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