerhead turtle breeding populations in Western Australia. Extrapolations from these census data from Northwest Cape green and loggerhead turtle nesting populations should be made with caution. Uniform sampling effort was applied in the census studies across the years (Prince, 2000).





Regression analysis of the Northwest Cape green and loggerhead turtle nesting data (NS = not significant):

	r^2			F		
Species	value	Df	p	value	df	p
Green turtle	0.05	9	>0.25 (NS)	0.50	1,9	>0.25 (NS)
Loggerhead turtle	0.03	10	>0.25 (NS)	0.29	1,10	>0.25 (NS)



The high variability in the size of the annual green turtle population is a characteristic of green turtles and is a function of the impact of regional climate variability on the populations in their scattered foraging areas as they prepare for breeding seasons (Limpus and Nicholls, 2000).

In the absence of substantial trend data for populations, an alternative could be to gauge the level of threat to the various stocks via the analysis of comprehensive summaries of mortality from anthropogenic sources throughout the state. There appear to be no such summaries of quantified mortality data for marine turtles in Western Australia.

Staff comments during the review and some reports indicate that turtle mortality is widespread and common in the Shark Bay and Ningaloo Marine Park regions and in the vicinity of Broome. Some regional staff have been recording strandings but the data had not been collated to computerised files.

Turtle mortality resulting from a wide range of direct or indirect human activities were identified during the review (Dr Prince, pers. comm.; L Baird, pers. comm.; DCLM staff at Denham, Coral Bay and Exmouth. Kowarsky, 1982; Nishimura and Nakahigashi, 1990; Prince, 1994, 1998; Poiner and Harris, 1996; Mack, 2000; Morris and Lapwood, 2002):

- harvest of turtles and their eggs by traditional owners;
- harvest of turtles and their eggs by non-traditional owners and non-indigenous persons;
- fisheries bycatch in prawn trawls, longlines, gillnets, floatlines to lobster pots and other fish/crustacean traps;
- boat strike;
- ingestion of synthetic debris including fishing line;
- hatchling disorientation to lighting (streets, buildings, oil and gas industry);
- increased fish predation of hatchlings trapped in light pool from anchored boats at night adjacent to significant turtle nesting beaches;
- increased hatchling predation resulting from sea birds actively foraging at night in the illuminated areas associated with gas flares and off shore platforms;

Turtle egg mortality was also identified during the review:

- fox predation of marine turtle eggs laid on mainland rookeries from south of the Ningaloo Coast to north of Port Hedland;
- feral and domestic dog predation of turtle eggs laid on beaches near Broome;
- compaction of nest sites caused by vehicle traffic over nesting habitat on mainland rookeries from south of the Ningaloo Coast to north of Port Hedland.

Additional turtle mortality and strandings have been recorded from the south-western area of the state for some decades, especially for leatherback turtles (Limpus and McLachlan, 1978) and post-hatchling loggerhead turtles (Limpus, Walker and West, 1994).

Veterinary and parasitology studies are identifying some of the health issues impacting marine turtles in Western Australian waters (Edmonds *et al*. 1994; Platt and Blair, 1998; Radial and Prince, 1996; Radial *et al*. 1998).

Because of the lack of quantified data, I will provide my impressions of the status of the Western Australian turtle stocks as I have gained it from the available reports and the discussions with those interviewed. This is offered as a starting point for identifying conservation issues for consideration.

Green turtles:

Western Australian green turtles have been subject to organised commercial harvest for decades prior to 1973 (Appendix 4). For about 20 years there were many thousands of large immature and adult-sized turtles harvested annually. This will have caused some reductions in nesting populations and serious reductions in localised foraging populations.

Atomic Bomb tests:

- 1st test occurred on 3 October 1952 near Trimouille Island, Montebellos. This would have coincided with green turtle courtship time at Montebello (Fig 2c). It can be assumed that this nuclear test would have killed an appreciable number of the green turtles that were aggregated in the shallow waters for the 1952-1953 breeding season.
- All three tests (3 October 1952, 16 May 1956, 19 June 1956) can be assumed to have had a significant negative impact on the locally foraging populations of marine turtles within the Montebello Archipelago.

Following the closure of commercial harvesting in 1973, I would have expected the WA green turtle stock to commence its recovery mode. Given the generation time of decades for the species, I would have expected this recovery to be still in evidence. However, the census data from Northwest Cape (Figure 6) is not consistent with a turtle population in recovery.

Indigenous use: Coastal indigenous communities have regarded marine turtles as a significant resource and cultural icon since long before European colonisation (Figure 7).

Figure 7. Marine turtle representations in Aboriginal petroglyph art on basalt boulders, Dampier. Photo by Keith Morris.

Green turtles that breed at Western Australian rookeries continue to be harvested by most coastal indigenous communities from Shark Bay in Western Australia, throughout Arnhem Land and across the Gulf of Carpentaria to western Cape York Peninsula (Prince, 1994). Most of this harvest is poorly quantified. Morris and Lapwood (2002) recorded 96 green turtles, harvest biased to adult-sized females, during 4 months in October 2001 - January 2002. Morris (pers. comm.) expressed the opinion that the annual harvest for the Dampier Peninsula area could be about 500 turtles annually. Three partial clutches of green turtle eggs were harvested during this study period. The level of hunting reported in this study is an order of magnitude higher than that reported from the late 1970s (Kowarsky, 1982). In 1990, Dr Prince also expressed the opinion that the indigenous harvest in the Dampier Peninsula area was considerably larger than that reported by Kowarsky (Prince, 1994).

Prince (1988) identified that Torres Strait Islanders that had immigrated to the Pilbara Coast were actively involved in turtle hunting. This hunting by non-traditional residents appears to be continuing at an unquantified level.

Based on tag recoveries, the majority of the harvested green turtles in recent years that breed in Western Australia have been harvested outside of Western Australia in Northern Territory, Queensland and eastern Indonesia (Prince, 1994, 1998). Current indigenous harvest statistics are mostly poor to non-existent throughout this region (Hope and Smit, 1998; Kennett *et al.* 1998). However, there is a high probability that the combined harvest of the Western Australian green turtle stock from throughout western and northern Australia and beyond could be of the order of some thousands of turtles annually. Given the bias to hunt large immature and adult-sized turtles (Morris and Lapwood, 2002; Kennett *et al.* 1998), there is a high probability that this level of indigenous harvest exceeds sustainability for the Western Australian stock.

Add to the above the additional unquantified mortality from bycatch in trawling and other fisheries, from boat strike and ingestion of synthetic debris (including fishing line) broadly throughout the state, from fox predation of eggs and 4x4 vehicle damage to eggs on the Ningaloo Coast and from increased hatchling mortality associated with lighting disorientation near oil and gas production facilities.

