MARINE TURTLES

in the Great Barrier Reef World Heritage Area

A compendium of information and basis for the development of policies and strategies for the conservation of marine turtles

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GREAT BARRIER REEF
MARINE PARK AUTHORITY

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ABOUT THIS PUBLICATION

This document about conservation of marine turtles in the Great Barrier Reef Marine Park is released for information and public comment. It will be used as a basis for the development of policies and strategies for the conservation of marine turtles in the World Heritage Area.
Comments on the document are welcome and should be addressed to:

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FOREWORD

The objective of this document is to provide a basis for managing human activities that will, or are likely to, affect the turtle populations occurring in the Great Barrier Reef World Heritage Area so as to ensure their conservation and, where necessary, recovery.

Six of the world's seven species of marine turtle are found within the Great Barrier Reef World Heritage Area ('the World Heritage Area'): the loggerhead, green, hawksbill, flatback, leatherback and olive ridley. Many spend at least part of their life outside the World Heritage Area's borders. The conservation of these highly mobile animals requires cooperation across local, State, national and international boundaries. Indeed, many of the issues concerning marine turtles are global in scope.

This document identifies the major impacts of human activities on marine turtles occurring in and around the World Heritage Area and the possible effects of those impacts on individual animals and on populations. Whilst global issues and threats are recognised, the principal focus is on managing threats to turtles arising from human activities in and around the World Heritage Area. This document identifies known and anticipated problems; as well as information gaps.

This document complements a considerable amount of other work on Australian marine turtles and the management of human activities affecting them, including the *Draft National Recovery Plan for Marine Turtles in Australia* (Environment Australia 1998) and the *Turtle and Dugong Conservation Strategy for the Great Barrier Reef Marine Park* (Great Barrier Reef Marine Park Authority 1994). The national recovery plan outlines actions managing agencies need to take to assist with the recovery of marine turtles in Australia. Actions identifying GBRMPA as a lead agency are described in Appendix 1.

The information in this document is based on the current scientific understanding of marine turtles, on analysis of present and, to some extent, predicted future patterns of human activity, and on prudent application of the precautionary principle. Whilst much is known about Queensland's marine turtles, as more information becomes available about the populations (e.g. abundance, distribution, key habitats), and as human activities within and adjacent to the World Heritage Area change, it will need to change as well. It should be considered to be a 'living document', and will be subject to review and modification as necessary to ensure that the objective in the first paragraph is met.

Many agencies, organisations and individuals have assisted in the preparation of this document.

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1. INTRODUCTION

Established under the *Great Barrier Reef Marine Park Act 1975*, the Great Barrier Reef Marine Park ('the Marine Park') covers an area of approximately 340,000 km^2, and includes one of the most complex and biologically diverse ecosystems on earth.

The Marine Park comprises nearly 98% of the Great Barrier Reef World Heritage Area, which was inscribed on the World Heritage List in 1981 on the basis of its outstanding natural universal values and its ecological integrity.

The Great Barrier Reef Marine Park Act also established the Great Barrier Reef Marine Park Authority ('the Authority'). The Authority's Goal is:

> *'To provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park'.*

The stated Aims of the Authority include protecting the natural qualities of the Great Barrier Reef while providing for reasonable use of the Reef Region, and minimising regulation of, and interference in, human activities, consistent with meeting the Goal and other Aims of the Authority. Consistent with these obligations, the Authority is responsible for conserving turtles in the Marine Park. This is achieved through managing human activities that impact on turtles occurring in the Marine Park, including both current activities and predicted future activities. To the extent that it is consistent with protecting the natural values of the Great Barrier Reef, including marine turtles, the Authority provides for ecologically sustainable use of the Marine Park. There is a need to address impacts on marine turtles, because three of the six species inhabiting in the World Heritage Area show evidence of a population decline.

The Authority also seeks to ensure that the interests of Aboriginals and Torres Strait Islanders are reflected in the management of the Great Barrier Reef World Heritage Area. The particular relationship between Aboriginals and Torres Strait Islanders and marine turtles within the Area is well documented (Cook 1994, Hunter and Williams 1998, Ponte et al. 1994).

To conserve turtles and the other natural values of the World Heritage Area over the long term, management should seek to be proactive. Current problems must be addressed, but possible future problems should be anticipated to the extent possible. Further, management within the World Heritage Area cannot occur in isolation, but must operate effectively in the context of other Commonwealth, Queensland, and, to some extent, international initiatives.

In harmony with the Draft *National Recovery Plan for Marine Turtles in Australia* (Environment Australia 1998), the goal for marine turtle conservation in the Great Barrier Reef World Heritage Area is *'to reduce impacts on Australian stocks of marine turtles and hence promote their recovery in the wild'*.

2. CONTEXT AND LINKAGE WITH OTHER POLICIES

None of the marine turtle species found in Australian waters are exclusively Australian; however, the flatback turtle nests only on Australian beaches and has not been reported off the Australian continental shelf[1]. Thus, conservation of marine turtles requires efforts at the local, state, national, and international levels.

At the international level, Australia participates in several international conservation initiatives that apply to marine turtles, including the *Convention on Biological Diversity,* the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES), The World Conservation Union (IUCN), and the *Convention on the Conservation of Migratory Species of Wild Animals* (Bonn Convention).

Nationally, the *Environment Protection and Biodiversity Conservation Act 1999* is the core conservation legislation applicable to marine turtles. In July 2000, this Act replaced the *National Parks and Wildlife Conservation Act 1975,* the *Whale Protection Act 1980*, the *World Heritage (Properties Conservation) Act 1983*, the *Endangered Species Protection Act 1992*, and the *Environment Protection (Impact of Proposals) Act 1974.* One of the objects of the Act is 'to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance'. The Commonwealth marine environment, world heritage areas, nationally threatened species, and migratory species protected under international agreements (such as the Bonn Convention) are considered to be matters of national environmental significance.

Another object of the Environment Protection and Biodiversity Conservation Act is to 'promote the conservation of biodiversity'. All species of marine turtles are nationally listed as threatened species and are listed under conventions protecting migratory species (including the Bonn Convention), thus receiving additional protection under the corresponding provisions of the Act. The Act requires that within 10 years of its commencement, inventories must be prepared that identify and state the abundance of marine turtles in Commonwealth marine areas.

The Environment Protection and Biodiversity Conservation Act provides a framework for the protection of species listed as endangered and vulnerable, and ecological communities listed as endangered. The Act provides for the preparation of recovery plans for all scheduled species and ecological communities. Each recovery plan must provide for the research and management actions necessary to stop the decline of, and support the recovery of, the species or community so that its chances of long-term survival in nature are maximised. As a Commonwealth agency, the Authority must not take any action that contravenes a recovery plan or threat abatement plan. All six species of marine turtles are scheduled as endangered or vulnerable under the Act. The Commonwealth Department of the Environment has developed a Draft *National Recovery Plan for Marine Turtles in Australia*. It is intended that the Recovery Plan will provide a base level of guidance, and that regional, temporal and species-specific issues will be addressed at the State, regional and local levels.

The Great Barrier Reef Marine Park Act also provides for the protection of marine turtles within the Marine Park, through zoning, issuing of permits and implementation of plans of management that collectively enable management of human activities. The Act establishes the requirement to obtain permits to undertake a range of activities in both zoned and unzoned areas of the Marine Park. Under the Regulations, the Authority must not grant a permit to enter, use, or carry on an

[1]The species is considered reproductively endemic to Australia and has the most restricted range of all marine turtle species.

activity in the Marine Park unless an assessment has been made of the impact that entry, use or activity is likely to have on the Marine Park, including on marine turtles.

Under the Great Barrier Reef Marine Park Act, the Authority must have regard to the protection of World Heritage values of the Marine Park and the precautionary principle in preparing management plans. The 'precautionary principle' in the Act is defined by the *Intergovernmental Agreement on the Environment 1992*, which states that in the application of the precautionary principle, public and private decisions should be guided by:

(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and,

(ii) an assessment of the risk-weighted consequences of various options.

In Queensland, the *Nature Conservation Act 1992* protects marine turtles Indigenous to Australia. All six species found in Queensland are listed as either 'Endangered' or 'Vulnerable' under the *Nature Conservation (Wildlife) Regulations 1994.* The Act provides for the development of conservation plans for wildlife. Also in Queensland, the *Marine Parks Act 1982* provides for the protection of marine turtles through zoning and the issuing of permits, similar to the Great Barrier Reef Marine Park Act.

3. JURISDICTIONS AND BOUNDARIES IN THE GREAT BARRIER REEF

The Great Barrier Reef extends offshore from the tip of Cape York Peninsula to just north of Bundaberg and is composed of the Great Barrier Reef World Heritage Area, the Great Barrier Reef Region and the Great Barrier Reef Marine Park. The Great Barrier Reef World Heritage Area encompasses all land and seas within the proclaimed World Heritage Area. The GBR Region encompasses all Commonwealth-owned lands and seas in the area, except land above low water mark on Queensland-owned islands. The Marine Park covers nearly all the Great Barrier Reef Region except for various inshore areas precluded when the Marine Park was first declared. The Commonwealth and Queensland Governments are negotiating to incorporate these excluded areas within the Marine Park. In total, over 20 State and Commonwealth agencies have some interest in the Great Barrier Reef World Heritage Area (Lucas et al. 1997).

Marine turtles provide a classic example of the complexities associated with management in the Marine Park because throughout their life cycle, they cross many jurisdictional boundaries. Kenchington (1990) described the complexities of managing turtle populations in the Marine Park. They *'hatch from nests on land under Queensland jurisdiction, move to the sea across the intertidal areas under state jurisdiction, cross the low water mark to enter Commonwealth jurisdiction, and then move on to feed and grow for years in international waters. Eventually they return to the Great Barrier Reef to mate in areas under Commonwealth jurisdiction and for females to lay eggs on Queensland territory'*.

All marine turtles must come ashore to lay eggs; they often nest on islands and cays in the Great Barrier Reef World Heritage Area. Of the approximate 600 continental islands and 300 coral cays in the World Heritage Area (Lucas et al. 1997), fewer than 50 (less than 10%) are owned or leased by the Commonwealth. The remainder is State of Queensland lands (often as National Parks), or owned privately. Although many of the Commonwealth-owned or leased islands provide beaches for low density nesting by marine turtles, none are critical key nesting sites for the turtle populations in the World Heritage Area. Nevertheless, management strategies are required for these sites. Actions taken at these sites should complement the conservation requirements of the turtle populations in the Marine Park.

4. CHARACTERISTICS OF MARINE TURTLES

Six of the world's seven species of marine turtle are found in waters around Australia, representing two families (Cheloniidae, Dermochelidae); all are found within the World Heritage Area (Table 1). Some species are frequently seen, such as the loggerhead and green turtle. Others, such as the olive ridley and leatherback, are known to occur in the Marine Park but are seldom seen.

For effective management of human impacts on marine turtles information is needed about the animals. For most species of Australian turtles, including those found in the World Heritage Area, there is inadequate knowledge of the sizes of their populations, distributions, or the location of key foraging habitats. However, the conservation status of individual species and populations has been assigned on the basis of available information. Table 1 lists conservation status of Australian marine turtles at the International, Commonwealth and Queensland levels.

The Marine Turtle Specialist Group of the World Conservation Union (IUCN) assesses the conservation status of marine turtle species at a global level. After a particular species is evaluated, it is placed in one of the following categories: extinct, extinct in the wild, critically endangered, endangered, vulnerable, lower risk, or data deficient (IUCN 1996). Taxa included in the lower risk category are further classified as conservation dependent, near threatened or least concern. All six marine turtle species in the World Heritage Area are listed as either critically endangered (hawksbill turtle), endangered (green, loggerhead, olive ridley, leatherback turtle) or vulnerable (flatback turtle) (Table 1).

Table 1. Marine turtle species occurring in the Great Barrier Reef World Heritage Area and their conservation status as assessed by IUCN (the World Conservation Union), by the Australian Government, and by the State of Queensland.

Common Name	Scientific Name	IUCN (The World Conservation Union)	Australian *Environment Protection and Biodiversity Conservation Act 1999*	Queensland *Nature Conservation (Wildlife) Regulation 1994*
Family: Cheloniidae				
Loggerhead	*Caretta caretta*	Endangered	Endangered	Endangered
Green	*Chelonia mydas*	Endangered	Vulnerable	Vulnerable
Hawksbill	*Eretmochelys imbricata*	Critically Endangered	Vulnerable	Vulnerable
Flatback	*Natator depressus*	Vulnerable	Vulnerable	Vulnerable
Olive ridley	*Lepidochelys olivacea*	Endangered	Endangered	Endangered
Family: Dermochelidae				
Leatherback	*Dermochelys coriacea*	Endangered	Vulnerable	Endangered

At the national level, the Australian Environment Protection and Biodiversity Conservation Act provides for species to be listed as Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Lower Risk, Data Deficient. All six marine turtle species are listed either as endangered (loggerhead, olive ridley) or vulnerable (green, hawksbill, flatback, leatherback).

In Queensland, in accordance with the Nature Conservation Act, species are scheduled under the

Nature Conservation (Wildlife) Regulation as presumed extinct, endangered, vulnerable, rare, or common. Green, hawksbill and flatback turtles are scheduled as vulnerable, and loggerhead, olive ridley and leatherback turtles are scheduled as endangered.

Each turtle species has been listed because the cumulative affects of various anthropogenic impacts have caused declines of their global and national population or because it is expected that current impacts are likely to cause them to become endangered.

4.1. Characteristics of Marine Turtles Relevant to Management

4.1.1. Life Cycle

Although the specific biological characteristics of marine turtles differ between species, the present understanding is based primarily upon the life cycle for green and loggerhead turtles. At an unknown age (estimated at 20-50 years, Balazs 1980, Limpus 1992, Limpus and Walter 1980), male and female turtles migrate, from foraging areas 100-1000's of kilometres away, to a nesting location considered to be their natal (place of birth) beach (Allard et al. 1994, Meylan et al. 1990). Mating generally takes place offshore of the natal beaches (although it can occur at considerable distance (greater than 10 nautical miles) from the nesting beach), approximately 30 days prior to the first nesting (Owens 1980). Males leave the breeding area once females commence fortnightly trips to the beach to lay eggs (Limpus 1993). Female turtles lay multiple (2-7) clutches each season, each containing from 50-200 eggs (Dodd 1988, Hirth 1997, Witzell 1983). Females return to their foraging area after the nesting season and will not nest again for at least two and perhaps as many as eight years (Carr 1984, Limpus et al. 1992). Hatchlings usually emerge at night approximately 60 days after egg deposition, their sex determined by incubation temperature (Mrosovsky and Yntema 1982). To find the sea, hatchlings orient towards the brightest direction and use the topography of the surrounding horizon line (Limpus 1971, Mrosovsky and Shettleworth 1968). Once in the sea, hatchlings use a combination of cues (wave direction, current, and magnetic fields) to orient themselves to deeper offshore areas (Lohmann and Lohmann 1998). Crossing and swimming away from the beach are believed to imprint the hatchlings with the cues to allow individuals to find their way back to their natal beaches when preparing to breed. Once in the offshore areas, hatchlings are believed to enter regions of convergent water systems (Carr 1986, 1987a) where they associate with floating seaweed mats driven by surface currents[2]. Young, free-swimming turtles migrate to inshore foraging areas after their developmental years (Carr 1986) which can take 5 to 20 years (Limpus 1992).

Within this life cycle of a marine turtle, there are certain common biological characteristics of particular relevance to management.

- There is high mortality before adulthood through natural and anthropogenic causes.

  Although marine turtles have the capacity to lay hundreds of eggs during a nesting season (high fecundity), not all eggs develop into hatchlings, not all hatchlings survive to enter the sea and not all hatchlings entering the sea survive to adulthood. Although incubation success (percentage of eggs producing hatchlings) for nests is known for most key nesting beaches, hatchling mortality across the beach and in the sea remains relatively unknown. Scientists studying marine turtles believe that about one in 1000 hatchlings survive to adulthood to breed. A study of green turtle hatchling survivorship at Heron Island showed that on average 31% of the hatchlings that made it to the sea were predated by fish before reaching the edge of the reef flat (Gyuris 1994).
- There are a limited number of nesting sites (natal beaches).

  Because marine turtles return to the region of their birth (Allard et al. 1994), beaches whose nesting populations become depleted will not be 'colonised' by other turtles (see section 4.1.2).

[2]However, hatchling flatback turtles are unique in that they do not have an oceanic pelagic phase, rather they are believed to inhabit inshore areas of the clear reefal waters (Walker and Parmenter 1990).

Key nesting habitats for marine turtles breeding within the World Heritage Area are largely known (Limpus 1995, Slater et al. 1998). Olive ridley turtles do not nest on islands in or the mainland adjacent to the Marine Park. The information below does not include key sites in the Torres Strait or in the Gulf of Carpentaria.

- **Loggerhead turtles:** In the southwest Pacific Ocean region, the only major breeding and nesting area of loggerhead turtles occurs in Queensland, mainly on the islands offshore of southern Queensland (Capricorn–Bunker Islands; Sandy Cape, Swains Complex) and on the adjacent mainland near Bundaberg (Elliott River to Round Hill Head) (Limpus 1983, Limpus and Reimer 1994, Slater et al. 1998). In July 1984, the Authority decided that the welfare of the Mon Repos turtle nesting site was of importance to the turtle populations occurring in the Marine Park (MPA 72/23). In 1989, there was an estimated total breeding population of 1000 females, today, approximately 300 female loggerhead turtles nest annually in the region. Major factors that have played a role in the decline of the loggerhead turtle in Queensland include intense fox predation of eggs along the Bundaberg coast and incidental catch of immature and adult turtles in commercial fisheries (Limpus and Reimer 1994).
- **Green turtles:** The largest concentrations are on Moulter Cay, Raine Island, Sandbank No. 7, Sandbank No. 8 for the northern GBR stock (see section 4.1.2), and on the Capricorn–Bunker Islands for the southern GBR stock. There is low density nesting on many islands and along the Queensland coastline.
- **Hawksbill turtles:** Although hawksbill turtles forage along the entire World Heritage Area, nesting occurs only north of Princess Charlotte Bay (Limpus 1980). The only high-density nesting site in the World Heritage Area is at Milman Island (Miller et al. 1995) although the species nests on many islands between Princess Charlotte Bay and the northern boundary of the World Heritage Area. The entire northern World Heritage Area and Torres Strait region is of international significance for the species, given the decline in the number of hawksbill turtles in other parts of the world (Groombridge and Luxmoore 1989). An estimated 2,500 hawksbill turtles nested in the World Heritage Area and Torres Strait in the summer of 1990/91 (Miller et al. 1995).
- **Flatback turtles:** Flatback turtles are endemic to the continental shelf of Australia. Although they forage around Papua New Guinea and Indonesia as well as within the Marine Park, they have only been found nesting in Australia (Parmenter 1994). Breeding is centred in the southern Great Barrier Reef around Peak, Wild Duck, Avoid, Curtis and Facing islands. However, low density nesting by flatback turtles occurs on many mainland beaches and offshore islands north of Gladstone. The largest known nesting site in Queensland (Crab Island) lies outside the World Heritage Area.
- **Leatherback turtles:** Leatherback turtles are known to forage and occasionally nest within the World Heritage Area at Wreck Rock and adjacent beaches, and sporadic nesting has been documented at other widely scattered sites in Queensland. Leatherback turtles nesting in Queensland represent animals at the extremes of their ranges, with the survival of the foraging population in eastern Queensland dependent upon the large nesting populations in neighbouring countries, Papua New Guinea and Indonesia (Limpus and McLachlan 1994). Key sites include mainland beaches from Wreck Rock to Mon Repos (Bundaberg).

• There is high fidelity to nesting site, internesting area (area used between nesting attempts) and foraging area.

  During successive breeding seasons, marine turtles will return to the same general/geographic region to nest and spend the internesting period. Upon completion of breeding, the turtles will return to the same foraging areas. Turtles usually do not relocate to 'new' areas (Limpus et al. 1992, Limpus et al. 1994, Spring 1999).

• Hatchlings and adults are influenced by environmental cues.

