Review of current and historical research on the ecology of whale sharks (*Rhincodon typus*), and applications to conservation through management of the species

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by

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Executive Summary

The report reviews the current and historical research on whale shark ecology, relevant to the management of the whale shark tourism industry of the Ningaloo region. Essentially, the work undertaken at Ningaloo Marine Park (NMP) over the previous two decades represents an example of some of the most structured and successful of any region in the world.

The marine environment presents a challenging medium in which to undertake targeted research projects. As an example, although whale sharks have been known to man since 1828, this species has (until relatively recently), been sighted on few rare occasions throughout their extensive global range. Their evolutionary relationship to bottom-dwelling sharks, combined with their highly migratory nature, has resulted in few data becoming available for review when making specific decisions concerning management of the species.

The whale shark has been the focus of targeted fisheries at certain locations within their range. Over recent years the numbers of whale sharks in the wild appears to be in decline and several countries have implemented a ban on the hunting of this species. In 2000, the whale shark was afforded the global conservation status of 'vulnerable' and further protected in 2002 through restrictions on international trade via listing on the *Convention on International Trade in Endangered Species* (CITES).

At NMP, the large numbers of whale sharks continue to appear each year, usually between the months of April – June. At this time, there is a proliferation in food abundance, caused in part by a mass spawning of Ningaloo Reef corals. Although highly migratory (with a global distribution), the whale sharks feed extensively at NMP on a variety of prey (which includes tropical krill), providing the opportunity for a very successful whale shark ecotourism industry to develop.

In order for the whale shark ecotourism industry to remain sustainable, the Western Australian Department of Conservation and Land Management (CALM) must draw on all available research data and general information on this species to assist in the ongoing development and refinement of the 'best practice' management guidelines. To facilitate this, CALM in cooperation with industry, research organisations and conservation groups have supported and implemented broad research on the whale sharks within NMP.

In the absence of a complete set of data however, CALM continue to invoke a precautionary approach to management of the ecotourism industry revolving around the whale shark resource at NMP. This has established a maximum number of whale shark licences and an industry 'Code of Conduct' to minimise any impacts to the sharks resulting form ecotourism practices.

To assist managers to sustainably manage the resource, a set of indicators is employed. An indicator points to an issue or condition, its purpose to show (or indicate) how a system is working, and if there is a problem, an indicator assists in determining what direction to take to address the issue. Effective indicators are relevant, easy to understand, reliable and based on accessible data.

Although indices of sustainability for whale shark ecotourism are difficult to define because of the study difficulties presented by the nature of these highly migratory sharks within their marine environment, preliminary research on whale shark behaviours, especially under tourism pressure, has established preliminary indicators of disturbance (impacts), requiring further study. And in the absence of any project to define indicators at any other location worldwide, NMP provides a most appropriate location to undertake a dedicated study program to refine current indicators and also expand the type of indicators available to assist the future sustainable management of whale sharks there. In addition, it is possible to review similar studies undertaken on other large marine animals (e.g. whales) and use previously tested methodologies to identify suitable sustainability indicators (even though different species are involved).

Any amount of tourism use results in some impact, and tourism communities and managers must determine level of acceptability and subsequent management of these tourism impacts. Impacts maybe monitored through indicators and then used to help ascertain carrying capacity of the resource. As a direct extension of this process, cost effective monitoring of indicators in the whale shark ecotourism industry must be implemented as a priority.

At NMP, the habits of the whale sharks and the nature of the associated industry presents challenges to data gathering and monitoring. However, by drawing on results obtained during previous studies at NMP and utilising the continued support of stakeholders in the region, the implementation of new and developing methodologies will ensure appropriate information will be available to sustainably manage the sharks and associated industry for future generations.

Acknowledgements

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In particular, I must thank Rhiannon Bennett for her assistance and advice throughout the drafting of this report.

Research on the whale sharks at Ningaloo continues to provide important data to assist efforts for the conservation of this species, and is possible through the support of CALM and local whale shark ecotourism operators.

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1. Introduction

Whale sharks (*Rhincodon typus*) are the world's largest living fish (Last & Stevens, 1994; Norman, 1999). They are also rare and vulnerable to extinction (Norman, 2000). Although widely distributed throughout warm tropical waters, they are not regarded as common.

Ningaloo Marine Park (NMP), adjacent to the Gascoyne region in Western Australia is arguably the best location in the world to predictably locate whale sharks. Large numbers aggregate here each year (usually between March – July). Although only recently developed, the whale shark ecotourism industry at NMP has expanded significantly in recent years, and may have contributed in the vicinity of AUD $16 million to the economy of the region in 2002 (D. Davis pers. comm.; Norman, unpub. data).

As whale shark tourism continues to grow in popularity, there is a concurrent concern for sustainability, long-term management and ultimate protection of the whale shark resource (Colman, 1997). The ecotourism industry is a significant drawcard for the Gascoyne, with tourism regarded as the second largest industry (and the fastest growing) in this region, attracting more than 500 000 visitors spending in excess of AUD $150 million there (Gascoyne Economic Perspective, 2001).

The State Government (of Western Australia) has made a commitment to the development of a Western Australian strategy for sustainability. In this case, the State Government has adopted the following:
'*Sustainability is defined as meeting the needs of current and future generations through simultaneous environmental, social, and economic improvement'* (WA Department of the Premier and Cabinet, 2002).

The Western Australian Department of Conservation and Land Management (CALM) is the State Government department with responsibility to manage the natural environment of NMP and the human activities that are undertaken within. Ecologically Sustainable Development (ESD) is an important component of this management regime.

In addition, the National Strategy for Ecologically Sustainable Development (NSESD) (Environment Australia, 2002) commits CALM to the following three (3) core objectives:

- To enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- To provide for equity within and between generations; and
- To protect biological diversity and maintain essential ecological processes and life-support systems.

In order to ensure long-term sustainability, the relevant management agency identify suitable indicators to monitor the resource and all that interacts with it.

Indicators of sustainability for the whale shark and associated ecotourism industry at NMP would ideally be:

- Relevant to these NSESD objectives;
- Scientifically and statistically credible;
- Sensitive to change;
- Reliant on data which are already available in other contexts;
- Reasonably easy to understand.

Importantly, consistent review of data relevant to these indicators and subsequent actions to facilitate 'best practice' management will help ensure the future conservation of whale sharks and the sustainable development of the associated ecotourism industry in WA.

2. The Whale Shark *Rhincodon typus* (Smith, 1829)

2.1 Taxonomy

Class	Elasmobranchii
Order	Orectolobiformes
Family	Rhincodontidae
Species	Rhincodon typus

2.2 Scientific Synonyms

Rhiniodon typus Smith, 1828

2.3 Common Names

English	whale shark
Indian	Panai meen, Uravi, Pullian surrow, Pulli-udoombu, Makara sravu, Osman shira, Karaj, Bharait, Bahiri, Vori mas meer, Barrel
Pakistan	Mhor
Sri Lanka	Muni-muthu-mora
Philippines	Butanding, balilan, toki, tawiki, tuki-tuki
China	Jing Sha, tofu shark
Japan	Ebisuzame, Jinbei
France	Requin-baleine
Mexico	Tiburon ballena
Spain	Tiburon ballena, pez dama
Taiwan	Tofusa, tofu shark

3. Role of the species in its ecosystem

The role of the whale shark in its ecosystem is largely undefined because intensive research on this species has been restricted. However, as a large plankton feeder, it's role may be similar to that of the smaller baleen whales *i.e.* migrating extensively and feeding opportunistically. The species may time their movements to coincide with localised productivity events or changes in behaviour of prey (Wilson *et. al*,2001) and is recorded occasionally feeds on eggs released by spawning aggregations of reef fish (Heyman *et al*. 2001), coral spawn, tropical krill and mysids (Norman, 1999).

Whale sharks are known by traditional tuna fishermen to be associated with schools of tuna (Anderson & Ahmed, 1993; Silas, 1986; Waller, 1996) and have been used as natural 'fish aggregation devices' by tuna purse seiners in the Pacific and Caribbean (*e.g*. Stretta *et al*., 1996). Predators include the killer whale, *Orcinus orca* (O'Sullivan & Mitchell, 2000) and, for juveniles, blue marlin and blue shark (Norman, 1999).

The sharks are an important host for many species of fish, an din particular providing protection for juveniles (Norman, 1999). Whale sharks are known to be a host for a new species of commensal copepod *Pandarus rhincodonicus* (Norman *et. al*, 2000). Ningaloo Marine Park has provided researcher Denyse Newbound with the opportunity to undertake a study to determine the potential to use this species of copepod as a biological tag to monitor whale shark movements (Newbound, 2002).

4. Threats

Sharks in general are more vulnerable to exploitation than most other fishes, because of their longevity, delayed maturation and relatively low fecundity (Camhi *et al.*, 1998). Available evidence suggests that whale shark populations are, like those of other large sharks, very vulnerable to targeted fisheries (perhaps even more so, because they have so very few natural predators) (Compagno, 1984; Trono, 1996). Populations rapidly decline due to unregulated over-exploitation and, as described for other depleted shark populations, may remain low for many decades into the future (Holden, 1974; Natanson & Cailliet, 1986). The main threat to whale shark populations is, therefore, from fishing operations – targeted and incidental or as by-catch in other fisheries. Other threats are vessel collisions and, potentially, harassment by unregulated shark watching or diving operations (Norman, 1999).

Collisions appear to be a relatively frequent occurrence (*e.g*. Budker, 1971) – missing sections of fin and large areas of scarring are often observed on the head and dorsal surfaces, although scarring heals very rapidly (Taylor, 1994; Norman, 1999).

5. Conservation status

The whale shark is protected in the waters of very few of the approximately 100 countries where this species is known to visit. At several locations, illegal, unregulated and/or unreported fishing for whale sharks is apparent (M. Levine pers. comm.). The effort is expanding, with the number of whale sharks caught (relative to effort) appearing to decline (Chen *et. al*, in press).

5.1 Individual Range States

Australia: The whale sharks are identified as both a migratory species and recently as a threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. Protected under the *Great Barrier Reef Marine Park Act* in those Queensland waters where it is known to occur, and although not seen in Tasmania, the species is under the Tasmanian *Fisheries Regulations* 1996. In Western Australian waters, the whale shark is fully protected under the *Wildlife Conservation Act 1996* and the *Fish Resources Management Act 1994*.

Belize: Gladden Spit, on the Belize Barrier Reef (the feeding ground for whale sharks in spring) was declared a marine reserve on 18 May 2000, Decree No.68 of 2000. Whale shark tour regulations have been drafted and tour guides trained in these regulations, even though they have not yet been gazetted.

Honduras: A government decree (Presidential Decree No. 321-900) conferred full protection on the whale shark on 28 October 1999.