Even though Western Australia supports one of the largest nesting populations of green turtles in the world, this stock is exposed to substantial unquantified losses from a broad range of anthropogenic activities. Strong concern should be held for the capacity to maintain this stock at its current high population level. A very large green turtle population is essential if a substantial harvest by indigenous people is to be maintained.

At Browse Island, breeding adult green turtles have been killed to obtain oviducal eggs (39 recently dead turtles on the beach in October 1999. Saunders, 1999). This unquantified illegal harvest has extended over at least several years. It is presumed that these turtles were killed by Indonesian fishers. If the Browse Island nesting population is a unique genetic stock or part of a small stock that breeds on offshore islands including Scott Reef, then this level of mortality is not sustainable in the long-term. On the other hand, if the Browse Island population is part of a very large, interbreeding Northwest Shelf green turtle stock, the impact of this mortality needs to be assessed along with the other mortality impacting this larger stock. I expect the former to be the case. Until there is evidence to the contrary, I would treat this loss of green turtles at Browse Island as unsustainable.

Increases in the incidence of green turtle fibropapilloma disease (GTFD) are generally regarded as related to human impacts on the coastal environment (Davidson, 2001). GTFD was first reported from Western Australian green turtles in 1996. L. Baird (pers. comm.) has recently recorded two additional cases at Broome. The occurrence of this disease warrants monitoring.

Loggerhead turtles:

Loggerhead turtles were not significantly targeted, if at all, during past commercial harvests for turtle meat and skin (Appendix 4). They also have never been identified as significant in any report on traditional harvests of turtles in Western Australia (Kowarsky, 1982; Morris and Lapwood, 2002).

Foxes have been active on the beaches of the Ningaloo Marine Park coast, including Cape Range National Park since the 1960s. In the absence of fox-control measures, foxes can destroy the vast majority of loggerhead turtle clutches laid on these beaches (Mann, 2000). The loggerhead turtle is the principal nesting species along much of the southern part of this coast with green turtles also occurring in abundance at the northern end. On many of these same beaches, there is regular vehicle traffic over nesting habitat (Mann, 2000). Vehicle traffic in nesting habitat can compact nests with resulting death of eggs. Deep tyre ruts (Figure 8) can trap hatchlings crossing the beach and expose them to increased predation by crabs and birds. In contrast, Western Australian loggerhead turtles that are nesting on the islands such as Dirk Hartog and Muiron Islands are not exposed to egg or hatchling losses from fox predation and compaction of nest sites by beach traffic.

Figure 8. 4x4 vehicle tracks on turtle nesting habitat of the southern Ningaloo Coast.

a. Bateman Bay **b. Janes Bay**

There is a high probability that the egg loss to foxes and vehicle traffic within this total complex of nesting beaches exceeds the sustainable level of loss for the western Australian loggerhead turtle population.

However, there is another significant biological dimension to these differences in incubation success. Marine turtles exhibit temperature dependent sex determination (Limpus *et al*. 1985). While the pivotal temperature has not been measured for the Western Australian loggerhead turtles it can be expected to be close to the 28.6^{o}C to 29.0^{o}C values measured in Queensland (Limpus *et al*. 1985) and eastern USA (Mrosovsky, 1988), respectively. Nest temperatures below the pivotal temperature will produce mostly or all males. Nest temperatures above the pivotal temperature will produce mostly or all females.

I do not have access to sand temperatures at nest depth (standardised at 50cm depth) from these loggerhead turtle rookeries during the nesting season. However, in early October 2002 there was a 2.7-3.7^{o}C temperature differential in sand temperatures at nest depth between Dirk Hartog Island (Turtle Beach: 24.2-24.3^{o}C) and the Ningaloo Coast (Bateman Bay: 28.0^{o}C. Surf Beach, Exmouth: 27.0^{o}C). I would expect this temperature differential to be maintained as the beaches warm up into the summer and if they are like other nesting areas that I have examined, the pivotal temperature for the species will lie between the temperature ranges available within its nesting distribution (Limpus *et al*. 1983). Therefore there is a high probability that the cooler beaches of Dirk Hartog Island produce predominantly male hatchlings and the warmer beaches of the Ningaloo coast produce predominantly female hatchlings. However, as seen above, the principal areas for egg mortality for loggerhead turtles are the beaches that are almost certainly the female producing beaches. Therefore the impact of the fox predation and vehicle traffic can be expected to be even more negative with respect to population dynamics than one would expect.

Add to this the additional unquantified mortality from bycatch in trawling, longline fisheries and entanglement in floatlines within the lobster fishery, from boat strike, even within Marine Parks and from increases in hatchling mortality associated with lighting disorientation near oil and gas production facilities.

Even though Western Australia supports one of the largest nesting populations of loggerhead turtles in the world, this stock is exposed to substantial unquantified losses from a broad range of anthropogenic activities, compounded by the possible impact of temperature dependent sex biased within the reduced hatchling production. Strong concern should be held for the capacity to maintain this stock at its current high population level.

Flatback turtles:

Flatback turtles were not targeted during past commercial harvests for turtle meat and skin (Appendix 4). Flatback turtles have not been identified as significant in any report on traditional turtle harvests in Western Australia (Kowarsky, 1982, Morris and Lapwood, 2002). However, harvesting flatback turtles and their eggs from the nesting beach appears to have been a feature specifically for the indigenous communities that inhabited the coast strip from Broome to the Pilbara Coast (Greenop, 1968) where flatback turtle nesting is abundant. Dr Prince and Karratha staff reported during interviews that in the Port Hedland to Mundabullangana area there has been an on-going harvest of flatback turtle eggs and to a lesser extent nesting flatback turtles by non-indigenous people and possibly indigenous folks. There are file records supporting this flatback egg and turtle harvest that date back to at least 1968 (DF&F file248/50: p.100). Prince (1994) expressed the opinion that flatback turtle eggs appeared to be an important resource for coastal indigenous people.

Reports from a number of staff indicated that foxes are active on the beaches in the Mundabullangana area of the Pilbara Coast. In the absence of fox-control measures, foxes reportedly destroy a large number of the flatback clutches laid here. Baiting is ongoing at some locations such as the coastal strip along Mundabullangana Station and appears to be locally successful in reducing clutch loss to foxes.

Dr Prince and Karratha staff reported that in the Port Hedland area there was regular disorientation of flatback turtle hatchling by street lights. It is expected that a good proportion of the disoriented hatchlings will be lost through increased bird and mammal predation and heat exhaustion come daylight. At Port Hedland, there was identified the added mortality factor of disoriented hatchlings being run over on roads.