  Alterations in the incubation temperature of marine turtle nests affect the sex of the hatchlings produced. Embryo development of marine turtles generally only occurs when the incubation environment is between 24°C and 33°C. In relation to pivotal temperature that produces 1:1 male to female ratios, warmer incubation temperatures produce female hatchlings; cooler incubation temperatures produce male hatchlings. Hatchlings also need natural light horizons to find the sea and uninterrupted wave and current patterns to enable them to reach deepwater areas offshore of nesting beaches. Hatchlings are unable to actively swim against oceanic currents until they have grown. As such, they float passively, until they reach sufficient size to swim against the currents.

The proportion of a green turtle population that nests each year is highly variable (up to an order of magnitude difference) and is linked to the El Niño Southern Oscillation Index which influences worldwide ocean productivity (Limpus and Nicholls 1988). Green turtles are the only species of marine turtle for which this correlation has been shown and it is possibly based upon variable primary productivity in littoral seagrass pastures (Bjorndal 1997).

- Marine turtles have developed the ability to hold their breath for long periods, over an hour in some instances, and to dive to great depths (greater than 1000 m for the leatherback). Hibernating turtles have been known to remain submerged in a torpid state for period up to a week or more (Carr et al. 1980). However, turtles undergoing forced submergence (e.g. incidental capture in prawn trawls) can deplete oxygen stores within 15 minutes (see references in Lutcavage and Lutz 1997).
- Most marine turtle species feed near the bottom or middle of the marine food chain (Table 2). Thus, like all predators, they are vulnerable to perturbations in the marine environment that can affect lower levels of the food chain, and they can acquire significant loads of toxins and contaminants through bioaccumulation of small amounts of such substances found in their prey (see section 5.3.12).

These characteristics have three main implications for management.

1. Turtles are vulnerable not only to short-term or acute impacts, but also to cumulative or chronic impacts. Thus impacts that seem insignificant in isolation or over the short term can become significant when combined with other impacts and accumulated over the life of an animal. Thus, management must seek to take a risk-averse, integrated approach, considering the cumulative potential effects of a wide array of human activities, and to focus particularly on cumulative impacts that accrue over years or even decades and collectively result in significant adverse effects on populations.
2. Because turtles are so mobile, management efforts must be mounted at local, State, national, and international levels to ensure that they are protected throughout their ranges.
3. Because of the difficulty in obtaining accurate population counts and estimating the reproductive status of turtles, trends in numbers can take many decades to detect. This is a challenge for management because it is extremely difficult to assess whether populations are stable, increasing, or declining and to assess the effectiveness of management strategies. Turtle stocks present today are the result of impacts and actions 20-50 years ago; the effectiveness of management strategies implemented today will not be measurable for another 20-50 years.

4.1.2. Genetic Stocks

The following information about distinct genetic stocks is derived from material collected from nesting turtles and hatchlings. The stocks are classified on their distinctiveness at a breeding location.

- **Loggerhead turtles:** The eastern Queensland loggerhead population is genetically distinct from loggerhead turtles breeding in Western Australia (Moritz et al 1998).
- **Green turtles:** Queensland has three distinct genetic **breeding** stocks of green turtles, which need to be treated as separate management units as very little interbreeding occurs

and one stock would not replenish declines in the other stock (Limpus 1997, Moritz et al. 1998). The stocks are:

- ***southern GBR (sGBR):*** has nesting concentrated in the Capricorn/Bunker group of islands and in the Coral Sea Islands Territory, with an annual average nesting population estimated at about 8000 females (Limpus 1997).
- ***northern GBR (nGBR):*** has nesting concentrated around Raine Island and Moulter Cay with an annual nesting population estimated at about 30 000 females (Limpus 1997).
- ***Gulf of Carpentaria (GoC):*** has nesting concentrated around the Wellesley Group of islands with an annual nesting population estimated at about 5000.

Whilst, they are genetically distinct at nesting grounds, the three stocks can occupy the same foraging habitats (Moritz et al. 1998). Genetic studies indicate that the nGBR green turtle breeding stock provides most green turtles in northern GBR feeding areas (samples from Clack Reef, Princess Charlotte Bay), and sGBR breeding stock provides most in southern GBR feeding areas (samples from Shoalwater Bay). The stock composition of green turtles in other foraging areas remains unquantified, but is probably dominated by sGBR stock south of Clack Reef, as evidenced by turtle tag recoveries.

- **Hawksbill turtles:** Studies reveal that hawksbill turtles breeding at Milman Island are of a similar genetic breeding stock to those nesting in North East Arnhem Land, but different to those breeding in Western Australia. The Milman Island genetic breeding stock is also different to those hawksbill turtles foraging on Clack Reef in Princess Charlotte Bay, which were from an unknown breeding stock (Broderick et al. 1995)
- **Flatback turtles:** Analysis of tissue samples from nesting flatback turtles indicates that the populations nesting on the eastern Queensland coast are genetically distinct from those in the Gulf of Carpentaria and Torres Strait, the Northern Territory and Western Australia (Moritz et al. 1998). There is also limited evidence that the two stocks in Queensland do not generally inhabit the same foraging areas (Moritz et al. 1998).
- **Leatherback turtles:** The leatherback turtles encountered in Queensland have not been included in the global population genetics assessment of stocks (Dutton et al. 1999) and their genetic relatedness to other leatherback turtles in the southwestern Pacific Ocean remains unknown.
- **Olive ridley turtles:** There is no information on the genetic make-up of olive ridley turtles in Queensland. Nesting populations elsewhere in Australia are genetically distinct from populations nesting in other countries.

4.1.3. Known threats to survival

The following threats have been identified for the marine turtle populations in Queensland.

- **Loggerhead turtles:** Fox predation of nests and incidental catch in fisheries gear have been identified as the most important threats to the Queensland loggerhead turtle population. Other threats to survival include incidental catch in shark control program gear, ingestion of synthetic materials (e.g. plastic bags, discarded fishing line), vessel strike, coastal development, tourism, and increased incidence of disease (Limpus 1997). Approximately 11% of a foraging population in Moreton Bay, Queensland exhibited signs of anthropogenic impacts and/or health problems (Limpus et al. 1994a), with propeller cuts the most frequently recorded.
- **Green turtles:** Threats to survival include boat strike, Indigenous harvest of adults and eggs both within Australia and overseas, increased incidence of disease (see section 5.3.3), ingestion of synthetic materials, incidental catch in shark control program and commercial fisheries gear, predation of eggs at nesting beaches, and tourism (Limpus 1997). Approximately 10% of a foraging population in Moreton Bay, Queensland exhibited signs of anthropogenic impacts and/or health problems (Limpus et al. 1994b), with propeller cuts the most frequently seen.

- **Hawksbill turtles:** Threats to survival include harvest of immature and adult turtles for tortoiseshell, Indigenous harvest of adults and eggs both within Australia and overseas, predation of eggs at nesting beaches, ingestion of synthetic materials, vessel strike, increased incidence of disease, incidental catch in shark control program and commercial fisheries gear (Limpus 1997).
- **Flatback turtles:** Four major threats to flatback turtles that have been identified include coastal development pressure, Indigenous harvest of adults and eggs both within Australia and overseas, greenhouse effects (sea level rise) and incidental mortality in commercial fisheries (Parmenter 1994). Other threats to survival include incidental catch in shark control program gear, ingestion of synthetic materials, vessel strike, predation of eggs at nesting beaches, and increased incidence of disease (Limpus 1997).
- **Leatherback turtles:** Threats to survival include Indigenous harvest overseas for food, ingestion of synthetic materials, incidental catch in shark control program and commercial fisheries gear, and predation of eggs at nesting sites (Limpus 1997).
- **Olive ridley turtles:** Prawn trawling may be the main anthropogenic impact on olive ridley turtles in Australia (Harris 1994), although the level of this impact is uncertain. Other threats to survival include ingestion of synthetic materials, incidental catch in shark control program and commercial fisheries gear, entanglement in discarded and lost nets, predation of eggs at nesting sites and Indigenous harvest overseas for food (Limpus 1997).

4.1.4. Population Status

- **Loggerhead turtles:** The eastern Australian loggerhead turtle nesting beaches support the only significant stock for the species in the South Pacific Ocean (Limpus and Reimer 1994; Slater et al. 1998). This population has declined by 70-90% since the 1960's (Limpus and Limpus 1999, Limpus and Reimer 1994). This decline, combined with their long maturation and low reproductive rate, means that the remaining Queensland loggerhead populations are at risk from any increases in mortality (Chaloupka and Limpus 1997). Continued losses of adult and subadult loggerhead turtles from anthropogenic sources could result in extirpation of the Queensland population (Heppell et al. 1996b).
- **Green turtles:** To date, there have been no declines detectable in the number of nesting green turtles at nGBR and sGBR beaches. However, the 20-25 years of data for the key sites (Raine Island, Heron Island) does not cover a single generation for green turtles. Trends are difficult to determine with the large fluctuations in nesting numbers that occur as a result of ENSO. Nevertheless, based on the following information, Limpus (1999, 2000) suggests that the nGBR and the sGBR stocks may be exhibiting characteristics of a population under threat, as evidenced by the following:

  Northern GBR stock

  a) A reduction in the size of nesting turtles as evidenced from average curved carapace length. Although size is not an indication of maturity, random measurements of hundreds of animals each year over 20 years should encapsulate 'smaller' and 'larger' turtles at a nesting beach. Why 'larger' turtles are not nesting is unknown, but could be related to excessive mortality of adult females.
  b) An increase in the remigration interval (years between breeding seasons) is occurring as evidenced from average remigration intervals. Experienced breeders (animals with a past breeding history) renest at shorter remigration intervals than first-time breeders.
  c) No evidence of increasing numbers of green turtles in the dispersed feeding areas.

  Based on the above indication, losses of turtles (both sexes and including adults and immature turtles) from the combined anthropogenic sources of mortality should be managed at no more than a few thousand turtles per year.

Southern GBR stock

a) Elevated adult female recruitment rate. There is a high adult female recruitment rate of about 24-32% into the annual breeding population at Heron Island (Limpus 1999, 2000).
b) No evidence of increasing numbers of green turtles in the dispersed feeding areas but anecdotal reports of reduced numbers of turtles in some feeding areas.
c) Decreasing size of the adult females at nesting beaches (see above).

Based on the above indication, losses of turtles (both sexes and including adults and immature turtles) from the combined anthropogenic sources of mortality should be managed at no more than a few hundred turtles per year. Continued losses of subadult and adult turtles in the order of hundreds annually may be driving the downward trend in the population. This has implications for managing agencies as well as for Aboriginals and Torres Strait Islanders, whose way of life is reliant upon green turtles in maintaining their culture and tradition.

- **Hawksbill turtles:** The only hawksbill turtle nesting population for which there is sufficient information, at Milman Island, indicates a downward trend (Limpus 1997, Limpus and Miller 2000).
- **Flatback turtles:** There is insufficient information to determine population trends.
- **Leatherback turtles:** Recent reports of a significant decline in the Pacific Ocean leatherback turtle populations (Spotila et al. 2000) raises concerns for the species in the World Heritage Area.
- **Olive ridley turtles:** There is no information for determining the stability of the olive ridley turtle population in Queensland.

4.2. Summary and conclusions

Although much is known about the populations of marine turtles within the World Heritage Area (Table 2), little is known about the developmental years spent in the pelagic zone of the open ocean. Turtles are difficult to study; they spend large but variable proportions of their time under water, and all but nesting females and hatchlings are relatively inaccessible because they stay at sea. The absolute population sizes of species occurring in the World Heritage Area are unknown, although estimates of the numbers breeding or foraging at particular sites have been derived for some species. Also, estimates of biomass (quantitative estimate of the entire amount of turtles in a particular habitat, expressed as kilograms per hectare) and density (numbers of turtles per km^2) have been derived for hawksbill turtles foraging at Heron Reef (Limpus 1992). Population structure (ratio of males to females and immature to adult turtles) has been determined at a few long-term study sites in southern Queensland (Limpus 1992, Limpus et al. 1994a,b).

The effective conservation of marine turtles requires the protection of key habitats. These include feeding, mating, and nesting areas, and migratory pathways. Animals may be particularly sensitive to human activities in and adjacent to the key habitats. The Turtle Research Group of QPWS is working to identify key habitats from information collected on a continuous basis over the past 20-30 years. Many key habitats occur outside the World Heritage Area or outside of Australia. Therefore, collaboration with the Queensland government and international agencies is required to ensure a holistic approach to the conservation of marine turtles within the World Heritage Area.

Key nesting habitats are mostly known for those species nesting within the World Heritage Are (see section 4.1.1). However, key foraging habitats for each turtle species remain largely unknown within the World Heritage Area. Most reefs and coastal waters host populations of marine turtles, while some key foraging habitats may occur outside the World Heritage Area. Shoalwater Bay and Princess Charlotte Bay are two key green turtles foraging sites in the World Heritage Area.

Whilst information gaps must be addressed for management to be successful over the long term, the precautionary principle must be applied in the absence of this information. Thus, as well as reacting to issues after they have arisen and developing and implementing effective solutions, management actions must strive to prevent significant negative impacts from occurring. Management should seek to employ the known data and to err on the side of caution and prudence in managing turtles.

5. GENERAL IMPACTS OF HUMAN ACTIVITIES ON MARINE TURTLES

5.1. Terminology: Impacts, Effects and Threats

Human activities may affect marine turtles in many different ways. Any such effects are caused by particular impacts. For example, being struck by a boat may kill a marine turtle. In this case, being struck is the direct impact and death is the effect.

The effect caused by an impact may or may not pose a threat to an animal or a population. For example, a marine turtle may be startled by the noise of a vessel. The noise (the impact) causes the startle reaction (the effect), but this may not pose a threat to the survival or well-being of the animal. If the noise occurs repeatedly and continues to cause a startle reaction, the animal's behaviour may be disrupted sufficiently to threaten its survival. If a sufficient number of animals in a population are threatened, then the population itself can be threatened.

When assessing the possible consequences of human activities to marine turtles (or any other organisms) and developing management measures, it is important to identify impacts, effects and threats. Generally, management should strive to eliminate or minimise adverse impacts in order to eliminate or minimise consequent effects and threats. It should be noted however that not all effects are necessarily adverse.

5.2. Characteristics and Effects of Impacts

Human activities on land and at sea can cause several different types of impacts on marine turtles. Impacts may affect an individual directly or indirectly and range in geographic scope from localised, affecting only animals in a limited area, to global, affecting marine turtles around the world. The duration of a particular impact may be short-term, ceasing within minutes or hours of the causal event or activity, or long-term, persisting for months or years. Similarly, effects may be acute (short-term), chronic (long-term) or permanent (e.g. permanent injury or death).

Impacts that affect one or a few animals are of concern, but particular vigilance is required for impacts that affect many individuals, thereby threatening entire populations or genetic stocks and possibly risking species extirpation (loss of a species in an area) or extinction (loss of a species worldwide). Global-level impacts are equal if not more serious than those that operate at a smaller scale. However, the purpose of this document is to provide a basis for managing human activities that will, or are likely to, affect marine turtle populations occurring in and around the Great Barrier Reef World Heritage Area.

Marine turtles vary significantly in their vulnerability to impacts. Thus, the effects resulting from impacts, singly and cumulatively, vary, as do the consequent threats. For example, species or populations that are already endangered, or are confined to limited geographic areas, are generally more vulnerable than those that are abundant or cosmopolitan in distribution. Within a population, animals may be more vulnerable at certain times in their lives, for example when they are very young, at certain times of the year, such as during breeding seasons, or when engaged in particular behaviours, such as feeding. Particular species may also be more vulnerable to certain impacts because of physiological, behavioural, or other factors.

Further, exposure to some impacts can lead to habituation, meaning that the effect of the impact on the animal declines with time as animals become 'accustomed' to the specific impact. However, habituation does not always occur, and it is not easily distinguished in the wild from tolerance, in which the animal 'puts up with' an impact in order to meet ecological needs. For example, if turtles stop using a particular bay when it becomes an area of high vessel traffic, but then return, it is difficult to determine whether this is because they have habituated (i.e. no longer disturbed) to, or are tolerating the traffic because the bay is a key habitat. If the animals have habituated to the traffic, there may be little effect of the traffic on the animals. However, if the turtles are tolerating the traffic, then the effects of the traffic on the animals can be significant over the long term.

A third possibility is sensitisation, in which the sensitivity or responsiveness to an impact increases with time. However, this has not been demonstrated in marine turtles, as it has for other animals (e.g. whales, Richardson 1995).

Thus, it is extremely difficult to assess the extent to which a particular impact will affect, or is affecting, individual animals or a population. Possible effects of impacts include mortality, injury or disease, reduced reproductive success, and behavioural modification. Many human activities can cause a turtle to change its behaviour.

Behavioural modifications that are typically reported as a result of human activities include:

- changing swimming speed or direction (for example to approach or avoid a boat);
- changing dive depths or durations;
- changing breathing rates;
- changing or ceasing particular activities (e.g. feeding, nesting); and
- leaving an area.

These kinds of behavioural changes may not be significant if they occur infrequently, but may become a serious threat to the animals if they are frequent or persistent. For example, regular interruptions of feeding and other activities could threaten the survival of individual animals and ultimately of populations. Similarly, if human activities cause animals to leave key habitats such as sheltered bays used for foraging (i.e. if the animals neither habituate to nor tolerate the impacts), this could have serious consequences for a population.

Thus, the precautionary principle must be followed to take reasonable actions to avoid or minimise potentially serious or irreversible effects. Management decisions must take into account reasonable predictions of likely effects of human activities on the animals, despite a paucity of supporting scientific evidence. Regular evaluation of the effects of human activities on marine turtles, as well as determination and monitoring of the conservation status of the various populations, are essential to facilitate early detection of problems and allow evaluation and modification of management measures.

Following is a discussion of the broad types of impacts to turtles that can be caused by human activities on land and at sea, and which can result in the kinds of effects discussed above.

5.3. Specific Types of Impacts and Possible Effects

The main categories of impacts and resulting effects upon marine turtles within the World Heritage Area are summarised below. The impacts are in alphabetical order, as the significance of each impact depends on a variety of factors, including the species of marine turtle (e.g. some species are more susceptible to impacts than others).

5.3.1. Accidental Ingestion of and Entrapment in Marine Debris

Marine turtles, like cetaceans, seabirds, and other species, can ingest or become entrapped in marine debris. This can be immediately fatal, if it prevents an animal from digesting food normally or surfacing to breathe, or can cause injury that may or may not ultimately be fatal.

The life history characteristic of hatchling turtles associating with convergent zones of ocean currents (see section 4.1.1) places them in the same areas where oceanic debris concentrates. The dumping of garbage is prohibited inside the Marine Park, but large and increasing amounts of debris, including plastic objects, enter the marine environment every year (Haynes 1997, Malcolm et al. 1999). For example, a 1991 survey of 21 islands in the Far Northern Section of the Marine Park recorded 4855 items, with the largest number recorded for plastics (Miller et al. 1995).

Debris is mistakenly eaten as food by some turtles. Hatchlings and immature and adult turtles are indiscriminate feeders and may consume plastic bags, plastic beads and tar balls (Carr 1987b). Ingested debris may interfere with feeding and cause stomach or intestinal blockages, toxicity, or other injuries that may result in death. Debris on nesting beaches can interfere with a turtle's ability to dig an egg chamber to deposit eggs or may prevent hatchlings from reaching the sea (Hutchinson and Simmonds 1991). Turtles have been found entangled in monofilament line after being hooked. Turtles are also known to scavenge baited hooks that are lost or discarded as well as those being actively fished (QPWS Marine Wildlife Stranding and Mortality Database). The number of turtles hooked each year is unquantified (see section 5.3.7).

Turtles also will die if they are unable to reach the surface to breathe. In 1999, a green turtle was found floating dead in Cleveland Bay, near Townsville, its flipper having been caught in heavy chain that had been discarded.