India: Following concern over the unregulated and likely unsustainable nature of the Indian whale shark fishery, the Indian Central Government's Ministry of Environment and Forests granted full legal protection to whale sharks in Indian territorial waters by adding the species to Schedule I of the Wildlife (Protection) Act, 1972, under sub section (1) of section 61, on 28t May 2001.

Indonesia: The whale shark is not currently protected in Indonesian waters.

Maldives: Whale sharks have been fully protected in the Maldives since 1995 (Environment Law 4/93) in view of the declining population (attributed to the local fishery), important function in aggregating tuna schools, high value for ecotourism and the comparative low value of its fishery products.

Mexico: There is a whale shark sanctuary under consideration for Bahia Los Angeles, Gulf of California. Whale sharks were listed in the NOM-029-PESC-2000. Which is a Law in Mexico of "Responsible Shark Fishery and alike species". It states that whale shark fishery is prohibited (N. Rodriguez Dowdell, pers. comm.).

Philippines: Fully protected since 1998 under Department of Agriculture Fishery Administrative Order No. 193, which prohibited "the taking or catching, selling, purchasing and possession, transporting and exporting of whale sharks and manta rays". (As noted above, some illegal exploitation and export has continued and there are difficulties with enforcement along the islands' extremely long coastline.)

South Africa: Full legal protection under consideration. Permits required (from Department of Marine and Coastal Management) for ecotourism or scientific interactions with whale sharks.

Taiwan: Common Commodity Codes assigned for seven whale shark products in order to monitor international trade in the Customs database. Taiwan can now apply Article 11 of the *Foreign Trade Law* to regulate imports and exports, as a result of the whale shark listing on CITES Appendix II (Chen, pers. comm.).

Thailand: Protected through a fishery ban under Section 32 (7) of the *Fishing Act* B.E. 2490 on 28 March 2000.

USA: Fully protected in Florida State waters (out to the three mile limit on the east coast, and nine miles on the Gulf coast) and in Atlantic and Gulf of Mexico federal waters (3-200 miles) under the US Fishery Management Plan, which prohibits directed commercial fishing and landing or sale. This prohibition recognises the biological vulnerability (limited reproductive potential and slow surface movements) of the species and was enacted in order to prevent targeted fisheries from developing.

International

The whale shark is listed on the Bonn Convention for the Conservation of Migratory Species (CMS). This identifies the whale shark as a species whose conservation status would benefit from the implementation of international cooperative agreements.

This species is also included in the United Nations Convention on the Law of the Sea (UNCLOS) Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks as a highly migratory species, recognising that co-ordinated management and assessment of shared migratory populations would promote an understanding of the cumulative impacts of fishing effort on the status of shared populations. However, to date, no such initiatives are known to be underway.

The whale shark was listed on *the Convention on the International Trade in Endangered Species* (CITES) Appendix II at the 12th Conference of Parties meeting (Santiago, Chile November 2002) (http://www.cites.org/eng/news/press_release.shtml). The whale shark meets the criteria for listing in that 'it is known, inferred or projected that harvesting of specimens from the wild for international trade has, or may have, a detrimental impact on the species by exceeding, over an extended period, the level that can be continued in perpetuity'. This listing will enable closer monitoring and restriction in trade of whale shark products to assist with conservation of this species on a global scale.

6. Whale shark ecology

6.1 Distribution

Whale sharks have a broad distribution in tropical and warm temperate seas, usually between latitudes 30^0N and 35^0S. They are known to inhabit both deep and shallow coastal waters and the lagoons of coral atolls and reefs. Australia is one of the most reliable locations to find whale sharks, with large numbers sighted each year at Ningaloo Marine Park (NMP) in Western Australia. Regular sightings have also been recorded from many other regions including India, the Maldives, Taiwan, Seychelles, Honduras, South Africa, Kenya, Belize, Mexico, the Galapagos Islands, Chile, Thailand, the Philippines, northern Borneo, Malaysia, Mauritius and Indonesia (see Norman, 2000)

This species is thought to prefer surface sea-water temperatures between 21 - 25^0C (Compagno, 1984). Sightings at NMP, however, are most common in water temperatures around 27^0C (Norman, 1999). The sharks (regularly) appear at locations where seasonal food 'pulses' are known to occur. The predictable annual whale shark aggregation at NMP is closely linked with an increase in productivity of the region (see Section 6.2).

The species is certainly highly migratory, with satellite tracking of individuals demonstrating long-distance and long-term migrations. One shark, tagged at NMP in 2002, was tracked over a period of ~ 48 days on a journey covering more than 2000km toward Asia (near Christmas Island) away from the northwest Western Australian coastline (see Appendix 1). A second shark was tracked for approximately 1800km towards Indonesia (near Sumba) over a 35 day period (see Appendix 2). [http://www.aims.gov.au/pages/research/boeg2002/boeg-03-1-cruise%20objectives-leg-two.html]

Other researchers have tracked sharks for varying distances including a 550km journey completed within a few weeks off Belize (Graham & Roberts in prep). A shark was recently recorded migrating a distance of approximately 5000km from the Seychelles to a location near Thailand (D. Rowat pers. comm.). Another shark

undertook a 2000km migration from the Mindanao Sea in the inner Philippines to 280km south of Vietnam in a two month period (Eckert *et al*. in press), while another travelled 13000km from the Gulf of California, Mexico, to near Tonga over 37 months (Eckert & Stewart, 2001).

6.2 Habitat availability

Habitat availability is not considered to be a constraint for this species, unless associated with seasonal food concentrations (note: nursery and mating grounds have not been identified). Critical habitats presumably include coral reefs where whale shark aggregations are associated with synchronous spawning of corals in Western Australia (Taylor, 1994; Norman, 1999) and fishes near Belize (R. Graham pers. comm.). While preliminary observations by Norman (1999) recorded whale sharks feeding of tropical krill (*Pseudophausia latifrons*) at NMP, Wilson *et. al* (2001) indicates a circumstantial link between the seasonal occurrence of whale sharks off Ningaloo Reef, the occurrence of surface swarms of krill, and interannual variability in upwelling and subsequent pelagic predation. An expanded collaborative project between AIMS and CSIRO is currently being undertaken at this location to study these links (see http://aims.gov.au/pages/research/boeg2002-05-1-whale sharks.html).

Whale sharks are reported also to appear at Christmas Island following land crab spawning events (Norman, 1999), and in the Coral Sea at the time of myctophid spawning (J. Stevens pers. comm.). These sharks are also known to frequent shallow-water areas near estuaries and river mouths in northern Borneo and the Philippines (Alava *et al*., 1997, Alava *et al.*, in press; Alava & Kirit 1994), sometimes during seasonal shrimp blooms. The latter habitats are highly vulnerable to pollution, development and other human activities.

Whale sharks have also been observed from New Zealand waters, with most sightings during spring / summer. Sharks here were occasionally recorded feeding vertically on schools of anchovies (*Engraulis australis*) (Duffy, 2002).

Few seasonal whale shark habitats have been surveyed to assess extent, status and threats to their existence, nor the environmental factors that are important to this species. This is lacking and should be addressed as a priority.

6.3 Population status

The global status of the whale shark is assessed as *vulnerable* (A1b,d, A2d) in the *IUCN Red List of Threatened Animals* (Norman, 2000; http://www.redlist.org/). IUCN Criterion A, the basis for this assessment, refers to declining populations. *Sub-criterion 1* indicates that population reductions have been observed, estimated, inferred, or suspected in the past, based on *b)* an index of abundance appropriate for the taxon [in this case declining landings or catch per unit effort] and *d)* actual levels of exploitation. *Sub-criterion 2* indicates that a population decline is projected or suspected in the future, based on *d)* potential levels of exploitation (likely to occur if directed fisheries, driven at least in part by the demand for fins and meat in international trade, remain unmanaged, and as a result of by-catch). The *vulnerable* assessment indicates that the estimated and projected scale of this population reduction is between 50% and 20% of the population over a ten-year or three-

generation period, whichever is the longer. (In this case, the generation period for the whale shark is conservatively estimated as 24 years.)

The IUCN status report for the whale shark (Norman, 2000), the basis for the IUCN *Red List* assessment, states the following: *The life history of this relatively scarce but cosmopolitan tropical and warm temperate species is poorly understood, but it may be relatively fecund and certainly migrates extremely large distances. Catches have declined and populations have apparently been depleted in several countries by harpoon fisheries targeting localised concentrations of this huge, slow-moving and behaviourally vulnerable species. There is also incidental capture in other fisheries. Directed fisheries, high value in international trade, a K-selected life history, highly migratory nature, and low abundance make this species vulnerable to exploitation.*

There is no detailed study of whale shark life history; estimates of age at maturity range from 9 to over 20 or 30 years, generation time from 24 to over 60 years, and longevity from 60 to over 100 years (*e.g.* Wintner, in press). Even if the most conservative (lowest) estimates are taken, this is a very low-productivity, low-resilience species. The life history parameters calculated for the 20m long shark reported by Chen *et al*. (in press b) yields an estimate of 0.08/year intrinsic rate of population increase (r) using Fishbase (www.fishbase.org).

Gestation period and interval between births are both unknown; only one litter of about 300 small near-term pups of 48-58 cm TL which grew rapidly in captivity has been reported (Joung *et al*., 1996; Leu *et al*., 1997). Initial rapid growth of pups (Leu *et al*., 1997) would explain the scarcity of records of very small whale sharks, and it is likely that growth would slow rapidly at maturity (Pauly, in press). It is possible that the whale shark (~ 20m long and 34t in weight), as reported landed in Taiwan by Chen *et al*. (1997 and in press b), could be over 100 years old.

6.4 Population trends

There are several documented declines in seasonal catches by directed fisheries for the whale shark, with these declines having occurred in some areas over only a few years in relatively recent and short-lived intensive fisheries (see examples below for Philippines, Taiwan and India). Local populations have apparently declined drastically in some places, while fishing effort and price have greatly increased. Most of these fisheries are too recent and/or populations too poorly monitored to determine whether these declines would result in long-term (many decades) reductions in local populations even if closed. This may well be the case, by analogy with other large sharks, as a result of low productivity and rebound potential and a lack of migration into the area of unfished stocks from other sources.

It is not known to what degree fishing in one area affects population(s) in other areas, although the fact that at least some of the sharks migrate long distances (see Section 6.1) within ocean basins suggests that the effects may not be purely local. Thus a fishery in one location may affect numbers sighted in another area or even in a different region. There is increasing concern that unexplained declines in numbers sighted seasonally in apparently unfished areas such as Thailand and South Africa (where sighting numbers have declined by as much as 83% (A. Antoniou pers. comm.)) could be the result of fisheries impacting these populations elsewhere. The rapid collapse of localised fisheries for this widely distributed and apparently seasonally migratory species could be explained by the tendency for whale sharks to

be site-faithful and to return regularly to the same seasonal feeding locations. Despite their very wide-ranging nature, they are, therefore, effectively part of local stocks that are particularly vulnerable to depletion by fisheries activity.