Add to the above the unquantified mortality from bycatch in trawling and other fisheries, from boat strike and from increased hatchling mortality associated with lighting disorientation near oil and gas production facilities. Given that tag recovery data identifies that the Western Australian flatback stocks encompass foraging area to at least as far a field as north-western Arnhem Land (Prince, 1998), mortality beyond Western Australia must be considered. Many hundreds of flatback turtles were drowning annually in the Northern Prawn Fishery (Poiner and Harris, 1996) prior to the introduction of compulsory use of TEDs in April 2000 and an undetermined proportion of the mortality would have been from the Western Australian stocks. Flatback mortality in western Arnhem Land was also recorded from other trawl fisheries (Guinea *et al*. 1997); from inshore gill net fisheries (Guinea and Chatto, 1992) and from entanglement in discarded net and other debris (Chatto, 1994).

In the absence of good data on the size of the Western Australian nesting population for the flatback stocks and without reasonable quantification of egg loss and turtle loss from the populations, no reliable assessment can be made of the stability or otherwise of the stock. However, I have been left with the general impression that the Northwest Shelf flatback turtle stock could be functioning unsustainably. There was insufficient information for the western Arnhem Land stock, including Cape Domett, for me to form any impressions of its population function.

Hawksbill turtles:

It has been an on going surprise to me that there are so few records of hawksbill turtle harvest in Western Australia. This is particularly so given that hawksbill turtles have been targeted for extensive harvest and international trade of their scale (=tortoiseshell or bekko) during the late 1800s and early 1900s and then again from the 1950s until 1991. The Australian hawksbill turtle populations appear to have been largely excluded from these harvests and trade since World War II. The consequence of this is that Australia now supports what appears to be the last remaining large hawksbill nesting populations in the world.

Hawksbill turtles have not featured prominently in any reports of indigenous harvest of turtles and or their eggs in Western Australia.

The majority of hawksbill turtle nesting in Western Australia occurs on islands and is largely excluded from the impact of introduced predators. Because they feed primarily on reefs, hawksbill turtles have not featured commonly in trawl bycatch and inshore gillnet fishery bycatch.

The western Australian hawksbill nesting population occurs within the Western Australian coastal habitats with the greatest industrial development. The impacts through out the stock of altered light horizons on hatchling disorientation and associated mortality, on increased predation in adjacent waters, on possible reductions of the nesting population as females avoid illuminated nesting habitat are not being quantified. Similarly the impact of increased human populations on the islands through disturbance of nesting turtles, increased habitat disturbance on the islands and inshore marine habitats and the increased potential for boat strike are not being quantified. In addition, hawksbill nesting islands such as Rosemary and other islands in the Dampier Archipelago have holiday huts and are regularly used for bush camping. The impact of these activities on turtle reproductive success appears not to be monitored.

With the limitations of the available data, I am not in a position to judge the possible trends in the Western Australian hawksbill stock. As a precaution, I would recommend that there be a more concerted effort of collaboration between the oil and gas industry and the DCLM to focus on long term monitoring to judge the success of management of the regions turtle populations and to quantify the spatial and temporal distribution and size of hawksbill hatchling mortality and/or debilitation resulting from altered light horizons.

Leatherback turtles:

No comment can be made on the specific status of the leatherback population that migrates through Western Australian waters at this time. DCLM is encouraged to care for the welfare of these turtles in the same way that DCLM would like neighbouring countries to take good care of turtles that migrate into their waters from Western Australian stocks.

Dr Prince indicated that he has collated a comprehensive database on leatherback turtle mortality and is preparing a report on leatherback turtles in Western Australia that would include a review of fisheries bycatch for the species.

RECOMMENDATIONS

FUTURE DIRECTIONS (within constraints of current resources)

It is recommended that DCLM:

- Establish a small expert panel (Recovery Team) to determine priorities and direction for marine turtle conservation in Western Australia.

  The role of this team could be to develop a WA Turtle Management Plan that integrates with the Australian Draft Marine Turtle Recovery Plan and integrates with the Australian Government commitment to the Indian Ocean Southeast Asian MoU for regional marine turtle conservation.
- Makes a commitment to maintenance of the existing large, robust turtle populations of Western Australia.
- Focuses its marine turtle management to address threatening processes.
- Reconciles the need for whole of state management of marine turtles with the delivery of actions at the local management level. This is particularly relevant where district managers have responsibilities for addressing local "Reserve" issues.
- Engages in a partnership with the indigenous community for delivery of sustainable use of threatened species of wildlife such as marine turtles.
- Engages in a partnership with DOF and the fishing industry to minimise fisheries bycatch mortality to levels that do not contribute to population declines for the respective species.
- Engages in partnerships with academics and industry to plan, resource and implement focussed research and monitoring to provide results relevant to improving management of Western Australian marine turtle stocks.
- Plans for opportunities for interstate and international co-operation in management of their shared turtle resources.
- Establish a training / education program (probably at Exmouth) to train DCLM staff and volunteers about turtle biology, impacts and management techniques.

On the basis of the information provided to me during the review, I present the following conclusions as priority options for DCLM consideration with respect to marine turtle conservation planning:

1. **The four species of marine turtles known to nest in Western Australian are highly likely to be exposed to non-sustainable levels of mortality, each from a wide range of human related activities and warrant priority consideration for conservation action**.
   - For green turtles, the largest source of anthropogenic mortality currently comes from harvest by coastal people in Western Australia, Northern Territory and north-western Queensland in Australia and neighbouring eastern Indonesia.
   - For loggerhead turtles, the largest proportion of the mortality probably occurs on the mainland nesting beaches from fox predation of eggs and hatchlings, from vehicle traffic on beaches compacting nests and creating deep ruts that trap hatchlings with resulting increased mortality. This mortality is compounded by the high probability that these mainland beaches are the principal source of female hatchling for the stock. Fisheries bycatch remains

unquantified for the stock but given the serious negative impacts that fisheries bycatch have had on loggerhead populations elsewhere, concern should be had for the potential impact of fisheries impact on the Western Australian loggerhead stock.

- For flatback turtles, the Northwest Shelf stock is highly likely to be subjected to unsustainable losses on the mainland beaches of eggs from fox predation and human harvest and to a lesser extend of turtle harvest from the nesting beaches. There was insufficient data available to form an opinion on the status if the flatback turtle stock that breeds at Cape Domett.
- For hawksbill turtles, there was a general lack of quantified data on mortality for the species. The major nesting occurs within the most industralised part of the Western Australian coastal waters with highly modified light horizons from oil and gas installations, extensive shipping traffic and major port facilities. The altered light horizons are probably causing increased hatchling mortality and probably causing reductions in nesting density at illuminated beaches. Concern should be held for the stability of this globally significant hawksbill population.

For all the species there was a wide range of additional mortality sources identified that collective have the potential to significant increase the treat to each of the species.