5.3.2. Deliberate or Reckless Killing and Injuring

The Commonwealth Environmental Protection and Biodiversity Conservation Act, and the Queensland Nature Conservation Act prohibit the deliberate killing of turtles. However, turtle carcasses have been found with evidence of bullet wounds and other injuries indicating deliberate killing or injuring. Deliberate killing also occurs for the trade in turtle products (see section 6.12) and from Indigenous hunting[3] and egg collecting occurring without a permit from the Authority and/or QPWS.

On nesting beaches, uninformed people may actually collapse the egg chamber (thereby effectively killing all the eggs) whilst in close proximity to the turtle for photography.

The Environment Protection and Biodiversity Conservation Act requires (Chapter 5, Part 13, Division 1, Section 199) that if a person's action results in the death or injury of a member of a listed threatened species, the particulars about the incident must be notified within seven days of the incident to the Secretary of the Department that deals with the matter. If this does not occur, the person is guilty of an offence under the Act. This provision applies to all six species of marine turtles in the Great Barrier Reef World Heritage Area.

The effect of deliberately killing one turtle may not of itself cause a decline in a turtle population, but the cumulative effect of injuries and mortalities from all sources can cause population declines. In the case of Indigenous hunting, the Authority recognises the continuing cultural and economic use of the resource and through its management of the World Heritage Area is attempting to ensure that the use of green turtles remains ecologically sustainable[4] (see section 6.6).

5.3.3. Disease

Although disease can cause deaths in marine turtles, identifying diseases is often difficult. Frequently, turtle carcasses washed ashore on beaches are too decomposed to determine a cause of death. Turtles that are in close physical contact with people or with untreated human wastes may be at risk of contracting human diseases (as has been shown for dugong, Hill et al. 1997), but the degree of risk is difficult to assess.

The presence of toxic substances in the environment, or other factors that impose physiological stress on turtles, may increase the animal's susceptibility to disease, for example by impairing the

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[3] Indigenous hunting has the same meaning as traditional hunting, as defined in the zoning plans for the Great Barrier Reef Marine Park.

[4] Ecologically sustainable use is defined in the 'National Strategy for the Conservation of Australia's Biological Diversity' as 'The use of a species or ecosystem within the capacity of the species, ecosystem and bioregion for renewal or regeneration.'

immune systems of the animals. Disease outbreaks can also affect turtles indirectly, for example through mass mortality of prey such as particular seagrass species. The following information summary about turtle diseases is largely compiled from George (1997 and included references).

Malnourished turtles found in the wild may be suffering from a disease condition induced or exacerbated by starvation. Such conditions may present, for example, as an overload of parasites. In addition, chronic disease may inhibit normal feeding in a turtle. Such turtles have been found in the World Heritage Area, having a concave plastron, sunken eyes and upon necropsy, they exhibited reduced muscle and fat mass. If not fed a correct diet captive turtles can suffer from a range of other nutritional deficiencies including bone disease and iron deficiencies.

Bacterial infections in wild turtles are rare. Most bacterial infection seems to result from injuries to turtles. The tough skin and shell of a turtle minimises the risk of injury, and hence infection, although infection can also result from other health reasons or suppressed immune systems.

Two known viral infections that afflict turtles are a herpesvirus disease affecting the respiratory tract and a stress-induced disease (grey-patch disease) which is mainly known to afflict juvenile green turtles in captivity. Possible stress factors include warm water, rapid changes in water temperature, reduced water quality or overcrowding in captive situations.

Turtles act as host to a variety of external parasites. Many barnacle species are known to colonise the carapace of turtles in Queensland (Monroe and Limpus 1979). Whilst most are non-invasive, heavy barnacle loads may increase surface drag and burrowing barnacles may weaken the skin and carapace, allowing for other types of infections. Leeches can be found attached to the skin of turtles and leech egg masses can be found on the plastron and flippers. Severe infestations of leeches can occur on some turtles and may be involved in the occurrence of green turtle fibropapillomatosis (see below).

Green turtle fibropapillomatosis (GTFP), believed to be caused by a virus, is most commonly found on green turtles, but affects many species of turtles (loggerhead, hawksbill, olive ridley and flatback turtles). On the Queensland coast, there is a noted absence of GTFP on turtles inhabiting coral reef foraging grounds in comparison with nearshore seagrass beds (Limpus and Miller 1994). Higher incidences of GTFP are also noted in areas adjacent to large human populations and areas with low water turnover (e.g. lagoons) (Limpus and Miller 1994, Limpus et al. 1994b). Some theories suggest that pollution, reduced water quality or environmental stressors result in expression of the disease (Balazs and Pooley 1991, George 1997). Lesions associated with the disease generally take the form of large cauliflower tumours around the eyes, mouth, head, neck and flipper regions on turtles, which can impede the turtle's ability to forage. All size-classes of turtle are affected (Limpus and Miller 1994). Internal tumours have been known to lead to pneumonia, liver disease, intestinal obstruction, or kidney disease. Although GTFP was first described in 1938, the incidence has dramatically increased since the 1980s. GTFP has been identified in turtles from Moreton Bay to Repulse Bay with the disease present on 8% of the green and 4 % of the loggerhead turtles in Moreton Bay (Limpus et al. 1994a, b) and up to 22% of the green turtles in Repulse Bay (Limpus and Miller 1994). There is no known cure.

Documented fungal infections in wild turtles are rare. In captive situations water quality appears to play an important role in outbreaks of fungal infections. When fungal infections appear they often take the form of lesions of the skin or lung tissue. Turtles exposed to cold water may develop pneumonia as a result of reduced body temperature and suppression of the immune system.

5.3.4. Explosions

Underwater explosives have been used routinely for decades, principally for defence and demolition (Greene and Moore 1995). More recently, explosions were used in seismic exploration, although modern systems tend to employ other means. Explosions have also been used in ocean science, for example to study the way in which sound travels in the sea.

Explosions generate both noise and a shock wave or front. Both the acoustic and shock waves can cause temporary, recoverable effects (such as temporary hearing loss), permanent physical injury that may be mild or severe, or death (Klima et al. 1988, Minerals Management Service 1997). Other potential effects are similar to those described for noise (section 5.3.9), and include disturbance and disruption of behaviours, and displacement.

The effects of an explosion on an animal depend on the size and type of the explosive, the location of the explosion (e.g. water depth), the topography around the blast site, the location of the animal relative to the blast site, characteristics of the animal, and other factors (Ketten 1995). There is very little information about the acoustic effects of underwater explosions on marine turtles. Studies have shown that turtles are capable of hearing low frequency sounds (Moein-Bartol et al. 1999, Ridgeway et al. 1969) and behavioural responses have included swimming towards the surface, abrupt movements, slight retractions of the head, and limb extension during swimming (Lenhardt et al. 1983, Lenhardt 1994). In the United States, the explosive removal of petroleum platforms is known to have significant impact on marine turtles (Klima et al. 1988, Minerals Management Service 1997). However, explosions are probably unlikely to threaten marine turtle populations, except for very small populations that cannot readily sustain the loss of one or a few individuals.

Small explosives are sometimes used in deliberate attempts to scare away marine animals, for example from fishing gear or detonation sites of larger charges (e.g. Alaska, Gulf of Mexico, Eastern Tropical Pacific, see Richardson 1995). However, blasts often must be repeated frequently to be effective even in the short term, and can injure or kill animals. Animals may also habituate to the blasts, rendering them ineffective. Attempts to scare marine animals, whether by use of explosives or noise (section 5.3.9), are prohibited or restricted in many jurisdictions (Richardson 1995).

In the United States, Department of Navy environmental impact statements of shock trials on vessels recommend that a safety range of 3.7 km (2 nautical miles) be used for sea turtles (Department of the Navy 1998, 1999). The recommended safety range for turtles in the World Heritage Area would depend upon the bottom topography, size and type of blast to be used, prevailing weather conditions and season of the year (e.g. whether it was turtle breeding season).

Impacts from Defence activities can result from detonations of explosives or use of live munitions. In 1999, the Department of Defence reported a suspected instance of a turtle death from underwater explosives training in Shoalwater Bay. Shock waves from high explosives can kill or injure turtles, or be disturbing to the animals over great distances, possibly resulting in disruptions of activities and displacement (section 5.3.10) of animals from areas.

5.3.5. Food Depletion

Marine turtles exhibit a variety of feeding strategies during part their life (Bjorndal 1997, Table 2). Contrary to beliefs that turtles only eat seagrass, only the green turtle is primarily herbivorous, and then jellyfish and marine algae can be a more significant component of their diet, even when seagrass is the more abundant plant (Brand-Gardner et al. 1999, Limpus et al. 1994b).

Although much is known about the food preferences of green and loggerhead turtles in Queensland (Brand-Gardner 1999, Forbes 1994, Garnett 1985, Limpus 1985), little is known of prey items for other species of marine turtles in the area and can only be surmised from studies elsewhere in the world.

The effects of food depletion on marine turtles depends on many factors, including:

- the extent and magnitude of the depletion;
- the duration of the depletion;
- whether alternative food items are available; and
- whether the animals can access alternative food items.

The effects of food depletion may range from suppressed growth rates, to mortality of vulnerable individuals (e.g. very young or old animals, injured animals), to reproductive failure for a season or longer, to mass mortality. Prey depletion may also make animals more susceptible to other impacts, for example greater susceptibility to disease (see section 5.3.3) or consuming inferior food items (e.g. items of lower energy value).

Significant changes in prey species abundance and distribution can result from natural causes, such as the periodic warming of waters and altered primary productivity during El Niño Southern Oscillations. Depletion of prey can also be an indirect result of human activities, such as through pollution or other environmental changes, or a direct result, such as through overfishing of particular species, habitat destruction (Bjorndal 1997), sediment run-off increasing turbidity or smothering plants and other marine organisms, or anchor damage destroying seagrass habitat (Williams 1988).

Losses of seagrass habitats have been linked with anthropogenic inputs that effect water quality or clarity (Abal and Dennison 1996, Devlin 1999). The effect of eutrophication from terrestrial run-off, and contaminants such as pesticides and herbicides, on seagrasses in the World Heritage Area is just beginning to be understood. The impacts may include disruption of normal seagrass functioning and may present a threat to nearshore flora and fauna of the Great Barrier Reef region (Haynes et al. in press a, b).

The dumping of dredge spoil or other fill material can degrade or remove seagrass habitats through the movement and covering of seagrass, resulting in food depletion or physical displacement (section 5.3.10) as turtles forage elsewhere.

Indirect effects of fishing on marine turtles may result from competition between marine turtles and fishers for common target or prey species (e.g. crabs), and from any detrimental effects of fishing on the ecosystem. Declines in the abundance of turtle food items (e.g. seagrass, crabs, sponges), whether due to fishing or other causes, can adversely affect turtle populations. However, there is no evidence of such indirect effects on turtles from fisheries in and around the Marine Park. The ongoing efforts to ensure that Marine Park fisheries are ecologically sustainable will help to minimise the risk of such impacts.

Currently there is no evidence that marine turtle populations in the World Heritage Area are threatened by depletion of their food items, however, anecdotal reports of seagrass die-offs may impact some foraging turtles.

5.3.6. Harassment

Harassment of turtles (or other animals) involves disturbing them by altering their normal patterns of behaviour or activity. This can be deliberate, through chasing or riding on the back of a turtle, or inadvertent, if people are unaware of turtle behaviour and the possible effects their activities (e.g. shining a torch onto nesting turtles or having a campfire at a marine turtle nesting beach which then disorients nesting females or hatchlings). For example, lighting and construction from residential and commercial ventures along the coast can disorient turtle hatchlings and nesting females by altering natural lighting and topography horizons which are used as guidance mechanisms by turtles (Ehrenfeld 1968, Limpus 1971, Lohmann and Lohmann 1998, Mann 1977, Witherington 1992).

There are anecdotal reports of some turtles feeding on fish discards from prawn trawlers that operate in the World Heritage Area, but there is no evidence that this results in adverse effects on turtle populations. Current by-catch reduction programs, including the mandatory use of bycatch reduction devices (BRDs) in trawl nets, will reduce discards available to marine turtles.

The potential for injury from deliberate harassment by vessel operators is significant especially in bays or around islands, where the animals can be trapped against land or a reef crest.

The Commonwealth Environment Protection and Biodiversity Conservation Act prohibits the taking of a listed native species (which includes killing, destroying, damaging, collecting). The Queensland Nature Conservation Act prohibits the taking of protected animals without a permit. Under the Queensland Act, taking includes harming or injuring the animal.

5.3.7. Incidental Catch in Fishing Gear

Marine turtles, like cetaceans, seabirds, and other species, can become entangled in active, lost or discarded fishing gear. Although few turtles show scars that appear to have been caused by entanglement in discarded nets, lines or chains, entanglement is not uncommon. Turtles are also caught in 'ghost' fishing gear, i.e. equipment that is lost or abandoned at sea that continues to fish until it disintegrates or washes ashore (Hutchinson and Simmonds 1991).

Incidental injuries and deaths result from fishing where turtles are taken as by-catch in activities targeting other species, entanglement with nets or drumlines set for bather protection, vessel strikes (section 5.3.14), or by ingestion of marine debris (section 5.3.1). Although the legislation allows for this type of incident, the Environment Protection and Biodiversity Conservation Act requires that all protected species killed or injured, including marine turtles, be reported (see section 5.3.2).

Turtles are hooked in pelagic longlining operations throughout the world (Johnson et al. 1999, Williams et al. 1996) although records from Australian waters are few. Turtles become hooked on the front and hind flippers, head, mouth, neck and carapace and entangled with monofilament around the head and flippers, the mainline around the shell and flippers and the ball drop/buoy line around the neck and shell (Williams et al. 1996). Longlining for tuna and billfish does not occur in Marine Park.

The estimated annual catch of turtles in the US Atlantic pelagic longline fleet ranged from 664 to 3136 with loggerhead turtles the most commonly caught turtle species (Johnson et al. 1999). The Spanish longline fleet hooked more than 20,000 loggerhead turtles annually (Aguilar et al. 1995) while the Japanese tuna longline fleet captured 21,000 annually in the Western Pacific and South China Sea (Nishemura and Nakahigashi 1990). Mortality rates for turtles caught in longlines range from 0% to 95% (Aguilar et al. 1995, Johnson et al. 1999, Nishemura and Nakahigashi 1990). Recently, the US Environmental Protection Agency banned longline fishing in Hawaiian waters because of concern about the incidental catch of turtles in these operations.

From 1962-1998, the Queensland Shark Control Program (QSCP) caught more than 4300 turtles with about 80% released alive (Environmental Protection Agency 1999), but there has been no quantification of post-release survivorship of these turtles. Most turtles caught in the QSCP historically were not identified by species but based on recent captures, green turtles appear to be the most commonly caught species in nets and loggerhead turtles the most commonly caught species on drumlines (Gribble et al. 1998).

All species of marine turtle occurring within the World Heritage Area have been caught in trawl nets. The information below refers primarily to the East Coast Otter Trawl Fishery (ECOTF) or the Northern Prawn Fishery (NPF), which operates north of the World Heritage Area.

- **Loggerhead:** 50.4% of all turtles caught in the ECOTF, which equated to an estimated annual average of 100–200 turtles (Robins 1995) and might be more than the Queensland population can withstand (Heppell et al. 1996b).
- **Green:** 30.1% of turtles caught in the ECOTF (Robins 1995, Slater et al. 1998) and are caught less often (8% of turtles) in the NPF (Poiner and Harris 1994).
- **Hawksbill:** 1.5% of turtles caught in the ECOTF (Slater et al. 1998).
- **Flatback:** 10.9% of turtles caught in the ECOTF; most often caught in winter at 20–30m depths (Robins 1995). Catches were concentrated off Townsville to Cairns, and Port Stewart to Cape York. The cumulative capture of flatback turtles in trawl nets might have the potential to cause significant losses to the overall stock of the species (Slater et al. 1998).

- **Leatherback:** Occasionally caught in prawn trawls although there are no records of resulting mortality (Limpus 1995).
- **Olive ridley:** Mostly caught in the NPF in 30-40m depth, with about a 10% mortality rate (Harris 1994).

Otter and beam trawls are used to catch several species of prawns and scallops in the World Heritage Area (Great Barrier Reef Marine Park Authority 1998a). Turtles are caught in otter trawl nets that may be submerged for extended periods of time (range from 30 minutes up to two hours). Although turtles can dive for up to an hour, enforced submergence can deplete oxygen stores within 15 minutes and disrupt physiological acid-base balances (Lutcavage and Lutz 1997). Drowning is not the only direct impact from trawling.

Turtles may be injured whilst going through a turtle excluder device (TED) on a trawl net, however there is no information supporting this theory, although summaries of incidence of trauma to dead beach-washed turtles in the United States have implicated human-induced factors (Ruckdeschel and Shoop 1993). Turtles also are susceptible to injuries associated with the landing of trawl nets (Parmenter 1994).

Commercial, charter and recreational fishers use hand-held lines or mechanically operated reels and lines. There is little impact from the commercial line fishery and turtles that might be caught could be easily released, but the turtles may risk subsequent infection or have been injured as a result of capture. One of the problems facing turtles hooked by line fisheries is the subsequent release of the animal back into the sea. Sometimes, the lines to hooks are cut and the animal is released with the hook still attached to its mouth or flipper. A de-hooking mechanism and techniques need to be developed and fishers trained in their use.

The level of injury or mortality of turtles from interactions with crab fishing gear is unknown. Marine turtles are known to eat spanner crabs, so there is the potential for interaction with apparatus used to fish for crabs and also with conflict with fishers. Loggerhead and leatherback turtle mortalities result from entanglement in float lines in crab fisheries, and intentional killing or injury of loggerhead turtles particularly in the spanner crab fishery, has been reported in Moreton Bay (Limpus 1997). Green turtles also have been entangled in crab pot ropes. This source of mortality is not thought to be significant for the green turtle populations within the World Heritage Area (Limpus 1997).

Aquaculture operations involving the use of sea pens or cages (typically termed mariculture) can result in entanglement of turtles in the net walls of the cages or in protective netting placed around the cages, but the reported incidence of this globally is very low. There is no information on the incidence of such entanglements in and around the World Heritage Area, but mariculture cages are uncommon in the area and are unlikely to pose a significant threat to turtle populations at this time.

5.3.8. Live Capture

Capturing turtles affects not only individual animals, but also to some extent the populations from which they are removed. Further, the act of capturing or attempting to capture animals can involve repeated chasing, trapping or netting of individuals, until the desired animals are successfully caught. These activities generate noise, cause physical disturbance, and behavioural modification, and can be stressful and disruptive to the animals. High-speed vessel manoeuvring in close proximity to animals is often required, which poses the additional risk of strikes (section 5.3.14).

If a captured marine turtle is to be removed from the World Heritage Area, a permit is required regardless of whether the animal is to be removed for research, traditional hunting, or live display purposes.

5.3.9. Noise

Most human activities in the ocean generate underwater sound; the world's oceans are becoming increasingly noisy (Jasny 1999). Noise is produced not only by large ships, but also by small vessels, coastal and marine construction, seismic exploration, dredging, explosions, and aircraft.

The severity of the impact depends on the characteristics of the noise, (e.g. intensity or volume, frequency or pitch, duration, frequency of occurrence, distance between sound source), and the physical environment (e.g. water depth, bottom type). Marine turtles do not have an external hearing organ. Very few studies have been conducted on the impact of sound on turtles and their subsequent behavioural response. However, it is thought that turtle auditory perception occurs through a combination of bone and water conduction rather than air conduction (Lenhardt 1982, Lenhardt et al. 1983, Lenhardt and Harkins 1983, Moein-Bartol et al. 1999). Turtles are thought to hear low frequency sounds, with hearing ranges from 250 to 1000 Hz for loggerhead turtles (Moein-Bartol et al. 1999) and maximum sensitivity between 300 and 500 Hz for green turtles (Ridgeway et al. 1969).

Adverse effects of noise on turtles can range from behavioural modification, including mild disturbance, disruption or impairment of activities, and displacement from key habitats, to injury, disorientation, capillary damage, loss of motor control and even to death in severe cases (Lenhardt 1994, Lutcavage et al. 1997). There are anecdotal reports of probable or possible short- and long-term displacement of turtles; however, causal relationships are difficult to demonstrate conclusively. Documented cases of injury or mortality caused by noise are unknown.

