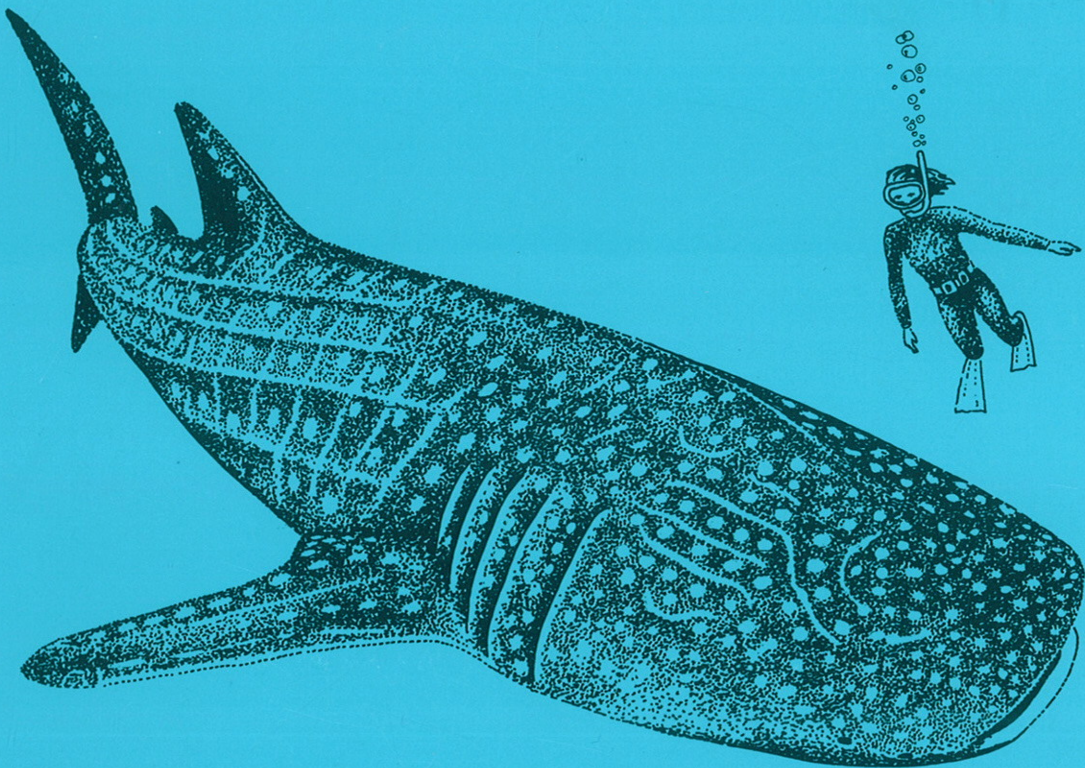
Whale Shark Interaction Management

with particular reference to

Ningaloo Marine Park

by Jeremy Colman, Marine Conservation Branch
Department of Conservation and Land Management



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WESTERN AUSTRALIAN WILDLIFE MANAGEMENT PROGRAM No. 27

WHALE SHARK INTERACTION MANAGEMENT, WITH PARTICULAR REFERENCE TO NINGALOO MARINE PARK

1997-2007

by

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by Ian Dickinson

PREFACE

The Western Australian Department of Conservation and Land Management (CALM) has a legislative responsibility to manage wildlife on CALM managed lands and waters under the CALM Act, and to manage fauna for conservation state-wide under the Wildlife Conservation Act. CALM is committed to preparing and implementing written management programs for specially protected species with the objective of ensuring that the species involved are conserved and not threatened due to human activities.

The Department also has a recreation policy, the objective of which is to facilitate the public enjoyment of the natural attributes of public lands and reserved waters in a manner that does not compromise conservation and other management objectives. Management of whale shark interactions in marine reserves requires an integration of CALM's conservation and recreation objectives, and the principal role of CALM in this respect is to manage the commercial and recreational activities of visitors. The level of exploitation of whale sharks associated with this activity requires that a Wildlife Management Program be developed and implemented. This Management Program provides a statement of the administrative, compliance auditing and research and monitoring measures to be followed to ensure that human-whale shark interactions in marine reserves, with particular reference to the Ningaloo Marine Park, are a sustainable activity that assists CALM in meeting both its conservation and recreation objectives.

This Wildlife Management Program has been approved by the Executive Director, Department of Conservation and Land Management, the Marine Parks and Reserves Authority and the Minister for the Environment. Approved Wildlife Management Programs are subject to modification as directed by new findings, changes in the status of the species and completion of management actions. Information in the Program is accurate at December 1997.