2. **There is an inadequate information base on the size of nesting populations at individual rookeries and collectively for the stocks for guiding decisions. There are no reliable long-term census data for any of the stocks by which population trends can be gauged. The following actions are recommended:**
   - **Marine Turtle Atlas:** Over the course of several years, the Western Australian beaches should be surveyed to determine the size of the annual nesting population at each rookery in a systematic and standard way that allows for rigorous comparison between sites and years within a GIS compatible format.
     - Aerial survey at the peak of the nesting season with ground truthing at selected rookeries can be a cost effective method for surveying large areas of coastline.
     - Beach based surveys conducted as adjuncts to other studies can provide data to supplement the aerial survey results.
   - **Index beach monitoring sites**: Within each stock for a species or subregion within each stock, select at least one representative rookery for conducting a long-term annual census of the size of the annual nesting population.
     - Index beaches should be selected for logistical ease of deploying field teams across years and for being a manageable length that can be completely surveyed each night. Mainland sites are usually cheaper to service than island based sites.
     - Index nesting beaches do not need to support the largest nesting populations for the species but sample sizes need to be robust. An annual nesting population of a few hundred females within the survey area is very workable.
     - The most comprehensive census method is the **total tagging census**, in which every turtle is tagged for every night of the several months of the entire nesting season. This however is usually very labour intensive and expensive.

A more cost effective census is a **two-week tagging census** in which every turtle is tagged during two weeks at the peak of the nesting season for the species. As long as the same nesting area is sampled for the same two week period each year, this census provides an effective index of the between seasonal variation in nesting populations. Two weeks is selected as the minimum interval because it equates to approximately one renesting cycle. During two weeks at the peak of the nesting season, between 60-80% of the annual nesting population should be encountered.

Track count census can also be used to provide an index of the size of the annual nesting populations. Again the census should be conducted over the same standard length of beach each year and at the same standard sampling dates (e.g. two weeks at high density nesting time). In a track census, turtle tracks can be counted at daylight to determine the number of each species that came ashore during the previous night for each species. Track census does not provide the contact with large numbers of turtles if the goal is also to tag a large number of turtles.

It is recommended that annual census monitoring continue for as long as there are management problems for the species.

Where resources permit, replicate census sites within the same stock are recommended.

These census monitoring tasks are well suited to community participation to provide the field labour force and extend community ownership of the conservation issues.

In conjunction with tagging census studies, measurement of the size of each nesting turtle provides an additional dimension to the annual variation in the population.

The results from these census studies are suitable for reporting in annual reviews of the state of the environment in Western Australia.

3. **There is a need to monitoring marine turtle mortality species to identify the temporal and spatial distribution of anthropogenic sources of mortality.** The following actions are recommended:
    - Establish a Marine Turtle Stranding and Mortality Database for Western Australia.

      This database can be linked to the existing marine mammal stranding database.

      Veterinarians are needed to participate in the project to determine cause of death, particularly from disease.

      The public needs to be encouraged to participate to increase the coverage of the coastline.

      The database should be GIS compatible and include information on the date, species, sex and size of the turtle; cause of death and location including latitude and longitude.

      Turtle mortality from as many sources as possible should be included into the database. I would recommend that negotiations be undertaken to include data from fisheries bycatch and indigenous hunting.

Migration tag recovery data needs to be integrated to provide a link between stocks and mortality sources.

These data need to be collated, analysed and reported at regular intervals. Annual reports are recommended.

- In partnership within indigenous communities in Western Australia, Northern Territory and Gulf of Carpentaria, quantify spatially and temporally the harvest of marine turtles and their eggs.

  The harvest of turtles should be quantified by species, size, sex and maturity.

  Using genetic analysis, analyse tissue samples to identify the contribution of the Western Australian stocks to these harvests. Dr Nancy FitzSimmons, Canberra University, is the most experience marine turtle geneticist in Australia.
- DOF has a responsibility to ensure that mortality for fisheries bycatch is being reliably monitored through its various fisheries action plans. These data need to be communicated directly with DCLM. DCLM and DOF in partnership should address the need for reduction in bycatch mortality.

4. **There is an urgent need to manage the mainland loggerhead and flatback turtle nesting beaches to ensure that hatchling production is maintained at sustainable levels. The following actions are recommended:**

Substantially reduce fox predation of turtle eggs on mainland nesting beaches**:**

- The priority areas would be the loggerhead and flatback nesting beaches of the Ningaloo Coast and Pilbara Coast.
- Protection of individual nests with "mesh screens or cages" or "stick teepees" can be effective for protecting those nests found. However, if the majority of clutches are to be protected, these types of individual clutch protection require persons to be on the beach nightly through out the months of the breeding season on multiple beaches. This is not a cost effective method for protecting the majority of clutches in the region.
- Baiting for foxes can provide for more cost effective beach wide and season wide reduction in eggs loss where authority or permission to conduct baiting programs is available.
- The goal should be to have clutch loss from foxes approach zero level for all rookeries for the respective stocks.

Minimise the movement of vehicle traffic by day and night along turtle nesting beaches.

Where possible have vehicles move along the coast on tracks behind the frontal dunes and provide pedestrian access points adjacent to areas of public interest.

Where vehicle traffic is considered necessary on the nesting beaches, it should be restricted to below the high tide level.

To address the significance of egg loss on the mainland loggerhead nesting beaches, **determine the sex ratio of loggerhead turtles hatchling production** at Dirk Hartog Island, the mainland beaches of the Ningaloo Coast and Muiron Island

- Quantify the pivotal temperature for WA loggerhead eggs using laboratory controlled temperature incubation experiments.
- Quantify sand temperatures at nest depth within the nesting habitat at representative rookeries within Dirk Hartog Island, the mainland beaches of the Ningaloo Coast and Muiron Island. Deployment of temperature dataloggers is the most cost effective method for gathering these data.
- Using a sampling protocol of 10 hatchling per clutch, quantify the sex ratio of representative clutches from through out the season from the representative rookeries in Shark Bay and on the Ningaloo Coast.
- Quantify the total number of clutches laid and the total hatchling production at the representative beaches and hence estimate the proportion female hatchlings coming from the various beaches.

With these data, a more informed decision can be made on the need for concerted clutch protection with respect to loggerhead turtle conservation.

5. **If green turtles are to be managed for sustainable harvest in the context of indigenous harvest**, then a great depth of demographic data is required for the modelling population dynamics to investigate potential impacts of management options. **If loggerhead turtles are losing appreciable numbers to fisheries bycatch**, then demographic modelling may be needed to assist in management planning. There is a dearth of demographic data that would be needed if modelling of population dynamics for any of the stocks were to be attempted. To obtain the necessary key demographic, two types of research studies are required to be conducted in parallel.
   - **Nesting beach tagging-recapture studies** to quantify particularly the number of clutches per female per season and the remigration interval. These data require a tagging census:
     - **Number of clutches per female per season**: Requires a total tagging census for an entire breeding season. This parameter need not be measured annually. In the first instance, it could be measured for a single season.
     - **Remigration interval**: Requires intense tagging activity (minimum recommended would be a two week mid-season tagging census) across many years (minimum recommended of two mean remigration interval duration or ~10yr).
     - Other parameters measured at the nesting beach such as size of nesting female, eggs per clutch and renesting interval have very little impact in changing the outcomes of the population modelling.
   - **Foraging area tagging-recapture studies:** Optimal results will be derived from studies that include tagging, length measurement of the turtle and gonad examination using laparoscopy to determine sex and maturity. Results should include:
     - Quantified size class composition of the foraging population, sex ratio, maturity ratio by sex, and proportion of the adult population that breeds each year for each sex.
     - Successive years of tagging-recapture, will provide growth data for analysis by sex and maturity.