Use of active sonar and other acoustic devices can also be disturbing to animals, depending on the characteristics and use of the sound sources, but the impact of this on turtles is also unknown.

Most human activities in the ocean generate underwater sound. Substantial evidence indicates that the overall level of sound in the oceans has increased significantly over the last 50 years, and the effects of this on marine organisms are of concern (Popper et al. 1998). Most human-generated noise likely to affect marine turtles arises from a few types of activities: transportation, dredging, construction, hydrocarbon and mineral exploration and recovery, geophysical surveys, sonars, ocean science studies and explosions (Greene & Moore 1995). Hydrocarbon exploration and recovery and mining are prohibited in the Marine Park. Explosions are discussed in section 5.3.4.

Most of the increase in underwater noise is attributable to shipping (Popper et al. 1998), and shipping is the major overall source of human-generated noise in the marine environment (Gordon & Moscrop 1996). All vessels produce noise and the amount of noise generally increases with vessel size, load and speed (Greene & Moore 1995). Changes in vessel speed or direction cause increased noise due to cavitation, the generation of tiny air bubbles. Much of the noise produced by vessels is caused by propellers, which generate more noise if they are damaged, operate asynchronously or lack nozzles. However, various types of machinery found on vessels can radiate noise through the hull into the water. Vessel noise is typically concentrated at low frequencies (less than 500 Hz: Greene & Moore 1995; Popper et al. 1998), and may therefore tend to affect marine turtles.

5.3.10. Physical Displacement

Vessels, structures, or people occupying or seeking to occupy the same physical space may displace turtles from their preferred habitats. Because turtles return to breed at the same location at which they were born, physical displacement from these sites could have a serious detrimental effect upon populations. For example, if activities occur at or near turtle nesting beaches, there is the possibility this could cause turtles to lay their eggs in sub-optimal habitats (Mann 1977).

The effects of physical disturbance or displacement depend on a variety of factors, including:

- whether animals are displaced from key habitats ;
- the frequency of displacement ;

- the duration of displacement ;
- the size of the area from which the animals are displaced; and
- the number of animals in a population that are displaced.

Changes in turtle nesting patterns have been observed on islands where vessels with their motors running are anchored offshore (QPWS unpublished information). Lights on vessels anchored offshore from nesting beaches attract hatchlings, increasing their risk of predation by large reef fish and reef sharks, and can disorient nesting turtles. Displacement might also occur in bays, inlets or on islands utilised by boaters, especially during the nesting season, causing turtles to nest on beaches away from the anchored vessel. The use of pilings and rockwalls for beach stabilisation has been shown to decrease nesting activity (Bouchard et al. 1998);

In-water activities could result in physical displacement of marine turtles through repeated filming and photography, catching or riding turtles, feeding, or deliberate relocation activities.

5.3.11. Physical Habitat Degradation or Destruction

In addition to increases in noise (section 5.3.9) and pollution (section 5.3.12), other forms of habitat degradation or destruction may impact marine turtles. Anchor chains may drag across seagrass beds, reducing plant productivity and depleting food (Bjorndal 1997, Gibson and Smith 1999, Williams 1988, see section 5.3.5), thus decreasing the area's capacity to support foraging turtles (Williams 1988). The impacts of reduced or inferior food resources can decrease growth rates and increase the time between nesting seasons for turtles.

The effects of physical habitat degradation or destruction depend on a variety of factors, including:

- whether the degraded areas are key habitats ;
- the size of the degraded area; and
- the degree and persistence of the degradation.

Key nesting sites for marine turtles in the World Heritage Area are mostly known (see section 4.1.1); however, key foraging habitats, pelagic zones and migratory pathways are largely unknown for turtles. Turtles are often sighted near shore which are the same areas often subject to high levels of use, construction, and other modifications, and which may be most affected by habitat degradation (Frazier 1980, Lutcavage et al. 1997).

Habitat degradation or destruction can also affect marine turtles indirectly:

- high-rise buildings can alter sex ratios by shading nesting beaches, creating a cooler incubation environment, which will produce more male hatchlings (Mrosovsky et al. 1995).
- sand renourishment may cause beach compaction, escarpments, and alter egg and hatchling survivorship (Crain et al. 1995);
- dust from a cement factory can solidify sand over egg chambers, preventing hatchlings from reaching the beach surface (Pilcher 1999);
- use of beach umbrellas and other beach structures can penetrate marine turtle clutches and destroy eggs and shade the clutches altering the incubation environment; and
- modifying shorelines or water depths, may degrade or destroy key marine turtle habitats such as bays used by animals to forage for food or increase turbidity by sediment runoff. Modifying the configuration of a shoreline can change hydrodynamics, thus affecting inshore currents and sediment rates. This may in turn affect key turtle habitats or result in environmental changes (e.g. changes in abundance or distribution of prey species) that adversely affect turtles.

Further, coastal waters are the most productive ecosystems in the marine environment, so degradation of coastal habitats can have a disproportionately adverse effect on overall marine productivity and entire ecosystems (Kemp 1996). The location of coastal developments and the subsequent increases in human uses of the area (e.g. increases in vessel traffic) also can indirectly impact marine turtles.

5.3.12. Pollution

Marine turtles, like other predators, can be affected by pollution both directly and indirectly. Toxic substances may be introduced directly into the sea, for example as industrial waste and sewage discharges, or they may be the result of terrestrial activities. The sea is the ultimate destination for many toxic substances produced or used on land. Some of the more common chemical contaminants include biocides (e.g. tributyl tin, or TBT) and hydrocarbons (e.g. oil).

There is no unequivocal evidence that any wild marine turtle has been killed by a build-up of toxic substances. However, toxic chemicals introduced into the marine environment from land- or sea-based sources can become incorporated into the prey that marine turtles consume, and thus into turtles (Gladstone 1996, Gordon et al. 1998) and their eggs (Clark and Krynitsky 1980). Toxic chemicals can also affect turtles indirectly (e.g. by affecting other links in the food chain). For example, high levels of cadmium have been found in green turtles taken as traditional food by Torres Strait Islanders (Gladstone 1996) and in the liver and kidney of green turtles stranded in southeast Queensland (Gordon et al. 1998). Cadmium concentrations from southeast Queensland turtles were some of the highest recorded in marine vertebrates, which might have implications for the health of Indigenous people who consume green turtles from that area (Gordon et al. 1998). Similarly, nutrients and sediments that are introduced into the sea can affect the environment dramatically, for example causing algal blooms or smothering coral reefs. Declines in water quality can affect turtles (see section 5.3.5), and other parts of the marine ecosystem.

The limited and fragmented available evidence suggests that pollutant levels in the water and sediments of the Marine Park are generally low, although some areas of high human use show localised contamination (Brodie 1995, Haynes and Johnson in review). However, the region is a focus of commercial shipping and tourism activities and coastal population centres discharge pollutants associated with recreational, urban and industrial activities (Haynes and Johnson in press, Haynes et al. in press a, b). Most of the contaminants entering the World Heritage Area come from land, including agricultural run-off and industrial discharges. As coastal development continues and human use of the World Heritage Area increases, it is critical to minimise, and where possible, prevent pollution at its source.

Oil spills are of particular concern for the World Heritage Area. Oils vary in their toxicity (Geraci 1990). Some types of oil release toxic vapours that can damage respiratory tissues. Harmful oil fractions may be ingested or consumed through eating contaminated prey. Oil spills may result in both direct and indirect impacts on marine turtles. Oil spill response procedures need to consider the impacts those activities will have on turtles, especially if they occur at nesting beaches and/or during the nesting season. The use of heavy machinery for cleaning oil spills might compress sand making it difficult for nesting turtles to dig an egg chamber or for emerging hatchlings to reach the beach surface. The removal of nests is not feasible because turtle eggs can only be moved successfully without mortality during the first 24-hours following oviposition (Parmenter 1980, Miller and Limpus 1983).

Depending upon the time of year (e.g. whether it is breeding season), the use of booms to contain oil spills can lead to entanglement of marine turtles and increases predation risks to hatchlings because ocean currents can no longer take them away from nesting beaches. Displacement from nesting/foraging habitats can also occur as vehicular and vessel traffic increases with incident responses (Lutcavage et al. 1997).

An oil spill contingency plan, called REEFPLAN, has been developed for the Great Barrier Reef World Heritage Area (Australian Maritime Safety Authority 1997a). REEFPLAN outlines the policies and strategies which will be implemented for effective and timely response to a marine or land-sourced oil spill occurring in the waters of the Great Barrier Reef World Heritage Area.

Under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), all ships, including fishing vessels and recreational craft, are prohibited from operational discharges of oily wastes between the coast and the outer edge of the Reef.

Although major oil spills pose serious risks to marine ecosystems, including marine turtles, small but frequent operational discharges introduce large quantities of oil into the sea on an annual basis, such as those from outboard motors. The toxic effects of oil on turtles can include immuno-suppression, reproductive impairment, developmental or behavioural abnormalities, disease (including tumours) and death. Oils vary in their toxicity, but in general the effects of exposure to oil include acute poisoning (e.g. through inhaled vapours or consumption of oiled prey), chronic poisoning and damage to skin and mucous membranes (Lutcavage et al. 1997 and included references). If oil washes onto a turtle nesting beach and does not weather to tar prior to turtles nesting, significant mortality may occur if the oil sinks to the level of the incubating eggs (e.g. at nest depth; Fritts and McGehee 1989).

Within Queensland approximately 37 turtles (1% of 3332 turtles recorded as stranded or dead) have washed ashore as a result of pollution or ingestion of marine debris between 1989 and September 1999 (QPWS Marine Wildlife Stranding and Mortality Database). This number must be considered as a minimum because

1. some turtles may not be disabled by the pollution;
2. some turtles may be temporarily disabled, but recover;
3. some disabled turtles die but not all wash ashore;
4. some turtles that wash ashore are not reported or recovered (e.g. remote coast, unpatrolled section); and
5. the cause of death for the turtles that are recovered is not able to be determined.

Non-toxic pollutants that are introduced into the sea, such as nutrients and sediments, can also affect the environment dramatically, for example causing algal blooms or smothering coral reefs. Declines in water quality will affect marine turtles, along with the rest of the marine ecosystem.

There is growing concern that *Lyngbya* outbreaks, such as those that which occurred in Moreton Bay in 2000, may be associated with GTFP through direct contact of the toxin with the skin. The cyanobacteria outbreaks may be associated with runoff from adjacent disturbed lands.

The Environmental Protection and Biodiversity Conservation Act requires that all protected species injured or killed, regardless of how the accident occurred, be reported (see section 5.3.2).

5.3.13. Predation by Feral Animals

Feral foxes and pigs are also known to dig up turtle nests, and foxes have been implicated as one of the significant factors in the recent decline of loggerhead turtle numbers in Queensland (Limpus and Reimer 1994). In some parts of the world, they can destroy up to 100% of nests laid (Stancyk 1982). Environment Australia has developed a *Threat Abatement Plan for Predation by the European Red Fox* to address fox predation on native Australian fauna, including marine turtles (Environment Australia 1999). European red foxes are listed in that plan as being a key threat to loggerhead and green turtles and as being a potential key threat to leatherback turtles in Australia.

Feral cats are also known predators of green turtle hatchlings in the Seychelles (Seabrook 1994). Although no reports are known for Queensland, feral cats are known to occupy ranges incorporating turtle nesting beaches (e.g. The Strand, Townsville).

5.3.14. Vessel Strikes

Any vessel, including commercial ships, fishing vessels, and recreational craft can strike marine turtles. Animals may be struck when they fail to detect an oncoming vessel, or they may perceive a vessel's approach but be unable to avoid being struck. The increasing number of high-speed vessels operating in waters frequented by marine turtles increases the risk of such collisions.

A ship or boat strike can kill an animal outright, or cause serious injury that ultimately results in death due to impairment of critical functions, attraction of sharks, or other factors. In some parts of the world, especially where shipping lanes pass through areas of high turtle density, mortality due to vessel strikes could pose a significant threat to local populations that might already be under pressure from other sources of mortality (e.g. loggerhead turtles in southeast Queensland). For example, the internesting loggerhead turtles from the Mon Repos rookery frequent the major shipping land for the port of Bundaberg, which comprises a zone of risk from vessel traffic (Tucker et al. 1996).

Not all vessel strikes to marine turtles result in fatalities. In a study of the marine turtles of Moreton Bay, 5.3% of loggerhead and 1.1% of the green turtles inhabiting that bay showed evidence of propeller cuts, more than any other visible sign of anthropogenic impact (Limpus et al. 1994a,b). On average, 14% of the marine turtles that strand or wash ashore along the Queensland coast show evidence of being struck by boats and/or propellers (QPWS Marine Wildlife Stranding and Mortality Database). An area with a high incidence of vessel strikes is Cleveland Bay offshore Townsville where from 10-56% of stranded carcasses per annum between 1994 and 1999 showed signs of vessel strike (QPWS Marine Wildlife Stranding and Mortality Database). Green turtles in particular are at risk of vessel strike as they have a habit of basking at the water's surface. In winter, marine turtles will inhabit deepwater channels where there is warmer water. These deepwater channels may also be the same used by large ships coming into ports along the Queensland coast (section 6.8). Submerged turtles are at increased risk from large draft vessels with minimum bottom clearance as the turtles can be bounced onto or along the bottom, or thrown up towards the propellers.

Many large vessels travel at high speeds (e.g. over 25 knots). The wheelhouse typically is located high above the water's surface. Marine turtles lying in the path of vessels do not appear on ships' radar, and are virtually impossible for pilots or operators to detect. Indeed, for very large vessels, operators may be unaware they have struck a turtle or if they do detect marine turtles lying in their path, they have limited options for avoiding the animals, depending on the vessel's size, speed, and manoeuvrability and on water depth, weather conditions, and other factors. The benefits of avoiding a possible turtle strike must be balanced against risks to vessel or human safety that could be posed by attempts to avoid animals.

5.4. Summary and Conclusions

The potential impacts of greatest relevance to turtle populations in the World Heritage Area are vessel strikes, deliberate killing or injuring, incidental catch, accidental entanglement in/ingestion of marine debris, and physical habitat degradation or destruction, although the level of significance varies depending on the species involved. Other potential threats, such as those arising from disease, could develop in the future. For loggerhead turtles, any mortality associated with human activities has the potential to threaten the Queensland population (Heppell et al. 1996, Limpus and Limpus 1999).

Management measures aimed at conserving turtles in the World Heritage Area should focus on gathering better information on their distributions, abundances and threats, and taking prudent and appropriate measures to reduce impacts judged to be most significant. However, management also needs to take reasonable measures to anticipate and respond to future issues, such as disease outbreaks or unfavourable environmental change(s). Management measures should reflect the level of threat, the degree of certainty, and incorporate the precautionary approach.

6. HUMAN ACTIVITIES IN THE GREAT BARRIER REEF WORLD HERITAGE AREA

The following discussion is based on impacts and effects of human activities on marine turtles, documented both in the World Heritage Area and from other parts of the world. The lack of information about specific impacts and the regularity with which some of these impacts occur is an issue for management of all activities. Table 3 is a summary of the impacts of human activities on marine turtles.

A variety of human activities occurring in and around the World Heritage Area are known, or thought likely, to adversely affect turtles. It is important to consider not only the potential impacts of individual activities, but also the potential cumulative impact of activities that are likely to affect the populations of each species, over both the short and long terms.

There is insufficient scientific information to determine definitively for each marine turtle species whether adverse effects resulting from human activities are ecologically sustainable, or, in some cases, whether they are actually occurring. However, there is growing information of the impacts on loggerhead and green turtles. In the absence of information and because there is a risk of serious or irreversible damage to turtle populations, the precautionary principle should be employed in the World Heritage Area. Whilst the absence of scientific certainty is not a reason for failing to take prudent measures to conserve turtles, management measures must also allow for reasonable human use of the Marine Park.

6.1. Boats, Ships and Other Vessels

Vessels using the World Heritage Area range from surfskis and personal watercraft to ocean-going freighters and cruise ships. Vessels are operated in association with a variety of activities, including recreational use, commercial tours (including cruise ships), public transport (ferries), defence activities, commercial and recreational fishing, and commercial shipping (Great Barrier Reef Marine Park Authority 1998a). All vessels for charter hire, ferry service or for tourism require a permit from the Authority to operate in the Marine Park. Cruise ships require a permit from the Authority if they wish to anchor and conduct commercial activities in certain areas of the Marine Park.

The World Heritage Area includes several major shipping routes and reef passages used by commercial ships. In 1997/98, 1500 large ships transited the Inner Route of the Great Barrier Reef (Great Barrier Reef Marine Park Authority 1998b).

The Great Barrier Reef has been designated as the world's first Particularly Sensitive Sea Area by the International Maritime Organisation (IMO), thus providing special marine environmental protection measures for shipping activities. Some vessels are required to use licensed pilots in specified areas; the Australian Maritime Safety Authority (AMSA) strongly recommends that all ships' masters unfamiliar with routes and reef passages use licensed pilots. The IMO has also recommended a central portion of the Capricorn/Bunker Islands and Reefs (a key nesting and foraging area for loggerhead and green turtles) as an Area to be Avoided by ships over 500 tons gross tonnage (Australian Maritime Safety Authority 1997b).

With the advent of sophisticated navigational aids (e.g. Global Positioning Satellite – GPS - systems) and other technological advancements (e.g. Emergency Position Indicating Radio Beacons-EPIRBs), boaters can venture further from shore, operate under a wider variety of weather conditions, and stay at sea for longer periods of time (Great Barrier Reef Marine Park Authority 1998a).

A comparison of recreational boat fishing in 1980 and 1990 showed an increase of 89% in the numbers of vessels participating in this type of activity in some areas adjacent to the Marine Park

(Blamey and Hundloe 1993, Hundloe 1985). With an increasing Queensland population and advances in technology, the number of recreational and commercial vessels accessing the World Heritage Area will continue to increase in the foreseeable future.

6.1.1. Potential Impacts

All vessels can produce impacts that can affect turtles including:

- Deliberate or reckless killing or injuring
- Harassment
- Noise
- Physical displacement
- Physical habitat destruction or degradation
- Pollution
- Vessel strike

The behaviour and experience of operators can influence the impacts of vessels on marine turtles. For example, boaters may be unfamiliar with an area or with basic boat-handling practices and may also be unfamiliar with turtles and not realise the possibility of disturbance to them. Vessel operators who are unaware that turtles inhabit an area, do not know about the potential impacts of vessels on turtles or are unaware of practices to minimise such impacts will be a greater risk to turtles than those who are better informed. Thus education and licensing programs can be effective tools to minimise impacts on marine turtles.

The types and magnitudes of impacts generated by a vessel are largely determined by characteristics such as size, speed, hull composition and propulsion system. Large vessels can pose a greater risk of serious injury or death in the event of a strike on marine turtles, and can also produce higher levels of noise and pollution. Fast vessels generally are noisier, and may be more at risk of striking marine turtles than slower craft. Additionally, faster vessels allow people to travel greater distances in shorter time periods, thus increasing use of areas that were previously inaccessible and extending the geographic extent of human activities. Hull composition affects the amount of noise that is transmitted into the water; motorised aluminium skiffs or 'tinnies' typically produce very high levels of underwater noise (see section 5.3.9).

The potential effects of the above impacts on marine turtles include injury, death, and behavioural modification, such as displacement from areas of high traffic, and depend on factors such as the:

- numbers and types of vessels;
- routing of vessel traffic relative to key marine turtle habitats; and
- timing of vessel traffic and activity relative to migration/breeding patterns.

6.2. Coastal and Land-Based Actions

Coastal developments and land-use practices can have marked effects on marine ecosystems. Nutrient inflows, sediment transport, freshwater discharges and other fundamental ecological processes that strongly influence coastal ecosystems can be profoundly affected by land-based activities, such as farming, logging, and grazing. Additionally, some land-use practices result in the discharge of pollutants, such as fertilisers and biocides, or acid sulfate soil run-off into the marine environment and which may cause algal and other plankton blooms. Sewage discharge is also an issue, because it poses risks of disease outbreaks as well as disruption of natural nutrient balances.