ACKNOWLEDGEMENTS

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SUMMARY

The whale shark (*Rhincodon typus*) is a protected species within all Western Australian State waters. Very little is known about the biology and ecology of the animal. Like many other sharks, the species probably has innate biological characteristics, such as large size, slow growth, late maturation and extended longevity, that limit recruitment and may make it particularly susceptible to exploitation. A seasonal aggregation of whale sharks occurs in the waters of the Ningaloo Marine Park from March to May each year. This predictable occurrence has led to the development of a small but expanding tourist industry, focusing on human-whale shark interactions. From 1993 onwards, commercial whale shark tourism within the Marine Park has been managed by the Department of Conservation and Land Management (CALM) through a system of controls, including the licensing of a limited number of operators for whale shark interaction tours. Currently, there is some demand for an increase in the number of interaction licences, over and above the 14 existing licences.

It is unclear whether increased tourism pressure is presently generating any short or long-term detrimental impacts on individual sharks or the group as a whole. The natural variability in whale shark abundance and distribution, the reasons for the aggregation at Ningaloo Reef and the carrying capacity of the industry are all unknown. Consequently, evidence of any impacts is difficult to obtain and interpret. With the limited information currently available a precautionary approach to management has been adopted. As such, limiting the number of commercial interaction licences is an appropriate strategy to manage tourism pressure on whale sharks.

This Wildlife Management Program consists of four sections. The first section provides an overview of the information available on the biology and ecology of the whale shark and describes the reasons for management. The second section describes CALM's management role and government policy in relation to management of whale shark tourism, establishes management objectives, reviews current management controls and compliance monitoring procedures, and describes future management actions. The third section details the research necessary to gain a better understanding of the animal's population biology, ecology and the natural variability of its environment, and the monitoring required to determine if any impacts are occurring as a result of increasing tourism pressure. The final section details the implementation and review of the program.

The objectives of the program are, in the short-term, to improve the management of whale shark interactions, and in the long-term, to provide the scientific basis to determine if the management strategies need to be modified to minimise any impacts. Once more detailed information is available and appropriate monitoring programs are implemented it will be possible to better ensure that whale shark populations, particularly at Ningaloo, are not being subjected to an unacceptable level of disturbance, and that development of whale shark tourism in marine reserves is sustainable and equitable.

ACTIONS AND RECOMMENDATIONS

MANAGEMENT ACTIONS

Licensing of commercial operators

- *All current commercial licences for whale shark interaction in the Ningaloo Marine Park will be renewed for 12 months to 31 December 1998.*

- *Licence renewals will be part of a competitive licensing system for eligible operators.*

- *The competitive application process for new licences for 1999 and beyond will commence during 1997.*

- *Five year licences will be issued by 31 December 1997.*

- *An increase in licence numbers will not be considered until more information is available from research and monitoring studies.*

- *The geographical boundary on existing whale shark interaction licences, currently set at Point Cloates, will be removed.*

- *The licence charges will remain at $15.00 per adult/day, and $7.50 per child/day, until the current licences expire.*

- *Licence charges will be reviewed annually from 1999 onwards.*

Industry code of conduct

- *A review of the code of conduct will be carried out by CALM, as soon as is practicable.*

- *Safety issues related to the interaction will be reviewed by the Department of Transport and CALM, in consultation with the industry, as soon as is practicable.*

- *Additional whale shark interpretive/educational material will be produced by CALM, as soon as is practicable.*

Compliance monitoring

- *The frequency of each of the available surveillance methods will be manipulated to provide the most efficient and effective combination for monitoring compliance.*

- *Periodic aerial surveillance will be undertaken using an aircraft dedicated to compliance monitoring.*

- *Sufficient Exmouth District and Pilbara Regional staff and resources will be allocated to ensure effective and efficient compliance monitoring during peak and shoulder periods of the season.*

- *A co-ordinated compliance monitoring records system will be developed.*

- *Strategies to facilitate greater industry self-regulation will be investigated, in consultation with the industry.*

Implementation and review

- *A CALM Management Team will be established to implement the Management Program.*

- *The Management Program will be subject to annual review by the Management Team.*

- *A Whale Shark Management Advisory Committee, comprised of representatives from CALM, the Department of Transport, the industry and local community will be established to provide advice to CALM.*

- *The management objectives and controls, and the research and monitoring strategies detailed in this Management Program will apply, with appropriate modifications, in all CALM marine reserves wherever relevant.*

RESEARCH AND MONITORING RECOMMENDATIONS

- *A long-term monitoring program should be undertaken to determine the extent of inter-annual variability in the whale shark population of the Ningaloo Marine Park.*

- *A suitable technique for monitoring resource size and tourism pressure should be determined over the next two seasons.*

