A BIOLOGICAL REVIEW OF AUSTRALIAN MARINE TURTLES.

5. FLATBACK TURTLE *Natator depressus* (Garman)

Colin J. Limpus
Freshwater and Marine Sciences Unit
Environmental Sciences Division

Queensland Government
Environmental Protection Agency

Cover photographs: Clockwise from top left: nesting female *Natator depressus*, Crab Island; nesting turtle tracks Western beach of Crab Island, July 1999; *Natator depressus* hatchling, Mon Repos; adult *Natator depressus* among trawl bycatch (Northern Prawn Fishery), before compulsory use of TEDs (photograph by Ian Stapleton).

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Author: Dr Col Limpus[1]*
Editor: Leisa Fien
Peer reviewers: Dr Mick Guinea[2] and Dr John Parmenter[3]

[1] Queensland Environmental Protection Agency.
[2] Charles Darwin University
[3] Central Queensland University

***Corresponding author**
Phone: 61 7 3227 7718
Fax: 61 7 3247 5966
Email: Col.Limpus@epa.qld.gov.au

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PREFACE

This review of the locally endemic flatback turtle provides the first comprehensive collation of biological data for the species. While peer reviewed scientific publications are the most significant source of information for the species, there is a large body of additional information available from many other sources within Australia. In particular, I have drawn together data contained in many unpublished reports on file in various government and non-government agencies. In addition, relevant information has been obtained from newspaper reports and from books and journals describing the early exploration and natural history of Australia. The review provides a comprehensive summary of information available up to August 2004.

To provide a more comprehensive summary of available information, previously unpublished data drawn from the Queensland Environmental Protection Agency (EPA) Turtle Conservation Project database have been summarised and included. These data are a collation of the results of private research undertaken by myself since 1968 and turtle research undertaken by EPA staff and trained volunteers within foraging and nesting populations in Queensland and adjacent areas within Australia and neighbouring countries.

My understanding of sea turtle biology has been greatly enhanced through collaborative studies with Dr John Parmenter, Dr Craig Moritz, Dr David Owens and Dr Joan Whittier and their respective post-graduate students.

Many folks have assisted in the preparation of this review both directly and indirectly. I am particularly indebted to the assistance and support that I received from Queensland Parks and Wildlife Service staff, in particular Dr Jeff Miller and Duncan Limpus and others who worked in our field studies: Barry Lyon, David Walters, Valonna Baker, Annette Fleay, Phillip Read, Emma Gyuris, Darryl Reimer, Mark Deacon, Ian Bell, Cathy Gatley and John Meech. Keith Morris, Dr Bob Prince and Kelly Pendoley provided guidance regarding turtles in Western Australia. Dr Mick Guinea, Scott Whiting, Ray Chatto and Dr Rod Kennett assisted with information regarding turtles in the Northern Territory.

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Colin J. Limpus
November 2007

A BIOLOGICAL REVIEW OF AUSTRALIAN MARINE TURTLES

FLATBACK TURTLE *Natator depressus* (Garman)

1. THE SPECIES

1.1 TAXONOMY

Flatback turtle

CLASS:	REPTILIA
ORDER:	TESTUDINES
FAMILY:	CHELONIIDAE
SPECIES:	*Natator depressus* (Garman, 1880).

There is one species for the genus and no subspecies have been described (Figure 1. Limpus *et al.* 1988; Zangerl *et al.* 1988). A search for information on this species should take into account that until recently this species had been identified as *Chelonia japonica* and *Chelonia depressa*.

1a. Nesting female, Crab Island

1b. Hatchling, Mon Repos

1c. Post-hatchling, Forster, New South Wales

1d. Immature turtle in trawl bycatch

Figure 1. *Natator depressus* from eastern and northern Australia

1.2 GLOBAL DISTRIBUTION

The monospecific genus *Natator* has a restricted distribution. It is one of only two marine turtles not having a global distribution. *Natator* has no recorded fossil history. All recorded nesting beaches are in Australia (Limpus *et al.* 1988). The species feeds widely through the waters over the Australian continental shelf to as far north as the Gulf of Papua in Papua New Guinea (Spring, 1982) and coastal waters of Papua in Indonesia. (Samertian and Noija, 1994). Outside the Australian continental shelf, the species has been recorded from the coastal waters of Kei, eastern Indonesia (Suarez, 2000). In addition, the author has examined photographs of two stuffed *N. depressus* from eastern and central Indonesia but there was no precise collection data for these specimens. In global distribution, *N. depressus* approximates to being endemic to the Australian continental shelf.

1.3 IDENTIFICATION

Typically, the species has non-imbricate (= non-overlapping) scutes on the carapace, four pairs of costal scutes, one pair of prefrontal scutes and one preoccular scute between each eye and adjacent nostril. It has four enlarged inframarginal scutes on the bridge, and no large inframarginal pores within the inframarginal scutes (Cogger, 1992; Limpus, 1971a, 1992a; Limpus *et al.* 1988) (Figure 2).

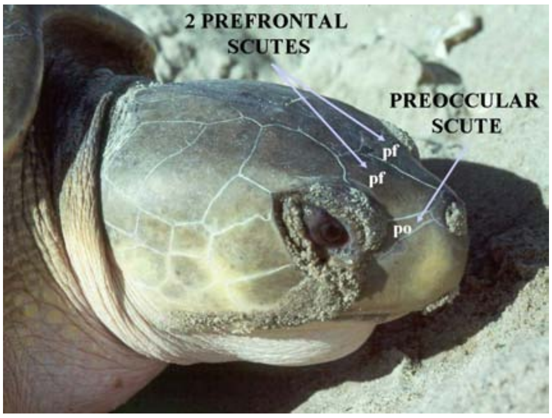


Figure 2. Diagnostic features for identifying *Natator depressus.*

N. depressus clutches are distinctive, containing large sized eggs (average egg diameter = 5.21cm) and rarely containing yolkless eggs (Limpus, 1971a).

When ashore, the nesting female moves with a breaststroke gait, pushing with all four flippers together and leaving distinctive tracks with very little front flipper print outside the hind flipper prints (Limpus, 1971a).

2. BIOLOGY OF THE FLATBACK TURTLE *Natator depressus* (Garman), IN AUSTRALIA.

Where possible, data will be derived from studies of *N. depressus* within the stock in question. Where relevant data are not available from a particular stock, data can be derived from studies on adjacent *N. depressus* stocks or extrapolated from appropriate studies with other turtle species. Because the most comprehensive data for the species are available from the eastern Australian stock, this stock has been described in greatest detail. Where the general biological characteristics have not been described for other stocks, readers are recommended to refer to the description of the eastern Australian stock.

2.1 GENETIC STATUS OF STOCKS

The *N. depressus* nesting populations of south east Queensland and the north-western Gulf of Carpentaria have been proposed to represent two stocks on the basis of adult size, egg dimensions and out of phase (summer/winter) timing of nesting seasons (Limpus *et al.* 1989; Limpus *et al.* 1993).

Genetic analysis has identified that there is a low level of genetic variability in the species and there is limited gene flow between the rookeries (Dutton *et al.* 2002). This genetic study identified four management units for the six major aggregations of *N. depressus* rookeries for Australia (Figure 3a. Limpus *et al.* 1989, 1993, 2000, 2002; Chatto, 1998).

Eastern Australia

Late spring/early summer peak nesting season:

- Eastern Australia (centred on Peak, Wild Duck and Avoid Islands).

Gulf of Carpentaria

All year nesting with winter peak nesting season and low density summer nesting:

- North-eastern Gulf of Carpentaria and western Torres Strait (centred on Crab and Deliverance Islands).
- Wellesley Group (centred on Bountiful Island).
- Western Gulf of Carpentaria (centred on Sir Edward Pellew Islands, South-eastern Groote Eylandt area (four sites between Ilyungmadja Point and Ungwanba Point) and Sandy Islet.

Western Northern Territory

All year nesting with mid-winter peak nesting season and low density summer nesting:

- Coburg Peninsula, Field Island, Quail Island and Bare Sand Island.
- The Cape Domett nesting population of Bonapart Gulf in Western Australia may be part of this stock.

Western Australia

Mid-summer peak nesting season:

- North-West Shelf (from Exmouth to the Kimberley Coast).

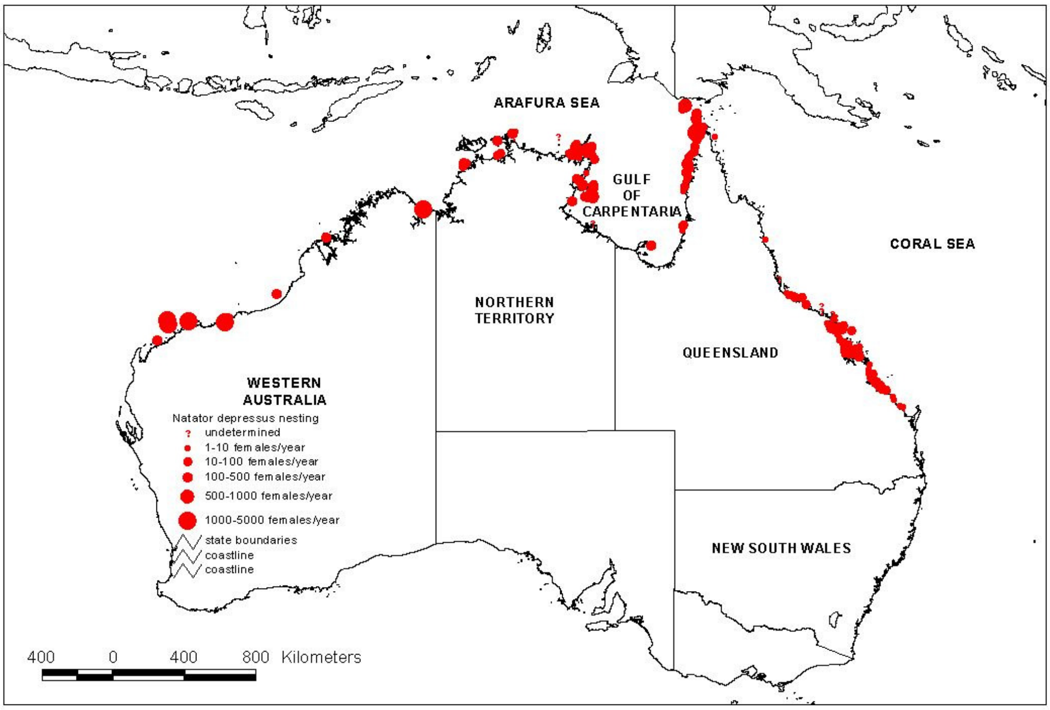


Figure 3a. Distribution of *Natator depressus* nesting beaches. The data are incomplete for the western part of Arnhem Land and Western Australia.

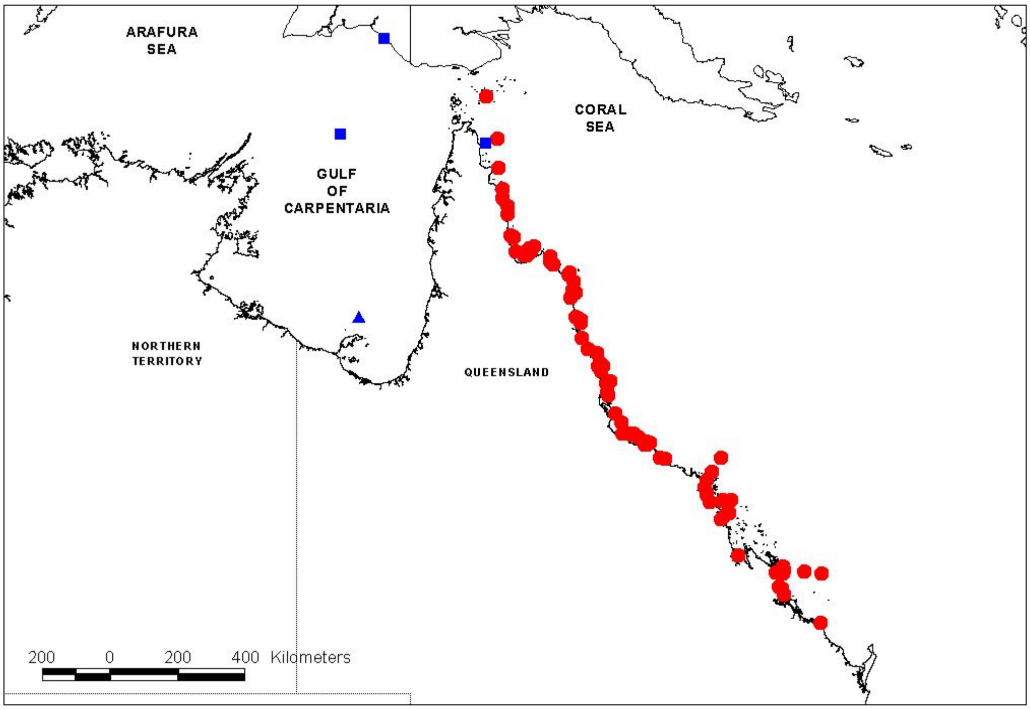


Figure 3b. Post-nesting dispersal of *Natator depressus* from Queensland rookeries to their respective foraging areas. Symbols denote rookery of origin for the females: circles - eastern Australian rookeries of Mon Repos, Curtis Island, Peak Island and Wild Duck Island; squares – Crab Island in NE Gulf of Carpentaria; triangle – Bountiful Island, SE Gulf of Carpentaria.