Over 410,000 km^2 of land is contained within the catchments that drain into the Great Barrier Reef lagoon (Creighton et al. 1997). Within these catchments are some of Queensland's most extensive river systems, including the Burdekin and Fitzroy Rivers. An estimated 23,000,000 tonnes of sediment, 77,000 tonnes of nitrogen and 11,000 tonnes of phosphorus enter the inshore coastal waters of the Great Barrier Reef World Heritage Area annually (Great Barrier Reef Marine Park Authority 1998a). The Authority is strongly advocating actions by Queensland and local governments, landowners and other stakeholders to reduce adverse impacts on the World Heritage Area resulting from land-use practices.

6.2.1. Potential Impacts

Coastal and land-based activities can pose direct and indirect impacts on marine turtles, including:

- Accidental ingestion of/entrapment in marine debris
- Deliberate or reckless injury or mortality
- Disease
- Food depletion
- Harassment
- Physical habitat destruction or degradation
- Physical displacement
- Pollution
- Predation by feral animals

The magnitudes and types of impacts depend upon the type of activity and its location relative to the coast or within the catchment adjacent to the World Heritage Area.

6.3. Defence Activities

There are ten designated Defence Areas within the World Heritage Area. They were established in the interest of public safety to regulate public use of and entry into these areas while they are being used for Defence activities. Most areas are invoked for short periods. For example, the Defence Area over Flora, Coates, Gibson and part of Maori Reefs in the Cairns Section is invoked for weapons testing on an average of one day per month, and rarely for more than about three hours on that day.

Defence activities may include naval exercises, low-altitude flights, high-speed flights generating sonic booms, detonations of explosives for a variety of purposes, use of active sonar and other underwater acoustic devices, use of infra-red laser sighting devices, and firing of live munitions.

Many of these activities are conducted with dedicated shipboard and aerial observers. These personnel may be able to collect data on marine turtle sightings, as well as ensure activities are delayed if turtles are present.

In addition, there are areas of the World Heritage Area, often unknown, where unexploded ordnance from World War II and more recent activities, is located. Accidental or deliberate detonation of these devices could pose threats to turtles and other species.

Military vessels can operate at high speeds and operators may be unable to alter their course if turtles are observed. Naval exercises may involve large numbers of vessels operating intensively in a particular area for days or even weeks.

6.3.1. Potential Impacts

Direct and indirect impacts resulting from Defence exercises include:

- Accidental entanglement in/ingestion of marine debris
- Explosions
- Food depletion
- Noise
- Physical displacement
- Physical habitat disturbance /degradation
- Pollution
- Vessel strikes

The Department of Defence has restricted the use of explosives and ordnance within the World Heritage Area to certain areas. The Department is also undertaking Environmental Impact Assessments for a number of training areas in Australia, including sites within the World Heritage Area. Environmental Management Plans are being prepared in order to identify the environmental impacts of Defence activities and to determine procedures to minimise and mitigate those impacts.

6.4. Feeding

Individuals may attempt to feed turtles in the World Heritage Area, for example by tossing them fish from vessels. Although there is little information on the prevalence of such activity, anecdotal reports are received infrequently. Turtles also may feed on the discards from commercial fishing vessels.

Deliberate feeding and attempted feeding of marine turtles within the World Heritage Area will be prohibited.

6.4.1. Potential Impacts

The potential impacts on turtles from feeding include:

- Disease
- Harassment
- Physical displacement
- Vessel strikes

Impacts by humans feeding turtles also arise from the type, quality, and amount of food, as well as the circumstances under which feeding occurs (e.g. whether feeding occurs in a high traffic or polluted area). Behaviour modification is always an effect of feeding, because animals that are coming to be fed are clearly not engaged in undisturbed behaviours, but the implications of this for the animals over the long term are unknown. Animals may become dependent on the food provided, and may therefore be at greater risk if the food supply is interrupted. Provisioned immature animals may not learn to forage for prey properly as they become accustomed to coming to the surface of the water for food (National Research Council 1990).

Feeding marine turtles also poses risks to humans because the animals may associate humans with food. For example, a loggerhead turtle resident at a popular dive site in Florida, USA harassed divers while looking for a food handout. This turtle has bitten dive equipment and divers and injured one person sufficiently to require hospitalisation (CTURTLE listserver September 1999).

6.5. Fishing, Shark Control Programs and Aquaculture

Fishing is a major activity in the World Heritage Area and is second only to tourism in economic importance (Tanzer and Russell 1999). Recreational, commercial and charter fishers use a wide range of gear types (mesh net, lines, trawl net) and target a variety of species (wide range of fish, prawns, scallops). The main fisheries operating in the Marine Park include the inshore and estuarine net fishery, reef line fishery and trawl fishery (principally ECOTF and the Scallop Otter Trawl Fishery). Reporting to the Queensland Fisheries Service of all bycatch in the trawl net fisheries is mandatory.

The Australian Fisheries Management Authority (AFMA) has responsibility under the Fisheries Management Act 1991 to ensure that fisheries under its control are conducted in an ecologically sustainable manner. They also must have regard to the impact of fishing activities on non-target species and the long-term sustainability of the marine environment. The only fishery managed by AFMA in the Marine Park is the Tuna and Billfish Fishery.

In the southwestern Pacific Ocean, pelagic longlines could pose a threat to young turtles that spend their developmental years in the open ocean before returning to the Marine Park to forage and breed (see section 4.1.1). There has been a decrease over the past six years in the number of young loggerhead turtles migrating from the pelagic zone to become resident at Heron Island Reef (Limpus and Limpus 1999). However, the relationship between pelagic longlines and the decrease in new resident turtles is unquantified.

Net fisheries operate along the Queensland coast in rivers, creeks, estuaries, foreshores and sheltered offshore waters. Although active forms of netting, (haul, ring and tunnel netting) are not thought to impact upon turtles as any that are captured can be released quickly, there has not been post-release studies to quantify this. Some fishers that use these methods deliberately avoid areas with turtles (Environment Australia 1998).

The Queensland Shark Control Program (QSCP) began in 1962 at many Queensland beaches for the protection of bathers from sharks. The QSCP is administered by the Queensland Department of Primary Industries (DPI) and makes use of mesh nets and drum lines to catch sharks that may pose a threat to humans. No nets or drumlines are set within the waters of the Marine Park, but ten nets operate seasonally in waters adjacent to the Marine Park, five each in the Cairns and Mackay regions. In addition, 154 drumlines are set in waters adjacent to or south of the World Heritage Area. Reporting of marine turtle by-catch in all shark control equipment is mandatory.

Since 1993, catches of marine turtles in QSCP gear have been significantly reduced because of changes to the program (eight deaths and 350 turtles released alive, Environmental Protection Agency 1999). However, there is little information on post-release survival. Mesh nets are associated with higher levels of by-catch of all non-target species (dugong, dolphins, whales, and turtles) than are drum lines and consequently have been replaced by drum lines in a number of places.

Aquaculture also occurs in and adjacent to the World Heritage Area. Operations vary significantly depending on the species being cultured. The most common types of aquaculture in the area are prawn and barramundi farming in land-based ponds with associated seawater intake/discharge, and sea-based long-line culture of pearl oysters. There is currently one barramundi sea cage that operates in Queensland waters and none in the Marine Park. Research and development of cage culture techniques for coral reef finfish species are currently in progress and may result in future pressure for the expansion of cage-culture operations.

Recreational fishers in the World Heritage Area must abide by restrictions contained in Queensland fisheries legislation in addition to complying with zoning plans declared under the Great Barrier Reef Marine Park Act.

6.5.1. Potential Impacts

Potential impacts from fishing, the QSCP and aquaculture operations include direct and indirect impacts:

- Accidental ingestion of/entrapment in marine debris
- Disease
- Food depletion
- Incidental catch in fishing gear
- Physical habitat degradation and destruction
- Physical displacement
- Pollution
- Vessel strike

Considerable work is being undertaken by fisheries management agencies and scientists to ensure that fisheries in the World Heritage Area are ecologically sustainable. Included in this work are efforts to develop sustainability indicators, investigate possible effects of fishing on fish habitat and numbers, determine the effect of area closures on reef fish stocks, and minimise by-catch (catch of species other than target species).

Foreshore and offshore mesh net could pose more of a threat to turtles than the active forms of netting although the interaction between these types of nets and turtles is believed to be minimal and remains unquantified. A DPI/Australian Institute of Marine Science project has examined the level of by-catch from inshore net fisheries in Queensland (Great Barrier Reef Marine Park Authority 1998a). The commercial netting industry is committed to modifying practices to minimise impacts on non-target by-catch, especially of protected species (including turtles). Recent regulations establishing Dugong Protection Areas and modifying netting practices are likely to benefit turtles inhabiting the same areas.

The Queensland trawl fishery has adopted 'Turtle Recovery Procedures' for turtles that are incidentally caught in trawls. In recent years, trawl fishers and scientists have developed and introduced TEDs and BRDs in trawl nets to exclude large animals and unwanted by-catch from the catch. A study of BRDs in the Northern Prawn Fishery showed that few or no turtles were caught or killed when these devices were used (Brewer et al. 1998), and trials of various TED designs along the east coast of Queensland suggest that large animals were significantly reduced in catches using the AUS TED II (Robins and McGilvray 1999).

TEDs are to be used in trawl nets throughout the World Heritage Area; however, implementation will be phased-in for certain fisheries (e.g. scallop, deep-water trawl) to allow for the TEDs to be modified to specific conditions for those fisheries. A review event specific to marine turtle capture has been set out in the Fisheries (East Coast Trawl) Management Plan 1999. It states that if capture or mortality for any species of marine turtles is in any year more than 5% of the average level of turtle capture or mortality for the species previously reported by Robins (1995), then the Plan will be reviewed.

If turtle populations are small, localised, or if they are threatened by other impacts, (e.g. Indigenous hunting, coastal development) then even minimal losses due to mortality in fishing, QSCP or aquaculture gear may be important, as in the case of the loggerhead turtle population in Queensland. It may become necessary to consider possible options to reduce the by-catch, such as modifications to equipment (e.g. use of pingers, hook design, TEDs, BRDs) or fishing practices (e.g. reduction in tow, trawl or set times, observer programs).

6.6. Indigenous hunting

Aboriginal and Torres Strait Islanders have hunted marine turtles for traditional food and medicines for thousands of years. Traditional hunting and the consumption of turtles, especially green turtles, serve important economic, cultural and social functions and forms part of the cultural and heritage values associated with the World Heritage Area. The Authority recognises the significant relationship Indigenous people have with turtles in the World Heritage Area.

Provided the Authority has granted a permit for the activity, traditional hunting can occur within all zones of the Marine Park, except Scientific Research Zones, Preservation ('pink') Zones and in the Central and Mackay/Capricorn Sections, Marine National Park 'B' Zones ('green'). Applications for traditional hunting are assessed against criteria set out in the Great Barrier Reef Marine Park Regulations sections 18[4(a-l)] and 18[5(a-g)]. Standard permit conditions include the collection of data (species, size, sex, capture location) about each turtle captured. However, there is little reliable quantitative data on the level of take by Indigenous hunting. This is a concern for Management Agencies.

The grant of a Marine Parks permit for traditional hunting is an important mechanism by which the Authority recognises and affirms the special relationship Indigenous people have with turtles. The Authority is committed to developing cooperative management arrangements with Indigenous communities for the sustainable take of turtles. In 1998, the Authority noted that *'For management to work in communities it must be compatible to the needs of individual communities and these needs have to be identified and understood. In general, community based management needs to ensure that turtles are hunted on a sustainable basis to fulfil community aspirations, expectations and the realistic* *ability to fulfil those expectations. It must maintain flexibility for the dynamics of Indigenous society and most importantly be initiated, monitored and maintained by the communities themselves thus empowering Indigenous communities'* (Hunter and Williams 1998).

Of the six species of marine turtle inhabiting the World Heritage Area, the green turtle is the primary species hunted, while the eggs of all species nesting within the World Heritage Area may be taken from time to time. Adult female turtles are preferred over males and other size classes of green turtles because of their greater fat reserves. After consultation with the local Indigenous community, the capture of loggerhead turtles was prohibited in the Whitsundays Area through implementation of the Whitsundays Plan of Management.

Some green turtles migrate outside of the World Heritage Area to return to foraging or nesting sites (Table 2, Limpus et al. 1992). The levels of harvest in neighbouring countries to which these animals migrate are for the most part unknown; however, they are considered to be high (tens of thousands of turtles hunted annually) in areas such as Indonesia (Groombridge and Luxmoore 1989).

Tag recoveries from hunted turtles indicate that east coast Queensland Indigenous communities are hunting primarily sGBR green turtles (Limpus 1995).

6.6.1. Potential Impacts

The types of potential impacts that may occur from Indigenous hunting include the:

- deliberate killing or injuring;
- harassment of turtles that may be chased repeatedly while in a breeding or nesting area or from inhumane treatment following capture;
- live capture of non-target sizes/sexes of turtles that are released upon the capture of an adult female turtle; and
- physical displacement of turtles from foraging locations as a result of hunting practices (e.g. by frequent chasing by boats).

The early warning signs about the long-term survival of the sGBR green turtle population (see section 4.1.4) may mean that a population decline is underway because too many large (adult) female turtles are being lost from that population. The sGBR population can lose only a few hundred turtles from human-related causes each year for the population to remain viable (Limpus 1999).

The Authority is committed to ensuring that the number of turtles around for hunting by Indigenous people can be maintained in the long term for future generations. The Commonwealth Government, including the Authority, is concerned about threats to marine turtles and is trying to reduce the impact of each threat on the turtles through initiatives identified in the Draft *National Recovery Plan for Marine Turtles in Australia.*

6.7. Live Display, Headstarting, Ranching and Captive Breeding

The capture of live turtles from the Marine Park, whether for public display or other purposes, requires a permit under the Great Barrier Reef Marine Park Act, as does the release of turtles into the Marine Park. In Queensland waters, a permit under the Marine Parks Act is required to capture a turtle from a State Marine Park, and a permit under the Nature Conservation Act is required to hold turtles in captivity in Queensland.

Headstarting is the rearing of hatchlings (either from eggs incubated in a laboratory or from hatchlings collected from nesting beaches) for a period of time prior to their release. This technique developed because mortality is highest for young turtles during the first year of their life (see section 4.1.1). With headstarting, the turtles are larger when released and theoretically have a better chance of survival in the wild. However, management measures that look solely at improving the survivorship of turtles in their first year of life are unlikely to be effective for long-lived species, such as marine turtles (Heppell et al. 1996a).

The suitability (Reichart 1995) or unsuitability (Ehrenfeld 1995) of turtles for captive breeding programs has been debated for decades. Captive breeding programs involve maintaining adults who breed in captivity and whose offspring are raised for use (meat, shell) and ranching involves the collecting of turtles (usually as eggs) from wild populations which are then raised in captivity for use (Ross 1999). Three turtle captive breeding or ranching programs have been attempted. One program, in the Cayman Islands took nineteen years to return an operating profit; another, on Reunion Island, switched to fish aquaculture, research and education after attempts to apply for international trading privileges under CITES were unsuccessful; and a third, in Torres Strait, was discontinued due to problems associated with diseases and feeding turtles (Ross 1999).

The lack of success by these three programs highlights logistic and maintenance problems associated with keeping and rearing turtles in captivity (slow growth and maturation rates, and susceptibility to disease and parasites).

Although the concept of headstarting is appealing, there is insufficient evidence of success and hard evidence would not be available for many decades, when reared hatchlings return as breeding adults (Woody 1990). However, due to natal imprinting, it is uncertain where they would return to breed (Eckert et al. 1994, Huff 1989, Sato and Madriasau 1991).

6.7.1. Potential Impacts

The types of potential impacts that could result from capture of turtles for live display, headstarting, captive breeding or ranching include:

- disruption of normal life-history cycle, including migration patterns;
- displacement if headstarted turtles are released into habitats not normally inhabited by young turtles;
- introduction of different genetic stocks into an area;
- transfer or introduction of diseases as a result of captivity; and
- disruption of the imprinting process that hatchlings use to find their way back to their natal beaches.

Captive turtles, because they are in closed ecosystems, are more susceptible than wild turtles to disease and to nutritional deficiencies (see section 5.3.3). Therefore, regular health checks of animals kept in captivity are necessary, especially if an animal is to be released into the wild. This rule should also apply to animals brought into holding facilities for rehabilitation so that upon release, new pathogens are prevented from entering the sea and infecting healthy turtle populations.

Also, there is the possibility that over-harvesting of eggs or adults for stocking ranches or captive breeding programs could result unless controlled (Tisdell 1986).

6.8. Marine Construction

Marine construction includes building of wharves and piers, dredging, filling, and establishment of other offshore structures, such as artificial islands/reefs, jetties, etc. The construction and maintenance of any structure within the Marine Park is subject to environmental impact assessment and requires a permit issued by the Authority. Assessments of marine construction projects proposed for the Marine Park include, where appropriate, evaluation of potential adverse effects on marine turtles and key turtle habitats, and, where necessary, mitigative measures.

In Queensland, there is a lack of deepwater ports for commercial trade. Thus, there is a need to dredge (remove sediment from the seafloor) channels to allow large ships to access the mainland. To keep the channels sufficiently deep for these vessels, maintenance dredging occurs on a regular, semi-regular or infrequent basis, depending upon the characteristics of the channel. There are two main types of dredges utilised in Queensland: grab bucket dredges and suction dredges (Department of Primary Industries 1998).

Dredging has killed marine turtles where the activities have occurred in areas with high numbers of turtles (Lutcavage et al. 1997). There are anecdotal reports of marine turtles being injured or killed in dredges in Queensland. Turtles often inhabit nearshore areas where dredges operate and during the cooler months often seek the warmer waters of deepwater channels. At two shipping channel sites in Florida, USA, 149 turtles were confirmed caught in dredging operations between 1980 and 1990 (National Research Council 1990).

6.8.1. Potential Impacts

The most significant potential impacts to marine turtles from marine construction are likely to result from large-scale projects. The types of impacts depend upon the type of project, and may vary in magnitude and duration, but can include:

- Accidental ingestion of and entrapment in marine debris
- Deliberate or reckless killing or injuring
- Explosions
- Food depletion
- Harassment
- Noise
- Physical displacement
- Physical habitat degradation or destruction
- Pollution
- Vessel strikes

6.9. Photography and Filming

Photography and filming of marine turtles typically involves close approaches to animals by vessels, may involve placing people in the water close to animals to obtain underwater images, or may involve nesting turtles being approached.

The public interest in marine turtles is generally high, so this type of activity is likely to persist and perhaps increase. Additionally, technological improvements allow filming and photographing of marine turtles under an increasing variety of conditions, which may also lead to growth of the industry.

Photography and filming commonly occurs in the World Heritage Area. Photography and filming can require a Marine Parks permit, depending on the activities and locations proposed. Photography and filming for commercial purposes that is conducted on Island National Parks requires a permit from QPWS.

6.9.1. Potential Impacts

The potential impacts on turtles from filming and photography include:

- Deliberate or reckless injuring or killing
- Harassment
- Physical displacement
- Physical habitat degradation or destruction
- Vessel strikes

The impacts of filming and photography to turtles will vary depending upon factors such as the:

- type of activity (e.g. vessel type, whether in-water or on-land filming is involved)
- number of vessels/people involved;
- way in which vessels are operated/people act;
- number and species of animals involved;
- knowledge of marine turtle biology by persons involved; and
- number of close approaches required.

As a general rule, turtles should not be approached on a nesting beach until they have completed laying their eggs. At this time, the animal is less likely to be disturbed and if disturbed, the negative impact is lessened because the eggs have already been laid. Photographs may be taken at this time; however, care should be taken not to aim a flash directly at the turtle’s head, as it may disorient the animal as it returns to the sea.

Nesting female turtles should not be disturbed from their nesting routine, nor should they or hatchlings be held back from returning to the sea to await suitable filming conditions (e.g. sunrise). Hatchlings need to enter the sea as quickly as possible so that they do not waste valuable yolk reserves.