- *Long-term monitoring of physical and biological parameters should be undertaken to examine possible links between environmental parameters and whale shark population fluctuations in the Ningaloo Marine Park.*

- *Research to study behavioural patterns and movements of whale sharks within the Ningaloo Marine Park and in surrounding waters should be continued.*

- *A central whale shark photo-identification database should be established as a priority.*

- *Research to study large scale migratory patterns of whale sharks should be undertaken.*

- *Participant surveys should be regularly carried out, in collaboration with the industry, to monitor experiential and economic aspects of human/whale shark interactions.*

- *A whale shark research workshop should be held within the next two years.*

1. INTRODUCTION

1.1 Description of species

The whale shark *Rhincodon typus* (Smith, 1828) was first described and named by Dr Andrew Smith from a specimen harpooned in Table Bay, South Africa in 1828 (Smith, 1828, 1829, 1849). Historically, there has been considerable synonymy at family, generic and specific level, and in 1984 the International Commission on Zoological Nomenclature rejected previous generic variations in favour of genus *Rhincodon* Smith, 1829, family Rhincodontidae (Melville, 1984). Alternate generic names most commonly used are *Rhiniodon* and *Rhineodon*. Systematically, Rhincodontidae (with the single species *Rhincodon typus*) is placed in the order Orectolobiformes, which also includes nurse sharks (Ginglymostomatidae), leopard sharks (Stegostomatidae), and wobbegongs (Orectolobidae). The interrelationships between these families are based upon a number of anatomical and morphological similarities, including skeletal anatomy, tooth and dermal denticle morphology, fin placement and barbel morphology (Compagno, 1973; Dingerkus, 1985).

The species is the world's largest living fish and is externally characterised by a broad, flattened head, a very large and nearly terminal mouth, very large gill slits, three prominent longitudinal ridges on its upper flanks, a large first dorsal fin, a semi-lunate caudal fin and a unique 'checkerboard' pattern of light spots and stripes on a dark background (Compagno, 1984; Last & Stevens, 1994). The function of this distinctive pattern of body marking is unknown. Many bottom-dwelling sharks have bold and disruptive body markings that act as camouflage through disruptive colouration (Bass, 1978). The whale shark's markings could be a result of its phyletic relationship with bottom-dwelling orectolobiform carpet sharks. Sharks have a high degree of visual development (Gruber, 1977) and distinctive markings in a pelagic species could be important in social activities such as postural displays and recognition processes (Myrberg, 1991). Another possibility is that these pigment patterns could be an adaptation for radiation shielding, important in a species that may spend a significant proportion of time in surface waters possibly exposed to high levels of ultra-violet radiation. The whale shark is one of the three species of very large filter-feeding sharks that occur in Western Australian waters, the other two being the basking shark *Cetorhinus maximus,* and the megamouth shark *Megachasma pelagios*.

1.2 Distribution and habitat

R. typus is thought to be cosmopolitan in distribution, occurring in all tropical and warm temperate seas apart from the Mediterranean. It is found in a band around the equator between about 30°N and 35°S, in both coastal and oceanic waters (Compagno, 1984). It occurs throughout the Indian Ocean and has been reported from the Maldives, Seychelles and Comores Islands, and along the coastlines of Madagascar, South Africa, Mozambique, Kenya, Pakistan, India, Sri Lanka, Thailand, Malaysia and Indonesia. In Australia whale sharks occur mainly off northern Western Australia, the Northern Territory and Queensland, with isolated reports from New South Wales and Victoria (Wolfson, 1986).

In contrast to the majority of orectolobiform sharks, which are benthic species, the whale shark has a pelagic habitat. Iwasaki (1970) collated and analysed environmental data from skipjack tuna fishing vessels that encountered whale sharks in the Western Pacific from 1955 to 1967. Analysis of air temperatures, seawater temperature and salinity profiles, and wind and current patterns revealed changes in the seasonal frequency and distribution of whale sharks that appeared to be linked to a number of environmental variables, including the warm Kuroshio current and warm SSW-WSW winds. Off the east coast of Japan their range encompassed areas with surface water temperatures from 18-30°C, but they appeared to prefer locations with surface water temperatures between 21-25°C, where cool nutrient-rich upwellings mingle with warm surface waters of salinities between 34-34.5‰ (Iwasaki, 1970). These conditions may well be optimal for the production of the planktonic and nektonic prey upon which the sharks feed.

Sightings of whale sharks during aerial surveys along the south coast of Texas were made in water with surface temperatures of 29°C (Hoffman *et al.*, 1981). Arnbom & Papastavrou (1988) reported several sightings of whale sharks in the Galapagos Islands, in an area of very deep water (2,000-3,000 m) close to the edge of the continental shelf, known for its upwellings and high primary productivity. Surface seawater temperatures recorded during these encounters were between 23.5 and 26.5°C.