Figure 3. Distribution of nesting beaches and post nesting dispersal for *Natator depressus*.

2.2 EASTERN AUSTRALIAN MANAGEMENT UNIT

2.2.1 ROOKERIES

N. depressus rarely come ashore to nest on beaches fronted by intertidal coral reef flats. The major eastern Australian breeding aggregations occur on continental islands in inshore areas of the southern Great Barrier Reef (GBR) at Peak, Wild Duck, Avoid and Curtis Islands (Figure 4a. Limpus, 1971a, 1985; Limpus *et al.* 1981). These rookeries are fronted by sand/mud intertidal substrates. Minor breeding aggregations occur at other sites on the mainland coast and adjacent continental islands north from Mon Repos to Herald Island near Townsville (Figure 3a).

Most nesting for this eastern Australian stock (>70%) is contained in protected habitat of National Parks or Conservation Parks declared under the *Nature Conservation Act 1992.*

Major rookeries

- Peak Island (surrounded by a Great Barrier Reef Coast Marine Park and Great Barrier Reef Marine Park Preservation Zones).
- Wild Duck Island (surrounded by a Great Barrier Reef Coast Marine Park and Great Barrier Reef Marine Park Marine National Park Zones. There is a tourist resort lease adjacent to the nesting beach).

Minor rookeries

- South Queensland: Mon Repos;
- Central Queensland: Inflex Islets, Flock Pigeon Island, Aquilla Island, Red Clay Island, Brampton Island, St Bee's Island, Rabbit Island. Cockermouth Island, Penrith Island, Wigton Island;
- North Queensland: Cape Cleveland, Cape Bowling Green.

Many of the minor rookeries along the mainland coast do not lie within protected habitat and are being impacted by encroaching coastal development (Figure 4b).

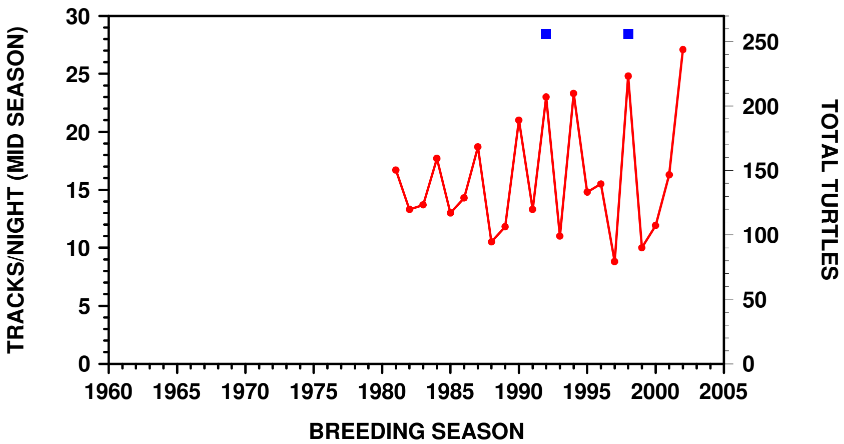
4a. South-east Beach on Avoid Island (an inshore continental island) in Central Queensland.

4b. Sarina Beach, near Mackay in central Queensland. This is an example of a mainland beach with low density nesting impacted by encroaching coastal development

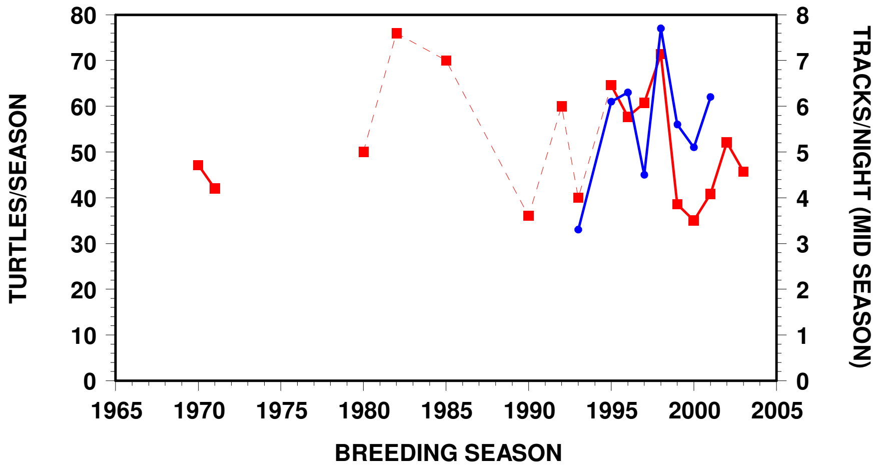
Figure 4. *Natator depressus* nesting habitat in eastern Australia.

Nesting census

Peak Island, Wild Duck Island, Curtis Island and the Woongarra Coast (including Mon Repos beach) have been index beaches for monitoring the population dynamics within the eastern Australian stock. Peak and Wild Duck Islands support the two largest nesting populations in eastern Australia. Curtis Island is an intermediate sized nesting population, while Woongarra Coast supports a minor population. In addition to total tagging census studies, the average number of females ashore per night at peak nesting season has been used as a census measure. Mid-season nightly census studies at Wild Duck Island since 1981 (Figure 5a),at Curtis Island since 1970 (Figure 5b) and total tagging census studies at Woongarra Coast since 1968 (Figure 5c), demonstrate no obvious trend in the size of the annual nesting population at these rookeries over 3 decades (Limpus *et al.* 2002).

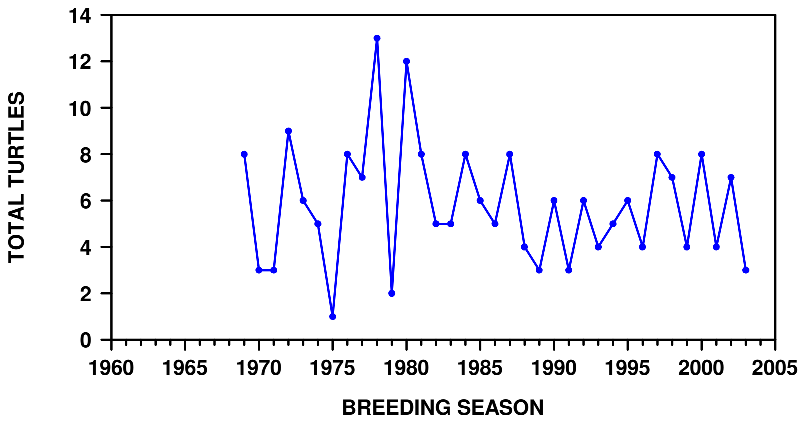


5a. Wild Duck Island. Squares denote results of total tagging cenus; dots denote average number of beachings (tracks) per night by nesting females during the two-week, mid season standard census period (after Limpus *et al.* 2002).



5b. Curtis Island. Squares denote results of entire season, total tagging census; dots denote average number of beachings (tracks) per night by nesting females during the two-week, mid-season standard census period (after Limpus *et al.* 2002).

Figure 5. Nesting census data for *Natator depressus* index beaches in eastern Australia.



5c. Woongarra coast, including Mon Repos. Total tagging census for the entire breeding season for five beaches between Burnett and Elliott Rivers.

Figure 5. continued.

2.2.2 FIDELITY TO NESTING SITES

The adult female displays a high degree of fidelity to her chosen nesting beach, with most females returning to the same small beach for their successive clutches within a nesting season, and in successive nesting seasons (Limpus *et al.* 1984, 1992).
It remains to be demonstrated whether this fidelity is the result of imprinting to the natal beach during the egg or hatchling phase, or whether the hatchling is imprinted to the region of her birth and subsequently to the specific rookery as an adult during her first breeding season.

2.2.3 MIGRATION

There is no evidence that these turtles travel in schools or all turtles follow that one path on their breeding migrations. Each adult migrates with a high degree of faithfulness to its particular rookery over distances in excess of 1300 km (Limpus *et al.* 1983a, 2002). Females tagged at the southern GBR rookeries have been recaptured throughout the inner shelf area of the GBR from Gladstone northwards to Torres Strait (Figure 3b). The foraging range for this stock lies almost totally within the Great Barrier Reef World Heritage Area and the associated Great Barrier Reef Marine Park and adjacent Great Barrier Reef Coast Marine Park.

2.2.4 BREEDING SEASON

In eastern Queensland breeding is very seasonal (Limpus, 1971a, 1985):

- Mating occurs before nesting commences in mid October.
- Nesting activity reaches a peak in late November - early December, and ceases by about late January.
- Hatchlings emerge from nests during early December until about late March, with a peak of hatching in February.

2.2.5 BREEDING ADULTS

Adult *N. depressus* are olive to grey dorsally and whitish or cream ventrally. They have very thinly keratinised scutes on a smooth low-domed carapace that is reflexed dorsally along the mid-body margin of the carapace (Limpus, 1971a; Limpus *et al.* 1988). The size of adults is summarised in Table 1.

Table 1. Summary of the size of breeding adult *Natator depressus* from eastern Australia.

		Measurement				References
		mean	SD	Range	N	
Curved carapace length (cm)						
Female	Bundaberg coast	93.2	-	88.0-96.0	14	Limpus, 1971a
	Peak Island	94.0	2.60	85.5-100.0	212	Limpus *et al.* 1981
	Wild Duck Island	94.0	2.60	85.5-100.0	133	unpublished data, EPA Queensland Turtle Research Project

On average, females recruiting to breed for the first breeding season are significantly smaller than turtles with a past breeding history (= remigrants) (Parmenter and Limpus 1995). Limpus *et al.* (2002) reported a constant mean size of turtles at three rookeries across three decades of census (Figure 6) that is indicative of a long term, approximately constant ratio of first-time breeders to remigrants in these populations.

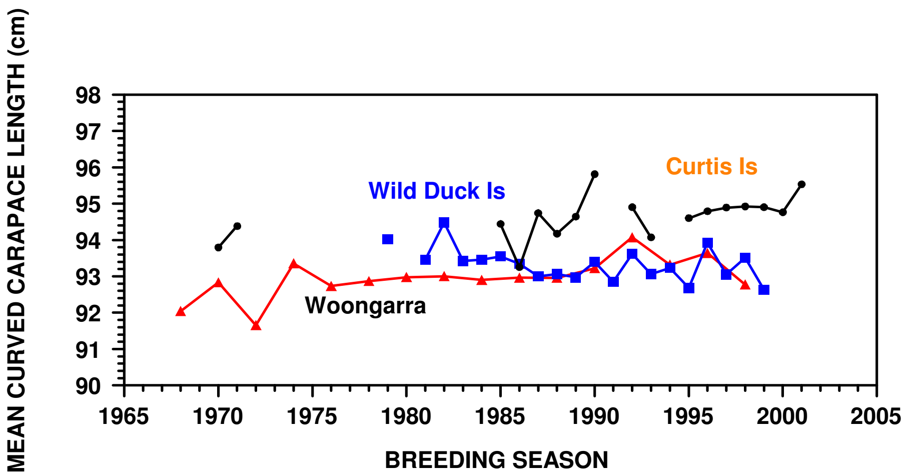


Figure 6. Comparison of seasonal changes in mean curved carapace length of nesting female *Natator depressus* at three eastern Australian index beaches: Wild Duck Island (squares), Curtis Island (circles) and Woongarra Coast (including Mon Repos) (triangles) (After Limpus *et al.* 2002). Data from the small Woongarra Coast population has been pooled at 2yr intervals.