With a minimum of 4 years of consecutive tagging-recapture data, a rigorous analysis can provide quantified annual survivorship and recruitment data by sex and maturity status.

The tagging-recapture study needs to be conducted within the same foraging area over a minimum of 4 years.

Sample sizes ideally should be several hundred individuals in each annual sample or at least 30% of the resident population if population sizes a small.

Study sites should be chosen on logistical ease of access and capture and processing of turtles as well as availability of adequate numbers of catchable turtles.

- **Replicate study sites** for the species are essential for the foraging area studies.
- **Dr Gerald Kuchling**, University of Western Australia, has expressed interest in collaborating in marine turtle research and monitoring studies in foraging areas demography. He has considerable skills with respect to the relevant techniques of endoscopy and ultrasound imaging. He is qualified to teach the use of these techniques and is interested in supervision of post-graduate students working in this field.
- Queensland Parks and Wildlife Service can assist with training of personnel in methodologies for these types of studies.
- Modelling of these data needs to be undertaken by a skilled modeller.
- Shark Bay would appear to be a potential site in the south for developing demographic studies in foraging areas for green and loggerhead turtles.

6. **Because the broader Dampier Archipelago region is of major significance for hawksbill turtles and because the same area is also a major oil and gas production and processing area, priority should be given to managing the region to maintain large populations of hawksbill turtles.**
    - While strong concerns are held for the future of these hawksbill turtles, there are uncertainties regarding the scale and the significance of the impacts of these major industrial developments on sustainability of the hawksbill turtle populations.
    - Of particular concern, is the impact of the region-wide alteration of light horizons, not just on individual nesting beaches, and its impact on hatchling dispersal and survival and on the continued maintenance of adult nesting populations.
    - DCLM is encouraged to form partnerships with the Petroleum Industry to plan, resource and deliver effective research and monitoring projects to enhance management capacity for maintaining this important turtle stock at high population levels.

The disorientation of hatchlings turtles on beaches and at sea should be quantified spatially and temporally in a GIS compatible format.

The industry should be strongly encouraged to find methods for substantially reducing light pollution to the region. This will require a significant input from electrical engineers and workplace health and safety officers.

Beach census monitoring programs need to be implemented within and outside the light polluted areas to assess the long-term impact of altered light horizons over the nesting beaches on the adult female nesting population.

7. **To determine the effectiveness of management decisions, monitor projects should be implanted that address the specific management actions**: For example,
    - At rookeries with high density tourist visitation, monitor the impact of human activity on nesting success and nesting beach fidelity.

      Using a nightly tagging-recapture study, quantify nesting success of adult females and quantify the extent to which adult females move away to breed at adjacent rookeries.
    - At beaches with altered light horizons, monitor the proportion of hatchling that fail to make it successfully to sea, mapping the distribution of the events temporally and spatially.
    - At beaches with fox control programs, quantify the proportion of clutches being preyed on by foxes and other predators.

DCLM coordination of a statewide marine turtle conservation field program
It was apparent during the review that district staff have a significant role to play in the monitoring of turtle resources in their area and in the deployment of volunteers teams within their districts. They wished to be an integral part of the program. However, it was equally apparent that there needs to be a DCLM officer who has explicit responsibility for:

- Maintaining an integrated overview and summary of turtle conservation actions through out Western Australia.
- Ensuring that standard methodology for conducting the studies are available, defined and applied in the field.
- Ensuring that tags are available for use by field teams.
- Working in collaboration with district staff and field teams to validate the quality of the data and facilitate its entry to the statewide marine turtle database.
- Working in collaboration with district staff and field teams to ensure that timely and rigorous reports are produced from the field studies.

  I would encourage the involvement of the field teams in analysis and preparation of reports wherever possible. This will increase their understanding of the work and increase their ownership of results.
- Collating the results from the field team reports into a state wide annual report to senior management and the Recovery Team.
- Working in collaboration with district staff and field teams to ensure that a review of each long-term monitoring study is completed at about 5yr intervals. These reviews should include a reassessment of methodology and a comprehensive analysis of all data from the site. Where possible these reviews should be published with peer review. In some instances, it will be more appropriate to aggregate reporting from multiple sites to form a comprehensive report for the stock as a whole.

It is recommended that DCLM be proactive in seeking out skilled academics to undertake marine turtle research and monitoring projects that DCLM recognises as significant and which are outside the scope of present staff. Within these studies:

- DCLM can facilitate permits and access to specific key study sites.
- With forward planning, universities may be able to partly resource the studies through the Universities grants system.
- With co-supervision of postgraduate students, quality research can be delivered that is beneficial to both institutions.
- As major stakeholders in sustainable development within the major marine turtle habitat, the petroleum industry should be encouraged to be an integral partner within these partnerships.

Data from these studies needs to be reported into the state wide marine turtle database as well as to the relevant regional and district staff.

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APPENDIX 1.

WA MARINE TURTLE REVIEW

Terms of Reference for Dr Col Limpus

October 2002

1. To examine and review the previous and current marine turtle management and research activities in WA.

2. Specific issues to be addressed are:

   a. Nesting and feeding site distribution.
   b. Adequacy of current tagging program.
   c. Tagging database structure and management
   d. Modelling of population trends.
   e. Other monitoring programs, including community monitoring.
   f. Guidelines for tourist interactions and commercial operators.
   g. Impact of indigenous harvest.
   h. Impact of fisheries by-catch and net entanglements.
   i. Impact of lighting.
   j. Impact of nest /hatchling predation.
   k. Petroleum industry support
   l. Need for WA turtle management plan.

3. Provide expert advice on future directions within the constraints of current resources.

4. Provide a report to DCLM within 6 weeks, by 29 November, 2002.

APPENDIX 2.