6.5 Catch statistics

China: A type of fishing gear known as *Angshagou* (a spear to harpoon large sharks and set of hooks for lowering under the speared shark to bring it to the boat) was commonly used to capture large whale, basking and blue sharks in the 1960s. Two whale sharks were landed using this method in 1995, but fishermen reported that this and other large species are now seldom caught (Parry-Jones, 1996).

India: Small-scale harpoon fisheries traditionally existed in Pakistan and India for local utilization (Compagno in prep; Hanfee, 2001); the species was harpooned in order for oil to be extracted from the liver (Rao, 1986; Silas, 1986; Prater, 1941; Vivekanandan & Zala, 1994). Demand in Taiwan stimulated a huge increase in effort and landings in the Veraval (Gujarat, India) fishery in the 1990s (Hanfee, 2001), when the value of landed whale sharks increased steeply, particularly after whale shark meat began to be utilised in 1994. Prices were particularly high from 1997 onwards. Landings increased significantly in the late 1990s, with 279 whale sharks taken during the main January and May whale shark season in 1999. Despite continued high market demand and a possible increase in fishing activity the following year, the whale shark fishery appeared able to take only 160 whale sharks during the following season, January to May 2000. An additional 145 sharks were taken offshore (10-15km) in December 1999, well outside the normal seasonal fishery. There have also been other reliable reports of more than 1000 whale sharks killed per year in Indian coastal waters (M. Levine pers. comm.). The fishery closed in May 2001 when the Ministry of Environment and Forests legally protected the species in Indian territorial waters.

Maldives: Anderson and Ahmed (1993) note that fishermen were taking 20-30 whale sharks a year throughout the Maldives, using the liver oil to treat their boats. Local fishermen reported that numbers had declined significantly; a single atoll used to take 30 a year in the late 1970s/early 1980s. There has been no monitoring for possible population recovery since this fishery was closed in 1995.

Philippines: An artisanal subsistence harpoon or gaff fishery for whale sharks was initially pursued by a small number of former whaling villages in the Bohol Sea (Alava *et al*,.1997; Alava *et al.*, 1993; Barut & Zartiga, in press). Very small numbers of whale sharks were taken for subsistence and a small amount of local trade. A subsequent increase in demand for whale shark meat in Taiwan stimulated the development of a targeted fishery for the species. Alava *et al.* (in press) describe the fishery from 1990 to 1997, during which period some 450-799 sharks were taken, averaging between 56-100 sharks per site per year in four of the primary fishing sites. This fishery peaked in 1993 when about 180 sharks were landed, then declined at an average of 27% per year in the following years. The catch per boat (the closest equivalent to catch per unit effort) in two of the traditional whale shark fishing villages in the Bohol Sea also declined steeply: from 4.4 to 1.7 sharks per boat in Pamilacan Island, Baclayon of Bohol province, and from 10 to 3.8 sharks per boat in Guiwanon, Talisayan of Misamis Oriental province. New whale shark fisheries were opened up in five other provinces in Visayas and Mindanao in order to meet demand

for export to Taiwan, with catch averaging at 13 sharks per site in at least 11 sites in 1997. The Philippine government introduced legal protection for the species throughout Philippines waters in 1998 after poaching occurred in a locally proclaimed whale shark sanctuary and ecotourism site in Donsol, Sorsogon. This protection has been hampered by continued demand for whale shark meat for export, which has resulted in poaching to supply Taiwanese and Hong Kong markets. A significant decline in Donsol whale shark sighting rate, from 8 to 1-2 sharks per trip, was noted in 1998 and 1999, respectively (Groves, 1999).

South Africa: Whale sharks occur seasonally (October to March) on the east coast of South Africa, mainly during the summer months (Bass *et al*., 1975). Numbers of reported strandings (declining according to Beckley *et al*., 1997) provide an indicator of abundance. More detailed information is available from aerial surveys undertaken by the Shark Research Institute from 1993-1998. This documented a significant decline in numbers of whale sharks sighted per hour, as follows: 1993/94: 7.26/hour; 1994/95: 1.58/hour; 1995/96: 0.96/hour; 1996/97: 0.97/hour; 1997/98: 1.62/hour (Gifford in prep.). Off the Kwa Zulu coast, there has been an 83% decline recorded (A. Antoniou pers. comm.).

Taiwan: Demand for 'Tofu shark' has increased significantly in Taiwan (Province of China) during the past two decades. Chen *et al* (1996) report that a whale shark meat wholesaler estimated in 1995 that about 250 whale sharks were landed annually in Taiwan, close to their own estimate of 272 (158 as bycatch in set nets, 114 by harpoon). Concern was expressed, however, that landings were declining. Joung *et al*. (1996) previously noted anecdotal reports that captures south of Penghu (off the west coast) had declined significantly during the 1980s. Billfish harpoon fishermen from Hengchun Harbour fishing south of Penghu had reportedly landed some 50-60 whale sharks each spring in the mid-1980s, but landings had declined over the next decade until only about ten sharks were caught annually. Fewer than ten were caught in this area in 1994 and 1995. The most recent survey of the whole Taiwanese fishery (Joung pers. comm.), aided by the introduction of a government whale shark harvest reporting system, identified total catches of just 89 whale sharks throughout 2001 (38 by set nets, 36 in the billfish harpoon fishery and 15 by other methods). Chen (2002) reports that 94 whale sharks weighing about 104 t were caught in Taiwan during the 12 months from March 2001 to March 2002. It appears that the catch has declined by 60-70% in the seven years since surveyed by Chen *et al*. (1996), despite increased market demand.

Thailand: Whale shark sighting numbers have also declined in Thailand, with seasonal sightings by one dive-boat operation decreased from 45-60/year to only two sightings in 1999 (Shark Research Institute, 1999). There is no evidence of whale shark fisheries in Thailand, but this migratory population could be depleted by fisheries elsewhere.

7. International concerns

7.1 Overview

It is clear (see Chapter 6) that the whale shark has been subjected to unsustainable fishing pressure in several parts of the world, including the Philippines, Taiwan, Maldives, and India. The data from these fisheries (see Section 6.5) indicate that

catches (in some cases expressed as per unit effort) have fallen significantly over relatively short periods. For example, catches at various sites in Taiwan are reported to have declined by 30-90% from 1960s to 1980s; 50-80% from the mid 1980s to 1990s; and around 70% during the four years from 1997 to 2001 (Chen, 2002). In the Philippines, catches declined at an average of 27% each year during the short-lived fishery in the mid 1990s (M. Alava, pers. comm.). Two years of seasonal fishery data from Gujarat in India (1999 and 2000) appeared to indicate a 40% decline in landings, although the time series of data is so short that these results are inconclusive.

There are apparent declines in numbers of seasonal sightings in areas without fisheries, which may be due to unsustainable fisheries affecting migratory populations elsewhere in their range.

7.2 United Nations Food and Agriculture Organization

The United Nations Food and Agriculture Organization (FAO) notes that large, long-lived, late-maturing species, with both high and low fecundity (particularly the latter), that are vulnerable to exploitation are at relatively high risk of extinction from exploitation (FAO, 2000).

Productivity, or ability to sustain exploitation, is the single most important consideration when assessing population status and vulnerability to fisheries. Generation time is a useful surrogate for productivity. The most vulnerable species are those with an intrinsic rate of population increase (r) of <0.14 and a generation time of >10 years (FAO 2001). Population status data presented in Section 6.3 above ($r = 0.08$, generation time = 24 to >60 years) indicate that this species falls into FAO's lowest productivity category.

7.3 International management

Other than unilateral protection in some countries noted previously, there is no international management of fisheries or populations. Management and monitoring of the whale shark and other species of sharks is theoretically required under the International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks), adopted by FAO in 1999. The objective of this FAO IPOA is to ensure the conservation and management of sharks and their long-term sustainable use. It notes that the current state of knowledge of sharks and shark fisheries practices causes problems in the conservation and management of sharks due to the lack of available catch, effort, landings and trade data. The IPOA requires States that adopt the Plan (it is voluntary) to identify and pay special attention, in particular, to vulnerable or threatened species, and to facilitate the identification and reporting of species-specific biological and trade data. Progress with implementation of this wholly voluntary IPOA has been extremely limited since its agreement, with very few countries adopting their own plans. This IPOA seems most unlikely to deliver regulation of whale shark fisheries or management or conservation of stocks in the foreseeable future.

7.4 Future directions

Importantly, further research will greatly assist with the management of global whale shark stocks. This must be progressed as a priority.

The successful outcome from the CITES Appendix II nomination, adopted in Chile (November 2002), provides a means to further monitor the status of the whale shark and the extent of the threats to its worldwide conservation.

8. Nature-based tourism: can it benefit whale shark conservation?

Whale shark ecotourism has the potential to provide substantial economic return (Norman, 1999; Newman *et al.*, in press) when compared to whale shark hunting (see e.g. Chen, 2002). Whale sharks continue to grow in importance for the ecotourism sector. However, it must be well regulated, otherwise this activity has the potential to disrupt feeding patterns and to drive whale sharks away from critical seasonal feeding grounds.

A pilot whale shark ecotourism project in the Seychelles was undertaken in 1996 to investigate the economic potential for whale shark ecotourism there. Newman *et al*. (in press) calculated that this industry could be worth US$ 3.95 to $4.99 million per annum to the Seychelles, derived from a short season of just 14 weeks a year. In addition, whale shark tourism, based on live-aboard dive boats, could be worth a minimum of US$3 million in the Phuket area of Thailand alone (Newman *et. al*, in press).

Whale shark ecotourism is actively promoted in the Philippines as a non-consumptive and sustainable alternative to whale shark hunting, using similar regulations to those established in Australia (Alava *et al*., in press; Yaptinchay, 2000; Yaptinchay *et al*. 1998; Yaptinchay & Alava, 2000). Whale shark interaction tourism in Donsol attracted over 1700 people for the 1998-1999 seasons alone, with estimated average revenue from tourist registration fees and boat rentals of about PhP 403138 (US$8063) per year (Groves, 1999; Alava, 2002). This does not include revenue from the transportation, food and housing sectors, which provides a significant contribution to the local and national economy. In addition, at least four other sites outside Donsol have initiated whale shark ecotourism activities in their municipalities (*e.g.* Talisayan in Mindanao, Leyte in Visayas, Pilar and Bacon in southern Luzon) (M. Alava, pers. comm.).

An important whale shark ecotourism industry has been established in the Gulf of California, Mexico, using spotter planes to direct boats to whale sharks. A small, newly established whale shark tourism industry in Belize netted at least US$165000 from boat tour fees in 2001, but is worth in the region of US$1.5 million if whole trip costs are included in the estimate (R. Graham pers. comm.). Honduras is presumably also benefiting from whale shark tourism, and there are likely to be significant economic benefits also for other Caribbean countries, east African states (including South Africa, Mozambique, Tanzania and Kenya), and several Red Sea and Indian Ocean range states where dive tourism occurs.