2.2.6 BREEDING CYCLES AND RECRUITMENT

Studies of the long-term biology of *N. depressus* have been impeded by the higher rates of tag loss than are being recorded with the other cheloniid turtles (Limpus, 1992b; Parmenter, 1993, 2003). Breeding cycles have only been measured for females (Table 2). These data are expected to improve with time, as long-term recoveries from PIT tagging become available.

Table 2. Summary of eastern Australian *Natator depressus* breeding cycles.

		Mean	SD*	range	N	References
Renesting interval (d)						
	Bundaberg coast	16.0	1.89	12-23	115	Limpus *et al.* 1984
	Wild Duck Island	13.0	1.28	10-15	83	unpublished data, EPA Queensland Turtle Conservation Project
Remigration interval (yr)						
	Bundaberg coast	2.7	0.92	1-5	40	Limpus *et al.* 1984
	Peak Island	2.2	0.44	1-5	215	Parmenter and Limpus, 1995
Annual recruitment of 1st time breeders to nesting population						
	Peak Island	14.2%				Parmenter and Limpus, 1995
	Wild Duck Island	10-20%				Limpus *et al.* 2002
	Woongarra Coast	10-20%				Limpus *et al.* 2002

The annual recruitment of first-time breeding females into the breeding population was 14.2% of the annual nesting population at Peak Island (Parmenter and Limpus, 1995) and in the range of 10-20% at Wild Duck Island and the Woongarra Coast (Limpus *et al.* 2002).

2.2.7 EGGS

The eggs are cleidoic, white and spherical. They must be laid in 25-33^{o}C, well ventilated, low salinity, high humidity nest substrate and not subjected to flooding for successful incubation (Limpus, 1971a; Miller, 1985; Hewavisenthi and Parmenter, 2001, 2002a). There is no parental care of the eggs or hatchlings (Limpus, 1971a). Nesting behaviour has been described by Bustard *et al.* (1975). Embryos can be killed by rotation of the eggs during incubation, as has been demonstrated with other marine turtle species (Chan *et al.* 1985; Limpus *et al.* 1979; Parmenter, 1980). Measurements of *N. depressus* eggs and nests are summarised in Table 3.

N. depressus eggs may be more tolerant of excursions into high temperature ranges during incubation and of severe moisture stress than other species of marine turtle (Hewavisenthi and Parmenter, 2002a). With controlled temperature incubation, hatchlings derived from the lower range of incubation temperatures (26-29^{o}C) were larger but had lower energy reserves than those produced from the higher temperature range (32^{o}C) (Hewavisenthi and Parmenter, 2001).

2.2.8 HATCHLINGS

Hatchlings are grey dorsally with each scute outlined in black. The carapace and trailing edges of flippers have white margins. The ventral surfaces are completely white, and the iris of the eye is blue. (Figure 1b. Limpus, 1971a). Based on studies with other species, the hatchling is presumed to be imprinted to the earth's magnetic field at the nesting beach as it leaves the nest (Lohmann *et al.* 1997; Light *et al.* 1993). Imprinting may also be to the smell of the sand or the water the hatchling first contacts as occurs with *Lepidochelys* (Grassman *et al.* 1984). This age class does not feed or sleep as it digs its way out of the nest, nor between leaving the nest and swimming to deep offshore water. The duration of the hatchling phase is for a few days until the hatchling ceases dependence on the internalised yolk sac and commences foraging. Measurements of *N. depressus* hatchlings are summarised in Table 4.

Hatchlings orient to low elevation light horizons when moving from the nest to the sea (Limpus, 1971b). Bright lights that change light horizons can disorient hatchlings. It is presumed that they experience minimal disorientation by the yellow wavelengths of low-pressure sodium vapour lights or by intermittent flashing lights (Witherington and Bjorndal, 1991; Mrosovsky, 1978; unpublished data, EPA Queensland Turtle Conservation Project). It is presumed that, as with other species, by orienting to swim perpendicular to wave fronts, the hatchlings are directed to swim out to open waters (Lohmann *et al.* 1997).

Table 3. Summary of eastern Australian *Natator depressus* egg and nest measurements.

		Measurements				References
		Mean	SD	Range	N	
Clutches per season						
	Bundaberg coast	2.84	0.78	1-4	43	Limpus *et al.* 1984
Eggs per clutch						
	Bundaberg coast	50.2	10.7	7-73	87	Limpus, 1971a
	Peak Is. 1980-86	53.35	0.48SE	18-80	409	Parmenter and Limpus, 1995
	Wild Duck Island	53.8	8.97	15-68	50	unpublished data, EPA Queensland Turtle Conservation Project
Yolkless eggs per clutch						
	Mon Repos	0.36	-	0-2	22	Limpus, 1971a
	Peak Island	0.05	-	0-1	44	Limpus *et al.* 1981
Egg diameter (cm)						
	Bundaberg coast	5.21	0.11	47.5-56.0	250	Limpus, 1971a
	Wild Duck Island	5.20	0.12	48.4-54.1	69	unpublished data, EPA Queensland Turtle Conservation Project
Egg weight (g)						
	Bundaberg coast	77.8	4.46	67.6-86.0	220	Limpus, 1971a
Nest depth (cm)						
Top						
	Bundaberg area	28.8	9.4	0-57	45	Limpus, 1971a
Bottom						
	Bundaberg area	55.0	8.4	36-102	81	Limpus, 1971a
	Peak Island	49.9	7.4	35-78	45	Limpus *et al.* 1981
Incubation period(d)						
	Bundaberg coast	53.4	-	47-58	15	Limpus, 1971a

Table 4. Summary of measurements of eastern Australian *Natator depressus* hatchlings.

		Measurements				References
		Mean	SD	Range	N	
Straight carapace length(cm)						
	Woongarra coast	6.12	-	5.66-6.55	190	Limpus, 1971a
Weight (g)						
	Woongarra coast	43.6	-	33.3-49.1	190	Limpus, 1971a

2.2.9 EGG and HATCHLING SURVIVORSHIP

No comprehensive studies have been undertaken to summarise the nett incubation success and hatchling production for the numerous rookeries supporting the eastern Australian stock. Total clutch failure from natural causes is variable:

- Peak Island and Wild Duck Island: These beaches appear to be relatively stable under cyclone conditions, and total failure of clutches is expected to be uncommon.
- Woongarra coast: Total failure of a clutch is rare, with <5% of clutches being estimated to produce no hatchlings in an "average" season (Limpus, 1971a, 1985).
- Other mainland beaches such as Wreck Rock beaches: Higher losses from erosion and flooding are expected than at Mon Repos (Limpus, 1985).

Total clutch failure resulting from feral predators is highly variable:

- For the majority of island rookeries, including Peak Island, Wild Duck Island. And Avoid Island, there are effectively no feral predators that interact with the eggs and hatchlings.
- Curtis Island: An estimated 90-95% of clutches were lost to feral dog predation during the late 1970s-1988. Effectively zero predation by dogs in 1993 followed the removal of the dogs. By the late 1990s, predation by foxes (*Vulpes vulpes*) had become significant. In 2001, a fox-baiting project was introduced to reduce egg loss.
- Wreck Rock: An estimated 90-95% of clutches were lost to fox (*V. vulpes*) predation during 1976-82. As a result of a 1080 baiting project, there has been approximately zero fox predation of *N. depressus* eggs in the last few years.
- Woongarra coast: Approximately zero loss to feral predators of *N. depressus* eggs or hatchlings has been recorded in recent decades.

Nesting turtles digging into existing clutches destroyed 3.15% of the season's egg production at Peak Island in the 1986-1987 breeding season (Parmenter and Limpus, 1995).

The success of incubation and emergence of hatchlings from the nest onto the beach surface from undisturbed natural clutches that produce hatchlings is reliably high (Table 5).

Table 5. Summary of measurements of success of incubation and emergence of hatchlings from the nest onto the beach surface from natural clutches which produce hatchlings at eastern Australian *Natator depressus* rookeries.

		Measurements	References
		Mean	
Success of incubation and emergence of hatchlings			
Mon Repos	1968-1969	0.818	Limpus, 1971a
	1969-1970	0.703	Limpus, 1971a
Curtis & Facing Is.	1969-1970	0.834	Limpus, 1971a
Peak Is.	1980-1986	0.746	Parmenter and Limpus, 1995
Langham	1969-1970	0.898	Limpus, 1971a
Wild Duck Is.	1979-1980	0.887	EPA Queensland Turtle Conservation Project database.

There may be some reduction in egg production or decrease in incubation success of eggs laid in suboptimal habitat at some *N. depressus* rookeries as a result of fencing constructed to reduce beach erosion that prevents adult turtles from reaching nesting habitat in the vegetated dunes (unpublished data, EPA Queensland Turtle Conservation Project). This type of disturbance of nesting females has been recorded at low-density rookeries at Kellys Beach (Woongarra Coast), Emu Park and Holloways Beach.

Survivorship of hatchlings on the beach during the crossing from the nest to sea (including the impact of crab and diurnal bird predation) was estimated at >0.96 at Mon Repos (Limpus, 1973).

Survivorship of hatchlings in the water while swimming from the beach to deep water has not been quantified. Mainland and continental island beaches with no fringing reef are expected to be associated with very high hatchling survivorship (>0.9) as is the case with *C. caretta* hatchlings in the same habitat (see *C. caretta* review, Limpus, in prep.).

2.2.10 HATCHLING SEX RATIO

The sex of hatchlings is a function of the temperature of the nest during middle incubation (unpublished data, EPA Queensland Turtle Conservation Project).

Pivotal temperature:
A pivotal temperature, the temperature that theoretically produces a 50/50 sex ratio, of 29.3^{o}C was recorded at Mon Repos (unpublished data, EPA Queensland Turtle Conservation Project). During temperature shift experiments between 26°C and 32°C, the thermosensitive period was confined to stage 24 of embryonic development and once an embryo has been endrogenised (i.e. made male) the sex cannot be reversed (Hewavisenthi and Parmenter, 2000). The sex ratio was not a function of the hydric environment of the incubating eggs (Hewavisenthi and Parmenter, 2000).

Hatchling sex ratio:
At Peak Island, the hatchling sex ratio is likely to be biased towards females because high density nesting occurs when beach temperature appears to produce almost all female hatchlings (Hewavisenthi and Parmenter, 2002b). At Mon Repos, the hatchling sex ratio for the entire breeding season is biased towards females (unpublished data, EPA Queensland Turtle Conservation Project).

2.2.11 AGE, GROWTH

Absolute age has not been directly measured on wild turtles. Turtles from this population are presumed to be slow growing, taking decades to grow from hatchlings to breeding adults, based on growth rates of other Cheloniid species in Australian waters (Chaloupka and Limpus, 1997; Limpus and Chaloupka, 1997).

Adult female *N. depressus* that are nesting for their first breeding season are on average just slightly smaller than average size for the entire breeding population (Parmenter and Limpus, 1995; Table 6). The average female commences breeding when it is much larger than the size of the smallest breeding female and adult females grow very slowly. (Table 6).

Table 6. Comparison of size of adult female *Natator depressus* at first breeding and as remigrant turtles.

		Measurements				References
		Mean	SD	Range	N	
Curved carapace length (cm)						
Woongarra coast						unpublished data, EPA Queensland Turtle Conservation Project
	at 1st breeding	91.9	2.85	88.0-96.0	5	
	as remigrant	94.1	2.51	89.5-98.0	33	
Adult female growth rate (cm/yr)						
Peak Is.		0.012	0.21	-	440	Parmenter and Limpus, 1995

A growth/aging experiment is in progress in which 3276 hatchling *N. depressus* were "tagged" and released at Mon Repos during January 1974 to February 1982 (Limpus, 1985). The first adult that had been marked as a hatchling at the Mon Repos rookery has returned for her first breeding at 21 years of age (C. Limpus, unpublished data).