1.3 Biology and ecology

1.3.1 Feeding

The whale shark is a filter-feeder that appears to feed on a wide variety of planktonic and nektonic prey, including small crustaceans such as krill, crab larvae and copepods, small schooling fishes such as sardines, anchovies, mackerel, and occasionally larger prey such as small tuna, albacore and squid (Compagno, 1984; Last & Stevens, 1994). Phytoplankton and macroalgae may also form a component of the diet (McCann, 1954; Kaikini *et al.*, 1959; Satyanarayana Rao, 1986; Karbhari & Josekutty, 1986). An analysis of the stomach contents of a specimen caught off the coast of India in 1961 revealed a variety of material, "..... including large quantities of zooplankton, partly digested remains of fish, crustaceans, molluscs, and small quantities of seaweed and algae, undoubtedly suggesting an omnivorous diet" (Silas & Rajagopalan, 1963). However, it is possible that algal matter found in the gut contents of these specimens could have been swallowed accidentally, either during the course of normal feeding activities or whilst being captured.

The animal is not dependent on forward motion to operate its filtration mechanism, but rather relies on a versatile 'suction' filter-feeding method, which enables it to draw water into the mouth at higher velocities than 'dynamic' filter-feeders, such as the basking shark (Compagno, 1984). This enables it to capture larger, more active nektonic prey as well as zooplankton aggregations, but probably means it can filter a far smaller volume of water making it less efficient in concentrating diffuse planktonic food. The whale shark may, therefore, be more dependent on dense aggregations of prey organisms. Taylor, *et al.* (1983) reviewed the feeding biology and filter apparatus of *Rhincodon* in relation to *Megachasma* and *Cetorhinus* and concluded that the dense filter screens of the former act as more efficient filters for short 'suction' intakes, in contrast to the 'flow through' systems of the latter two species.

Individuals have been observed feeding 'passively' (cruising with mouth agape) and also sometimes hanging vertically in the water and 'actively' feeding by opening their mouths and sucking in prey-rich water (Clark & Nelson, 1997). They have been observed feeding in this manner on aggregations of small crustaceans (including euphausids), squid, anchovy and sardines (Silas, 1986). They have also been observed 'coughing' which is thought to be a mechanism employed to clear or flush the gill rakers of accumulated food particles. Groups of individuals have been observed 'actively' feeding at dusk or after dark by ploughing through the surface waters with mouth agape and jaw distended, sometimes also moving their heads from side to side 'vacuuming' in seawater rich in prey, or aggressively cutting swathes through schools of prey (Clark, 1992; Taylor, 1994). At Ningaloo Reef, individuals and groups of whale sharks have been observed actively feeding on swarms of the tropical krill *Pseudeuphausia latifrons* (Taylor & Grigg, 1991).

1.3.2 Reproduction and development

Information about the reproduction and development of the whale shark is very limited. Historically, there has been much debate about their mode of development, and it was unclear whether the whale shark is oviparous (egg cases expelled from the female's body and hatching on the sea floor) or ovo-viviparous (egg cases hatching *in utero*, with the female giving birth to live young). Southwell

(1912/13) reported that a specimen taken off the Sri Lankan coast was found to contain a "......very large ovary, oviduct full of eggs, 16 cases counted, same form as in dogfish." This observation suggested oviparity.

Until recently, the only known whale shark embryo was a near-term 36 cm specimen retrieved alive from a large egg case trawled from the sea floor in the Gulf of Mexico in 1953 (Baughman, 1955; Reid, 1957; Garrick, 1964). Whilst this appeared to suggest an oviparous mode of development, Wolfson (1983) believed it was more likely that the egg case had been aborted, and that the whale shark is actually ovo-viviparous. This conclusion is based on the absence of other occurrences of 'free-living' egg cases and the fact that the Gulf of Mexico egg case was extremely thin and lacked tendrils (which anchor the eggcase to the sea floor). The embryo also had large reserves of yolk and only partially developed gill sieves, which combined with the discovery of umbilical scars on a free-living juvenile of 55 cm length (Wolfson, 1983), provide further support for the theory that whale sharks have an ovo-viviparous mode of development.

In July 1995, a female whale shark, measuring approximately 11 m in length, was harpooned off the eastern coast of Taiwan (Joung *et al.*, 1996). The twin uteri of this specimen were found to contain nearly 300 embryos, from 42-63 cm in length (Chang *et al.*, 1997). Fifteen of the embryos were alive and one, measuring 58 cm in length, was reared for 143 days in an aquarium in Japan where it developed from fetal through to juvenile stage (Leu *et al.*, 1997). This discovery finally confirms that the species is a live-bearer, with an ovo-viviparous mode of development.