Importantly, as documented with whale watching (see Lien, 1999), whale shark watching can be an important educational experience for ecotourists. It can provide people with the opportunity to become more aware of the ocean environment and the global distribution and conservation concerns for the threatened whale shark. Indeed previous studies have indicated that 86% of whale watchers greatly increased their

support and commitment to the cause of whale conservation after seeing whales in the wild (Tilt, 1986).

8.1 Whale sharks at Ningaloo Marine Park

8.1.1 The economic importance to the region

Western Australia is internationally recognised as arguably the best place in the world to find and swim with whale sharks (Norman, 2001). The shark has become an excellent mascot species for the state. The predictable aggregation of whale sharks there has resulted in the establishment of a lucrative whale shark ecotourism industry in the state's north west (near the towns of Exmouth and Coral Bay). Recent figures indicate more than 5000 guests were involved in whale shark ecotourism at Ningaloo Marine Park in 2002 (CALM industry log book data). Using an estimated expenditure of AUD $3198 per person (calculated during an previous survey of paying ecotourists at NMP in 1995) (D. Davis pers. comm.), it is estimated that the whale shark ecotourism industry at NMP may introduce as much as AUD $16 million into the economy of the region in some seasons. While it is likely that this figure fluctuates between years, it is generally agreed that the communities of these isolated towns rely heavily on the support provided by these industries (D. Hall pers. comm.; D. Hunt pers. comm.).

Colman (1997) argues that the whale shark 'phenomenon' (*i.e.* the predictable aggregation) off Ningaloo Reef should be managed with a 'substantial application of the precautionary principle'.

To ensure longevity of the industry, economic stability for the local communities, and especially minimisation of any negative impacts on the species, sound management practices must be implemented and enforced as appropriate. Several state and national management strategies including the National Strategy for Ecologically Sustainable Development (Commonwealth of Australia, 1992), National Ecotourism Strategy (Commonwealth Department of Tourism, 1994), A Nature Based Tourism Strategy (Department of Conservation and Land Management, 1993) have outlined the need for detailed information on ecological resources, visitor profiles and visitor experiences to assist with managing natural resources in an ecologically sustainable manner (Birtles *et al.* 1996).

It is imperative to establish a well-planned research and monitoring program to gather a robust data set on these associated activities at NMP. The resultant information can then be analysed to assist 'best practice' management of the industry at NMP and achieve the goals of economic, social and ecological sustainability.

8.2 The Role of the Department of Conservation and Land Management

CALM is entrusted to conserve and manage wildlife, lands, waters and resources in Western Australia for the benefit of present and future generations. Importantly, in this capacity, CALM must ensure that human usage of natural attractions that come under the provisions of the *Wildlife Conservation Act* 1950 or *CALM Act* 1984 is managed for ecological sustainability.

With reference to whale shark interaction tours at NMP, CALM take responsibility for the management and protection of the resource. To this end, a limited number of 'whale shark interaction licences' have been granted each year since 1993 and industry and ecotour participants must obey strict interaction guidelines.

For licence holders (see *State Govt. WA, 1984*):

1. Only one vessel may operate at any one time within a radius of 250m (the 'contact zone') around a shark;
2. Only one vessel at a time may operate within the 'contact zone' for a maximum period of 90 minutes;
3. All other vessels must remain a minimum of 250-400m from the shark;
4. Vessel speed must not exceed 8 knots when in this 250m contact zone vessels must not approach closer than 30 metres to a shark;
5. Vessels should approach from ahead of the shark's direction of travel when dropping swimmers into the water;
6. Vessels must display both 'whale shark' and dive flags when swimmers are in the water.

For ecotourists swimming with whale sharks:

1. Swimmers must not attempt to touch or ride on a whale shark;
2. Swimmers must not restrict the normal movement or behaviour of the shark;
3. Swimmers must not approach closer than 3 metres from the head or body and 4 metres from the tail;
4. Flash photography is prohibited;
5. Motorised propulsion aids are prohibited;
6. A maximum of 20 swimmers may be carried by a licensed vessel;
7. No more than 10 swimmers must be in the water at any one time.

This 'Code of Conduct' – Commercial Whale Shark Interaction Tours (*Conservation and Land Management Act 1984 (Section 101) Conservation and Land Management Regulations 1992 (Part 5)*) (see State Govt. WA, 1984) was developed in consultation with CALM and the commercial whale shark licence holders. It has been in place since the inception of the regulated whale shark industry at Ningaloo (1993). A small, yet significantly important change to these regulations was implemented after the 1996 'season', specifically an increase in the distance from the sharks required by swimmers (from 1 to 3 metres). Tours also operate under the *Wildlife Conservation Act 1950* Wildlife Conservation (Close Season for Whale Sharks) Notice 1996.

8.3 Research and management in partnership

To increase our overall understanding of the whale sharks at NMP, especially their behaviour and the potential impacts resulting from ecotourism activities, CALM gave broad support to an intensive study undertaken by the author (Norman, 1999). Results from this research (initiated in 1994) were encouraging (see Norman, 1999) indicating that, in general, the industry participants were taking part in whale shark ecotours with the conservation of the sharks in mind, with ecotourists generally following management guidelines to minimise impacts on the sharks. Importantly, the study identified a list of suggested amendments to further minimise human-

induced impacts on the whale sharks at NMP and assist sustainability of the associated ecotourism industry.

Of great importance to our understanding and future management of whale sharks in the Asian / Australian region was the success of a joint research project at NMP 2002 to monitor whale shark migration patterns using satellite telemetry. The collaborating partners in this project were Woodside Energy, CALM, CSIRO, AIMS, the whale shark industry at Ningaloo and ECOCEAN. The major supporters of this project were Woodside Energy, AIMS CSIRO and CALM.

Prior to the 2002 study, there had been initial success in satellite-tracking a whale shark that moved 420km north from NMP in 1999, and mapping the short-term movements of whale sharks using acoustic tracking technology in 1997 (see Gunn *et al*, 1998). However, the work undertaken in 2002 has proven a long-term theory of migratory habit suggested by the author (see Norman. 1999) – that some whale sharks observed at NMP migrate away from Australia (where they are protected), towards Asia. Unfortunately, it is at certain locations within Asia that unregulated, unsustainable fishing practices continue for whale sharks (V. Wu, pers. comm.; M. Alava, pers. comm.).

The satellite-tagging project in 2002 produced excellent results, with two whale sharks successfully tagged. The first shark (code-named *Hope Traveller)* had moved offshore from NMP passing Christmas Island, travelling more than 2000km (see Appendix 1). The second shark (code-named *Mandu)* had moved in excess of 1700km to Indonesian waters (see Appendix 2). At the time of writing this report, the location of both sharks is unknown.

With the expansion of a program involving electronic tagging of sharks in waters of NMP, data collected will assist managers and scientists gather additional information to continue the work for whale shark conservation on a global scale.

9. Global initiatives to aid whale shark conservation

9.1 Study to assist 'best practice' whale shark ecotourism

Australia continues to be at the forefront of global whale shark conservation. A successful study program (Norman, 1999) undertaken by the author at Ningaloo since 1994, with the strong support of CALM and the ecotourism industry at NMP, has provided new and important scientific information to assist our understanding of this species. Importantly, the research and subsequent recommendations are available to CALM and industry at NMP to refine 'best practice' ecotourism management there.

Drawing on all available information collected in this study and other associated research, the author was commissioned by the World Conservation Union (IUCN) in 1997 to prepare a 'species report' to assess the global conservation status of the whale sharks. The subsequent report resulted in the conservation status being amended from 'Indeterminate – Data Deficient' to 'Vulnerable to Extinction' in the 2000 IUCN *Red List of Threatened Species* (Norman, 2000).

The predictably of sightings, and the proximity to shore of the whale shark aggregation at NMP, continues to provide an ideal location to undertake further conservation on this species. Concurrently, NMP provides an ideal location to test and refine management guidelines to ensure 'best practice' ecotourism. This information will be sought after by industry and management agencies at other international locations where whale shark ecotourism is underway or planned for the future.

9.2 Australia promotes whale shark conservation

In Australia, as the result of the nomination prepared and submitted by ECOCEAN in 2000, the whale shark was listed as a 'threatened' species on the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*, ensuring greater protection for the whale shark in all Commonwealth waters.

In 2001, Australia hosted the World Tourism Convention (http://www.worldtourismconvention.com/home.html). A key theme of the conference was focussed on the sustainable development of wildlife interaction. The author presented a paper entitled 'Whale Shark Ecotourism = Whale Shark Conservation' (Norman, 2001), with special reference to NMP, highlighting the benefits to the conservation of the species if well managed ecotourism is implemented.

Australia continues to be at the forefront of 'best practice' nature-based tourism (Norman, 2001). Indeed, with increased media attention focussed on NMP in recent times, especially Coral Bay and the pristine environment surrounding Ningaloo Reef, CALM and stakeholder's involved in whale shark ecotourism have an outstanding opportunity to continue to promote the benefits of ecotourism for conservation.

A major outcome from the tagging project undertaken by scientists from CSIRO, AIMS, ECOCEAN with the significant financial and logistic support provided by Woodside and CALM in 2002, was the successful tagging of whale sharks at Ningaloo Reef with acoustic and satellite tags (. This project extends the important work on satellite-tagging previously undertaken at NMP (see Taylor, 1994; Gunn *et. al*, 1999; Norman, 1999) and provides additional information to assist the global promotion of whale shark conservation. Some of these data were referenced by the author during discussions with international delegates at CITES (see www.cites.org) during the successful Appendix II listing.

9.3 Community involvement

The level of community awareness for the plight of the whale sharks is increasing each year through the campaigns of various conservation organisations (see www.amcs.org; www.ecocean.org; www.wildaid.org). CALM's work with industry and ecotourists (undertaken in Western Australia) by also extends these initiatives Environment Australia, through funding awarded to the AMCS from the Natural Heritage Trust and the Thyne Reid Education Trust, enabled the distribution of 15000 whale shark public awareness brochures throughout Australia (between 2000-2002) (see Appendix 3). Each ecotourist at NMP is also provided with a whale shark

'experience pass' from CALM with information on the whale sharks and the Ningaloo Reef.

The national and international ecotourist community at NMP continues to be provided with an opportunity to become closely involved with whale shark conservation via the collection of simple data and submission of identification photographs of whale sharks for inclusion in the ECOCEAN *Whale Shark Photo-identification Library*. In addition, a community-based 'Adopt-a-Shark' project provides an opportunity for the public to assist with future global conservation efforts (see www.ecocean.org). This increasing level of public interest / direct involvement in whale shark issues should continue to be actively promoted where possible.

10. Sustainability of whale sharks and associated ecotourism industry

10.1 Sustainable development in tourism

In recent times, particularly during the past decade, sustainable development on a global scale has become increasingly a priority for government. As testimony to this, a large gathering of world leaders was present in Johannesburg at the World Summit 2002 to discuss sustainability issues (http://www.johannesburgsummit.org/).