While individual tagged nesting females have been recorded breeding at Mon Repos for up to a 30 year span (EPA Queensland Turtle Conservation Project), Parmenter and Limpus (1995) estimated that the reproductive half-life for adult females in the Peak Island nesting population was 10.1yr.

2.2.12 POST-HATCHLINGS

The post-hatchling life history phase is here defined to span the period from when the hatchling commences feeding (ceases dependence on the internalised yolk sac) to when the turtle ceases dependence on planktonic food and shifts to foraging on benthic organisms.

This age class has been recorded frequently from GBR waters and is believed to follow a surface water dwelling, planktonic life over the continental shelf inside the GBR lagoon (Figure 7) (Limpus *et al*., 1994; Walker, 1991,1994; Walker and Parmenter, 1990).

There is no evidence that this species has an oceanic post-hatchling dispersal phase as is the case with the other marine turtle species.

This size class appears to feed on macro zooplankton.

In addition to being eaten by fish and sharks, post-hatchling *N. depressus* are regularly the prey of white-bellied sea-eagles (Walker, 1991; Walker and Parmenter, 1990).

The duration of the post-hatchling life stage is unknown.

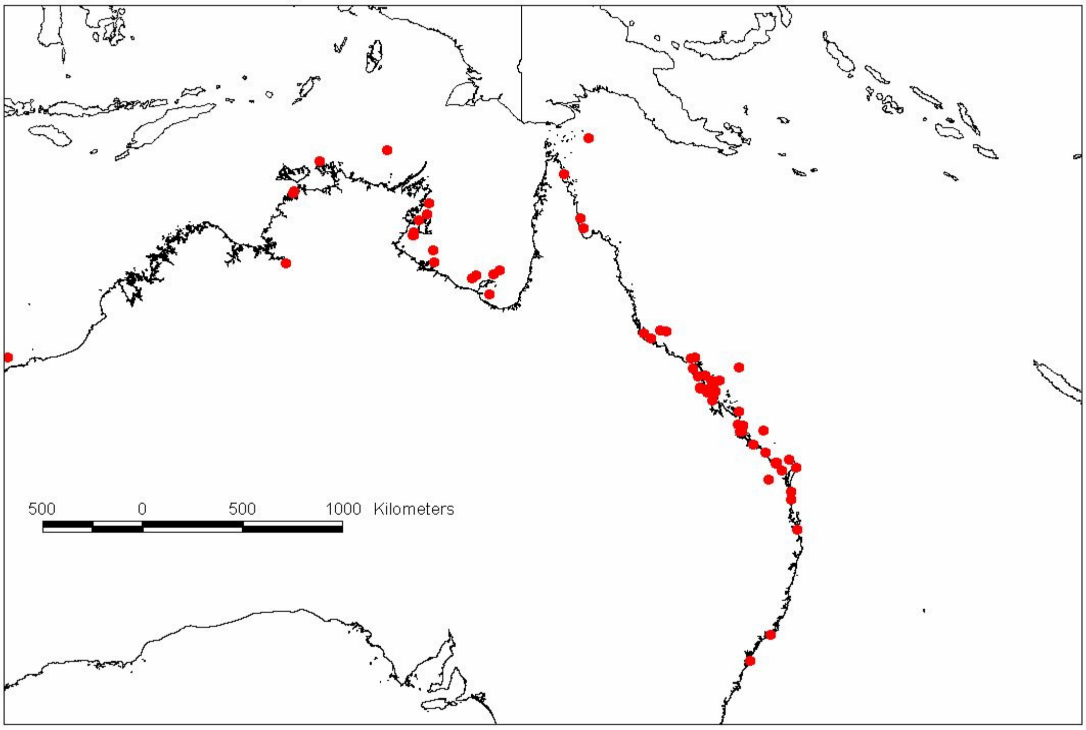


Figure 7. Distribution of post-hatchling records from northern and eastern Australia.

2.2.13 IMMATURE and ADULT TURTLES

Feeding habitat

After this species ceases its pelagic life history phase it changes to inhabit sub-tidal soft bottomed habitats inshore of the outer GBR, probably without changing the geographical distribution. The foraging distribution for this stock encompasses from Hervey Bay to Torres Strait and possibly into the Gulf of Papua (Limpus *et al.,* 1983a; Robins, 1995, 2002).

N. depressus has been rarely encountered in inter-tidal seagrass pastures or in coral reef habitat. Within trawl fisheries, *N. depressus* were captured in soft-bottomed waters mostly of 6-35m depth within the GBR and 11-40m depth in Torres Strait (Robins and Mayer, 1998).

Diet

Large *N. depressus* are carnivorous, feeding principally on soft-bodied invertebrates including soft corals, sea pens, holothurians, and jellyfish (unpublished data, EPA Queensland Turtle Conservation Project).

Sex ratio

No data is available.

Population structure and dynamics

Survivorship data is lacking for the majority of the life history for the species.

- Survivorship from hatchling emergence to maturity has been estimated to be less than 0.0026 (Parmenter and Limpus, 1995).
- Annual survivorship of adult females on the nesting beaches is >0.99 (unpublished data, EPA Queensland Turtle Conservation Project).

There are no data available for the annual survivorship of benthic feeding immature and adult *N. depressus*.

Recruitment rate of first time breeding females to the population has been estimated at 14.2% of the total annual breeding population at Peak Island (Parmenter and Limpus, 1995) and at 10-20% of the total annual breeding population at Wild Duck Island and Woongarra Coast (Limpus *et al.* 2002).

2.3 GULF OF CARPENTARIA AND TORRES STRAIT MANAGEMENT UNIT

This management unit encompasses three main concentrations of rookeries:

- North-eastern Gulf of Carpentaria and western Torres Strait (centred on Crab and Deliverance Islands). This group of rookeries supports the largest breeding population for the species with the 1991 nesting population being estimated at many thousands of females (Limpus *et al.*1993) and has the best studied rookeries for the area.
- Wellesley Group (centred on Bountiful Island.)
- Western Gulf of Carpentaria (centred on Sir Edward Pellew Islands, South-eastern Groote Eylandt area), (four sites between Ilyungmadja Point and Ungwanba Point) and Sandy Islet (Cogger and Lindner, 1969; Gow, 1981; Limpus and Reed, 1985; Limpus and Preece, 1992; Limpus *et al.* 2000).

2.3.1 ROOKERIES

Rookeries within this management unit span the jurisdictions of Queensland and Northern Territory with almost all major rookeries being within land that is owned or controlled by indigenous communities. No significant rookeries are in National Park or other secure tenure for conservation purposes.

The largest nesting concentration for the species occurs in the north-eastern Gulf of Carpentaria and western Torres Strait where the major rookeries include Crab Island, Deliverance Island and Kerr Island (Figure 8a. Limpus *et al.* 1983b, 1989, 1993; Sutherland and Sutherland, 2003). Many minor breeding aggregations are spread along the mainland coast south of the Jardine River mouth along western Cape York Peninsula to south of Weipa (Figure 8b. Limpus *et al.* 1993). Some very small rookeries that are presumed to be part of this management unit are on the islands of the inner shelf cays of the northern GBR and central Torres Strait.

8a. Western beach of Crab Island, July 1999.

8b. Flinders Beach, north of Pennyfather River, western Cape York Peninsula, November 2000.

Figure 8. Views of *Natator depressus* nesting beaches in north-eastern Gulf of Carpentaria.

2.3.2 FIDELITY TO NESTING SITES

Fidelity to nesting sites has not been quantified, but is presumed to be highly developed, similar to that recorded at the eastern Australian rookeries. See Section 2.2.2 for general discussion. Several recaptures of females that had been originally tagged while nesting at Crab Island have occurred at Crab Island within and between breeding seasons (Sutherland and Sutherland, 2003). None have been reported from other rookeries.

2.3.3 MIGRATION

Three long distance migration recaptures of females that had been tagged while nesting at Crab Island were recorded. Two from the Arafura Sea and one from the far northern GBR (Figure 3b. Limpus *et al.* 1993).

There have been no tag recoveries within the Gulf of Carpentaria of females tagged while nesting at Crab Island or Deliverance Island.

There has been one tag recovery of a Bountiful Island nesting female that was trawled within the Gulf of Carpentaria (Figure 3b).

2.3.4 BREEDING SEASON

Nesting occurs all year round within this population but with a peak of nesting activity in mid year (Limpus *et al.* 1983b, 1989, 1993).

2.3.5 BREEDING ADULTS

See Section 2.2.5 for general description. The size of adults is summarised in Table 7.

Large crocodiles, *Crocodylus porosus*, are predators of nesting female *N. depressus* while they are ashore for egg laying (Limpus *et al.* 1983b). Sutherland and Sutherland (2003) recorded a predation rate of 1.17 females/week by crocodiles during July 1997 at Crab Island.

Table 7. Summary of the size of breeding adult *Natator depressus* from the Gulf of Carpentaria – Torres Strait stock.

		Measurement				References
		mean	SD	Range	N	
Curved carapace length (cm)						
Female:						
	Crab Is.	89.3	2.66	80.5-97.0	326	Limpus, *et al.*, 1993
	Crab Is.	88.2	3.09	-	69	Sutherland and Sutherland, 2003
	Deliverance Is.	88.8	2.96	81.5-94.0	18	Limpus, *et al.*1989
Male:						
	Crab Is.	83.1	-	-	1	Limpus, *et al.* 1993
Weight (kg)						
Female:						
	Crab Is.	71.0	5.80	59.5-84.0	28	Limpus, *et al.* 1983b

2.3.6 BREEDING CYCLES

Renesting interval and remigration interval have not been quantified within this population. It is presumed that these parameters will be similar to those for the southern GBR stock (Section 2.2.6).

2.3.7 EGGS

See Section 2.2.7 for general description. Measurements of *N. depressus* eggs and nests for this stock are summarised in Table 8.

2.3.8 HATCHLINGS

See Section 2.2.8 for general description. Hatchling measurements are summarised in Table 9.

Table 8. Summary of north-eastern Gulf of Carpentaria and western Torres Strait *Natator depressus* egg and nest measurements.

		Measurement				References
		mean	SD	range	N	
Eggs per clutch						
	Crab Is.	55.9	9.57	34-74	32	Limpus, *et al.* 1993
	Crab Is., 1997	57.0	7.31	-	54	Sutherland and Sutherland, 2003
	Deliverance Is.	52.0	14.0	36-87	12	Limpus, *et al.*1989
Yolkless eggs per clutch						
	Crab Is.	0.06	0.29	0-3	217	Limpus, *et al.* 1993
Egg diameter (cm)						
	Crab Is.	4.93	0.17	4.52-5.17	60	Limpus, *et al.* 1993
	Deliverance Is.	5.08	0.14	4.79-5.34	30	Limpus, *et al.* 1989
Egg weight (g)						
	Crab Is.	72.7	4.66	50.0-83.5	238	Limpus, *et al.* 1983b
Nest depth (cm)						
Top						
	Crab Is.	36.1	13.1	11-51	22	Limpus, *et al.*1983b
Bottom						
	Crab Is.	54.4	9.8	36-67	22	Limpus, *et al.* 1983b
	Crab Is., 1997	65.0	10.5	-	54	Sutherland and Sutherland, 2003

Table 9. Summary of north-eastern Gulf of Carpentaria and western Torres Strait *Natator depressus* hatchling measurements.

		Measurement				References
		mean	SD	Range	N	
Straight carapace length (cm)						
	Crab Is.	5.97	0.19	5.39-6.65	211	Limpus, *et al.* 1983b
	Deliverance Is.	5.70	0.16	5.11-5.97	69	Limpus, *et al.* 1989
Weight (g)						
	Crab Is.	39.3	4.25	30.5-51.5	168	Limpus, *et al.* 1983b

2.3.9 EGG and HATCHLING SURVIVORSHIP

See Section 2.2.9 for general description.

The proportion of clutches that fail to produce hatchlings from natural causes has not been recorded.

Incubation/emergence success of nests that have not been disturbed by predators or nesting turtles or impacted by flooding or erosion is usually high (Table 10).

Predation of clutches by feral mammals or varanid lizards does not occur at the major island rookeries such as Crab or Deliverance Islands (Limpus *et al.* 1989, 1993; Sutherland and Sutherland, 2003). Loss of clutches to feral pigs (Figure 10c) along the mainland coast south of the Jardine River is presumed to be approaching 90%. (Limpus *et al.* 1993).