1.3.3 Life history

A total of only nine juveniles, ranging from 55-93 cm in length, have been recorded in the literature (Wolfson, 1983; Anon., 1989; Kukuyev, 1996). One of the juveniles recorded by Kukuyev (1996) was found in the stomach of a blue shark (*Prionace glauca*), caught in central tropical Atlantic waters. A further specimen, measuring 61 cm in length, was found in the gut contents of a blue marlin (*Makaira mazara*) caught off the northern coast of Mauritius in 1993 (D. Goorah, pers. comm.). The juvenile was alive when recovered from the marlin, as it had just been ingested prior to the intake of a bonito (*Sarda orientalis*).

There are no confirmed records of whale sharks between 93 cm and 3 m. Animals over 3 m in length are encountered world-wide. Most specimens reported in the literature are between 4 and 10 m, but maximum total length is uncertain. The largest accurately measured specimen was 12 m in length (Karbhari & Josekutty, 1986), but there is a report of a specimen from the Seychelles that measured nearly 14 m in length (Wright, 1870), and a specimen measuring just over 14 m was landed in India in 1975 (Devadoss *et al.*, 1990). Whale sharks may possibly reach as much as 18 m in length, although the very large specimen reported from the Gulf of Siam (Smith, 1925) was not accurately measured and therefore total length may have been over-estimated.

Information about size at sexual maturity and longevity is sparse. Taylor (1994) speculated that whale sharks do not reach sexual maturity until they are over 30 years of age, and that they may have a life-span of over 100 years. He also observed that the only sexually mature male seen at Ningaloo Reef was probably over 9 m in length. Two large female sharks captured off the Indian coastline (Pai *et al.*, 1983; Satyanarayana Rao, 1986), which measured 8-9 m in length, were both found to have immature ovaries. The evidence suggests that sexual maturity in both sexes may not occur until the sharks are over 9m in length. Data on sex ratio is also very limited. Of 31 specimens reported from India, 17 were male and 14 were female (Silas, 1986). A 1:1 sex ratio was reported for the 297 embryos removed from the pregnant female in Taiwan, with 150 females and 147 males (Chang *et al.*, 1997; Joung *et al.*, 1996). Taylor (1994) observed that the majority of whale sharks encountered at Ningaloo Reef are immature males. On the basis of current information it is not possible to say whether sexual segregation, of either a behavioural or geographical nature, occurs.

1.3.4 Growth and ageing

Virtually nothing is known about growth rates or ageing in whale sharks. As accurate measurements of size parameters are difficult to obtain from whale sharks in the water, morphometric studies of this species have made little progress. Growth curves for sharks have generally been derived from age estimates based upon growth zones (bands or rings) in calcified structures such as vertebral centra. The growth of whale sharks has been opportunistically studied from animals held in captivity in the Okinawa Expo Aquarium in Japan (Uchida *et al.*, 1990). One of these had been fed food laced with tetracycline, on several occasions over more than a year (Cailliet *et al.*, 1986). Preliminary results indicated that one pair of growth zones was deposited per year in captivity. How this relates to growth in the wild can only be determined by examination of growth zones in vertebral centra samples collected from dead specimens. Studies of this nature are hampered by sample size, as very few dead animals are available for collection of hard tissues. There are no records of whale shark strandings along the Western Australian coastline, although there is an unconfirmed report of a small (2 m length) whale shark being found on the beach at Sandy Bay, North West Cape in 1982 (N. Nannup, pers. comm.). A total of 36 whale shark strandings have been reported for the South African coastline from 1984-1995 (Beckley, *et al.*, 1997) and researchers have recently been retaining vertebrae samples from specimens stranding along the KwaZulu/Natal coast (G. Cliff, pers. comm.). Some information on ageing of whale sharks may be available from subsequent examination of these samples.

1.3.5 Movement patterns

In general, occurrences of whale sharks appear to be sporadic and unpredictable, which is partly a reflection of the lack of knowledge about the animal's habitat and ecology. The animals are generally encountered singly but aggregations of over a hundred animals have been seen (Anon., 1961), which suggests that schooling activity does occur. They are usually observed on or near the surface and at times have been seen apparently basking. Whale sharks are thought to be highly migratory but there is currently no direct evidence to support this. Their movements are probably related to increases in local productivity such as plankton blooms and invertebrate spawning events, with associated increases in zooplankton and bait fish shoals, and also to changes in water temperature, currents, winds and other environmental parameters (Compagno, 1984). Gunn *et al.* (in preparation) have suggested that whale sharks, with their suction filter-feeding strategy, are probably more dependent on localised productivity events. Different locations appear to be preferred at various times of the year and they may undertake either fairly localised migrations or alternatively large scale trans-oceanic movements, governed by the timing and location of production pulses and possibly by breeding behaviour. Seasonal migrations have been postulated for various areas but more information is needed to confirm these patterns (Wolfson, 1986).