In line with the general conclusions of the summit, it is fair to say that it is the role of tour operators and management agencies to continue to research and then implement examples of 'best practice' ecotourism. In respect of NMP, implementation of this philosophy will help ensure both the long term conservation of whale sharks at NMP, and the long term economic benefit to stakeholders resulting from a sustainable industry. While the whale shark industry at NMP is internationally regarded to be at the forefront of well-managed ecotourism activities (Norman, 2001), there is a need to further test the management practices currently adopted (via a dedicated research and monitoring program) and refine where appropriate.

10.2 Socio-economic relevance of ensuring sustainable development

Diving and water-based activities represent the main attraction for tourists to the Ningaloo region (D. Hall, pers. comm.), with the whale shark ecotourism industry estimated to be worth approximately AUD $16 million to the economy (see Section 8.1.1). If the resource is not adequately protected, and a downturn in the industry results from inadequate and/or inappropriate management, there will likely be significant social and economic ramifications for the communities of Exmouth and Coral Bay. This could, in turn, have wider implications for the broader Western Australian tourism industry.

To ensure the future sustainability of the whale shark ecotourism industry, all available data must be reviewed prior to making management decisions. Subsequently, there should also be a study program implemented to assess the appropriateness of any management change to achieving the goal of ensuring sustainability.

CALM manage the whale shark ecotourism industry at NMP with this in mind, and continue to restrict the number of whale shark interaction licences granted each year until an estimate on the carrying capacity of the industry can be accurately determined. With continued (and appropriate monitoring) within a well-structured study regime, it should be possible in the future to make an informed decision on this carrying capacity, thereby ensuring economic growth combined with sustainability for the whale shark ecotourism industry at NMP.

10.3 Fluctuations in sighting numbers – is a function of tourism pressure?

10.3.1 Number of tourists

The challenge for the management agency (CALM) and indeed the ecotourism industry itself is to determine the carrying capacity of the attraction (the whale sharks) and the destination (*i.e.* NMP). In other words, how many tourists are too many?

The number of ecotourists undertaking whale shark tours has expanded considerably from its early development in 1989. Interest in whale shark ecotourism tours has fluctuated since this time, although showing an overall trend of increased numbers between 1993-2001 (Norman, 1999; Chapman, 2002). Early records indicate approximately 1000 tourists took part in 1993, expanding to an industry that was patronised by more than 3500 participants in 2001 (Colman, 1997; Chapman, 2002). The 2002 season was an excellent year for whale shark sighting numbers (industry logbook data), with ecotourists taking part in whale shark interaction tours until late July 2002.

10.3.2 Number of licences

There continues to be the need for effort to be controlled in to the whale shark ecotourism industry at Ningaloo Marine Park to ensure minimal impact on the whale shark resource. CALM had initially allocated 16 whale shark ecotourism interaction licences in 1993, with this number fluctuating down to a minimum of 13 since then (Colman, 1997; Chapman, 2002). A total of 14 licences were granted at Ningaloo for the 2002 whale shark 'season' (R. Mau, pers. comm.).

The question remains as to whether this number of licensed vessels undertaking whale shark tours at NMP is ecologically sustainable in the long term. In the absence of sufficient data to provide a definitive answer, it is important that the 'precautionary principle' continues to be invoked, with further monitoring undertaken as a priority.

In the 10 years that the whale shark ecotourism industry has been managed by CALM, participants in the industry have been fortunate to have had consistent access to whale sharks within NMP each 'season'. Inter- and intra-seasonal variations in the number of whale sharks sighted may be due to weather conditions (e.g. Cyclone Vance in 1999) and variations in food availability. Alternatively, these fluctuations may be related to hunting pressure in nearby Asian waters. However, with data limited at the present time, these hypotheses are as yet untested. The extensive environmental study currently being undertaken by CSIRO, AIMS and with the support of CALM (see Section 6.2), combined with the continuation of whale shark

conservation work being driven by ECOCEAN and AMCS, may soon provide important information to identify reasons for these whale shark sighting anomalies.

10.3.3 Number of sharks available for whale shark interactions

A key factor for sustainable management of whale shark/human interactions is a clear understanding of the population dynamics of whale sharks (Colman, 1997). Colman (1997) also states that until both intra- and inter-annual variability in abundance and distribution are known, it will be impossible to identify any long-term impacts. A dedicated research project should be undertaken to gather important data in this area. It will be important to employ expert staff to maximise the outcomes for management purposes. In addition, it is essential that the collection of data from industry representatives and the general public must continue beyond the short peak 'season' of whale shark sightings (*i.e.* throughout the entire calendar year), in order to fully understand the level in variability of whale shark abundance.

Some stakeholders have made observations (Norman, unpub. data) indicating that, on occasion, toward the end of the whale shark 'seasons' at NMP:

1. Whale sharks are more often found in increased numbers (*i.e.* with sharks sometimes seen swimming within close proximity of each other);
2. Sharks are often found feeding on 'bait balls' or aggregations of krill;
3. The number of tour vessels is reduced, theoretically reducing the likelihood of human-induced impact on the sharks;
4. The sharks sometimes appear slightly 'more relaxed' (and remain at the surface for longer periods at this time of the year).

It will be important to quantify these reports in future years.

10.4 Indicators of whale shark disturbance

The WA Department of CALM, as 'guardian' of wildlife within NMP, must ensure the well-being of the *threatened* whale sharks that visit the region. With continued monitoring of whale shark sighting numbers and behaviour, subsequent analysis should enable an assessment of the level of impact resulting from whale shark ecotourism activities. However, determining when whale sharks are disturbed can be difficult. Disturbance can show itself in behavioural and/or physiological changes and can be less obvious than initially anticipated.

In the early stages of development of the whale shark ecotourism industry at NMP, CALM identified the need to study whale shark behaviour and the impacts of tourism on the whale shark resource. In 1994, CALM supported the author in his completion of an intensive study of whale shark behaviour, resulting in the production of the Masters thesis entitled 'Aspects of the biology and the associated ecotourism industry of the whale shark (*Rhincodon typus*) in north-western Australia' (Norman, 1999). In addition, CALM have supported associated research on whale shark ecology undertaken by a further two PhD candidates (*i.e.* D. Newbound and S. Wilson).

It will be important to expand upon this initial time-series of data on whale shark disturbance indicators. This may, initially be implemented via a program to monitor

fluctuations in frequency of behavioural changes to the animals subjected to ecotourism pressure at NMP.

10.4.1 Short-term disturbance

In general, whale sharks visiting NMP waters move more slowly than vessels and so have limited options to avoid interaction when confronted by a vessel. The following reactions, when displayed by a shark during a whale shark / ecotour interaction, often indicate that a whale shark has been disturbed (Norman, 1999):

- An attempt by the shark to leave the area or proximity of a vessel;
- Regular changes in swimming direction and/or speed of a shark;
- Shark rapidly dives away from the surface;
- Banking behaviour (where the shark 'rolls' it's body to the side);
- The eye is rolled within the orbit for protection;
- Increased time spent diving (*i.e.* away from the surface) *cf*. where the shark remains at the surface.

Some of these changes could be viewed as adaptive responses to threats (e.g. removing the shark from danger of vessel or person collision). However, some of these short term changes may disrupt normal activities of the animals as Lien (2001) notes with whales, prevent completion of life processes and interfere with residential behaviour, movement and feeding.

Because many individual whale sharks exhibit fidelity between years to specific areas, and these areas receive greatest pressure from ecotour vessels because of proximity to mooring sites, whale shark watching may disproportionately impact a few individuals or groups of individuals (Gunn *et. al*, 1999; Norman, 1999).

10.4.2 Long-term disturbance

Even in whale watching - an industry that has been operating for considerably longer than whale shark ecotourism – studies of long term impacts are not available to date (Lien, 2001). And although the long-term consequences of whale shark ecotourism are yet to be fully understood, it is possible that these may be significant if not monitored and addressed appropriately. The potential effects may be minor in isolation, but may become significant in accumulation. The following represents some of the potential problems that may be caused by human disturbance:

- Displacement from important feeding areas;
- Disruption to feeding behaviour;
- Disruption of mating, reproductive and other social behaviours;
- Abandonment of preferred breeding sites;
- Changes to regular migratory pathways to avoid human interaction zones;
- Stress;
- Injury;
- Mortality.

Invoking the precautionary approach requires that the exploitation of any resource does not proceed faster than knowledge about the impact of exploitation (Lien, 2001). Therefore, in order to assess impacts of exploitation of the whale sharks at NMP, information collected via CALM's continuing research and monitoring program must be reviewed in conjunction with all available external data.

10.5 Assessment of impacts and potential responses

Following extended research undertaken by the author at NMP between 1994-1999 (Norman, 1999; Norman, unpub. data), suggested practices to reduce impacts on the whale shark resource include:

- Improved education of tour operators and tourists, prior to and within each 'season';
- Increase the minimum permitted distance between shark and ecotourists [Norman (1999) shows that although a minimum distance imposed within CALM guidelines was 3m, the average distance of swimmers was much closer. Touch was recorded on several occasions. With increased permitted distance, there is a reduced likelihood of accidental touch];
- Encourage industry to adopt the practice of dropping swimmers in the water from behind and to the side of the shark as the 'preferred' direction of approach;
- Impose an 'upper limit' on the total 'permitted' time that swimmers can swim with each shark. This may serve to reduce the opportunity for an individual shark to be the focus of ecotourists attention for the entire time it swims at the surface *i.e.* potentially many hours of interaction. [Data from Norman (1999) indicate that as the length of the interaction increases, so does the frequency of interactions within the permitted 3m 'no go' zone].

In a survey conducted Birtles *et al.* (1996), ecotourists indicated a preference for increased minimum person / shark distance and decreased number of swimmers in the water on each 'interaction'. Most survey participants (70%) indicated that there should be a maximum of six divers in the water with whale sharks at any single time (Birtles *et al.*, 1996). Importantly, within the constraints of visibility, ecotourists also indicated that the quality of the experience did not alter with increasing distance from the shark.

Although the suggested amendments to management guidelines identified by Norman (1999) have yet to be implemented by CALM and the majority of industry participants, one operator at NMP has voluntarily incorporated these suggestions with encouraging results (Norman, unpub. data.). Importantly, this was supported by data collected during field research at Coral Bay in 1999 (post Cyclone Vance) as part of a NHT-funded Coastwest / Coastcare project, showing sharks were less likely to move away from an interaction if approached from the side or behind (Norman, unpub. data).

Therefore, an appropriate study program must be implemented to facilitate an expansion of this preliminary work and ascertain the benefits to be gained from incorporating these suggested changes. Importantly, a well-structured program that incorporates a high level of industry support will enable there to be a relatively

smooth transition to the use and implementation of new 'improved' guidelines for whale shark / ecotourist interactions.