On Crab Island, nesting turtles kill 0.6% - 0.9% of eggs in existing clutches when they dig into them. (Limpus, *et al.* 1983b).

Disorientation of hatchlings from altered light horizons resulting from coastal development is effectively nil for these rookeries.

Native predators of hatchlings crossing the beach include: small crocodiles, nocturnal birds (such as nankeen night herons) and ghost crabs. (Limpus and Preece, 1992; Limpus *et al.* 1993; Sutherland and Sutherland, 2003). The intensity of predation of hatchlings as they cross the beach by these native predators is variable (Table 10).

Survivorship of hatchlings in the water while crossing from the beach to deep water has not been quantified at any of these rookeries. However, predation of hatchlings swimming from the beach by pelicans and small sharks, has been recorded. (Limpus *et al.* 1983b).

Table 10. Success of incubation and emergence of *Natator depressus* hatchlings from undisturbed nests onto the beach surface from natural clutches that produced hatchlings.

		Measurement				References
		mean	SD	Range	N	
Emergence success of eggs to hatchlings at the beach surface						
Crab Is	Dec 1976	0.924				Limpus, *et al.* 1983b
	May 1978	0.779				Limpus, *et al.* 1983b
	Dec 1978	0.867				Limpus, *et al.* 1983b
	Jul 1991	0.786				Limpus, *et al.* 1983b
	Jul 1997	0.934			33	Sutherland and Sutherland, 2003
Deliverance Is.	Oct 1987	0.834				Limpus, *et al.* 1989
Hatchling mortality on beach from bird and predation						
Crab Is.	Dec 1976	0.028				Limpus, *et al.* 1983b
	May 1978	0.378				Limpus, *et al.* 1983b
	Dec 1978	0.033				Limpus, *et al.* 1983b

2.3.10 HATCHLING SEX RATIO

There are no data for this population. However, given the differences in sand colour of the various rookeries (Figure 8), differences in hatchling sex ratio can be expected to result from the different temperature regimes. The mainland rookeries with their darker sand are expected to produce a higher female hatchling ratio.

2.3.11 AGE and GROWTH

There are no data on age structure for this population. Adult turtles are slow growing with a mean annual growth rate = 0.101cm/yr (SD = 0.24, range = -0.26-0.45cm/yr, n = 10. Sutherland and Sutherland, 2003).

2.3.12 POST-HATCHLINGS

Post-hatchling sized *N. depressus* occur widely throughout the Gulf of Carpentaria and southern Arafura Sea (Figure 7. Limpus *et al.* 1994). They can be expected to aggregate at convergence zones where other pelagic species are also aggregated (Limpus and Preece, 1992). The rookeries from which these turtles originate is undetermined but can be expected to include the Gulf of Carpentaria unit. See section 2.2.12 for general comments on this age class.

2.3.13 ADULT and IMMATURE TURTLES

See Section 2.2.13 for general description.

Feeding habitat
At this time it is presumed that this population lives primarily in the open water, soft-bottomed habitats of the Arafura Sea, Gulf of Papua and far northern GBR.

Diet
Diet is presumed to be similar to that of the species elsewhere.

Sex ratio
No data are available for this population.

Population structure and dynamics
No data are available for this population.

Survivorship
No data are available for this population.

Age duration
No data are available for this population.

2.4 WESTERN NORTHERN TERRITORY BREEDING UNIT

2.4.1 ROOKERIES

The extent of *N. depressus* breeding in the western Northern Territory has been extensively mapped (Figure 3. Chatto, 1998) but the size of many of the rookeries remains unquantified (Whiting and Guinea, in press).

Nesting beaches are widely scattered on the Coburg Peninsula and adjacent islands including the McCluer Group of islands, Field Island, Greenhill Island, Quail and Bare Sand Islands (Fry, 1913; Cogger and Lindner, 1969; Guinea, 1994a, b; Schauble *et al.* in press). The Cape Domett nesters of Western Australia may be part of this stock.

Nesting census
The only index of the population trends for the western Northern Territory *N. depressus* is provided by the annual census of the size of the *N. depressus* nesting population at Bare Sand Island (). Over a seven year period from 1996 to 2002, the number of clutches laid per year during the 14 day, mid nesting season, census period has declined by 3% per year. When this population decline began, has not been identified. This rate of decline across a generation could result in an 80% decline in the size of the adult breeding population.

2.4.2 BREEDING SEASON

Some nesting occurs year round, however, nesting density reaches a peak in July (Fry, 1913). At Fog Bay, the breeding season spans from February to November (Blamires and Guinea, 2000; Whiting and Guinea, in press). This dry season peak of nesting activity may be adaptive to protect the eggs from the high lethal sand temperatures that occur during the summer/wet season (Guinea, 1994b, Blamires and Guinea, 2000).

2.4.3 BREEDING ADULTS

There is an emerging pattern (Table 11) indicating that adult female *N. depressus* that breed in north-west Arnhem Land are smaller than the females that breed in the Gulf of Carpentaria – Torres Strait which are in turn smaller than those that breed in eastern Australia.

2.4.4 BREEDING CYCLES

There is a paucity of data for the *N. depressus* breeding cycles from this area (Table 12).

Table 11. Size of breeding adults from the western Northern Territory.

		Measurement				References
		mean	SD	Range	N	
Curved carapace length (cm)						
Female:	Fog Bay	87.6	5.1	-	5	Guinea, 1994b
	Fog Bay, 1997-8	89.3	2.1	-	13	Blamires *et al.* 2003
	Bare Sand Island	86.4	2.97	67.0-96.9	-	Whiting and Guinea, in press
	Greenhill Island	86.3	3.64	75.0-95.0	181	Hope and Smit, 1998
	Field Island	86.3	3.5	-	215	Schauble *et al.* in press
	Kakadu	85.5	4.9	73.5-91.2	10	Vanderleley, 1993
Curved carapace width (cm)						
Female	Greenhill Island	72.0	3.94	58.4-88.5	180	Hope and Smit, 1998
Weight (kg)						
Female:	Greenhill Island	67.8	8.5	50-90	107	Hope and Smit, 1988
	Field Island	67.4	8.2	-	205	Schauble *et al.* in press
	Kakadu	65.3	5.9	55-75	7	Vanderleley, 1993
Track width						
Female	Greenhill Island	88.5	7.9	-	59	Hope and Smit, 1998

Table 12. Summary of breeding cycles of *Natator depressus* from the western Northern Territory.

		Measurement				References
		mean	SD	Range	N	
Renesting interval (d)						
Female	Greenhill Island (1995-1997)	14.8	2.2	9-17	11	Hope and Smit, 1998
Remigration interval (yr)						
Female	Greenhill Island (1996-1997)	1.4	0.5	0.9-1.9	12	Hope and Smit, 1998
	Field Island	-	-	1-7	-	Schauble *et al.* in press

2.4.5 EGGS

Measurements of *N. depressus* eggs and nests are summarised in Table 13.

2.4.6 HATCHLINGS

Measurements of *N. depressus* hatchlings are summarised in Table 14.

Table 13. Measurements of *N. depressus* eggs and nests from the Western Northern Territory.

		Measurement				References
		mean	SD	Range	N	
Eggs per clutch						
		~50	-	24-78		Fry, 1913
		53	-	41-74	14	Cogger and Lindner, 1969
	Fog Bay: 1989	43.9	9.4	28-56	7	Guinea, 1994b
	Fog Bay: 1997-8	51.52	8.64	-	85	Blamires and Guinea, 2000
	Greenhill Island	52.2	10.7	-	137	Hope and Smit, 1998
	Field Island	52.4	8.6	-	127	Schauble *et al.* in press
	Kakadu	53.2	7.1	41-75	25	Vanderleley, 1993
Yolkless eggs per clutch						
	Kakadu	-	-	0-1	-	Vanderleley, 1993
Egg diameter (cm)						
		5.21	-	4.9-5.4	-	Cogger and Lindner, 1969
	Fog Bay	4.9	0.16	4.47-5.72	70	Guinea, 1994b
	Bare Sand Island	4.78	0.15	4.50-5.01	-	Whiting and Guinea, in press
	Greenhill Island	4.93	0.20	4.25-6.10	806	Hope and Smit, 1998
Egg weight (g)						
	Kakadu	72.0	5.44	60.0-82.5	102	Vanderleley, 1993
	Greenhill Island	67.5	7.6	52-82	776	Hope and Smit, 1998
Nest depth (cm)						
Top	Fog Bay	32.1	4.6	-	7	Guinea, 1994b
	Greenhill Island	37.8	8.5	-	97	Hope and Smit, 1998
	Field Island	34.3	11.4	-	105	Schauble *et al.* in press
Bottom	Fog Bay	53.3	5.8	-	7	Guinea, 1994b
	Fog Bay, 1997-8	56.9	9.8	-	85	Blamires and Guinea, 2000
	Greenhill Island	60.4	9.1	-	98	Hope and Smit, 1998
	Field Island	56.4	16.2	-	103	Schauble *et al.* in press
Incubation period to emergence (d)						
	Coburg Pen	50.2	-	45-56	6	Cogger and Lindner, 1969
	Fog Bay, 1997-8	53.2	10.91	-	-	Blamires and Guinea, 2003

Table 14. Measurements of hatchling *N. depressus* from the western Northern Territory.

		Measurement				References
		mean	SD	Range	N	
Straight carapace length (cm)						
	Greenhill Island	5.78	0.48	4.2-7.0	282	Hope and Smit, 1998
	Kakadu	5.66	0.111	5.44-5.86	48	Vanderleley, 1993
Weight (g)						
	Greenhill Island	33.6	4.8	22-49	282	Hope and Smit, 1998
	Kakadu	33.9	1.21	31.0-36.5	48	Vanderleley, 1993

2.4.7 EGG and HATCHLING SURVIVORSHIP

Total clutch failure because of predators is high on a number of mainland beaches:

- Coburg Peninsula (Black Point and Smith Point), the majority were disturbed by predators: 40.5% by *Varanus* sp., 14.0% by dingo and 3.2% by crabs (Hope and Smit, 1998).

- At Fog Bay, 60% of clutches were destroyed by *Varanus gouldii* in 1988 (Guinea, 1994b) and 52% of clutches during 1997-1998 (Blamires and Guinea, 2003).
- At Kakadu in 1993, 82% of clutches were preyed on by *Varanus gouldii* (Vanderleley, 1993).

In contrast, egg loss to terrestrial predators is very low on a number of the important island rookeries:

- Greenhill Island, 1995-1997: predation of clutches by dingos and varanid lizards was rarely encountered (Hope and Smit, 1998).
- Field Island, 1990-2001: predation by vertebrate predators is not a significant issue that warranted investigation (Schauble *et al.* in press).
- Bare Sand Island, mid 1990s: nil (M. Guinea, pers comm.)

Hatchling emergence from undisturbed nests (measured as the proportion of eggs producing hatchlings to the beach surface for undisturbed natural clutches that produced hatchlings) (Table 15) is variable among rookeries.

Relocation of eggs to artificial nests on the dune crest, on natural nesting beaches at Fog Bay, may be a management option for reducing varanid predation of natural clutches (Blamires *et al.* 2003) but it needs to be tested. Horizontally laid mesh with 90mm grid size may give more effective protection for eggs from varanid predation (Blamires *et al.* 2003).

Table 15. Summary of measurements of success of incubation and emergence of hatchlings from the nest onto the beach surface from natural clutches which produce hatchlings at western Northern Territory *Natator depressus* rookeries.

		Measurements				References
		Mean	SD	Range	N	
Hatching success from natural nests producing hatchlings						
Field Island	1990-2001	88%	17%		16 clutches	Schauble *et al.* in press
Success of incubation and emergence of hatchlings from natural nests producing hatchlings						
Greenhill Island	1995-1997	90.5%	-		64 clutches, 4372 eggs	Hope and Smit, 1998
Field Island	1990-2001	64%	32%	-	16 clutches	Schauble *et al.* in press
Fog Bay	1997-1998	94.7%	-		85 clutches	Blamires and Guinea, 2000

2.4.8 POST-HATCHLINGS

This age class has been recorded from coastal waters and is believed to follow a surface water dwelling, planktonic life over the continental shelf (Limpus *et al.* 1994; Zangerl *et al.* 1988).