Taylor (1994) postulated that the appearance of whale sharks at Ningaloo Reef during the austral autumn period is linked to the high levels of productivity associated with mass synchronous coral spawning events after the March and April full moons (Simpson, 1991). It is currently unknown whether the whale sharks present at Ningaloo in March to June are resident in the eastern Indian Ocean throughout the rest of the year. These animals could move offshore to deeper waters and may only be seen when they come inshore and into surface waters to exploit periodic increases in plankton productivity, such as those around the time of mass coral spawning. Inshore sightings of significant numbers of whale sharks have been made in December and January along the Western Australian coastline between Kalbarri and Shark Bay (P. Wieland, pers. comm.). Unconfirmed reports suggest the occurrence of numbers of whale sharks around the Montebello Islands at the same time of year. Whether any of these separate aggregations consist of the same individuals as those occurring at Ningaloo is not known.

Episodic aggregations of whale sharks also occur in two other locations in Australian waters. During December and January significant numbers of whale sharks have been reported from Christmas Island in the Indian Ocean (Gunn *et al.*, in preparation), and these occur at the same time that the red crab (*Gecarcoidea natalis*) spawns *en masse*. In the Coral Sea regular sightings of whale sharks occur in October and November in association with aggregations of tuna (Gunn *et al.*, 1992). It is believed that these aggregations may be associated with large concentrations of the spawning lantern fish (*Diaphus* spp.), rather than with synchronous coral spawning along the Great Barrier Reef that occurs during the same period (Gunn *et al.*, in preparation). In the Maldives whale sharks show distinct seasonal movements, in phase with the changing monsoons and associated current movements, upwelling events and plankton blooms (Anderson & Ahmed, 1993).

There are several reports in the literature of seasonal aggregations of whale sharks in Indian coastal waters from December to April (Silas, 1986), in the Seychelles during July/August and November/December (D. Rowat, pers. comm.) and off the west coast of Mexico from Cabo San Lucas to Acapulco from March to August (Wolfson, 1986, 1987). Significant numbers of whale sharks have also been reported from inshore waters off southern Mozambique and the northern coast of South Africa from October through to March (A. Gifford, pers. comm.). Since 1993, researchers from the Shark Research Institute in South Africa have been carrying out whale shark aerial surveys and a tagging programme along the KwaZulu/Natal coastline (A. Gifford, pers. comm.). An aerial survey in January 1994 recorded a total of 95 whale sharks in a distance of 110km. During the 1994 and 1995 seasons a total of 72 sharks were tagged. The researchers are hoping to expand their tagging effort along the east African coast, using tags of identical design but with different colour coding according to the tagging location. Returns could assist in the determination of large scale migratory patterns throughout the Indian Ocean region. The Kenya Wildlife Service recorded 60 whale sharks, whilst carrying out an aerial survey of marine mammals, turtles sharks and rays in November 1994 (Wamukoya, *et al.*, 1996). The sharks were distributed all along the Kenyan coast, but with a higher frequency of sightings in the central section of the 500 km coastline.

1.3.6 Faunal associations

Whale sharks are often associated with schools of pelagic fish that are probably feeding on the same prey organisms. There are numerous references in the literature to sightings of whale sharks in association with several tuna species, and with bonito, mackerel and schools of small bait fish such as sardines and anchovies. These associations could have foraging advantages for the whale sharks. Wolfson (1987) reported the sighting of a whale shark swimming amongst a school of more than 500 hammerhead sharks (*Sphyrna lewini*) off Baja California, and Arnbom & Papastavrou (1988) observed tiger sharks (*Galeocerdo cuvieri*) swimming close to whale sharks in the Galapagos Islands. Groups of whale sharks have been observed swimming with manta rays (*Manta birostris*) off Baja California (Wolfson, 1987) and off the Zuytdorp Cliffs, north of Kalbarri in Western Australia (P. Weiland, pers. comm.). Other common associates include several species of remora (*Remora* spp.) and the pilot fish (*Naucrates ductor*). At Ningaloo Reef, Taylor (1994) reported that whale sharks are often seen accompanied by juvenile golden trevally (*Gnathanodon speciosus*).