6.10. Research and Monitoring

Marine research and monitoring includes not only biological studies, but also studies of physical and chemical oceanography, marine geology and geophysics, marine archaeology, underwater acoustics, and a host of other areas of investigations.

Studies that contribute to the understanding of marine systems may ultimately benefit turtles. Specific studies of marine turtles and their use of the marine environment, including estimates of relative and absolute abundance, distribution, ecology, and behaviour are needed to assess the conservation status of marine turtle species, support management, and allow evaluation of the effectiveness of conservation measures.

Depending on the activities and locations proposed, conducting research in the World Heritage Area might require a permit. Part of the permit assessment process involves an evaluation of whether the proposed research should be reviewed by the Authority's independent Environmental Research Ethics Advisory Committee (EREAC). Because all marine turtles within the World Heritage Area are listed as threatened, all research applications involving marine turtles are referred to the EREAC. All manipulative research proposed for the Marine Park is, when appropriate, evaluated for potential adverse impacts on marine turtles. Proposed research involving seismic exploration or other intense sound sources will be subject to particular scrutiny to balance the benefits of the research against the risks to marine turtles and other species.

For management to be effective over the long term, it must incorporate information on turtle population abundance and distribution within the World Heritage Area. Reliable information is needed on:

- the distribution and abundance of marine turtle species in the World Heritage Area;
- patterns of use of the World Heritage Area by marine turtle species (e.g. seasonal movements, long-term population trends); and
- locations of any key habitats for particular species.

Another source of information necessary for effective management is dedicated scientific monitoring. This is often the only way to answer definitively certain questions, such as those concerning genetics or population trends (Parmenter 1993). However, such monitoring studies are often expensive and securing funding can be difficult.

While scientific studies of marine turtles should be accorded high priority, supplementary sources of information are also needed. Tour operators, fishers, Indigenous people, Defence personnel, recreational boaters and government personnel spend significant amounts of time out on the water and thus are potentially useful sources of information about marine turtles. If data collection procedures and protocols are carefully developed in advance of data collection, and if the correct statistical analyses are performed, then the information can augment that gathered through formal scientific investigations. These kinds of data collection programs can also help build public awareness about marine turtles and the marine environment in general, as well as involve key stakeholders in management. The results of the data collection program are useful not only in formulating and evaluating management measures, but also should be fed back to the data collectors.

6.10.1. Potential Impacts

The types of impacts on marine turtles generated by research depend on the type of research but may include:

- Deliberate or reckless killing or injuring
- Harassment
- Live capture
- Noise
- Physical displacement
- Physical habitat degradation or destruction
- Pollution
- Vessel strikes

Vessels used for research pose similar threats to marine turtles as those used for other purposes (see section 6.1.1), but the level of risk depends on the type of craft used and the manner in which it is operated.

Marine turtle research often requires close approaches to or captures of animals, for example to take identifying photographs, or to obtain skin samples used for genetic analysis, stomach samples for feeding studies, and tissue samples for assessments of contaminant loads. Some research requires the temporary capture of animals, for example for taking of physical measurements or blood samples or to attach radio or satellite tags that allow animals to be tracked. These kinds of activities could be disruptive to the animals. The potential impacts of these activities depend on the species, its conservation status, age and sex, the number of animals involved, the duration of the study and importantly, the experience of the researcher. The kinds of information resulting from these studies can be useful for management.

6.11. Tourism and Recreation

Commercial tour operators undertake a wide variety of activities, including scenic cruises, island and reef trips, glass-bottomed boat rides, snorkel and diving trips, and marine thrill rides. Trips may last an hour or less, or extend for a few days, weeks, or even months. The sizes and types of vessels used similarly vary. Within the World Heritage Area, there are no known tourist operations focussing specifically on marine turtles (e.g. turtle watching tours); however, tourist permits focussing on turtles have been issued by QPWS in Moreton Bay Marine Park, near Brisbane.

Observing marine turtles underwater can provide better understanding of the animals, and can be a particularly exciting and rewarding experience for people. However, it provides increased incentive to get close to the animals in order to be able to see them underwater (see below), and there are additional potential risks posed by having people in the water in close proximity to turtles. It is likely that incidental swimming-with-turtles occurs, on both a commercial and recreational basis.

Tourism has the potential to educate large numbers of people about turtles and to encourage an appreciation of the marine environment as a whole. Tours can occur on nesting beaches and through interpretive talks for people visiting the World Heritage Area (Tisdell and Wilson 2000). The potential benefits of turtle watching include increased information about local turtle populations; increased awareness by tourists (Australian and overseas) of turtle conservation and management actions in the World Heritage Area, and greater potential for conservation initiatives through economic potential of wildlife-based eco-tours.

All tourist programs operating within the Marine Park require a permit from the Authority. Tourist operators accessing islands within the World Heritage Area require a permit under the Nature Conservation Act from QPWS if accessing a National Park or a permit from the Authority under the Great Barrier Reef Marine Park Act if accessing a Commonwealth island.

6.11.1. Potential Impacts

Potential impacts on marine turtles from tourism differ, depending on where the activities occur (e.g. in the water, on land), but may include:

- Accidental ingestion of or entrapment in marine debris
- Deliberate or reckless killing or injuring
- Disease
- Harassment
- Noise
- Physical displacement
- Physical habitat degradation or destruction
- Pollution
- Vessel strikes

The QPWS operates a guided tour of the Mon Repos nesting beach near Bundaberg from November to February and tourists visiting Heron Island often encounter researchers who explain the biology of marine turtles and the nesting process. However, without appropriate training even well meaning individuals and eco-tourist ventures may unknowingly disrupt turtles (e.g. through shining lights or driving on nesting beaches). Wilson and Tisdell (2000) estimate that the Mon Repos turtle watching season generates close to $1,000,000 per year to the Bundaberg region. In some countries, the economic return obtained from taking tourists onto nesting beaches prevails over the previous requirement to harvest eggs and females (Tambiah 1991). The concern that large numbers of visiting tourists could impact key nesting habitats can be overcome with training, temporal or spatial closures, and compliance with permit conditions and guidelines.

Tourist programs do not necessarily have to focus their programs on turtles in order to have an impact on the animals. If a particular reef location is popular with tourists and is also a key habitat for turtles, there is the potential for turtles to be adversely affected.

As eco-tourism increases in popularity around the world, there is the possibility that operators will want to watch and possibly swim with turtles as part of a dedicated tour program. As with whales and dolphins, impacts from turtle watching are potentially much greater when swimming activities are involved. There are also potentially elevated risks of vessel strikes because vessels must operate in close proximity to the animals. Similarly, the effects of vessel noise, pollution, harassment and other impacts may be higher.

There are additional risks of swim interactions for both people and animals. If humans and marine turtles come into physical contact, there is the risk of physical injury to the animals and to humans. Turtles are wild animals, and have been known in rare instances to injure people in the water who were physically interacting with them (see section 6.4). It is also possible that diseases could be transferred from people to turtles or from turtles to humans (Herbst 1999).

The key management challenge for this activity, as with vessel-based turtle watching, is to ensure that the animals largely control the interactions. Deliberate attempts by people to swim with turtles are unlikely to be successful unless the animals choose to remain nearby or unless animals are trapped (e.g. in reefal lagoons) or entangled. Turtles are generally able to readily avoid people in the water. Nonetheless, repeated vessel approaches by people attempting to swim with turtles could be a serious source of disturbance to the animals and must be managed accordingly. Of particular concern are the cumulative effects of avoidance behaviour, if animals spend large amounts of time and energy avoiding vessels.

The Authority has developed the following Best Environmental Practices for Turtle-Watching:

The Great Barrier Reef is a critical breeding ground for four species of turtles. They come ashore at night to lay eggs. With care it is possible to watch the fascinating events of females laying eggs and hatchling emerging from the sand without disturbing the turtles.

- Keep the use of lighting (e.g. torches) to a minimum. Hint: put a red cloth or cellophane over the torch.
- Lights should be no more than a three-volt, two-cell, hand-held torch.
- Do not approach too close to turtles leaving the water and moving up the beach.
- Do not shine lights directly on turtles leaving the water, moving up the beach, building nests, or laying eggs.
- Avoid loud noise and sudden movements near turtles while they are laying their eggs.
- Do not touch the turtles, hatchlings or eggs.
- Keep dogs away.
- Do not light campfires on turtle nesting beaches.
- Report sick, injured, stranded or dead turtles to the Marine Animal Hotline phone: 1300 360 898 (24 hr)
- Learn about the habits and needs of turtles to increase your appreciation of them.

Codes of practice for swimming with large marine animals have been developed to minimise risks to the animals and humans from these types of activity (Arnold and Birtles 1998). Observations to date suggest that practices, which promote safety also, lead to longer encounters with the animals.

6.12. Trade of Turtles and Turtle Products

Most parts of a turtle can be of economic value. Outside Australia, turtle eggs and meat are sold for food, the skin of flippers and the neck is made into leather articles, the oil is used in the production of cosmetics, the offal is used to make soup and the shell is used to make jewellery and ornaments (Mack et al. 1995). Young turtles are also stuffed and sold as ornaments.

Although the above products could be obtained from all turtle species, three species have been heavily exploited around the world: the green, olive ridley and hawksbill turtle. Green turtles are taken primarily for their meat and eggs; olive ridley turtles for their skin and secondarily for meat and oil and hawksbill turtles are the source of tortoiseshell because of the thick scutes covering their carapace, but are taken also for meat and eggs (Groombridge and Luxmorre 1989, Mack et al. 1995).

Food, souvenirs and tortoiseshell harvests in Australia and nearby countries currently pose a considerable threat to the region's turtle populations. Improvements in fishing technology and the growth of large-scale industries in which marine turtle products are sold for profit have meant that turtles, particularly green and hawksbill turtles, have become locally scarce in some parts of the world, including areas of the southwestern Pacific Ocean region (Groombridge and Luxmoore 1989). All marine turtle species in Australia are listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which prohibits the commercial trade of turtle products by all signatories to CITES. Essentially this means that wild caught turtles or turtle products can not be exported or imported into Australia. Within Australia, turtles and products from turtles may not be sold and are protected against commercial take under Queensland's Nature Conservation Act and the Commonwealth's Environment Protection and Biodiversity Conservation Act.

Recently, trade of turtle products over the Internet has become a problem, with auction websites advertising tortoiseshell items for sale. Although the United States Fish and Wildlife Service, and the owners of the Internet site are addressing the issue, this type of occurrence will probably increase with increased use of the World Wide Web.

6.12.1. Potential Impacts

The potential impacts from the trade of turtle or turtle products include:

- Deliberate killing or injuring
- Harassment
- Live capture
- Noise
- Physical displacement
- Vessel strikes

The major effect of the trade in turtles or turtle products has been the subsequent population decline resulting from ecologically unsustainable trading practices.

7. LIVE STRANDINGS AND CARCASSES

Marine turtle stranding/carcass incidents usually involve single individuals, although hundreds have been known to strand after cyclones (Limpus and Reed 1985). The reasons for the marine turtles stranding/dying are not well understood, and are likely to vary. Natural (e.g. disease) and anthropogenic (e.g. pollution) causes have been implicated in some stranding events, but others have shown no obvious contributory factors (QPWS Marine Wildlife Stranding and Mortality Database).

All of these events pose important issues for management for several reasons, including the:

- threatened status of marine turtles,
- effort and resources required to respond to live strandings, entanglements or carcasses,
- high public and media interest in these events,
- possibility of contributing to or prolonging the suffering of animals, and
- risks to humans who try to free entangled or trapped animals and/or return them to deeper waters.

Dead marine turtles are potentially valuable sources of information, and can provide insight into causes of mortality and species distribution. The amount and quality of information that can be retrieved depends to a large extent on how fresh and intact is the carcass. Because of the threatened status of marine turtles occurring in the World Heritage Area, high priority should be placed on responding to reports of dead animals as quickly as possible in order to obtain the maximum amount of information from each carcass, especially for loggerhead, olive ridley and leatherback turtles. Speedy detection and reporting of carcasses facilitates collection of useful data.

In addition, stranded (live) animals can be valuable sources of information, and measurements and samples should be taken whenever possible, without further jeopardising the health of the animals.

Reliable information on marine turtle by-catch in the World Heritage Area would be useful, both to evaluate direct impacts on turtles and to help gather information on their distributions and habits. Further, turtles accidentally killed in fishing, QSCP or aquaculture gear are a very valuable source of basic information about the animals. In contrast to stranded animals, animals caught in nets are more likely to be fresh when discovered and less likely to be diseased. Thus, they can contribute to an understanding of basic biology (e.g. age at sexual maturity). Additionally, levels of contaminants, such as pesticide residues, in incidentally caught animals should be more typical of the population at large.

In the World Heritage Area, the QPWS responds to stranding/carcass incidents that occur in State waters or on State beaches, whereas stranding/carcass incidents that occur in Commonwealth areas (e.g. in reef lagoons) are the responsibility of the Authority. Therefore, joint management of stranding and carcass incidents is essential and is coordinated by the Day to Day Management Coordination Unit.

For both live and dead animals, it is essential that samples and measurements be collected according to agreed, standardised procedures to ensure that the data will be useful and comparable to that collected from other sites. Some information (e.g. pollutant loads) can only be retrieved if samples are properly collected, stored and analysed.

Workshops focussed on other marine wildlife (e.g. live-stranded and dead cetaceans) have produced detailed guidelines for responding to live strandings and carcasses, including guidelines for determining the likelihood of success for possible attempts at rescue or rehabilitation, humane methods of euthanising animals, and proper collection and storage of biological samples. Guidelines have also been developed detailing the appropriate procedures for dead marine turtles, including performing necropsies (Wolke and George 1981), taking of measurements, and collection and storage of samples, etc.

8. LITERATURE CITED

Abal, E. G. & Dennison, W. C. 1996, 'Seagrass depth range and water quality in southern Moreton Bay, Queensland, Australia', *Marine and Freshwater Research*, 47, 763-771.

Aguilar, R., Mas, J. & Pastor, X. 1995, 'Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the western Mediterranean', pp 1-6, in *Proceedings of the 12th Annual Workshop on Sea Turtle Biology and Conservation*, NOAA Technical Memorandum NMFS-SEFSC-361, compilers J. I. Richardson, T. H. Richardson, National Technical Information Service, Springfield, Virginia.

Allard, M. W., Miamoto, M. M., Bjorndal, K. A., Bolten, A. B. & Bowen, B. W. 1994, 'Support for natal homing in green turtles from mitochondrial DNA sequences' *Copeia* 1994, 34-41.

Arnold, P.W. & Birtles, R.A. 1999, *Towards Sustainable Management of the Developing Dwarf Minke Whale Tourism Industry in Northern Queensland*, CRC Reef Research Centre, Townsville, CRC Reef Research Technical Report No. 27. 30 pp.

Australian Maritime Safety Authority, 1997a, *REEFPLAN: An oil spill contingency policy document for the Great Barrier Reef World Heritage Area*. Prepared by the Australian Maritime Safety Authority in cooperation with the Great Barrier Reef Marine Park Authority, Queensland Department of Transport and the Queensland Department of Environment and Heritage.

Australian Maritime Safety Authority, 1997b, *Reef Guide, A shipmaster's handbook to the Torres Strait and the Great Barrier Reef, Third Edition*, Queensland Transport and the Australian Maritime Safety Authority.

Balazs, G. 1980, *Synopsis of the biological data on marine turtles in the Hawaiian Islands*, NOAA Technical Memorandum NMFS-SWFC-7, National Technical Information Service, Springfield, Virginia.

Balazs, G. H. & Pooley, S. G. 1991, *Research plan for marine turtle fibropapilloma*, NOAA Technical Memorandum, NMFS-SWFC-156, National Technical Information Service, Springfield, Virginia.

Bell, I. P., Miller, J. D. & Dobbs, K. A. 1999, 'Hawksbill turtle migrations in the Coral Sea', p.95, in. *Proceedings of the Eighteenth Annual Sea Turtle Biology and Conservation Workshop*, NOAA Technical Memorandum NMFS-SEFSC, compilers F. A. Abreu-Grobois, R. Briseño, R. Márquez, F Silva, L. & Sarti, National Technical Information Service, Springfield, Virginia.

Bjorndal, K. A. 1997, 'Foraging ecology and nutrition of sea turtles' pp 199-231 in *The Biology of Sea Turtles*, eds P. L. Lutz, J. A. & Musick, CRC Press, Boca Raton, Florida.

Blamey, R. K. & Hundloe, T. J. 1993, *Characteristics of recreational boat fishing in the Great Barrier Reef region*. Unpublished report to the Great Barrier Reef Marine Park Authority.

Bouchard, S., Moran, K., Tiwari, M., Wood, D., Bolten, A., Eliaazar, P. & Bjorndal, K. 1998, 'Effects of exposed pilings on sea turtle nesting activity at Melbourne Beach, Florida', *Journal of Coastal Research* 14, 1343-1347.

Brand-Garnder, S. J., Lanyon, J. M. & Limpus, C. J. 1999, 'Diet selection by immature green turtles, *Chelonia mydas*, in subtropical Moreton Bay, south-east Queensland', *Australian Journal of Zoology* 47, 181-191.

Brewer, D., Rawlinson, N., Eayrs, S. & Burridge, C. 1998, 'An assessment of bycatch reduction devices in a tropical Australian prawn trawl fishery', *Fisheries Research* 36, 195-215.

Broderick, D., Moritz, C., Miller, J. D., Guinea, M., Prince, R. I. T. & Limpus, C. J. 1995, 'Genetic studies of the hawksbill turtle *Eretmochelys imbricata:* evidence for multiple stocks in Australian waters', *Pacific Conservation Biology* 1, 123-131.

Brodie, J. 1995, 'The water quality status of the Great Barrier Reef World Heritage Area', pp 69-89, in *State of the Great Barrier Reef World Heritage Area Workshop. Proceedings of a technical workshop held in Townsville, Queensland, Australia, 27-29 November 1995, Workshop Series No. 23* eds D. Wachenfeld, J. Oliver & K. Davis, Great Barrier Reef Marine Park Authority, Townsville.

Carr, A. 1984, *The Sea Turtle, So Excellent a Fishe*, University of Texas Press, Austin.

Carr, A. 1986, 'Rips, FADS, and little loggerheads', *BioScience* 36, 92-100.

Carr, A. 1987a, 'New perspectives on the pelagic stage of sea turtle development', *Conservation Biology* 1, 103-21.

Carr, A. 1987b, 'Impacts of nondegradable marine debris on the ecology and survival outlook of sea turtles', *Marine Pollution Bulletin* 18, 352-356.

Carr, A. F., Ogren, L. & McVea, C. 1980, 'Apparent hibernation by the Atlantic loggerhead turtle *Caretta caretta* off Cape Canaveral, Florida', *Biological Conservation*, 19, 7.

Chaloupka, M. & Limpus, C. 1997, 'Heuristic simulation modelling of trawl fishery impacts on sGBR loggerhead population dynamics', pp 26-29, in, *Proceedings of the 17th Annual Symposium of Sea Turtle Biology and Conservation*, NOAA Technical Memorandum, NMFS-SEFSC-415, National Technical Information Services, Springfield, Virginia.

Clark, D. R. Jr., Krynitsky, A. J. 1980, 'Organochlorine residues in eggs of loggerhead and green sea turtles nesting at Merritt Island, Florida – July and August 1976', *Pesticides Monitoring Journal*, 14, 7-10.

Cook, C. 1994, 'Aboriginal and Torres Strait Islander traditional hunting and native title', *Reef Research*, June 1994, 6-8.

Crain, D. A., Bolten, A. B. & Bjorndal, K. A. 1995, 'Effect of beach nourishment on sea turtles: review and research initiatives', *Restoration Ecology*, 3(2), 95-104.

Creighton, C., Rowland, P. & Capon, S. 1997, 'Managing catchments to minimise downstream effects', pp 503-521, in *State of the Great Barrier Reef World Heritage Area Workshop. Proceedings of a technical workshop held in Townsville, Queensland, Australia, 27-29 November 1995, Workshop Series No. 23*, eds D. Wachenfeld, J. Oliver & K. Davis, Great Barrier Reef Marine Park Authority, Townsville.