WA MARINE TURTLE REVIEW

Itinerary

Wednesday 2 October	Col Limpus departs Brisbane 0920, arr Perth 1245, check into Pagoda Broadwater Motel. Meet with Neil Burrows (Director of Science) 1430.
Thursday 3 October	0900 Meet with Gordon Wyre (Director Nature Conservation), Peter Mawson (Wildlife Branch), Chris Simpson, Kevin Bancroft (Marine Conservation Bch), Col Ingram (Parks and Visitor Services) (or nominees) at Crawley (Acacia room). 1400 meet with Eve Bunbury and Victoria Slowik (Fisheries WA) at DCLM, Hackett Drive, Crawley.
Friday 4 October	0900 Meet with Kellie Pendoley (Murdoch PhD student / marine consultant to petroleum industry) at Kensington. Meet with MCB at Fremantle.
Weekend -	At leisure, visit/discussions with: Saturday: Dr Gerard Kuchling, University of Western Australia. Sunday: Dr Bob Prince, DCLM.
Monday 7 October	Depart Perth 1000 arr Denham 1225 (Skywest), board "James Scheerer" and depart for Dirk Hartog Is / Turtle Bay (Loggerhead rookery), overnight on board.
Tuesday 8 October	Dirk Hartog Is – Denham via Peron Peninsula.
Wednesday 9 October	Depart Denham 1200, arr Exmouth 1305 (Skywest), meet with District staff.
Thursday 10 October	Exmouth – Coral Bay (Loggerheads, tourists)– Exmouth (Jurabi coast interp centre etc), evening public lecture "The Mon Repos Turtle Program".
Friday 11 October	Depart Exmouth 0900 for Karratha (aerial charter via Barrow Island, Montebellos) 1300 meet with Pilbara Region staff. Evening public lecture "The Mon Repos Turtle Program"
Saturday 12 October	Dampier Archipelago by boat (Rosemary Is hawksbill rookery)
Sunday 13 October	Mundabullangana, Port Hedland, return to Karratha. Depart Karratha 1700 arr Perth 1900 (Qantas)

Monday 14 October	Library work and discussions with Dr Andrew Burbidge.
Tuesday 15 October	1215 Lunch time seminar at Kensington. 1430 Meet with petroleum industry reps Stephan Fritz (Chevron), Libby Howitt (Apache) and Greg Oliver (Woodside) at DCLM Kensington.
Wednesday 16 October	Col Limpus departs Perth 0905, arr Brisbane 1710, via Melbourne.

APPENDIX 3

MARINE TURTLES: GENERALISED LIFE HISTORY

Colin J. Limpus,
Queensland Turtle Research, Australia

Life cycle:
Seven species of marine turtles are well recognised worldwide and five species have a global distribution in tropical and temperate waters. Two species have a restricted distribution: the flatback turtle is confined to the waters of the Australian continental shelf while the kemps ridley turtle occurs in the Gulf of Mexico and the north-western Atlantic Ocean. While some aspects of the nesting biology have been understood for centuries, since 1980 there have been major advances in many other aspects of marine turtle biology: stock identification with population genetics; temperature dependent sex determination; geomagnetic imprinting of hatchlings to the area of their birth; oceanic dispersal of post hatchlings; extended life to first breeding; fidelity of adult turtles to both their feeding and nesting areas; migratory dispersal of adults and population modelling.

Marine turtles have many common features in their life cycles that are summarised in Figure 1.

Marine turtles utilise feeding grounds often far removed from the nesting beaches. With the onset of the breeding season adult males and females migrate to copulate near the nesting area. There is no pair bond between individuals and copulation may occur with several different partners during the mating season. At courtship the female stores the sperm from her mate(s) for use later in the breeding season. At the completion of mating the males depart, presumably returning to the distant feeding grounds. Each female moves to an area adjacent to her selected nesting beach and commences making eggs, fertilising them from her sperm store. Because of the mixture of sperm she carries, several males may contribute to the fertilisation of any one clutch. The female comes ashore, usually at night, to nest several weeks after her first mating. For those beaches fronted by reef flats, nesting coincides with the higher tidal levels. Within the one nesting season each female typically lays several clutches at about two-week intervals. During that two-week period she does not need to find a new mate, she moves just offshore from the nesting beach to make the next clutch of eggs, again fertilising them from her sperm store. The breeding turtles do not feed, or else feed to only a limited extent, while migrating, courting or making eggs at the nesting beach area. They live off the stored fat reserves they accumulated before the breeding season began.

Each female usually chooses to return to the same beach or island to lay several clutches within the one nesting season. However, several percent of females can be expected to lay on more than one beach within a few hundred kilometres of the initial nesting site. At the completion of the nesting season the females do not use the adjacent shallow water habitats as year round feeding grounds but return to their respective distant feeding grounds, each to the same area that she left at the start of her breeding migration. After two to eight years many of these females will make yet another breeding migration, each generally returning to nest on the same beach as before. This behaviour and the annual use of traditional nesting beaches have led to the assumption that a marine turtle returns to nest on the precise beach of her birth. In reality the homing is probably not that exact. Genetic studies suggest that the female returns to breed in the general region of her birth. For example, a turtle born in the southern Great Barrier Reef, when it grows up, should return to breed in the southern Great Barrier Reef or a turtle born in the Hawaiian Islands should return to breed in the Hawaiian Islands..

Females lay their eggs high up on the beach usually within the vegetated strand. No parental care is exercised. The incubation period, incubation success and the sex of the resulting hatchlings are a function of the temperature of the surrounding sand. A warm nest at mid incubation results in all or mostly female hatchlings while males come from cool nests. The eggs hatch about 7 - 12 weeks after laying (Miller 1985). The hatchling turtles dig their way unaided and as a group through the 50 cm or more of sand to the surface. On surfacing they immediately cross the beach to the sea. This hatchling emergence is almost entirely nocturnal. During the beach crossing they orient towards low elevation bright horizons. The hatchlings are imprinted to the dip and strength of the earth’s magnetic field at the beach. For most turtle rookeries only a small percentage of hatchlings is lost to terrestrial predators during the beach crossing. Immediately the hatchlings reach the water they begin oriented swimming into the wave fronts that takes them away from the beach and into deep water. The hatchling at this stage is living off a yolksac internalised just prior to hatching. Hatchlings do not feed while on the beach or while swimming out to sea. In coral reef areas when the hatchlings are crossing the reef flat, they are probably exposed to the greatest level of depredation during their life cycle. This is a period of transfer to predatory fish of nutrients derived from adult turtles via eggs and hatchlings. For all except flatback turtles, the hatchlings, on reaching the deep water areas, continue to swim out to sea and this activity presumably brings them under the influence of the open ocean currents where they drift for the first few years of their lives. The post-hatchling flatback turtles remain over the continental shelf. Post-hatchling turtles do not feed nor take up residence in the vicinity of where they were born.