1.3.7 Human interaction

In the past the animal has been of little interest to man, as it poses no threat nor is it widely exploited for human consumption or for other products. Consequently, there has been virtually no sustained scientific research on this species and it has been the target of only limited commercial fisheries in the past. The flesh is soft and bland and has a very high water content, with levels of 68% (Satyanarayana Rao, 1986) and 75% (A. Gifford, pers. comm.) being reported. Whale shark meat is sought after in Taiwan (Joung *et al.*, 1996), where it is described as being like tofu and sells at around US$2.50 to US$6.50 per kilo (Chen *et al.*, 1996). Whale shark skin is also served in restaurants in Taiwan (Rose, 1996). Currently, whale sharks from coastal fisheries fetch up to US$7 per kilo (ungutted) at Taiwanese fish markets and a 1995 survey of set net and harpoon fisheries along the east and north-west coasts of the island estimated the annual catch at 272 individuals (Liu *et al.*, in press). Seasonal (January to May) fisheries exist in the Philippines, where an estimated 95 sharks were taken at four sites in the Bohol Sea during the 1996 season (Anon., 1996). These fisheries have been increasing in recent years and there are indications that they may be unsustainable and that the whale shark population is under threat (Trono, 1996; Alava *et al.*, in press).

Sudhakara Rao (1986), recorded the landing of 40 whale sharks over a four day period in 1982, from a harpoon fishery off the Veraval coast in India. After removal of the liver the carcasses were discarded as there was no local demand for the flesh. In the past small harpoon fisheries have been reported from India (Sudhakara Rao, 1986), Pakistan (Anon., 1955; Silas, 1986), Indonesia (Muller, 1995) and Iraq (Mahdi, 1971). Whale sharks are occasionally taken accidentally in gill and purse seine net fisheries off the coast of India (Silas, 1986; Devadoss *et al.*, 1990; Seshagiri Rao, 1992). Until recently these specimens were usually discarded, as neither the flesh or other products were in high demand. Occasionally some of the flesh was eaten, either fresh or salted and dried, and the liver oil was utilised for water-proofing wooden fishing boats and other appliances, for the manufacture of shoe polish (Satyanarayana Rao, 1986) and as a treatment for some skin diseases (Karbhari & Josekutty, 1986).

The processing of whale shark fins and fin rays has been reported from India (Ramachandran & Sankar, 1990) and a recent WWF-India/TRAFFIC-India report on the trade in sharks and shark products gave details of whale shark fishing at two locations on the west coast. Whale sharks are taken at Veraval and Okha, mainly for fins, livers and meat, with the fresh or frozen meat being exported to Taiwan, Korea and Singapore at US$1 per kilo (Hanfee, 1997). Whale sharks occasionally form part of the incidental catch of the artisanal shark fishery in Somalia (Rose, 1996). The anti-tumorogenic properties of whale shark liver oil have been investigated in China (Zhang *et al.*, 1988).

The species is often used as a fish 'aggregator' or indicator of waters rich in plankton and plankton-feeding fish that will, in turn, attract more valuable species such as tuna. In the Gulf of Guinea and Caribbean Sea purse seiners routinely seek out floating aggregating objects, such as whale sharks, on the surface and set nets in the area around them to improve the probability of catching large schools of tuna (Stretta & Slepoukha, 1983; Gaertner *et al.*, 1996). However, potential damage to fishing gear from entangled whale sharks causes them to be avoided in other areas. Several whale sharks have been kept in captivity at the Okinawa Expo Aquarium in Japan (Roth, 1986; Uchida *et al.*, 1990). Currently both the Okinawa Expo Aquarium and the Kaiyukan Aquarium in Osaka have live whale sharks on display. There have been a few cases reported of whale sharks inadvertently ramming boats (Smith, 1967), but generally the sharks are more at risk from being accidentally struck by vessels whilst basking or feeding on the surface. There are numerous reports, from the first half of this century, of collisions between steam ships and whale sharks (Anon., 1962; Gudger, 1938a, b, 1940).

1.4 Published literature

The published literature on whale sharks is extensive and consists mainly of sightings records, anecdotal reports, speculative reviews of distribution and movement patterns, and limited observations of general biology, feeding and behaviour. Much of the material is derivative, superficial in content, and of limited scientific use. The definitive bibliography (Wolfson & Notarbartolo di Sciara, 1981) collated all available literature to 1980, listed and annotated 345 references, and categorised these under 19 broad headings. This review was later updated by a consolidation of reported sightings (Wolfson, 1986). Silas (1986) updated records from Indian waters and carried out an excellent review of the information available on the whale shark's biology and ecology.