Diet

This size class feeds on macroplankton including: siphonophores (*Porpita*), gastropods (*Janthina*), pelecypods, cuttlefish, storked barnacles (Zangerl *et al.* 1988; unpublished data, EPA Queensland Turtle Research Project).

See Section 2.2.12 for general comments.

2.4.9 ADULT and IMMATURE TURTLES

The feeding ground distribution of these turtles is poorly documented. While normally associated with offshore coastal waters (Poiner and Harris, 1996), adult and immature *N.*

depressus occur at low density within some coastal waters such as Darwin Harbour (Whiting, 2001).

Diet
See Section 2.2.13 for general comments.

Diet records from the Arafura sea region include: holothurians, sea-pens, cuttlefish (*Sepia*), jellyfish (*Catostylus*) (Chatto *et al.* 1995; Zangerl *et al.* 1988). Conway (1994) expressed caution in using the mollusc records he obtained from the body cavities of his beachwashed *N. depressus*.

2.5 NORTH-WEST SHELF BREEDING UNIT

2.5.1 ROOKERIES

The North-west Shelf, Australian stock nests from approximately Exmouth to about the Lacapede Islands and is characterised by summer nesting. However, there are sparse data available on these nesting populations (Prince, 1994, 1998; Unpublished data from K. Morris and EPA Queensland Turtle Conservation Project).

- There are significant rookeries centred on Barrow Island, Monte Bello Group, Thevenard Island, Varanus Island and Dampier Archipelago and the Kimberley region. A number of these rookeries occur on islands with significant oil/gas industry infrastructure (Figure 9a, b).
- Nesting is wide spread along the mainland beaches from Mundabullangana on the Pilbara Coast north to Broome. While some of these beaches are on undeveloped coastlines bordered by cattle stations (Figure 9c), others are close to residential coastal development.

Minor rookeries are wide spread within this region. The status of the population(s) is undetermined. Although not well quantified, there is a reasonable probability that the size of this stock could equal that of the Gulf of Carpentaria – Torres Strait stock.

Whether the significant nesting population that nests in mid year in the Cape Domett area is part of the western Northern Territory or North-west Shelf populations remains to be determined.

9a. Thevenard Island, October 2002. Low sand island with sweeping sand beaches.

Figure 9. Views of *Natator depressus* nesting beaches in Western Australia.

9b. Varanus Island, October 2002. Rocky continental island with small sandy pocket beaches.

9c. Cowrie Beach, Mundabullangana on undeveloped mainland coast at Pilbara.

Figure 9. continued.

2.5.2 MIGRATION

Post nesting recaptures of adult female *N. depressus* tagged on nesting beaches have been recorded from Exmouth Gulf to off the Kimberley Coast in Western Australia and from north of Melville Island, Northern Territory (Prince, 1998). All four recaptures were in prawn trawls and were released alive.

2.5.3 BREEDING ADULTS, CLUTCH COUNTS AND BREEDING CYCLES

The breeding females within this stock (Table 16) appear to be similar in size to those that breed in western Northern Territory (Table 11).

2.5.4 EGG AND HATCHLING SURVIVORSHIP

Varanid lizards rarely raid *N. depressus* clutches at the important mainland rookery at Mundabullangana on the Pilbara Coast (Prince, 1994).

Reports from a number of staff of Western Australian Department of Conservation and Land Management (WACALM) in 2002, indicated that foxes were active on the mainland beaches in the Mundabullangana area. In the absence of control measures, foxes reportedly destroy a large number of the *N. depressus* clutches laid there. Baiting was ongoing at some locations such as the coastal strip along Mundabullangana Station in 2002 and appears to be locally successful in reducing clutch loss to foxes.

On western Barrow Island the majority of *N. depressus* clutches are dug into by perentie, *Varanus giganteus* (K. Pendoley, pers. comm. August 2004). The other island rookeries appear to be largely free of vertebrate predation of *N. depressus* eggs.

Table 16. Size of breeding adult *Natator depressus* from Western Australia.

		Measurement				References
		mean	SD	Range	N	
Curved carapace length (cm)						
Female:	Mundabullangana	88.7	2.6	-	241	Blamires *et al.* 2003
Eggs per clutch						
	Varanus Island	49.29	9.2	-	31	Pendoley, 1999
Remigration Interval (yr)						
Female	Varanus Island	2.1	1.2	1-6	-	Pendoley, 1999

2.5.5 IMMATURE AND ADULT TURTLES

There are sparse data available on the feeding ground life history stages associated with these rookeries.

3. ANTHROPOGENIC IMPACTS, MORTALITY AND DISEASE

N. depressus populations are being negatively impacted through a wide range of anthropogenic activities throughout northern Australia (Figure 10). These impacts have been, for the most part, poorly quantified in recent years and usually ignored in the past.
There has been no commercial harvest of this species or its eggs in Australia in the past and currently, commercial harvest is not permitted under any State or Federal legislation in Australia.

10a. Adult *N. depressus* among trawl bycatch, (Northern Prawn Fishery), before compulsory use of TEDs. *Photograph by Ian Stapleton*.

10b. Adult-sized *N. depressus* live but tangled in a beachwashed net, north of Duyfken Point, Weipa. March 1, 2003. *Photograph by Vance Wallin*.

10c. *N. depressus* nest that had been destroyed by pigs, North of Duyfken Point, Weipa, November 2000.

10d. Indigenous harvest of *N. depressus* eggs using 4x4 vehicles to access the nests, south east of Gove, October 1997.

10e. X-ray of a beachwashed post-hatchling *N. depressus* showing gut blocked with plastic debris.

Figure 10. Illustrations of a range of anthropogenic impacts on *Natator depressus* in northern Australia.

3.1 INDIGENOUS HARVEST FOR FOOD

Indigenous peoples with a recognised Native Title right can legitimately hunt marine turtles in Australia for communal, non-commercial purposes.

3.1.1 QUEENSLAND

In Queensland, while most indigenous turtle hunters appear to preferentially hunt green turtles (*Chelonia mydas*), *N. depressus* are taken occasionally for food in the Crab Island – south-western Torres Strait area (Johannes and MacFarlane, 1991; Kwan, 1989; Tag recoveries, Unpublished data Queensland Turtle Conservation Project).

The harvest of turtle eggs by indigenous people (Donat, 1936) has probably been occurring for as long as the people have inhabited coastal areas adjacent to *N. depressus* rookeries. In recent times, eggs have been gathered by indigenous peoples living adjacent to *N. depressus* rookeries across northern Queensland (Limpus *et al.* 1983b, 1989, 1993). The size of the harvest is largely unquantified. While this is normally occurring at a low level at any one rookery, there are a few locations where increasing human populations have the potential for future over-harvesting of the resource. At Crab Island this is particularly relevant given the substantial egg loss to feral pigs that is occurring from this same breeding unit along the adjacent mainland coast. Mackay on the central Queensland coast has low density *Natator* nesting along the mainland beaches and there is the potential for locally high harvest pressure on the eggs (unpublished data, EPA Queensland Turtle Conservation Project).

During the 1988 survey of the Deliverance Island rookery, a nesting female *N. depressus* was killed to obtain her eggs without the turtle itself being used for food (Limpus *et al.* 1989).

There is a belief among some indigenous communities in northern Cape York Peninsula that *N. depressus* is poisonous to eat unless undefined parts are removed during butchering. These beliefs are not supported by clinical reports in the past century (Limpus, 1987).

3.1.2 NORTHERN TERRITORY

The size of the harvest of *N. depressus* turtles and eggs in the northern Territory remains mostly unquantified.

- Flatback turtles have been frequently recorded being eaten in Arnhem Land, apparently as a second choice of species after the preferred green turtle *Chelonia mydas* (Thompson, no date).
- During 13 months, July 1995 – August 1996, in the Gove area (Kennett *et al.* 1998):
  - Two *N. depressus* were among a sample of 64 harvested marine turtles. With an estimated total of approximately 480 turtles harvested annually, this indicates that about 10-20 *N. depressus* annually are harvested in the area.
  - The rate of egg harvest was high, with 22 *N. depressus* clutches among a reported sample of 45 harvested marine turtle clutches. Based on two surveys of 11km of beach at Nanydjaka, 87% to 95% of eggs laid were collected and nests of all four turtle species present were taken. However, the representativeness of these data to other sections of the coast is not clear.
- The harvest of *N. depressus* and/or its eggs on Coburg Peninsula and the adjacent Crocker Island is not quantified (Hope and Smit, 1998).
- Hatchling *N. depressus* are eaten by some coastal communities in Arnhem Land (Thompson, no date).

On accessible mainland beaches, the use of 4x4 vehicles has made it possible for the indigenous egg harvester to collect over a greater length of beach than would have been possible on foot in the past, and to transport more eggs than previously could have been carried (Figure 10d). On beaches such as the one illustrated, the indications were that the beaches were driven on a regular basis and effectively all clutches were being harvested. Again, the proportion of nesting beaches with this intensity of harvest is not known. There is an additional problem of eggs being killed when nests are driven over by vehicles.

3.1.3 WESTERN AUSTRALIA

Flatback turtles have not been identified as significant in major reports 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 strip from Broome to the Pilbara Coast (Greenop, 1968) where flatback turtle nesting is abundant. Dr Prince and WACALM Karratha staff (Pers. comm. October 2002) 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 WACALM file records (DF&F file248/50: p.100) referring to this flatback egg and turtle harvest that date back to at least 1968. Prince (1994) expressed the opinion that flatback turtle eggs appeared to be an important resource for coastal indigenous people.
The size of this harvest remains unquantified.

3.1.4 INDONESIA

One long distance recapture of a tagged *N. depressus* from Crab Island was reported eaten in southeast Papua (formerly Irian Jaya) (Limpus *et al.* 1993). Saurez (2000) reported the harvest of two *N. depressus* during a six-month survey of village harvest in Kei, eastern Indonesia.

The scale of this harvest across the numerous coastal villages in eastern Indonesia is not quantified.

3.2 ACCIDENTAL CAPTURE IN FISHING GEAR

3.2.1 SHARK CONTROL PROGRAMS

N. depressus has occasionally been captured in Queensland Government shark nets in past decades (EPA Queensland Turtle Conservation Project). Based on capture and mortality rates up to the early 1990s, *N. depressus* was expected to rarely die in the Queensland Shark Control Program (QSCP) (Kidston *et al.* 1992; Unpublished data from Department of Primary Industries "Sunfish Shark Control Subsidiary Database" for the years 1986-1992; Unpublished data, EPA Queensland Turtle Conservation Project).

- Prior to 1993, the species of turtle was not normally recorded by the contractors and hence the species composition of the catch was not available. Since 1986, most captured turtles have been scored for their survival or otherwise. For the 7yr period, 1986-1992, 586 turtles were recorded captured. Of these, 410 were released alive, 81 were recorded as not released and survivorship was not recorded for the remaining 95. Therefore somewhere between 12 and 25 (probably close to 25) turtles have been killed annually by the QSCP. Very few of these would have been *Natator*. It is presumed that this species would on average account for less than 1 of these mortalities annually. Since 1992 the management of this program has changed to increase the survivorship of captured turtles.

Since tagging of most of the turtles captured in the QSCP and their identification to species commenced in 1993, no *N. depressus* have been recorded captured within this program. Therefore there has been a zero mortality of *N. depressus* in the QSCP since 1993.

There are no records of *Natator* being captured in the corresponding New South Wales beach meshing program (Krogh and Reid, 1996).

3.2.2 COMMERCIAL FISHERIES

The highest mortalities recorded for the species are associated with commercial fisheries, especially the trawling and gillnet fisheries. While no precise figure can be placed on the total mortality of *N. depressus* in commercial fisheries, it is presumed that they account for the death of many hundreds of these turtles in northern and eastern Australia annually.