10.5.1 CALM response

A short-term approach that should be assessed to help minimise the potential negative impacts of tourism may include:

- Setting of an upper limit on the total number of persons allowed to undertake whale shark interactions in any 'season' and then allocate 'tourist quota' to each licensed operator;
- Pricing strategies, which involve raising the cost of each individual whale shark tour until the number of tourists wishing to take part in a tourism activity fall (although this is an approach that can raise concerns about equity);
- A type of 'lottery' system to allocate scarce places at the priority destination (e.g. splitting access rights to the 'best' commercial area);
- Time limits on the period that tourists are permitted to take part in whale shark ecotours (*i.e.* i) total number of minutes of each interaction, and ii) access to sharks limited to between the hours of 9:00am – 4:00pm) – allowing sharks to not be constantly subjected to tourist activity and have periods of likely feeding activity free from potential human disturbance;
- Construction of specific 'interaction zones' and 'management areas' that restricts industry participants to undertake interaction tours where the management agency can easily monitor all activities.

10.5.2 Industry response

The last point could provide an outstanding opportunity for industry participants to take a proactive approach to whale shark conservation management. It will in fact serve a dual purpose:

- Save on industry management costs usually recovered from levies paid by industry to CALM;
- Ensure there are 'no go' or 'refuge' areas for the whale sharks (where they will not be subject to any tourist interaction pressure).

Importantly, this 'zone' will provide a perfect location to undertake a localised 'control study' to determine if in fact this will have a benefit to the animals and the future sustainability of the whale shark ecotourism industry at Ningaloo. This should be undertaken in full consultation with all stakeholders (*i.e.* industry, CALM and independent researchers). It may be appropriate to initiate a pilot study for one 'season' and allocate set 'no go' periods within each day at NMP to successfully undertake this research. The results of this 'test' study could be analysed to ascertain whether of sufficient benefit to the industry as a whole.

This positive forward thinking will only increase Australia's reputation worldwide of implementing ecotourism 'best practice' co-management. It can be achieved without depriving the industry of the ability to remain financially viable. A well structured, yet simple program supported by the industry will also serve to engender a greater sense of stewardship within the local community in the natural environment at NMP. It can provide important information to assist CALM with sustainable management of the whale sharks and associated ecotourism industry.

When marketed appropriately, this form of co-management will be seen by the local and international ecotourism community as a positive example of how the industry has reacted to concerns for i) the welfare of the whale sharks at NMP, and ii) the long-term sustainability of the whale shark ecotourism industry there.

11. Indices of sustainability

11.1 Role of management

The WA Department of CALM has granted licenses to enable whale shark ecotourism industry to operate at NMP under CALM guidelines since 1993. The industry has been successfully managed for ecological and economic sustainability since that time. However, to ensure continued success in management, CALM must be assured that there is compliance to licensing regulations (by industry and tourists) and modify these where appropriate.

11.1.1 Choice of indices

A review of whale shark ecotourism at other international locations indicate that although management practices are (essentially) similar to those employed at NMP, indicators of disturbance have either not been defined and/or not tested (A. Antoniou pers. comm..; M. Alava pers. comm..; A. Aitken pers. comm..). There is also an absence of specific scientific studies to reasonably predict the long term impacts of human presence on cetaceans (Lien, 2001), an industry with an even greater period of development.

In the absence of these well-defined indicators, it is appropriate to draw on previous in depth studies undertaken at NMP (e.g. Norman, 1999). Through expansion and refinement of this research, it should be possible to monitor disturbance to the whale sharks and modify management practices to ensure sustainability.

Choosing the appropriate spatial and temporal scales for capture of data on indices of sustainability for the whale shark ecotourism industry are critical. Inappropriate choices will mean that monitoring data will fail to adequately reflect changes at scales that are meaningful for the management agency, and render indicator data of little value for management of whale shark ecotourism at NMP.

When developing indices of sustainability, choices of temporal scales will be largely unique for each indicator and should be established separately for each monitoring program – as various issues and elements targeted by these indicators of whale shark ecotourism sustainability will have different natural dynamics. A monitoring program to detect change will need to employ a temporal scale appropriate to the natural scales of change but, importantly, modified according to the management needs for information on rates of change. In particular, elements that change only slowly may need to be measured only infrequently in order to detect change. However, if a change in short time scales are of importance, then they may need to be measured frequently to address such changes.

It will be particularly important to create linkages between local and international ecotourism activities, with continued review of the data being collected in various locations around the world. This will enable an ongoing improvement of our understanding of the species under varying circumstances (e.g. whale shark behaviours under varying levels of industry 'pressure') and enable refinement of 'best practice' management of the whale shark resource. This aims to ensure the long-term sustainability of the associated ecotourism industry at NMP and the conservation of species.

11.1.2 Reporting

In addition to identifying appropriate scales and linkages, it is also imperative that processes to capture, maintain and report on the uncertainty within initial data gathering programs, and the uncertainties introduced by any aggregation processes imposed are identified. Since detection of change is so important, it is essential that any reporting is accompanied by estimates of uncertainty for the data and information reported.

Estimating the risk of falsely indicating no change when important change has in fact occurred – and of the converse, indicating change when in fact no important change has occurred – is critical to establishing and maintaining the credibility and broad acceptance of the whale shark ecotourism sustainability process. As such, it will be necessary to engage appropriately credentialed investigators, with a strong understanding of experimental biological survey design.

11.2 Key indicators to be used

1. Fluctuations in whale shark appearance numbers in the commercial whale shark watching area at NMP;

2. Increase in level of behavioural changes displayed by whale sharks at NMP during ecotourism interactions in particular dive frequency (NB: a control study will be required for comparison);

3. Decrease in time spent at the surface by whale sharks;

4. A reduction in the frequency of whale shark sightings in commercial 'high use' areas (collected during aerial surveys), to an increase in sighting numbers in locations less frequented by industry vessels.

11.3 Refinement of key indicators selected to monitor whale shark ecotourism sustainability

As noted in Section 11.1.1, the author has found no evidence suggesting management of whale shark ecotourism operations for sustainability are further advanced at any other international location than currently employed at NMP. Appropriate sustainability indicators have yet to be identified (A. Antoniou pers. comm.; M. Alava pers. comm.; A. Aitken pers. comm.; N. Rodriguez Dowdell pers. comm). In addition, the whale shark management guidelines employed in Mexico and the

Philippines are based largely on the guidelines used at NMP (M. Alava pers. comm.; N. Rodriguez Dowdell pers. comm.).

Therefore, to ensure that the most appropriate indicators are used in this process, the following steps should be explored as a matter of priority:

1. Refinement of indicators currently used in whale shark ecotourism at NMP;
2. Test appropriateness of using similar sustainability indicators employed when assessing other forms of marine wildlife based (non whale shark) ecotourism industries *i.e.* behavioural changes especially avoidance (see e.g. GBRMPA, 2000; Hale, 2002; Higginbottom, 2002);
3. Convene a workshop drawing together key stakeholders both from ecotourism industries worldwide and in Australia, scientists with experience in studying the animals in question, extensive consultations with colleagues from various state and national management agencies;
4. Continual review of the relevant scientific literature.

While CALM have an important, well-structured log-book monitoring program (supported by the local whale shark industry at NMP), additional fine-scale monitoring must continue within an extended research program at NMP. As further information becomes available, the current CALM logbooks should be refined / amended as appropriate (in full consultation with industry), with stakeholders informed of relevant recent information / findings. Stakeholders must also be provided with a clear explanation of the benefits of continued data collection. This consultation process would be most effective during 'stakeholder workshops' that are convened with, and attended by, researchers and management agency staff.

Importantly, as previously identified, a study of whale shark behaviour under natural (non-tourist) conditions at NMP must also be undertaken as a priority. This control study should include research to determine frequency of 'natural' behaviours (e.g. dive rate), collected using long-term data loggers (e.g. archival tags). The study of whale shark behaviour at other locations where ecotourism pressure is minimal (e.g. Christmas Island) should also be undertaken as a priority.

12. Cost effective whale shark population monitoring

There are a number of options for whale shark population monitoring. These include invasive and non-invasive, interactive and non-interactive techniques. All have respective merit, with the most cost-effective and least impacting identified below:

12.1 Visual identification fin/body tags

In 1992, Exmouth medical practitioner Dr J.G. Taylor conducted a non-electronic tagging program at NMP, with 25 sharks tagged using plastic identification tags. Although this preliminary work provided some evidence that whale sharks do retain the tags over a number of years (prior to expelling these from the skin), Taylor estimated a tag shedding percentage of 40-50% (Colman, 1997). However, from this and other more extensive marine tagging studies at other locations, much has been learned on the benefits of this form of research (A. Antoniou, pers. comm.). In order to ensure this method of monitoring can be successful, many sharks must be tagged and the 'tags' must be large and easily visible. If implemented at NMP, it will be

important to utilise photo-identification to provide a 'back-up' record of the sharks tagged, in the event that the implanted identification tags are shed. Ideally the identification tags should include the following information:

- *Identification number;*
- *Contact details of research group undertaking project;*
    - *Email address*
    - *Postal address*
    - *Phone number*
    - *Website address*
- Request to '*please contact (allocate website address) with these sighting details to help whale shark conservation'* (potentially translated to a foreign language in addition to English - to be determined).

The tags should be of sufficient size to enable researchers / ecotourists to note the information on each tag without the need to remove or manipulate the tag while swimming alongside the shark.

Although this will provide immediate recognition of specific, easily identifiable whale sharks, there will likely be some immediate concerns expressed by:

i. Conservationists – because of the invasive requirement to implant tags on all sharks (*i.e.* use of spearheads);
ii. Ecotourists / underwater photographers – because of the aesthetics of having a large plastic tag on each shark involved in this nature-based activity / undesirable compromise to the experience;
iii. Industry – the fear that if tags are applied to all sharks at NMP, this may result in an unacceptable level of pressure, such that the sharks may leave the area and become wary of further human interactions;
iv. Industry / conservationists – because of the need to swim within the 3-4m 'no go' zone around the shark to
    i. Implant the tag
    ii. Subsequently retrieve / record the tag information.

Similar projects have been successfully implemented by researchers at a number of international locations, including Seychelles, Honduras, Belize, La Paz, Galapagos Islands etc. (A. Antoniou, pers. comm.; D. Rowat, pers. comm.). However, there are limited data available on the rate at which these tags are retained.

Integral to the success of this program will be the appointment of appropriate supervisory staff *i.e.* coordinated by a researcher/s with an appropriate level of experience at applying tags to whale sharks. This high degree of expertise is required as the skin of the whale shark is thicker (and tougher) than any extant species (Norman, 1999), and if for example, a tag was deployed at an inappropriate angle, the tags and tagging apparatus will be likely to 'bounce' off the skin of the shark and potentially be lost. Failed attempts are likely to significantly increase the level of stress endured by each shark and negatively impact upon these individuals.