Department of Primary Industries, 1998, *Dredging, extraction and spoil disposal activities – departmental procedures for provision of fisheries comments FHMOP004*, Department of Primary Industries, Brisbane.

Department of the Navy, 1998, *Final environmental impact statement. Shock Testing the SEAWOLF Submarine*, Department of the Navy, North Charleston, South Carolina.

Department of the Navy, 1999, *Draft environmental impact statement. Shock Testing the WINSTON S. CHURCHILL (DDG81)*, Department of the Navy, Arlington, Virginia.

Devlin, M. 1999, 'Seagrass and nutrients: what are the potential effects of increasing nutrient levels?', *Reef Research*, 9, 16-20.

Dobbs, K. A., Miller, J. D., Limpus, C. J. & Landry, A. M. Jr. 1999, 'Hawksbill turtle, *Eretmochleys imbricata*, nesting at Milman Island, northern Great Barrier Reef, Australia', *Chelonian Conservation and Biology*, 3, 344-361.

Dodd, C. K. 1988, *Synopsis of the biological data on the loggerhead sea turtle Caretta caretta (Linnaeus 1758), Biological Report 88(14)*, U. S. Fish and Wildlife Service, Gainesville, Florida.

Dutton, P. H., Bowen, B. W., Owens, D. W., Barragan, A. & Davis, S. K. 1999, 'Global phylogeography of the leatherback turtle *(Dermochelys coriacea)*', *J. Zool. Lond.*, 248, 397-409.

Eckert, S. A., Crouse, D., Crowder, L. B., Maceina, M. & Shah, A. 1994, *Review of the Kemp's ridley sea turtle headstart program*, NOAA Technical Memorandum NMFS-OPR-2, National Technical Information Service, Springfield, Virginia.

Ehrenfeld, D. W. 1968, 'The role of vision in the sea-finding orientation of the green turtle (*Chelonia mydas*). 2. Orientation mechanism and range of spectral sensitivity', *Animal Behaviour*, 16, 281-287.

Ehrenfeld, D. W. 1995, 'Options and limitations in the conservation of sea turtles', pp 457-463, in *Biology and Conservation of Sea Turtles Revised Edition*, ed K. A. Bjorndal, Smithsonian Institution Press, Washington DC.

Environment Australia, 1998, Draft *National Recovery Plan for Marine Turtles in Australia*, Biodiversity Group, Environment Australia, Canberra.

Environment Australia, 1999, *Threat Abatement Plan for Predation by the European red fox*, Biodiversity Group, Environment Australia, Canberra.

Environment Australia, 2000 unpublished, Draft *National Recovery Plan for Marine Turtles in Australia*, Biodiversity Group, Environment Australia, Canberra.

Environmental Protection Agency, 1999, *State of the Environment Queensland 1999*, Environmental Protection Agency, Brisbane.

Forbes, G. A. 1994, 'The diet of the green turtle in an algal-based coral reef community-Heron Island, Australia', pp.57-59 in *Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation* compilers B. A. Schroeder & B. E. Witherington, NOAA Technical Memorandum, NMFS-SEFSC-341, National Technical Information Service, Springfield, Virginia.

Frazier, J. G. 1980, 'Marine turtles and problems in coastal management' pp2395-2410, in *Coastal Zone 80, Volume III, Proceedings of the Second Symposium on Coastal and Ocean Management* ed B. L. Edge, American Society of Civil Engineers, USA.

Fritts, T. H. & McGehee, M. A. 1989, 'Effects of petroleum on the development and survival of marine turtle embryos' pp321-322, in *Proceedings of the Second Western Atlantic Turtle Symposium*, NOAA Technical Memorandum NMFS-SEFC-226, ed L. Ogren, National Technical Information Service, Springfield, Virginia.

Garnett, S. T., Price, I. R. and Scott, F. J. 1985, 'The diet of the green turtles, *Chelonia mydas* (L.), in Torres Strait'. *Australian Wildlife Research*, 12, 103-112.

George, R. H. 1997, 'Chapter 14. Health problems and diseases of sea turtles', pp 363-385*, in The Biology of Sea Turtles*, eds P. L. Lutz & J. A. Musick, CRC Press Inc., Boca Raton, Florida, USA.

Geraci, J. 1990, 'Physiologic and toxic effects on cetaceans', pp 167-197, in *Sea Mammals and Oil: Confronting the Risks*, eds J. R. Geraci & D. J. St Aubin, Academic Press, San Diego.

Gibson, J. & Smith, G. 1999, 'Reducing threats to foraging habitats', pp184-188, in *Research and Management Techniques for the Conservation of Sea Turtles*, eds K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly, IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Gladstone, W. 1996, *Trace metals in sediments, indicator organisms and traditional seafoods of the Torres Strait. Report Series 5a*, Great Barrier Reef Marine Park Authority, Townsville.

Gordon, J. & Moscrop, A. 1996, 'Underwater noise pollution and its significance for whales and dolphins', pp. 281–319in *The Conservation of Whales and Dolphins: Science and Practice*, eds M. P. Simmonds & J. D. Hutchinson, John Wiley & Sons Ltd, Chichester, England.

Gordon, A. N., Pople, A. R. & Mg, J. 1998, 'Trace metal concentrations in livers and kidneys of sea turtles from south-eastern Queensland, Australia', *Marine and Freshwater Research*, 49, 409-414.

Great Barrier Reef Marine Park Authority, 1994, *Turtle and Dugong Conservation Strategy for the Great Barrier Reef Marine Park Issues paper for public comment*, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef Marine Park Authority, 1998a, *State of the Great Barrier Reef World Heritage Area 1998*, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef Marine Park Authority, 1998b, *1997-98 Annual Report*, Great Barrier Reef Marine Park Authority, Townsville.

Greene, C.R., Jr. & Moore, S. E. 1995, 'Man-made noise', pp 101-158, *in Marine Mammals and Noise* eds W. J. Richardson, C. R. Greene Jr., C. I. Malme & D. H. Thomson, Academic Press, San Diego.

Gribble, N. A., McPherson, G. & Land, B. 1998, 'Effect of the Queensland Sharks Control Program on non-target species: whale, dugong, turtle and dolphin: a review' *Marine and Freshwater Research*, 49, 645-651.

Groombridge, B. & Luxmoore, R. 1989, *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*, CITES, Cambridge, UK.

Gyuris, E. 1994, 'The rate of predation by fishes on hatchlings of the green turtle *(Chelonia mydas)', Coral Reefs*, 13, 137-144.

Harris, A. 1994, 'Species review: the olive ridley', pp 63-67, in, *Proceedings of the Australian Marine Turtle Conservation Workshop* compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Haynes, D. 1997, 'Marine debris on continental islands and sand cays in the Far Northern Section of the Great Barrier Reef Marine Park', *Marine Pollution Bulletin*, 34, 276-279.

Haynes, D. & Johnson, J. E. in press, 'Pollutant concentrations in the Great Barrier Reef (Australia) Environment: A review', *Marine Pollution Bulletin*.

Haynes, D., Müller, J. and Carter, S. in press a, 'Pesticide and herbicide residues in sediments and seagrasses from the Great Barrier Reef World Heritage Area and Queensland coast', *Marine Pollution Bulletin*.

Haynes, D., Ralph, P., Pranges, J. and Dennison, B. in press b, 'The impact of herbicide diuron on photosynthesis in three species of tropical seagrass', *Marine Pollution Bulletin*.

Heppell, S. S., Crowder, L. B. & Crouse, D. T. 1996a, 'Models to evaluate headstarting as a management tool for long-lived turtles', *Ecological Applications*, 6(2), 556-565.

Heppell, S. S., Limpus, C. J., Crouse, D. T., Frazer, N. B. & Crowder, L. B. 1996b, 'Population model analysis for the loggerhead sea turtle, *Caretta caretta*, in Queensland', *Wildlife Research*, 23, 143-159.

Herbst, L. 1999, 'Infectious diseases of marine turtles', pp 208-213, in, *Research and Management Techniques for the Conservation of Sea Turtles*, eds K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, and M. Donnelly, IUCN/SSC Marine Turtle Specialist Group, Publication No 4,

Hill, B. D., Fraser, I. R. & Prior, H. C. 1997, '*Cryptosporidium* infection in a dugong (*Dugong dugon*)', *Australian Veterinary Journal*, 75, 670-671.

Hirth, H. 1997, *Synopsis of the biological data on the green turtle Chelonia mydas (Linneaus 1758), Biological Report 97(1)*, U.S. Fish and Wildlife Service, Washington DC.

Huff, J. A. 1989, 'Florida (USA) terminates 'headstart ' program', *Marine Turtle Newsletter*, 46, 1-2.

Hundloe, T. J. 1985, *Fisheries of the Great Barrier Reef*, Great Barrier Reef Marine Park Authority Species Publication Series No. 2, Great Barrier Reef Marine Park Authority, Townsville.

Hunter, B. & Williams, R. 1998, 'Sustainable hunting in search of a solution', pp 63-65, in *Marine Turtle Conservation and Management in Northern Australia. Proceedings of a workshop held at the Northern Territory University, Darwin 3-4 June 1997* eds R. Kennett, A. Webb, G. Dugg, M. Guinea and G. Hill, Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin.

Hutchinson, J. & Simmonds, M. 1991, *A review of the effects of pollution on marine turtles, A Greenpeace Ecotoxicology Project*, Greenpeace, London.

Jasny, M. 1999, *Sounding the Depths: Supertankers, Sonar, and the Rise of Undersea Noise*, Report from the National Resource Defence Council, New York.

Johnson, D. R., Yeung, C. & Brown, C. A. 1999, *Estimates of marine mammal and marine turtle bycatch by the US Atlantic pelagic longline fleet in 1992-1997*, NOAA Technical Memorandum NMFS-SEFSC-418, National Technical Information Service, Springfield, Virginia.

Kemp, N.J. 1996, 'Habitat loss and degradation', pp. 263–280 in *The Conservation of Whales and Dolphins: Science and Practice,* eds M.P. Simmonds & J.D. Hutchinson, John Wiley & Sons Ltd, Chichester, England.

Kenchington, R. A. 1990, *Managing Marine Environments*, Taylor & Francis, New York.

Ketten, D.R. 1995, 'Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions', in *Sensory Systems of Aquatic Mammals*, eds R.A. Kastelein, J.A. Thomas & P.E. Nachtigall, De Spil Publishers, Woerden, The Netherlands, pp. 391–407.

Klima, E. F., Gitschlag, G. R., Renaud, M. L. 1988, 'Impacts of the explosive removal of offshore petroleum platforms on sea turtles and dolphins', *Marine Fisheries Review*, 50, 33-42.

Lenhardt, M. L. 1982, 'Bone conduction hearing in turtles', *Journal of Auditory Research*, 22, 153-160.

Lenhardt, M. L. 1994, 'Seismic and very low frequency sound induced behaviors in captive loggerhead marine turtles (*Caretta caretta*)', pp 238-241, in *Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation*, NOAA Technical Memorandum, NMFS-SEFC-351, compilers K. A. Bjorndal, A. B. Bolten, D. A. Johnson & P. J. Eliazar, National Technical Information Service, Springfield, Virginia.

Lenhardt, M. L., Bellmund, S., Byles, R. A., Harkins, S. W. & Musick, J. A. 1983, 'Marine turtle reception of bone conducted sound', *Journal of Auditory Research*, 23, 119-125.

Lenhardt, M. L. & Harkins, S. W. 1983, 'Turtle shell as an auditory receptor', *Journal of Auditory Research*, 23, 251-260.

Limpus, C. J. 1971, 'Sea turtle ocean finding behaviour', *Search*, 2(10), 385-386.

Limpus, C. J. 1980, 'Observation on the hawksbill turtle (*Eretmochelys imbricata*) nesting along the Great Barrier Reef', *Herpetologica*, 36(3), 265-271.

Limpus, C. J. 1983, 'Turtles of the Swain Reefs', p.30, in *Australian Coral Reef Society Annual Scientific Meeting Abstracts*, ed P. G. Flood, Australian Coral Reef Society, Armidale.

Limpus, C. J. 1985, '*A study of the loggerhead sea turtle, Caretta caretta, in eastern Australia*', Ph.D. Thesis, Zoology Department, University of Queensland, Brisbane.

Limpus, C. J. 1992, 'The hawksbill turtle, *Eretmochelys imbricata,* in Queensland: population structure within a southern Great Barrier Reef feeding ground', *Wildlife Research*, 19, 489-506.

Limpus, C. J. 1993, The green turtle, *Chelonia mydas*, in Queensland: breeding males in the southern Great Barrier Reef, *Wildlife Research*, 20, 513-523.

Limpus, C. J. 1995, 'Conservation of marine turtles in the Indo-Pacific region. Final report to Australian Nature Conservation Agency', Australian Nature Conservation Agency, Canberra.

Limpus, C. J. 1997, *Summary of the Biology of Marine Turtles in Australia*, Report prepared for Environment Australia, Canberra.

Limpus, C. J. 1999, *Green turtle, Chelonia mydas, in Queensland: population status and sustainable harvest. September 1999 review*, Unpublished report to the Queensland Parks and Wildlife Service, Brisbane.

Limpus, C. J. 2000, *Green turtle, Chelonia mydas, in Queensland: population status and sustainable harvest. June 2000 review*, Unpublished report to the Queensland Parks and Wildlife Service, Brisbane.

Limpus, C. J. & Couper, P. 1994, 'Loggerheads: a species in decline' *Wildlife Australia*, 30, 11-13.

Limpus, C. J., Couper, P. J. & Read, M. A. 1994a, 'The loggerhead turtle *Caretta caretta*, in Queensland: population structure in a warm temperate feeding area', *Memoirs of the Queensland Museum*, 37, 195-204.

Limpus, C. J., Couper, P. J. & Read, M. A. 1994b, 'The green turtle *Chelonia mydas*, in Queensland: population structure in a warm temperate feeding area', *Memoirs of the Queensland Museum*, 35, 139-154.

Limpus, C. J. & Limpus, D. J. 1999, *Summary report on the status of the eastern Australian loggerhead turtles, Caretta caretta: 1999*, Unpublished report to the Queensland Parks and Wildlife Service, Brisbane.

Limpus, C. J. & Limpus, D. J. 2000, 'Mangroves in the diet of *Chelonia mydas* in Queensland, Australia', *Marine Turtle Newsletter*, 89, 13-15.

Limpus, C. J. & McLachlan, N. 1994, 'The conservation status of the leatherback turtle, Dermochelys coriacea, in Australia', pp 68-78, in *Proceedings of the Australian Marine Turtle Conservation Workshop*, compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Limpus, C. J. & Miller, J. D. 1994, 'The occurrence of cutaneous fibropapillomas in marine turtles in Queensland', pp186-188, in *Proceedings of the Australian Marine Turtle Conservation Workshop*, compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Limpus, C. J., Miller, J. D., Parmenter, C. J., Reimer, D., McLachlan, N. & Webb, R. 1992, 'Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles to and from eastern Australian rookeries', *Wildlife Research*, 19, 347-358.

Limpus, C. J. & Nicholls, N. 1988, 'The southern oscillation regulates the annual numbers of green turtles (*Chelonia mydas*) breeding around northern Australia', *Australian Journal of Wildlife Research*, 15, 157-61.

Limpus, C. J., Parmenter, C. J., Baker, V. & Fleay, A. 1983, 'The flatback turtle, *Chelonia depressa*, in Queensland: post-nesting migration and feeding ground distribution', *Australian Wildlife Research*, 19, 557-561.

Limpus, C. J. & Reed, P. C. 1985, 'Green turtles stranded by Cyclone Kathy on the south-western coast of the Gulf of Carpentaria', *Australian Wildlife Research*, 12, 523-533.

Limpus, C. J. & Reimer, D. 1994, 'The loggerhead turtle, *Caretta caretta*, in Queensland: a population in decline', pp 39-59, in *Proceedings of the Australian Marine Turtle Conservation Workshop*, compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Limpus, C. J. & Walter, D. G. 1980, 'The growth of immature green turtle (*Chelonia mydas*) under natural conditions' *Herpetologica* 36, 162-165.

Lohmann, K. J. & Lohmann, C. M. F. 1998, 'Migratory guidance mechanisms in marine turtles', *Journal of Avian Biology*, 29, 585-596.

Lucas, P. H. C., Webb, T., Valentine, P. S. & Marsh, H. 1997, *The Outstanding Universal Value of the Great Barrier Reef World Heritage Area*, Great Barrier Reef Marine Park Authority, Townsville.

Lutcavage, M. E. & Lutz, P. L. 1997, 'Diving Physiology', pp277-296, in *The Biology of Sea Turtles*, eds P.L. Lutz and J. A. Musick, CRC Press, Boca Raton, Florida.

Lutcavage, M. E., Plotkin, P., Witherington, B. & Lutz, P. L. 1997, 'Human Impacts on Sea Turtle Survival', pp 387-409, in *The Biology of Sea Turtles*, eds P.L. Lutz and J. A. Musick, CRC Press, Boca Raton, Florida.

Mack, D., Duplaix, N. & Wells, S. 1995, 'Sea turtles, animal of divisible parts: international trade in sea turtle products', pp 545-562, in *Biology and Conservation of Sea Turtles Revised Edition*, ed K. A. Bjorndal, Smithsonian Institution Press, Washington DC.

Malcolm, H, Fontes, T. & Ashworth, T. 1999, 'An example of an ongoing refuse and illegal fishing problem at a popular anchorage in the Great Barrier Reef Marine Park', *Reef Research*, 3-5.

Mann, T. M. 1977, 'Impact of developed coastline on nesting and hatchling sea turtles in southeastern Florida', *Florida Marine Research Publications*, 33, 53-54.

Meylan, A. B., Bowen, B. W., and Avise, J. A. 1990, 'A genetic test of natal homing versus social facilitation models for green turtle migration', *Science*, 248, 724-727.

Miller, J. D. 1994, 'The hawksbill turtle, *Eretmochelys imbricata*: a perspective on the species', pp 25-38, in *Proceedings of the Australian Marine Turtle Conservation Workshop*, compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Miller, J. D., Daly, T., Card, M. A. & Ludecke, J. 1995, 'Status of hawksbill turtles and other fauna and flora on northern Great Barrier Reef and central Torres Strait islands 1991', Queensland Department of Environment and Heritage and Greenpeace Australia Ltd, Townsville.

Miller, J. D., Dobbs, K. A., Limpus, C. J., Mattocks, N. & Landry, A. M., Jr. 1998, 'Long-distance migrations by the hawksbill turtle, *Eretmochelys imbricata*, from north-eastern Australia', *Wildlife Research*, 25, 89-95.

Miller, J. D. & Limpus, C. J. 1983, 'A method for reducing movement-induced mortality in turtle eggs', *Marine Turtle Newsletter*, 25, 10-11.

Minerals Management Service *Gulf of Mexico OCS Region 1997, Gulf of Mexico OCS Oil and Gas Lease Sales 171, 174, 177 and 180, Western Planning Area, Draft Environmental Impact Statement*, U.S. Department of the Interior, New Orleans.

Moein-Bartol, S., Musick, J. A. & Lenhardt, M. L. 1999, 'Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*)' *Copeia*, 836-940.

Monroe, R. & Limpus, C. J. 1979, 'Barnacles on turtles in Queensland waters with descriptions of three new species', *Memoirs of the Queensland Museum* 19, 197-223.

Moritz, C., Broderick, D., Fitzsimmons, N., Lavery, S. & Johanson, H. 1998, *Genetic analysis of regional marine turtle populations*, Progress report to Environment Australia, Canberra.

Mrosovsky, N.,Lavin, C. & Godfrey, M. H. 1995, 'Thermal effects of condominiums on a turtle beach in Florida', *Biological Conservation*, 74, 151-156.

Mrosovsky, N. & Shettleworth, S. J. 1968, 'Wavelength preferences and brightness cues in the water finding behavior of sea turtles', *Behaviour*, 32, 211-257.

Mrosovsky, N. & Yntema, C. L. 1982, 'Temperature dependence of sexual differentiation in sea turtles: implications for conservation practices', pp59-66, in *Biology and Conservation of Sea Turtles Revised Edition*, ed K. A. Bjorndal, Smithsonian Institution Press, Washington DC.