Gill nets

- Twenty-four *N. depressus* were estimated to have drowned in one shark net in a 2 week period: 2000m of bottom set monofilament net (mesh size = 42.5cm, drop = 12m) approximately 4km off-shore in Fogg Bay, Northern Territory, 15-30 November 1991 (Guinea and Chatto, 1992).
- Immature *N. depressus* are regularly captured in gill nets set along the coast of the south-eastern Gulf of Carpentaria and some of these turtles are drowned (unpublished data, EPA Queensland Turtle Conservation Project). The annual kill of turtles in the inshore gill net fisheries of the Gulf of Carpentaria and Arnhem Land remains unquantified.

Trawling

- The capture of *N. depressus* in prawn trawls prior to 1990 (Figure 10a) was recorded by trained, on-board, EPA Turtle Conservation Project volunteers. 51% of 90 turtles captured in the Gulf of Carpentaria (Northern Prawn Fishery); 71% of 45 turtles captured in the northern GBR between Princess Charlotte Bay and Cape York; 23% of 30 turtles captured in the Townsville area (unpublished data, EPA Queensland Turtle Conservation Project) were *N depressus.*
- During a two year CSIRO study of turtle bycatch in the Northern Prawn Fishery (NPF), *N. depressus* made up 54-64% of the 165 and 161 turtles trawled in 1989 and 1990 respectively (Poiner and Harris 1994,1996): Catch rate = 0.0268±0.0029 turtles per trawl in 1989 and 0.0333±0.0033 in 1990. There was a 7.9% probability of being landed dead in the sorting tray in 1989 and 13.6% probability in 1990. This study estimated that the northern prawn fishery killed approximately 355 and 337 *N. depressus* in 1989 and 1990 respectively.
- One large immature *N. depressus* was among 15 dead marine turtles beachwashed in Fog Bay in the few weeks prior to September 1995 (Guinea *et al.* 1997). The death of these turtles was attributed to trawl bycatch mortality.
- Based on a logbook recording program, turtle bycatch in the Queensland East Coast Trawl Fisheries (ECTF) and in the Torres Strait Prawn Fishery (TSPF) during 1991-1996 was investigated (Robins, 1995; Robins and Mayer, 1998). This study found that *N. depressus* was a commonly reported turtle in the ECTF bycatch (20.1% of 1,527 turtles reported; range per year = 7% – 31%). *N. depressus* was the most frequently reported turtle species in the TSPF bycatch (66% of the 151 turtles reported.). The *N. depressus* impacted by both fisheries encompassed the full range of benthic feeding size classes from small immature to adult size ranges. The extrapolated mean annual catch of *N. depressus* within the entire fishery was 968 in the ECTF and 400 in the TSPF. The total annual direct mortality associated with these captures (assuming that some non-resuscitated comatose turtles could die on release) could be in the range of 2-4% (n=19-39) in ECTF and 1% (n=4) in TSPF. The majority of *N. depressus* were trawled in near-shore waters from Mackay north to Cape York and in central Torres Strait.

In the NPF studies (Poiner and Harris, 1996), there were large interspecific differences in probability of drowning when a turtle was captured in a trawl (Table 17). *N. depressus* appears to be the least susceptible to drowning of the marine turtle species in Australia.

Table 17. Probability of marine turtle mortality with trawling capture in the Northern Prawn Fisheries, 1989-1990 (Poiner and Harris, 1994).

Species	Mortality probability
Caretta caretta	21.9%
Chelonia mydas	12.0%
Eretmochelys imbricata	26.4%
Lepidochelys olivacea	12.5%
Natator depressus	10.9%

Mortality data from trawling studies that does not address post-release mortality of trawled turtles must be viewed as an underestimate. There is a need for more data to better assess the impact of forced submergence in nets on *N. depressus* mortality.

- Based on reports from trained crew, turtle bycatch in the NPF during 1998-2001 was investigated (Robins *et al.* 2002). This study spanned two years before and after the compulsory introduction of Turtle Exclusion Devices (TEDs) into the NPF and quantified a reduction in turtle captures of two orders of magnitude. About 60% of the turtles reported captured were *N. depressus*.

There has been no study that has extrapolated back in time to estimate the size of the impact on marine turtles by the Northern Prawn Fishery and East Coast Trawling Fleets as the number of vessels escalated in the 1970s. At the same time the industry changed with the use of larger boats, towing larger nets and for longer shot times than was the case in the late 1960s. The trawl fisheries off the coast of Queensland, Northern Territory and Western Australia have had the potential to kill hundreds or perhaps thousands of adult and large immature *N, depressus* annually since the 1970s. Fortunately this situation has for the most part changed as we moved into the 21st Century. The compulsory use of TEDs has been regulated in the NPF since April 2000, in ECTF since December 2000, TSPF since March 2002, and in Western Australian prawn and scallop trawl fisheries since 2002. The process for regulating the compulsory use of TEDs in trawl fisheries was partly facilitated by Otter Trawling being listed under the EPBC Act as a key threatening process (KTP) in 2001 due to the level of bycatch of marine turtles.

In addition to trawling bycatch within Australian waters, *N. depressus* is captured in trawls and gill nets in the Gulf of Papua and in Indonesian waters in the Arafura Sea (Limpus *et al.* 1993; Sahertian and Noija, 1994; Spring, 1982). In these countries, there is a reasonable probability that live turtles in the bycatch have been killed for food, by the crew. The extent of the trawl bycatch mortality of *N. depressus* in neighbouring countries is unquantified.

Drift nets

In the past, a drift net fishery similar to the current Taiwanese gill net fishery in Indonesian Arafura Sea waters also operated in northern Australian waters (Hembre, 1985-1986).

- An onboard-observer on a Taiwanese gill net boat (*Chyun Fure No.7*) off the Arnhem Land coast in 1985-86, recorded 7 *N. depressus* out of 16 turtles captured (56% mortality for the pooled species sample: Records over approximately a 4month period; 81 sets of a 10.5km monofilament net, surface headline, 15m drop, 14-15cm mesh).

Crabbing

- There are no reports of *N. depressus* being captured in floatlines to crabpots or similar buoy lines.

3.3 BOAT STRIKE

During the 9 years, 1995-2003, of systematic recording of stranded marine wildlife in Queensland there have been three cases of *N. depressus* killed by boat strike (EPA Marine Wildlife Stranding and Mortality Database).

3.4 MARINE DEBRIS

During the 9 years (1995-2003), of systematic recording of stranded marine wildlife in Queensland, there have been two cases of post-hatchling *N. depressus* killed by oil fouling and three cases killed by entanglement in, or ingestion of, plastic or other synthetic debris (Figure 10e) (EPA Marine Wildlife Stranding and Mortality Database). One case of *N. depressus* death following ingestion of plastic debris has been reported from Darwin (Chatto *et al.* 1995).

3.4.1 GHOST NETS

Large amounts of fishing net are discarded or lost from the fisheries of the Gulf of Carpentaria and Arafura Sea and end up beachwashed on the Queensland and Northern Territory beaches of the Gulf of Carpentaria (Limpus and Miller, 2002; White 2003, 2004). In addition, when cyclones pass from the Coral Sea across Cape York Peninsula into the Gulf of Carpentaria each summer, they cause erosion of the beaches of western Cape York Peninsula and the southern Gulf coast. With this erosion, thousands of nets can be returned to the sea only to drift and re-strand in the weeks that follow. For example, in the six weeks following Cyclone *Abigail* in February 2001, it is estimated that over 4000 nets washed ashore containing in excess of 400 turtles along the eastern Gulf of Carpentaria Coast (C. Limpus, unpublished data). Similar stranding of nets and entangled turtles has been recorded following cyclones in the three years since 2001 (V. Wallen, pers. comm.; EPA Marine Wildlife Stranding and Mortality Database). There are thus two separate issues with regard to the entrapment of turtles in these "ghost nets": new nets arriving at the beaches each year; and, recycling of nets from the beaches back to the sea and their subsequent re-stranding.

In northeast Arnham Land, turtles entangled in ghost nets strand mainly in spring (Leitch 1997, 2001).

The turtle mortality throughout the Gulf of Carpentaria within this "ghost net" fishery is unquantified but appears to be many hundreds of turtles annually. An unquantified proportion of the turtles stranding in these nets are adult and large immature *N. depressus* (Figure 10b) (EPA Marine Wildlife Stranding and Mortality Database; Leitch, 1997, 2001). The extent to which this type of mortality extends further across northern Arnhem Land is undetermined.

In addition to mortality of turtle entanglement in these nets in the sea, nesting turtles can become trapped in these nets and associated ropes on nesting beaches. Two adult females ashore for nesting were rescued from entanglement in the ropes of beach-washed nets during a three week nesting survey at Crab Island in July 1999 (D. Limpus, pers. comm. 1999).

These ghost nets have the potential to kill hundreds of adult and large immature *N. depressus* annually.

3.5 HABITAT DAMAGE

Nuclear testing on nesting habitat

The British Government in collaboration with the Australian Government conducted the first test of nuclear weapons in Australia with *Operation Hurricane* on 3 October 1952 near

Trimouille Island, Montebello Group, Western Australia (Figure 11a). The Montebellos are a significant breeding site for *C. mydas* and *N. depressus* (Pendoley, 1999) and this nuclear test would have coincided with courtship time for these populations. It can be assumed that the October 1952 nuclear test would have killed an appreciable number of the turtles that were aggregated in the shallow waters for the 1952-1953 breeding season. There is a brief account of a landing on beaches south of Pitt Point, Trimouille Island (1-1.5km north of the blast site) in June 1953, that describes the stench and devastation of the turtles (Kendrick, 2003): "….for the entire length of the beach (two beaches, each about 500 metres long) dead turtles were 'piled three or four deep, in a layer from six to ten feet (two to three metres) wide'. Turtles of all sizes were represented: some were too large for one man to lift, while others were clearly hatchlings being small enough to fit in one's hand'." A medium sized carapace, "about 0.5m long" was removed from the beach but discarded because it was "radioactive". While the number of turtles killed will never be known, one of the sailors who made the above observations claimed that he saw "tens of thousands" of dead turtles and Kendrick (2003) estimated from gross approximations without measurements of the turtles involved, that perhaps 5000 turtles were piled ashore on the two beaches. Based on the observations, turtles of all size ranges were killed, including large adults, intermediate sized immatures and hatchlings.

There were two additional nuclear tests among these islands on 16 May 1956 and 19 June 1956. All three tests would have killed resident turtles in the vicinity. Radiation poisoning would have killed or debilitated turtles that arrived to breed or feed for some years to come. Eggs laid on the beaches during the following years would have been bombarded with radiation from the sand. These nuclear tests probably caused the largest localised kill of marine turtles from human activities in Australia's history. The local foraging and breeding populations of *N. depressus*, *Chelonia mydas*, and *Eretmochelys imbricata* would have suffered large losses over some years.

11a. Detonation of the first atomic bomb in the Montebello Islands, Western Australia, 3 October 1952. *Photograph courtesy of Courier Mail.*

11b. Bare Sand Island, Northern Territory was a RAAF bombing range. *Photograph by Dr M. Guinea.*

Figure 11. Past Defence Force activities have been detrimental to significant *Natator depressus* breeding populations.

Bombing range on nesting habitat

Quail Island and adjacent Bare Sand Island, Northern Territory, are significant *N. depressus* rookeries and have been used as a bombing range by the Royal Australian Air Force (Figure 11b). The damage from the bombing over many years has not been quantified. Quail Island is closed to public access because of the presence of unexploded ordinance.

In Western Australia, substantial infrastructure for oil/gas storage and processing has been constructed on a several *N. depressus* rookeries, including Thevenard, Varanus and Barrow Islands (Figure 9a, b). The direct impact of these facilities through alienation of nesting habitat and alteration of light horizons and hence impact on female nesting beach selection and hatchling dispersal remains unquantified. 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.

Oil and gas industry impacts on breeding and feeding populations
The impact of the oil and gas industry within the Western Australian distribution of turtle foraging areas and rookeries, including very significant *N. depressus* rookeries is currently largely unquantified. The Industry is managed through Environmental Impact Assessment procedures under both Federal and State legislation. There is a Memorandum of Understanding between the Australian Department of Industry and Resources and the WA Environmental Protection Authority that provides guidance on which jurisdiction applies in which areas.

With each project, there is an environmental risk assessment undertaken which is usually encapsulated in an Environment Plan. Impacts on turtles and mitigation measures to minimise the potential for these impacts from proposed and current activities are presented in these Environment Plans. In addition to the risk assessment component of Environment Plans, there is also auditing and close out obligations and requirements for reporting back on environmental performance against set conditions.