12.2 Expansion of ECOCEAN Whale Shark Photo-identification Library Ó

With approximately 100 sharks already identified accurately within this *Library*, there is excellent scope to continue utilisation of this facility to monitor whale shark numbers and rate of return to NMP in ensuing years – with little or no adverse impact

to the sharks. Accurate data collected for each animal on subsequent sighting occasions will significantly expand the level of basic understanding of whale shark biology, ecology and movement patterns. The *Library* also provides an opportunity for the general ecotourist public to become involved in this work and ultimately assist with whale shark conservation efforts via the submission of simple data / identification photographs. Importantly, this project will serve to engender a sense of 'stewardship' amongst industry participants for the protection and sustainable management of the whale shark resource at NMP. Summary updates of these data may assist CALM with the future management of whale sharks within state waters of NMP. These data may also provide useful information on the movements of whale sharks within Commonwealth waters (important as this shark is a 'listed migratory' and 'vulnerable' species under the *EPBC Act*).
An appropriate natural progression will be to link photographic sighting information collected at other international locations with the ECOCEAN *Library*, thus providing a unique opportunity to monitor whale shark numbers and movements on a global scale.

12.3 Industry monitoring using CALM Logbooks and independent check via researcher onboard vessels

The CALM whale shark logbooks, which are completed by ecotourism operators at NMP each 'season', provide an opportunity for industry to play an important role in the collection of vital baseline data on this species. Upon analysis, it may be possible to draw conclusions and act on these to then enable improved management of the whale shark ecotourism industry and whale shark population within NMP.

Although CALM has previously assessed the 'official' whale shark season as beginning on 1 April and ending 30 May (to facilitate calculation of fee charges for industry), it is important to acknowledge that many whale sharks are seen at NMP both before and after these 'arbitrary' dates. Data on whale shark numbers / ecotourism interactions (and habits displayed by these animals) must be accurately collected within the CALM / Industry monitoring program - outside this defined period. However, this need not result in an extension of the fee-paying period. It will simply serve to provide a far more comprehensive set of data to further understand fluctuations in whale shark numbers to assist future sustainable management of the industry at NMP.

In addition, to enable analysts to be confident in the accuracy of the data collected by industry operators and recorded in the CALM logbooks, an independent 'test' must be employed. This can be achieved through provision of a place on industry vessels (chosen randomly each day of the whale shark 'season') for an independent researcher to collect similar data. The data collected by this independent researcher can be cross-referenced at the end of the season with the data collected in the commercial logs to assess the level of accuracy. It will then be possible to allocate an 'error' to standardise all data collected prior to any future analysis. This will also enable a review of the appropriateness of using data collected by industry representatives to assist future sustainable management of the industry and the whale shark resource at NMP. This will then provide CALM with a very accurate and cost-effective means for monitoring.

NB. The researcher will also have an important opportunity to collect further baseline environmental, ecological and biological data on the whale sharks at NMP to improve our understanding of this species.

12.4 Aerial surveying (Industry)

Previously, dedicated aerial survey programs have been undertaken at NMP to monitor whale shark numbers with varying success (Colman, 1997; Norman, 1999). This has proven very cost-prohibitive, and many 'surveys' have resulted in zero whale shark sightings. As an alternative, a low-cost survey program utilising support from pilots employed by the whale shark industry to search for sharks at NMP could be undertaken. Pilots have the opportunity to assist with whale shark research for conservation by collecting data on shark distribution and numbers within NMP during daily surveys linked to ecotourism operations.

To facilitate this program, air charter staff working within NMP should be provided with portable 'hands free' recording instruments for documenting whale shark sighting numbers. It will be important to develop an appropriate experimental design (to be coordinated through discussions with ecologists and statisticians) to ensure robustness. Assistance from researchers with previous experience in monitoring populations of large marine animals will be important in this instance. The resultant data can then be collated into a CALM database and updated regularly by CALM volunteers. This can then be analysed for population modelling.

12.5 Aerial surveying (Independent)

Alternatively, an independent aerial survey regime would have the advantage of not being restricted (or 'tied') to industry operations / demand. Within this focussed study, daily surveys would be undertaken to search all waters of NMP for whale sharks. Using previous research undertaken at NMP as a guide (e.g. Taylor, 1994; Norman, 1999), the area of greatest whale shark sighting frequency is between Coral Bay and Vlamingh Head, and within approximately 5km seaward of the reef front. As this area includes the Commonwealth waters of NMP, it will be important to involve both CALM and Environment Australia in any survey design.

12.6 Global repository of whale shark sighting numbers (establishment of central sightings database)

The most appropriate organization/s to undertake this project would be those exhibiting strong links with whale shark conservation initiatives. CALM, ECOCEAN, AMCS, , Environment Australia and WWF-Traffic have demonstrated experience in the Australian / Asian region, although the latter concentrates on monitoring trade in whale shark products. A priority outcome from the proposed *International Whale Shark Conference / Workshop* would be to identify protocols for the development and subsequent management of this database. Within Western Australian waters, data collected under such a program for wildlife monitored under the *Wildlife Conservation Act* should be curated by CALM.

A community monitoring program to collect whale shark sighting data was previously initiated at NMP by ECOCEAN in 2000. An expansion of this program would provide an appropriate and cost-effective option to facilitate CALM's requirements for research and monitoring. With some refinement, it may be possible to include/link this with the CALM *Community Monitoring Manual* without the high cost of developing a 'new' program, with CALM the curator of these data.

12.7 Mean length of whale sharks - is it stable?

An important aspect to the whale shark monitoring project will be to analyse whether the mean size of individuals within the whale shark 'population' at NMP is changing over time. There may be evidence indicating that the sharks seen at NMP are 'getting smaller' – perhaps a function of the slow growth rate of individuals within this species. If international fisheries continue to target the larger sharks (Joung *et. al*, 1996; Hanfee, 2001) then the relative total length of the group of sharks returning to NMP may decrease. Independent monitoring of whale shark length at NMP between 1995-1997 by Norman (1999), with random measurement of a proportion of the individuals sighted to ensure accuracy of estimated lengths, indicated a mean length of 7.0, 7.2 and 6.7m respectively. However, between 1995 and 2001, Chapman (2002) noted that data collected within whale shark industry logs indicate a decrease in the mean size of all whale sharks from 7.0 - 5.8m, respectively.

It is important to continue the collection of data on mean total length of the whale sharks visiting NMP in subsequent years. This can be easily achieved via the following means:

- Stereophotography (where only one person is required *i.e.* designated researcher in the water with each shark);
- Measuring height of the 1st dorsal fin of each shark, and extrapolating total length of the individual whale sharks (used previously by Taylor (1994)). (However, this method requires a researcher to 'touch' the shark and at least two people *i.e.* one on camera and one holding pole, are required);
- Using an underwater tape measure, the total length of a whale shark can be measured. Two people are required to successfully undertake this activity;
- A designated industry representative may be employed to collect video footage to measure whale shark length. A second person would hold a measured pole, measuring tape, or position oneself to represent 'one person' length (~2m). This activity may be undertaken at the same time as collecting footage for photo-identification library shots.

13. The next steps

To assist in managing the whale shark industry for sustainability, CALM have, within the 'Code of Conduct' – Commercial Whale Shark Interaction Tours (*Conservation and Land Management Act 1984 (Section 101) Conservation and Land Management Regulations 1992 (Part 5)*), ensured a facility is available to research and monitor whale sharks and the associated ecotourism industry (Colman, 1997). Specifically, the following conditions must be met:

1. Each licence holder must cooperate with CALM in gathering and providing any data which may be required for research and monitoring purposes; and

2. Each licence holder is required to make available on request a position on their vessel for any officer designated under the *CALM Act* 1984 as amended to monitor licence activities.

This clause effectively enables a designated Research Officer to have appropriate access throughout the whale shark 'season' at NMP to undertake important research on this species.

In CALM's earlier published document 'Whale Shark Interaction Management – with particular reference to Ningaloo Marine Park 1997-2007' (Colman, 1997), recommendations for research and monitoring and current status include:

- **A long-term monitoring program to determine the inter-annual variability in the whale shark population at NMP**
  Status

While this monitoring has been partially undertaken via CALM's logbook program, the sample period (*i.e.* 1 April - 30 May) is inadequate and will not provide a suitable data set to make inter-annual comparisons. A more appropriate analysis of inter-annual variability may be possible if used in conjunction with data collected within the ECOCEAN *Whale Shark Photo-identification Library Ó* tagging initiative..

- **A suitable technique for monitoring resource size and tourism pressure**
  Status

Although not yet implemented, a tagging program in conjunction with the photo-identification library, combined with an expanded study on whale shark behaviour and rate of return is required. This will enable appropriate analysis of the effects of repeat interactions on activities / behaviour of individual sharks. This must be assessed as the potential effect of cumulative 'harassment' (*i.e.* that may result when only one or two sharks are available on a single day of whale shark ecotourism interactions), may prove significant.

- **Long-term monitoring of physical and biological parameters to examine possible links between environmental parameters and whale shark population fluctuations in NMP**
  Status

Few analysed data are available on the links between fluctuations in whale shark sighting numbers and various environmental parameters. There are some preliminary indications that adverse weather conditions may result in whale sharks spending reduced periods at the surface (Norman, unpub. data). However this is as yet untested and may simply be a function of reduced numbers of sharks in an area or reduced search effort. With the implementation of an expanded monitoring program (using analysed CALM logbooks and further aerial and other survey techniques), it will be possible to test these links.

- **Continuation of research to study behavioural patterns and movements of whale sharks within NMP and surrounding waters**
  Status

Outstanding results on the movements of whale sharks are now available from the Woodside Energy joint research project undertaken by CSIRO, AIMS and CALM with assistance from ECOCEAN and the whale shark ecotourism industry at NMP (see http://www.aims.gov.au/pages/research/boeg2002/boeg-03-1-

cruise%20objectives-leg-two.html). While there are plans to continue this satellite tracking work in ensuing years, it will be important to also expand upon the behavioural study previously undertaken by the author (see Norman, 1999). Initially it will be important to refine the set of behaviours then used to monitor impacts on the sharks. These behaviours must be monitored for trends that can be used to then assist with 'best practice' management of the industry (and the whale shark resource) for long-term sustainability. A specific Project Officer position will be required to undertake this work, with planning to include a study of whale shark behaviour under little or no human-induced ecotourism pressure (e.g. at Christmas Island or in a designated 'no go' zone for industry) [see Section 10.6.2].

- **Establishment of a central whale shark photo-identification database**
  Status

The ECOCEAN *Whale Shark Photo-identification Library* represents an example of a well researched and well structured database that can be updated regularly with submission of relevant information and identification photographs from Australia and overseas. With the establishment of the dedicated website (funded by a private trust), there is the opportunity for easy access to summary data worldwide. Importantly, the site continues to be administered by the not-for-profit group ECOCEAN.