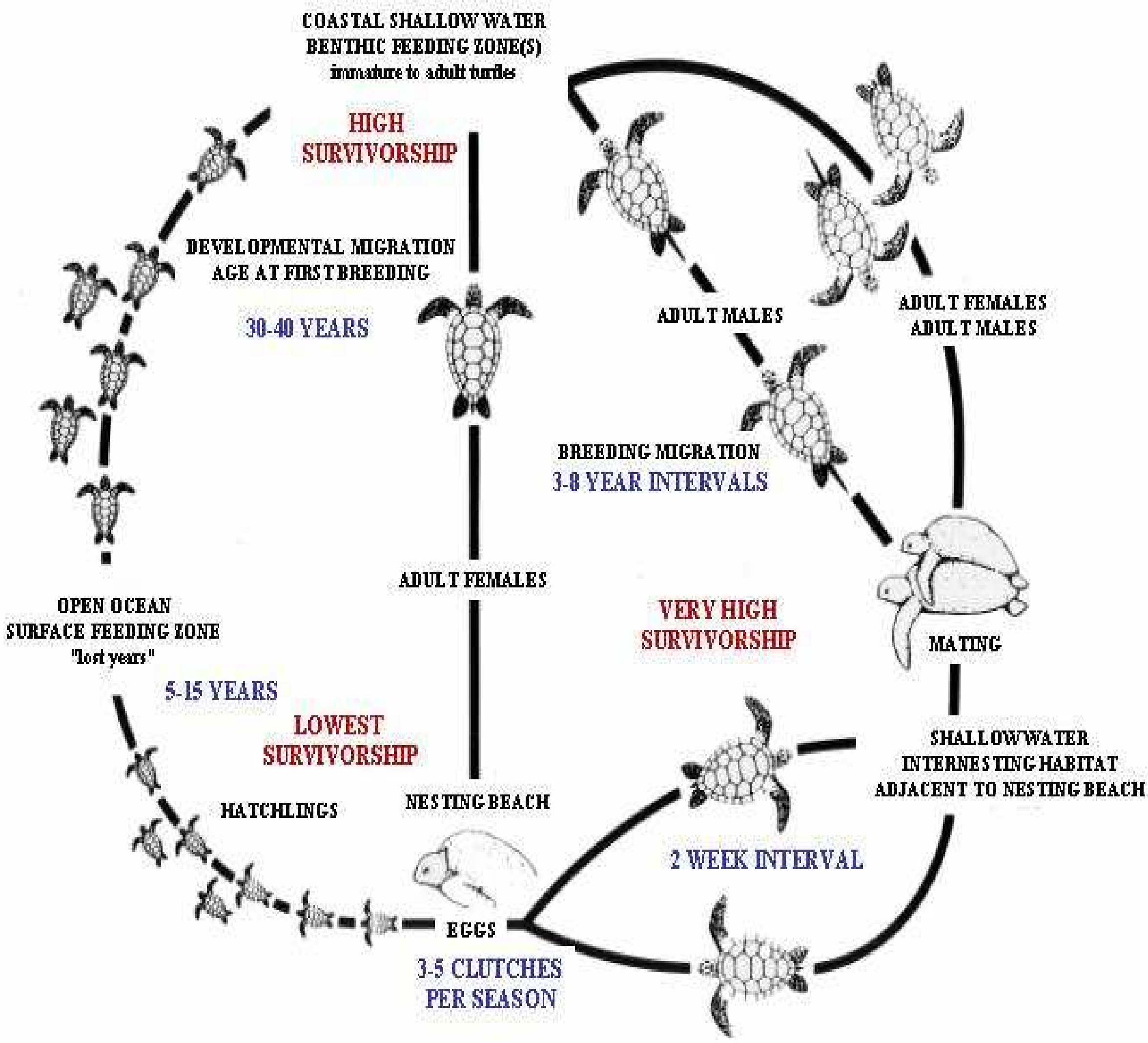
When the hatchlings disperse from the nesting beach they are virtually lost to study for the next few years. While in this drifting phase the turtles presumably feed on the macro-planktonic animals and/or algae at the surface. The young of all marine turtles except the leatherback turtle 'reappear' at about the size of a large dinner plate (curved carapace length 35-40 cm, age undetermined but possibly 5-10 yr old). Loggerheads recruit at a larger size, >70cm in carapace length. At this size they take up residence in the shallow water habitats of the continental shelf, feeding principally at the bottom on plants and animals depending on the turtle species. Green turtles feed mostly on seaweed, seagrass, and mangrove fruits. Loggerhead turtles feed mostly on shellfish and crabs. Flatback turtles feed mostly on soft corals and sea pens. Olive ridley turtles feed mostly on small species of crab and shellfish. Hawksbill turtles feed mostly on sponges and seaweeds. These turtles will also eat jellyfish and Portuguese man-of-war on occasions. These immature turtles may remain in the one feeding ground for extended periods, perhaps years, before moving to another major area. Several such shifts may occur in the life of the turtle in this coastal shallow water benthic-feeding phase. The offspring of a particular female will not all recruit to the same feeding area but are expected to recruit throughout the entire region occupied by the breeding unit. The leatherback turtle, which remains an inhabitant of oceanic waters for almost all its life, feeds mostly on jellyfish.

Tagging studies of turtles living within the Great Barrier Reef show that they are many decades old at first breeding and can have a breeding life spanning many more decades. At no stage in their life are sea turtles free of depredation. The young to adult sized turtles are potential prey to large cod, grouper, sharks, crocodiles, and killer whales. However in Australia and the neighbouring countries of South East Asia and the western Pacific Ocean, human actions continue to be the most significant threat to survival of our marine turtles.

Studies in the Great Barrier Reef indicate that marine turtles have very high annual survivorship throughout their lives in the absence of human impacts. This high annual survivorship appears to be essential for marine turtles to maintain population stability. Small increases in annual mortality over extended periods at any stage of the life cycle can be expected to cause population declines.

Green and olive ridley turtles have been harvested in large numbers especially for meat. The hawksbill turtle has been hunted excessively for tortoiseshell. All species are hunted for leather, oil and their eggs. Incidental capture in fishing gear can also cause significant mortalities of marine turtles, especially in prawn trawls, drift-nets, large mesh set-nets and long-lines. Terrestrial predators such as pigs, foxes, dogs and varanid lizards can cause the excessive loss of turtle eggs. In some areas, ingestion of plastic and other debris has been identified as a significant cause of mortality. Boat strikes are common in shallow areas with high density boating activity. Wherever there has been organised large-scale harvesting or killing of the turtles and/or their eggs over several decades, the turtle population has undergone significant decline. No one has ever successfully managed marine turtles at stable population levels while subjecting them to large-scale mortalities.

Figure 1. Generalised marine turtle life cycle



APPENDIX 4.

TURTLE HARVEST IN WESTERN AUSTRALIA

I have not attempted a comprehensive literature search on this subject for Western Australia. However, the following indicates a protracted and extensive harvesting, especially of green turtles, has occurred in the State.

Prior to European settlement, Macassan fishermen travelled out of Indonesia onto the Kimberley Coast (MacKnight, 1976) and possibly as far south as the Pilbara Coast (Stokes, 1846). Any hawksbill turtles that they encountered would have been harvested for tortoiseshell. This fishery ceased in about 1900.