The main legislation for assessment and approval of petroleum activities in Western Australia are:

<u>State Legislation</u>

- *Petroleum (Submerged Lands) Act 1982*
- *P(SL) Act Schedule (Specific Requirements as to Offshore Petroleum Exploration and Production) 1995*
- *Environmental Protection Act 1986*
- *Conservation and Land Management Act 1984*

<u>Commonwealth Legislation</u>

- *Petroleum (Submerged Lands) Act 1967*
- *Petroleum (Submerged Lands)(Management of Environment) Regulations 1999*
- *Environment Protection and Biodiversity Conservation Act 1999*

The potential for pollution impact on *N. depressus* populations from a future major malfunction within the Western Australian oil and gas industry should be considered with a pre-existing contingency plan in place to conserve these populations.

Port development impact on foraging habitat
Dampier/Karratha and Port Headland, Western Australia, support an expanding export infrastructure for gas, iron ore and salt. This can be expected to be accompanied by increased dredging of channels. In addition to their movement through these waters, the numerous bulk carriers anchor offshore from the port. Their anchors and the chains as they swing on their moorings damage the benthic habitat over many square kilometres. The ports with their shipping will have a negative impact locally on the environment. These impacts will be from the accumulation of minor spillages and rubbish disposal, the impact of their antifouling paints, sediment disturbance by propeller wash from large vessels, dredging of

navigation channels, and boat strike, etc. These issues can be expected to expand as coastal development continues to expand in the north-west. Similar port infrastructure and shipping activities are expanding in the Gulf of Carpentaria with port facilities being developed in *N. depressus* foraging habitat adjacent to Weipa and Karumba in Queensland and MacArthur River, Groote Eylandt, and Gove in Northern Territory. Their collective impact on *N. depressus* populations is not being addressed.

3.6 DISEASES

There are no reports of diseases from anthropogenic origins causing mortality among *N. depressus* in eastern Australia but few individuals have been subjected to pathology examinations.

Warty growths resembling green turtle fibropapilloma tumours have been recorded on nesting females at Crab Island (Limpus, Couper and Couper, 1993). Healing tumours were recorded on one of ten nesting females examined at Flinders Beach south of Mapoon (Unpublished data, EPA Queensland Turtle Conservation Project).

During studies of fungal invasion of marine turtle eggs, Phillott *et al.* (2002) identified at least six soil fungi present in the cloaca of nesting female *N. depressus* at Peak Island (Table 18).

Table 18. Recorded fungal infection of *Natator depressus* (adult nesting turtles) in Australia.

Species	In cloaca of adults	Reference
Aceremonium sp.	Nesting on Peak Is	Phillott *et al.* 2002
Aspergillus sp.	Nesting on Peak Is	Phillott *et al.* 2002
Fusarium solani	Nesting on Peak Is	Phillott *et al.* 2002
Penicillium sp.	Nesting on Peak Is	Phillott *et al.* 2002
Phialophora sp.	Nesting on Peak Is	Phillott *et al.* 2002
Sporothrix sp.	Nesting on Peak Is	Phillott *et al.* 2002

3.7 SEISMIC SURVEY

Based on extrapolations from a small sample of caged *C. caretta* and *C. mydas* exposed to air-gun signals, it has been estimated that a seismic vessel operating 3D air-gun arrays in 100-120m water depth should impact marine turtles by producing behavioural changes at about 2km range and avoidance at around 1km range (McCauley *et al.* 2000). Seismic surveys are not likely to cause direct mortality. In the absence of similar studies with *N. depressus*, this study provides a basis for recommending that a buffer zone of at least 2km radius should be maintained between seismic surveys and significant aggregations of marine turtles such as internesting, courtship or dense foraging aggregations. The highest priority would be to avoid causing disruptive behaviour for the turtles during the time-limited reproductive period.

3.8 LIGHT HORIZON DISORIENTATION

Eastern Australia

Disorientation of hatchlings by street and house lights as the hatchlings cross the beach and swim in inshore waters can result in increased hatchling mortality (lost in vegetation, dying of heat exhaustion, run over by cars, increased bird and fish predation).

- Disorientation appears to be rare at the larger rookeries at present.
- Disoriented hatchlings occasionally are found inland from the small nesting beaches adjacent to Mon Repos (Burnett Heads, Neilson Park) and mainland beaches near Mackay. Only isolated clutches are impacted annually.

Western Australia
Coastal Western Australia, from Exmouth to the Pilbara Coast with associated islands from North-west 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 significant *N. depressus* breeding and presumed 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.

Dr Prince and Kelly Pendoley (pers. comm. October 2002) identified the issue of altered light horizons associated with brightly illuminated oil/gas facilities on islands (lighting and flares) such as at Barrow, Varanus and Thevenard Islands (Figure 9) and more recently with similar brightly illuminated structures at sea. People employed to work on these island communities expect to have similar amenities as those 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 (Figure 9a). The petroleum industry has been funding research to address some 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 (wavelength, intensity). Beach studies have commenced to quantify the magnitude of the problems with respect to hatchling disorientation for the region (K. Pendoley, pers. comm. August 2004): How many sites are impacted? What is the size of associated turtle nesting populations by species? What proportion of hatchling production is being lost on the beaches due to disorientation?

Another consequence of changed night-time illumination over sizeable areas of sea, as can occur with oil and gas production platforms, 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 the 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 from other species that when the skyline of 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, at the time, the most significant of the 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 have 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, imprinting and dispersal), to breed on alternative beaches, it leaves them vulnerable to laying eggs in areas where the population may function sub-optimally. No one appears to be addressing this issue in relation to the Western Australian rookeries.

The more facilities that develop on an island and the more islands in the region that are developed (with associated increases in drilling rigs, work boats, offshore flares and construction barges), the greater the problem of altered light horizons will become. 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 *et al.* 2000).

Dr Prince and Karratha WACALM staff in 2002, reported that in the Port Hedland area there was regular disorientation of flatback turtle hatchlings 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, the added mortality factor of disoriented hatchlings being run over on roads was identified.

4. POPULATION STATUS

4.1 POPULATION DEMOGRAPHY

Eastern Australian stock

Limpus *et al.* (2002) presented circumstantial evidence of a substantial population decline for the eastern Australian stock during the 20th Century. However, the same study demonstrated stability in the size of annual nesting population and size of the breeding females over the last three decades at Wild Duck Island, Curtis Island and the Woongarra Coast. Given this population stability over about a generation, given that the foraging distribution for the stock is effectively contained within the Great Barrier Reef World Heritage Area and Great Barrier Reef Marine Park and given that >70% of the nesting distribution is contained within National Parks and Conservation Parks, the modest sized eastern Australian *N. depressus* stock can be regarded as currently secure but conservation dependent.

Gulf of Carpentaria and Torres Strait Stock

In the absence of long term census data or in-depth demographic data for this stock, assessment of its population status can only be made in general terms. Based on this review, the principal sources of mortality from non-natural processes impacting this stock include:

- Very high levels of egg loss from pig predation on all nesting beaches of north-western Cape York Peninsula. More generally for the stock, there is varanid and dog predation of eggs and vehicle damage to nests.
- Many hundreds of adult and immature *N. depressus* have been killed annually in the Northern Prawn Fishery in the decades prior to 2000. This mortality should now be reduced to a trivial level with the compulsory use of TEDs in this Fishery and in the Torres Strait Prawn Fishery. The unquantified mortality in the trawl fisheries in the Indonesian waters of the Arafura Sea and Papua New Guinea waters of the Gulf of Papua is continuing. Additional unquantified mortality occurs in inshore gill net fisheries of the Gulf of Carpentaria and southern West Papua.
- Hundreds or possibly thousands of adult and large immature *N. depressus* are killed annually in ghost nets throughout the Gulf of Carpentaria.
- There has been regular egg harvest and occasional turtle harvest by local indigenous communities throughout western Torres Strait and Gulf of Carpentaria coastal communities.

On the assumption that the population dynamics of *N. depressus* is not very different to that of the better studied species *C. caretta* (Chaloupka, 2003) and *C. mydas* (Chaloupka, 2002), and given the estimate of a few thousand nesting *N. depressus* females annually, the Gulf of Carpentaria and Torres Strait population is expected to be unable to sustain this collective level of annual mortality over the long term. There is a distinct possibility that this stock, the largest nesting population for the species, is already in decline.

Western Northern Territory and North-West Shelf Stocks

There is less information available for these two stocks of western Northern Territory and the North-West Shelf than for the preceding stocks. Preliminary data from a seven-year nesting census at the Bare Sand Island index beach indicates that the western Northern Territory stock could be declining at a rate consistent with an IUCN Red List Category of “Endangered.”

Impacting both these stocks, there is a wide range of identified, but largely unquantified mortalities, from anthropogenic sources. Based on this review, these mortality sources include:

- Bycatch mortality in trawl and gill net fisheries of Western Australia and Arnhem Land. The Northern Prawn Fishery and Western Australian prawn and scallop trawl fisheries bycatch mortality should be trivial since the compulsory use of TEDs was introduced in

2000 and 2002 respectively. The fisheries bycatch of *N. depressus* in Indonesian waters of the Arafura Sea is a significant data gap in these considerations. *N depressus* bycatch mortality in gill net fisheries within northern Australia warrants quantification.
- Excessive fox, dog, varanid and pig predation of eggs at widely scattered rookeries.
- Past Defence Force nuclear testing and bombing range damage to breeding populations.
- Negative impacts of coastal development, especially with oil, gas and port facilities and general coastal development in north-western Western Australia causing alteration to light horizons and other associated degradation of nesting and foraging habitat. Oil companies operating on the North-West Shelf have developed, or are developing, Lighting Management Plans to reduce these impacts.
- Mortality of adult and large immature *N. depressus* in ghost nets across Arnhem Land.
- Indigenous harvest of eggs and, to a lesser extent, nesting females.

In the absence of quantified data on the size of the Western Australian *N. depressus* nesting populations and without reasonable quantification of egg loss and turtle loss from the populations, there is a reasonable possibility that this significant *N. depressus* stock may be functioning unsustainably.

4.2 CONSERVATION STATUS WITHIN AUSTRALIA

Conservation management of the flatback turtle, *Natator depressus,* within Australia had its beginnings with the 18th July 1968 Order in Council under the Queensland Fisheries Act, that declared a year-round closed season for the harvest of all species of marine turtles and their eggs in Queensland.

N. depressus currently is recognised as a threatened species in Queensland, Western Australia and Australia generally (Table 19). Given the current level of threats to three of the four stocks for the species identified above the species warrants consideration as a vulnerable species across all jurisdictions.

Table 19. Summary of the legislatively defined conservation status of *Natator depressus* for Australia.

	Status	**Legal basis**
International obligations		
Convention for the Conservation of Migratory Species of Wild Animals (CMS)	Appendix I & II	Australia is a signatory state.
Convention for International Trade in Endangered Species (CITES)	Appendix 1	Australia is a signatory state.
Legislation		
Australia including Australian Territories	Vulnerable Migratory species Marine species	*Commonwealth Environment Protection and Biodiversity Conservation* (EPBC) *Act* 1999
Tasmania	Not listed	*Threatened Species Protection Act* 1995
Victoria	Not listed	*Advisory list of Threatened Vertebrate Fauna in Victoria* 2003
New South Wales	Protected	*Threatened Species Conservation Act* 1995
Queensland	Vulnerable	*Nature Conservation Act* 1992
Northern Territory	Data deficient	*Territory Parks and Wildlife Conservation Act* 2000
Western Australia	Rare or likely to become extinct	*Wildlife Conservation Act* 1950
South Australia	Not listed	*National Parks and Wildlife Act* 1972

The Australian Government has jurisdiction over waters beginning three nautical miles offshore to the end of the Exclusive Economic Zone (EEZ). In these waters marine turtles are protected under the EPBC Act. The respective Australian States and Territories have jurisdiction over intertidal waters and coastal waters out to three nautical miles offshore from their State lands. The respective State legislation are applicable to the management of marine turtles in these State and Territorial waters. Under the EPBC Act actions in all Australian waters that have, will have or are likely to have a significant impact on marine turtles are subject to a rigorous referral, assessment, and approval process.

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