National Research Council, 1990, *Decline of the Sea Turtles, Causes and Prevention*, National Academy Press, Washington DC.

Nishemura, W. & Nakahigashi, S. 1990, 'Incidental capture of sea turtles by Japanese research and training vessels: results of a questionnaire', *Marine Turtle Newsletter*, 51,1-4.

Owens, D. W. 1980, 'The comparative reproductive physiology of sea turtles', *American Zoologist*, 20, 549-63.

Parmenter, C. J. 1980, 'Incubation of the eggs of the green sea turtle, *Chelonia mydas*, in Torres Strait, Australia: the effect of movement on hatchability', *Australian Wildlife Research*, 7, 487-491.

Parmenter, C. J. 1983, 'Reproductive migration in the hawksbill turtle (*Eretmochelys imbricata*)', *Copeia*, 1983, 271-273.

Parmenter, C. J. 1993, 'Australian sea turtle research, conservation and management: a 1993 status review', *Herpetology in Australia*, 213-325.

Parmenter, C. J. 1994, 'Species review: the flatback turtle – Natator depressus', pp 60-62, in *Proceedings of the Australian Marine Turtle Conservation Workshop*, compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Pilcher, N. J. 1999, 'Cement dust pollution as a cause of sea turtle hatchling mortality at Ras Baridi, Saudi Arabia', *Marine Pollution Bulletin*, 38, 966-969.

Poiner, I. & Harris, A. 1994, 'The incidental capture and mortality of sea turtles in Australia's northern prawn fishery', pp127-135, in *Proceedings of the Australian Marine Turtle Conservation Workshop*, compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Ponte, F., Marsh, H. & Jackson, R. 1994, 'Indigenous hunting rights, Ecological sustainability and the reconciliation process in Queensland', *Search*, 25, 258-261.

Popper, A.N., Ketten, D., Dooling, R., Price, J.R., Brill, R., Erbe, C., Schusterman, R. & Ridgway, S. 1998, 'Effects of anthropogenic sounds on the hearing of marine animals', in *Proceedings: Workshop on the Effects of Anthropogenic Noise in the Marine Environment, 10–12 February 1998*, ed. R.C. Gisiner, Office of Naval Research, Arlington, Virginia, pp. 19–57.

Queensland Fisheries Management Authority, 1998, *Queensland Trawl Fishery. Proposed Management Arrangements (East Coast – Moreton Bay) 1998–2005*, Queensland Fisheries Management Authority, Fortitude Valley.

Queensland Fisheries Management Authority, 1999, *Queensland Blue Swimmer Crab Fishery, Discussion Paper No 8*, Queensland Fisheries Management Authority, Fortitude Valley.

Reichart, H. A. 1995, 'Farming and ranching as a strategy for sea turtle conservation', pp 465-471, in *Biology and Conservation of Sea Turtles Revised Edition*, ed K. A. Bjorndal, Smithsonian Institution Press, Washington DC.

Richardson, W.J. 1995, 'Documented disturbance reactions', pp 241-324, in *Marine Mammals and Noise*, ed W. J. Richardson, C. R. Greene Jr., C. I. Malme & D. H. Thomson, Academic Press, San Diego.

Ridgeway, S. H. E., Wever, E. G., McCornick, J. G., Palin, J. & Anderson, J. H. 1969, 'Hearing in the giant sea turtle, *Chelonia mydas', Proceedings of the National Academy of Sciences*, 64, 884-890.

Robins, J.B. 1995, 'Estimated catch and mortality of sea turtles from the East Coast Otter Trawl Fishery of Queensland, Australia', *Biological Conservation*, 74, 157-167.

Robins, J. B. & McGilvray, J. G. 1999, 'The AusTED II, an improved trawl efficiency device 2, Commercial performance', *Fisheries Research*, 40, 29-41.

Ross, J. P. 1999, 'Ranching and captive breeding sea turtles: evaluation as a conservation strategy', pp 197-201, in *Research and Management Techniques for the Conservation of Sea Turtles*, eds K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly, IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Ruckdeschel, C. A. & Shoop, R. 1998, 'Trauma to stranded sea turtle before and during required TED use', pp. 122-123, in *Proceedings of the Sixteenth Annual Symposium on Sea Turtle Biology and Conservation*, compilers R. Byles & Y. Fernandez, NOAA Technical Memorandum NMFS-SEFC-412, National Technical Information Service, Springfield, Virginia.

Sato, F. & Madriasau, B. B. 1991, 'Preliminary report on natural reproduction of hawksbill sea turtles in Palau', *Marine Turtle Newsletter*, 74, 5-7.

Seabrook, W. 1994, 'Feral cat predation on hatchling green turtles', p. 191, in *Proceedings of the Australian Marine Turtle Conservation Workshop*, compiler R. James, Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra.

Slater, J., Limpus, C. J., Robins, J., Pantus, F. & Chaloupka, M. 1998, *Risk Assessment of Sea Turtle Capture in the Queensland East Coast Otter Trawl Fishery, Final report prepared for TRAWLMAC*, Queensland Parks and Wildlife Service, Brisbane.

Spotila, J. R., Reina, R. D., Steyermark, A. C., Plotkin, P. T. & Paladino, F. V. 2000, 'Pacific leatherback turtles face extinction', *Nature*, 405, 529-530.

Spring, C. S. 1999, 'Satellite telemetry and green turtles', *Reef Research*, March, 6-7.

Stancyk, S. E. 1982, 'Non-human predators of sea turtles and their control', pp 139-152, in *Biology and Conservation of Sea Turtles*, ed K. A. Bjorndal, Smithsonian Institution Press, Washington DC.

Tambiah, C. R. 1991, 'Integrating tourists, local communities and sea turtles: facilitating sustainable programs', pp345-356, in *Ecotourism and Resource Conservation, A collection of papers Volume 1*, J. A. Kusler compiler, Ecotourism and Resource Conservation Project, Miami, Florida.

Tanzer, J. & Russell, M. 1999, 'Fisheries Management in the Great Barrier Reef Marine Park', pp 17-22, in *Asia-Pacific Fishing '99 Papers*, 17-22.

Tisdell, C. 1986, 'Conflicts about living marine resources in southeast Asian and Australian waters: turtles and dugong as cases', *Marine Resource Economics*, 3, 89-109.

Tisdell, C. and Wilson, C. 2000, *Economic, educational and conservation benefits of sea turtle based ecotourism: a study focussed on Mon Repos, Final Draft Report [29-09-2000]*, Department of Economics, The University of Queensland, Brisbane.

Tucker, A. D., FitzSimmons, N. N., & Limpus, C. J. 1996, 'Conservation implications of internesting habitat use by loggerhead turtles (*Caretta caretta*) in Woongara Marine Park, Queensland, Australia', *Pacific Conservation Biology*, 2, 157-166.

Walker, T. A. & Parmenter, C. J. 1990, 'Absence of a pelagic phase in the life cycle of the flatback turtle, *Natator depressa* (Garman), *Journal of Biogeography*, 17, 275-278.

Williams, P., Anninos, P. J., Plotkin, P. T. & Salvini, K. L. 1996, *Pelagic longline fishery-sea turtle interactions. Proceedings of an Industry, Academic and Government Experts, and Stakeholders Workshop held in Silver Spring, Maryland, 24-25 May 1994*, NOAA Technical Memorandum, NMFS-OPR-7, US Department of Commerce, Silver Spring, Maryland.

Williams, S. L. 1988, '*Thalassia testudinum* productivity and grazing by green turtles in a highly disturbed seagrass bed', *Marine Biology*, 98, 447-455.

Wilson, C. & Tisdell, C. 2000, *Sea turtles as a non-consumptive tourism resource especially in Australia' Economic Issues: No 11* Department of Economics, The University of Queensland, Brisbane.

Witherington, B. E. 1992, 'Behavioral responses of nesting sea turtle to artificial lighting', *Herpetologica*, 48, 31-39.

Witzell, W. N. 1983, *Synopsis of biological data on the hawksbill turtle, Eretmochelys imbricata (Linnaeus, 1766), FAO Fisheries Synopsis 137*, Food and Agriculture Organisation, Rome, Italy.

Wolke, R. E. & George, A. 1981, *Sea turtle necropsy manual*, NOAA Technical Memorandum NMFS-SEFC-24, National Technical Information Service, Springfield, Virginia.

Woody, J. B. 1990, 'Guest editorial: Is headstarting a reasonable conservation measure? 'on the surface, yes; in reality, no', *Marine Turtle Newsletter*, 55, 7-8.

Table 2. Life history parameters for marine turtles in the Great Barrier Reef World Heritage Area and eastern Queensland.

Parameter	Loggerhead	Green	Hawksbill	Flatback	Leatherback	Olive Ridley
Breeding season	late October to early March, peaks in December	late October to February	year round, conc. November to February, peaks in January	October to February	December & January	not known to breed in the GBRWHA
Years between breeding	3-4	2-8	2-5	1-5	not measured, 2-4 years in other breeding parts of the world	-
Hatchling emergence season	December through April	December to May	year round, conc. from February to April	December to April	February & March	-
Average hatching success (% of eggs in a clutch producing hatchlings to the beach surface)	80%	84%	79%	80%	low	-
Feral predators of eggs/hatchlings	Foxes, pigs	Foxes, pigs	Pigs	Foxes, pigs	Foxes	-
Foraging habitat	subtidal & intertidal coral & rocky reefs, seagrass meadows deeper soft-bottomed habitats of the continental shelf	subtidal & intertidal coral & rocky reefs, & seagrass meadows of the continental shelf	subtidal & intertidal coral & rocky reef, habitats of the the continental shelf	subtidal soft-bottomed habitats of the continental shelf	temperate waters, have been recorded as far south as Bass Strait & through the Gulf of Carpentaria to Arnhemland	continental shelf waters
Food / prey items	benthic gastropod & bivalve molluscs, crabs & echinoderms	seagrass, red algae, mangrove friut, & jellyfish	benthic invertebrates (sponges, soft corals, sea cucumbers)	benthic soft-bodied invertebrates (soft corals, sea-pens, holothurians), & jellyfish	macroplankton (jellyfish, salps)	molluscs, crabs, echinoderms & gastropods
Recoveries outside the Great Barrier Reef Marine Park of animals tagged while nesting or foraging in Queensland	Gulf of Carpentaria, Arnhemland, Torres Strait, & PNG	Gulf of Carpentaria, Arnhemland, Torres Strait, PNG, Indonesia Solomon Islands, Vanuatu & New Caledonia*	Indonesia, PNG, Solomon Islands, & Vanuatu	Indonesia (southern Irian Jaya)	No tags have been recovered	No tags have been recovered
References	Dodd, 1988, Limpus 1985, Limpus et al. 1992, Limpus et al. 1994a	Brand-Gardner et al. 1999, Forbes 1994, Garnett et al. 1985, Hirth 1997, Limpus 1995, Limpus et al. 1992, Limpus et al. 1994b, Limpus & Limpus 2000	Bell et al. 1997, Dobbs et al. 1999, Limpus and Miller 2000, Miller 1994, Miller et al. 1998, Parmenter 1983, Witzell 1983,	Limpus et al. 1983, Parmenter 1994	Limpus & McLachlan 1994, Limpus 1997	Harris 1994, Limpus pers. comm. in Harris 1994

PNG = Papua New Guinea

*Genetic studies of harvested animals indicate that the Solomon Islands harvest does not represent a substantial threat to the viability of the Australian breeding populations (i.e. they do not contain significant proportions of either GBR stocks). Genetic studies from turtles harvested in Bali indicate they come from four breeding populations, including the nGBR stock. Genetic studies from turtles harvested in Torres Strait and evidence from tag returns indicate they are primarily from the nGBR breeding stock. All tags returned from Queensland East Coast Indigenous communities (e.g. Hope Vale, Yarrabah, Palm Island Group) have been from green turtles tagged while nesting on sGBR rookeries. Tags returned from Indigenous communities harvesting sGBR green turtles in New Caledonia are approximately half of the number being returned from Indigenous hunters of the same stock in Queensland. This assumes that the number of tags not returned is equal between the two groups.

Table 3. Potential adverse impacts of human activities on marine turtles in the Great Barrier Reef World Heritage Area.

Human Activity	Marine Debris	Deliberate or Reckless Killing & Injuring	Disease	Explosions	Food Depletion	Harassment	Incidental Catch in Fishing Gear	Live Capture	Noise	Physical Displacement	Physical Habitat Degradation or Destruction	Pollution	Predation by Feral Animals	Vessel Strike
Boats, Ships & Other Vessels		•				•			•	•	•	•		•
Coastal & Land-based Actions	•	•	•		•	•				•	•	•	•	
Defence Activities	•			•	•				•	•	•	•		•
Feeding			•			•					•			•
Fishing, Shark Control Program, Aquaculture	•		•		•		•			•	•	•		•
Indigenous Hunting		•				•		•	•	•	•			•
Live Display, Headstarting, Ranching & Captive Breeding		•	•					•		•				•
Marine Construction	•	•		•	•	•			•	•	•	•		•
Filming & Photography		•				•				•	•			•
Research & Monitoring		•				•		•	•	•	•	•		•
Tourism & Recreation	•	•	•			•			•	•	•	•		•
Trade of Turtles & Turtle Products		•				•		•	•	•				•

APPENDIX 1

Management (M) and research (R) actions involving the Great Barrier Reef Marine Park Authority and criteria for their success.

Excerpted from the Draft *National Marine Turtle Recovery Plan* (Environment Australia 2000).

NB. Lead agencies are the environment management agencies in different Commonwealth/State and the Northern Territory jurisdictions. Only actions in which the Great Barrier Reef Marine Park Authority is involved have been listed. There are many other actions prescribed in the Draft *National Marine Turtle Recovery Plan* (Environment Australia 2000).

Prescribed Action	Manager	Criteria for Success
A.3.1. In consultation with lead agencies, the Department of Defence to: • ensure that all Environmental Impact Assessments and Environmental Management Plans developed for Defence activities recognise the importance of marine turtle conservation and minimise any possible effects on populations and habitats; (M) • cooperate with Lead agencies to develop management strategies for affected marine turtle stocks including the identification of opportunities to continue and/or establish research or monitoring sites on selected Defence estate. (M/R)	Department of Defence Lead agencies	Assessments and Plans recognise marine turtle conservation. Management strategies are developed.
A.4.1. Lead agencies to: • monitor the level of mortality of marine turtles due to entanglement in marine debris; and • identify the source of marine debris causing the mortality. (See also action C.1.3.) (R)	Lead agencies	The level of mortality is quantified and the source is identified.
A.4.3. Lead agencies to undertake remedial action to prevent/reduce marine turtle mortality in stranding events caused by marine debris. (M)	Lead agencies	Lead agencies wiil respond to debris events.
B.1.1. Lead agencies to support indigenous communities to develop management agreements that: • recognise customary law and the cultural significance of marine turtles; (M) • quantify existing harvest; (R) • identify and implement negotiated mechanisms that will ensure that customary harvest does not threaten the recovery of marine turtles; (M) • control marine turtle use within the communities' area; (M) • recognise the apparent drastic decline of l oggerhead turtles in Australia and implement a zero take where possible; (M) • identify the research requirements of indigenous communities regarding marine turtle conservation; (M) and • increase awareness of marine turtle conservation issues through information exchange. (M)	Aboriginal and Torres Strait Islander communities Lead agencies AFMA	Community management agreements are in place in each jurisdiction.
C.1.1. Lead agencies to cooperatively develop an agreed minimum set of key protocols for: • monitoring key nesting beaches; and • collecting mortality data from stranded marine turtles or other sources. (M)	Lead agencies	Protocols are developed, agreed and implemented nationally.

Prescribed Action	Manager	Criteria for Success
C.1.2. Lead agencies to monitor key nesting beaches for marine turtle stocks identified in Table 17 to develop population models in the longer term. (R)	Lead agencies	Complementary monitoring programs are established in each jurisdiction.
C.1.3. Lead agencies to: • monitor marine turtle mortality to determine the levels, distribution and causes of that mortality; and • conduct or support research on the prevalence and frequency of disease in potential risk areas. (R)	Lead agencies Lead fishing agencies	Lead agencies have established a marine turtle mortality database. Mortality data is collected through bycatch quantification programs and compulsory reporting requirements identified in accordance with fisheries management legislation. Prevalence and frequency of disease in wild marine turtles is identified.
C.2.2. Develop a population viability model for the withinsouthern Great Barrier Reef (GBR) green turtle stock that: • identifies the stock behaviours that give the model its predictive power; • determines the risk in applying the model to other stocks and species of marine turtle; and • determines the limits to the interpretation on the outputs from such a model. (R)	EA QPWS GBRMPA	Such a model is developed the second year of the plan
D.1.1. Identify nesting beaches affected by urban or industrial lighting. (R)	Lead agencies	Nesting beaches affected by lighting are identified.
D.1.2. Lead agencies to: • encourage local government to employ existing urban and industrial light management practices that do not adversely affect marine turtles, near affected nesting beaches; (M) • address lighting problems on affected beaches with local government responsible for their management; (M) • implement existing management practices such as zoning anchorage areas for boats; (M) • support research into suitable lighting technology for boats; (R) • support research into improved lighting technology and the impact of lights on loggerhead, hawksbill, green and flatback turtles. (R)	Lead agencies Local governments Transport/Boating authority	Suitable lighting technology is developed and employed.
D.2.1. Lead agencies to: • identify tour operators that currently access marine turtle nesting beaches; (M) • identify nesting beaches that have uncontrolled access; (R) • develop management arrangements for access and beach activities with other relevant local government authorities and landowners to ensure conservation of marine turtles; (M) • develop a nationally agreed code of conduct for tour operators with the Australian Eco-Tourism Association; and (M)	Lead agencies	Nesting beaches and tour operators are identified. Management arrangements for access and beach activities are developed. A code of conduct is developed and implemented with tourism industry representatives.

Prescribed Action	Manager	Criteria for Success
• implement these actions with particular reference to loggerhead turtles as a priority. (M)		
D.3.1. For significant nesting beaches, lead agencies to: • manage vehicle access to areas within their jurisdictions; and • negotiate the management of access with local government and other land managers. (M)	Lead agencies	Arrangements are developed to manage access to significant nesting beaches.
D.4.1. Lead agencies, in consultation with landowners, to identify sites where predation is a problem and initiate or continue appropriate management actions. (R & M)	Lead agencies	More than 70% of nests, for affected stock, produce hatchlings.
E.1.2. Each jurisdiction to identify the impact of development on marine turtles through administrative processes such as Environmental Impact Statements. (M)	Lead agencies	The impact of development is identified.
E.2.2. The Queensland East Coast Otter Trawl management plan to establish mechanisms to ensure that trawling is ecologically sustainable in the Great Barrier Reef World Heritage Area.(M)	QFMA GBRMPA	Trawling in the Great Barrier Reef Marine Park is conducted in an ecologically sustainable manner.
E.3.1. Lead agencies to respond to oil spills in accordance with the National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances. (M)	Lead agencies AMSA	Contingency plans are implemented in accordance with the national plan.
E.3.2. Lead agencies to provide advice on the impact of proposals for oil and mineral exploration and exploitation permit applications on marine turtles within their jurisdiction. (M)	Lead agencies	Advice provided as required in each jurisdiction.
E.3.3. Lead agencies to provide AMSA with information relating to significant nesting sites for marine turtles. (M)	Lead agencies	Information is provided to AMSA for distribution.
F.2.1. Lead agencies to encourage the participation and training of volunteers in agency monitoring programs. (M)	Lead agencies	Volunteers are trained and involved as practicable and needed in each jurisdiction.
F.2.4. AMSA and lead agencies to promote awareness of the effects of pollution on marine life compliance with laws restricting pollution from vessels.	AMSA Lead agencies	Material is developed and distributed to fishers and other boat operators.
F.3.1. EA and lead agencies to support the establishment of an indigenous coastal community network to support communities' management of marine turtles with lead agencies. (M)	EA Lead agencies	The network is established.