Early European explorers and navigators sought marine turtles wherever they could be encountered as a significant source of fresh meat. Live turtles could be carried beyond the capture point without the need to provide food and freshwater for the turtle to survive for extended periods. For example:

- Dampier, during his visits to Western Australia in 1688 and 1689, regularly recorded and harvested marine turtles (Masefield, 1906).
- Stokes (1846) took 30 large turtles, presumably greens, and 1 small hawksbill turtle from the reef flat at South Turtle Isle near Port Hedland in July 1840. Later that year in August he recorded taking 7 tons of turtle from Barrow Island. If these were breeding green turtles, this would equate to approximate 70 adult turtles. Stokes can also be credited with the first "trading" of turtles within Western Australia: p.211 - "Many of them (turtles) we gave to our friends at Swan River on our arrival."

Commercial exploitation of Western Australian turtles was operational by at least the 1930s onward:

- A turtle soup factory was established at Cossack in about 1931 by Monte Bello Sea Products Ltd (Douglas, 2000) and supposedly processed turtles caught in the Monte Bello Islands. Caldwell (1951) describes some of the operations of this cannery. His photographs show numerous large immature to adult-sized green turtles being hand-captured on reefs adjacent to Flying Foam Islands and transported to and held in an inter-tidal pen. 50 turtles per week were reported being processed at that time. While I could find no indication of the longevity of the cannery operation, these data are indicative of a possible harvest of some 2500 large green turtles annually. The Exclusive License for taking turtle by the "Australian Canning Co Ltd" at Cossack was cancelled on 18 November 1936 for non payment of license fees (DF&F file248/50).
- Wood (1940) reported that "a turtle soup cannery is in operation in Perth, working on turtles brought from the north west coast".
- 1950s: A turtle harvest to supply to a turtle cannery at Cossack was recommenced (DF&F file248/50: 18 April 1950). R. V. Randal advocated more controlled turtle harvesting to avoid mistakes of over harvests in other countries (DF&F file248/50: 17 Jan 1951).
- 1960s: Last 2 licenses (Tropical traders Ltd and West Coast Traders Pty Ltd) operated at Maud point and N.W. Cape and out to 3 mile offshore and were issued for the capture of turtles in the sea. See Table 1 for a summary of

available harvest statistics. Some reports indicate that some of the turtles were taken from the nesting beaches at that time.

- 1962: WA Meat Export Works was holding 5 ton of turtle eggs for sale (DF&F file248/50: 18 April 1962; Daily News 24 April 1962). This weight was estimated to contain ~128,000 eggs. Based on this number of eggs in 5 tons, they would have been mostly green turtle eggs. This many eggs would have been equivalent to about 1200 clutches, which would have been equivalent to the annual egg production of some 240 females. There was also "4 ton of red and green turtle meat" in storage along with the eggs. "red" turtle could indicate that loggerhead (= Indian Ocean red-brown) turtles as well as green turtles were being harvested at this time. This meat was dumped to make room for a consignment of salted turtle skins.
- 1968: Export of wet-salted turtle flipper skins to presumably Japan and probably Europe is implied to be an established export from Western Australia (DF&F file248/50: 9 Oct 1968).
- 1968: Turtles and turtle eggs were also being harvested for sale in unspecified amounts from the beaches near Port Headland (DF&F file248/50: p.100).
- 1970-1972: Cassidy (1998) was contracted to capture turtles by Tropical Traders who were licensed by WA Fisheries. He was of the opinion that a second license operated out of Onslow at the same time. Cassidy reported that his fishing accounted for some 10,000 large green turtles (>120lb dressed weight) harvested during 3 years, 1970-1972, from the Ningaloo Coast (40 mile lease running northward from Maud Point). Cassidy was specific that he did not catch small turtles. A minimum dressed weight of about 120lb would translate to turtles of about 90kg and above (= large immature and adult turtles) being taken. He was harvesting these large green turtles in the waters adjacent to nesting beaches during July-October. Cassidy reported convincingly that few green turtles were harvested from on the nesting beach. However, it is inevitable that they would have been harvesting not only the locally resident foraging green turtles but also breeding migrants aggregated for courtship along the Maud Point area coast as well as internesting adult females as they were preparing eggs for laying in their respective seasons.

- 1973, 30 June: No renewal of turtle harvesting licenses in Western Australia. This marks the end of commercial harvests of turtles in Western Australia.

The turtle skin trade that operated during the 1960s and early 1970s would have been in response to the demand within European and Japanese markets for high quality reptile skin for the luxury leather trade. Marine turtle skin was found to be a suitable substitute from the then scarce high quality crocodilian skins. The skins exported from Western Australia were almost certainly a by-product from the turtles that were harvested for meat.

Based on the incomplete data available from the commercial turtle harvest during 1960-1972, it is evident that many thousands of adult and near adult green turtles were harvested annually.

The loggerhead turtles were considered to be of little or no commercial value during the early 1950s (R. Randal in DF&F file248/50: 17 Jan 1951) and early 1970s

(Cassidy, 1998). In the early 1950s, loggerhead turtles were considered to be a nuisance by some folks because of their negative impact on the more valuable species (R. Randal in DF&F file248/50: 17 Jan 1951).

Turtle farming

- 1970s: The Bardi Community at One Arm Point participated in the turtle farming venture initiated by Dr H. R. Bustard of Applied Ecology Limited in the early 1970s and continued by Applied Ecology Pty Ltd (Carr and Main, 1973). Eggs gathered from Lacepede Island were incubated to provide turtles for captive rearing. This farming venture ceased, presumably on economic grounds, in the early to mid 1970s.

Table 1. Turtle harvest data from Western Australia

Year	**West Coast Traders Block 2113**			**Tropical Traders Block 2213**			**Whole of WA**			**Reference**
	Turtles	**Live weight (lb)**	**Dressed wt Export wt (lb)**	**turtles**	**Live weight (lb)**	**Dressed wt Export wt (lb)**	**turtles**	**Live weight (lb)**	**Dressed wt Export wt (lb)**	
1962								90,628		DF&F file.P71
1963								214,523		DF&F file.P71
1964	2001	400200		2430	349390		4431	749,590 or 869,632		DF&F file.P54 DF&F file.P71
1965								800,600 or 427,000		DF&F file.P71 DF&F file.P151
1966								357,454		DF&F file.P151
1967								509,510	299,030	DF&F file.P151 Anon, 1969
1968								744,483	362,027	DF&F file.P151 Anon, 1969
1969								633,445	356,241	DF&F file.P151
1970				Estimated 3000-4000 turtles/yr					398,139	Cassidy, 1998
1971									264,096	Cassidy, 1998
1972										Cassidy, 1998