- **Monitoring of experiential and economic aspects of human/whale shark interactions via participant surveys (in collaboration with industry)**
  Status

There has been little development in this area, although any survey program requires the support of industry and CALM and should therefore be developed in full consultation with these stakeholders. These data will then be available to CALM to assist sustainable management of the industry at NMP.

- **Hold a whale shark research workshop**
  Status

In 2000, the author was invited to participate and give a presentation on whale shark conservation at a special symposium convened as part of the annual conference of the peak international group involved in shark and ray research (the American Elasmobranch Society). The workshop drew together participants / researchers from around the world to discuss whale shark issues (including ecotourism and management) and identified several important areas where further work is required (particularly international collaboration). To facilitate this, in his role as Executive Committee member of AMCS WA, Mr Norman has had lengthy discussions with the Perth Convention Bureau (PCB) on the issue of convening a world whale shark conference in Western Australia in the near future.

13. Conclusion

Sustainability of the whale shark resource and the associated ecotourism at NMP are important to the economy of the whole region. Indeed, Birtles *et. al* (1996) suggests the sustainability of the whale shark seasonal aggregation phenomenon off Ningaloo Reef must take precedence over any utilisation of the resource. The level of any impacts on the whale shark resource at NMP should be confirmed using an appropriately designed set of feasible and achievable studies that focus directly on the ecotourism industry and its potential ecological issues. Only after a review of data

collected during these specific studies will CALM as management agency be confident in determining the optimum carrying capacity of the whale shark ecotourism industry at NMP. This will then enable CALM to implement future variations in the management program of whale sharks as deemed appropriate.

Therefore, in summary, this Report discussed several issues central to the conservation of the whale sharks within Ningaloo Marine Park, Western Australia. These include:

- Various research on the ecology of the species relevant to management at NMP;
- Implications of the relevant research which can assist management of the species;
- Indices of sustainability for monitoring and assessing the effects of human usage on the species; and
- Cost effective protocols for population monitoring to assist management decisions relative to species conservation.

It will be important to act on recommendations presented within this document to aid the long-term sustainable management of the whale shark ecotourism industry at NMP. Also, to ensure the ecotourism industry at NMP continues to be regarded internationally as an example of world's 'best practice', the additional suggestions for monitoring and research included in this document should be implemented as a matter of priority.

….if we succeed in keeping tourism from eating its own, from eating the assets that brings tourists there in the first place, tourism becomes a force for sustainable development – to the benefit of both the industry and the destinations which it targets…. (Manning, 1998)

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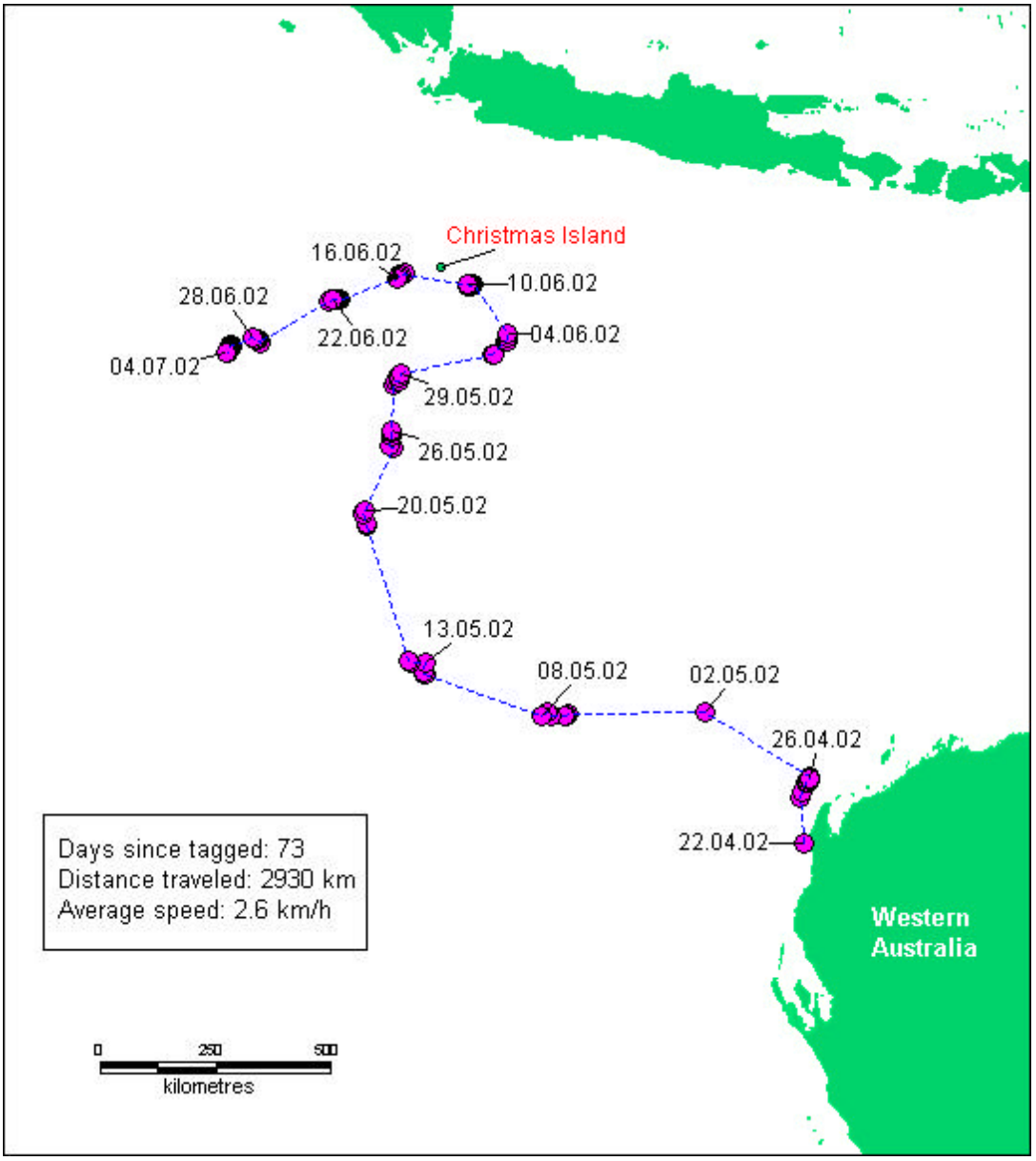
Appendix 1: Track of shark 'Hope Traveller'

Satellite track of whale shark ('Hope Traveller') which was tagged off Ningaloo Reef in April 2002. The shark was tracked for approximately 54 days and covered a distance of more than 2000km prior to the tag detaching from the shark near Christmas Island on or about 15 June, 2002.

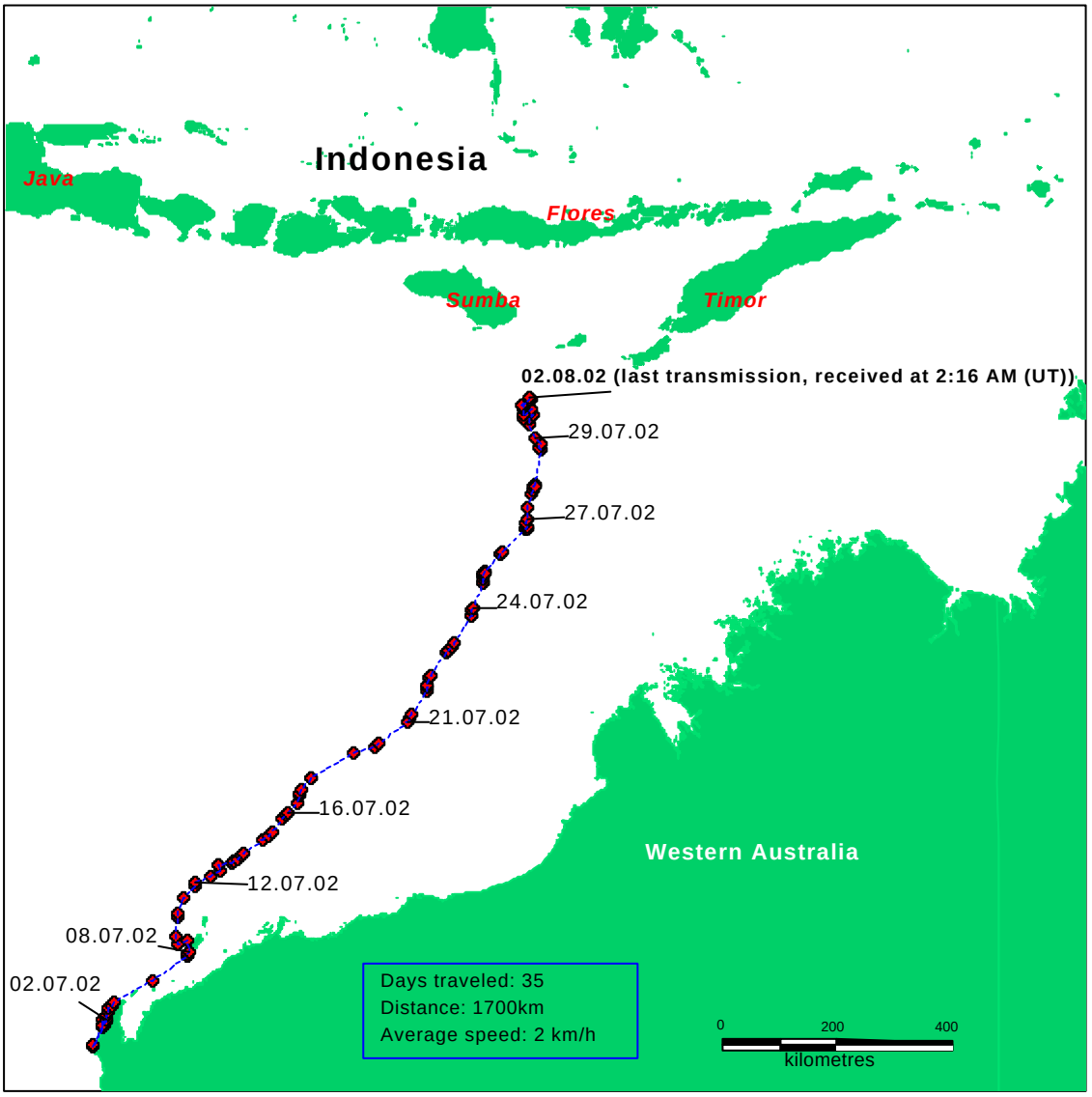
NB. The transmissions beyond this date provide information on the surface currents that are present in this area.



Appendix 2: Track of shark 'Mandu'

Satellite track of whale shark ('Mandu') which was tagged off Ningaloo Reef in July 2002. The shark was tarcked for a total of 35 days and covered a distance of approximately 1700km prior to transmission being lost on August 2, 2002.

NB. The shark had moved into Indonesian waters prior to contact being lost. Indonesia currently has no protection for whale sharks.



Appendix 3: Whale shark public awareness brochure

NHT Brochure whale sharks 2003.pdf