In order to review all the references listed in these bibliographic reviews, and to access any new material published since 1986 a comprehensive whale shark reference database and reprint collection have been established by CALM's Marine Conservation Branch. The database currently lists 565 references (copies of 60% of these are available in the reprint collection) and contains 160 new papers either not listed in previous reviews, or published since 1986. The database, which also includes a number of unpublished research reports, some magazine articles and educational/interpretive material, and the reprint collection are situated at CALM's office in Fremantle, and are available to researchers carrying out studies on whale sharks.

1.5 Whale shark research at Ningaloo Reef

1.5.1 Initial observations

Since 1982, whale shark enthusiast G. Taylor has been studying and photographing whale sharks at Ningaloo Reef. He was the first person to document the seasonal aggregation of whale sharks in the area, initially through the collection of informal sightings records from boats. Taylor conducted preliminary population surveys, and investigated the relationships between coral spawning, the Leeuwin Current, shark occurrences and movement patterns. With funding from the Australian National Parks and Wildlife Service (ANPWS) he carried out aerial surveys between 1989 and 1992, which suggested that whale sharks congregate along the reef front during the autumn months, shortly after synchronous mass coral spawning episodes (Taylor, 1996a). Further work involved limited plankton sampling to try and identify prey species, observations of feeding behaviour, and initial satellite tracking studies (Taylor, 1994).

In order to gather more information about population size, sex ratio and whether the same animals revisit Ningaloo on a seasonal basis, Taylor conducted a limited tagging study using conventional game fish tags. This study, with individuals being re-identified by the location of the tag rather than its number, was initiated in 1992 and a total of 25 individuals were tagged (Taylor, 1994). His estimates of local population size, based upon the frequency of re-sightings and an estimated tag shedding percentage of 40-50%, are between 200 and 300 individuals (Taylor, 1996b). Taylor also recorded the sex of whale sharks encountered on the reef and investigated the feasibility of identifying individuals through scars, deformities and the pattern of spots and stripes behind the gill slits. He has used gross scarring to verify the long-term stability of the lateral markings and has suggested that these distinctive patterns can be used as a repeatable method of identifying individuals (Taylor, 1994). He has compiled a library of identification records which contain photographic material on 162 individuals (Taylor, 1997). It is apparent from these data that some individual sharks are re-sighted at Ningaloo, not only during the course of a single season, but also in successive seasons. Additionally, there have been re-sightings of several easily identifiable individuals over periods of more than two years. A male, first filmed at Ningaloo in 1986, has since been re-sighted in 1993, 1995 and 1996 (Taylor, 1997), and a second male shark, which was first photographed in 1991, was recorded again in 1994 and 1996 (Taylor, 1996b).

In addition, Taylor has also undertaken a long-term study to measure the dorsal fins of whale sharks at Ningaloo. Repeated re-measurement of the height of the first dorsal fin of individual sharks, over a period of ten years or more, may provide an indication of the growth rate of the fin. If there is a relationship between this parameter and overall size of the shark, Taylor believes it may be possible to estimate age of the sharks and age at sexual maturity. Overall, Taylor's research has made a significant contribution to our knowledge and understanding of whale sharks at Ningaloo Reef.

1.5.2 Telemetry study

In 1994, researchers from the CSIRO Division of Fisheries successfully tracked two tagged whale sharks (one for a period of 26 hours) using acoustic telemetry, and attached archival tags to six individuals, one of which was recovered after 24 hours. The archival or 'smart' tags can collect data on the date, time, the shark's position and swimming depth, and the water temperature for up to five years, giving a record of the shark's long-term movements once the tag is retrieved (Gunn *et al.*, 1994). Detailed information on the short-term movements of the sharks was obtained from the acoustic telemetry tracking and from the single archival tag retrieved (Stevens, 1994; Gunn *et al.*, in preparation). Swimming speed ranged from approximately 0.1-1.5 m sec^{-1}, with the fastest speeds being recorded during the night. Data from both the acoustic telemetry and the archival tag revealed that the tagged sharks made numerous dives throughout the 24 hour period, to maximum depths of 90 m, often to within a few metres of the bottom. Diving behaviour of these individuals did not appear to be linked to the location of the thermocline, with the acoustically tracked sharks spending the majority of the time above the thermocline, and the archival tagged shark spending the day above the thermocline and most of the night either within or below it. Some of the tracks revealed that the sharks were circling on the surface off a reef passage, during ebb tides when water was flowing out of the lagoon, possibly to take advantage of aggregations of prey associated with mats of algae (Gunn *et al.*, in preparation).

1.6 Reasons for management

1.6.1 Conservation status

Like many other shark species, the whale shark has innate biological characteristics, such as large size, slow growth, late maturation and extended longevity, that probably limit recruitment and make it particularly susceptible to exploitation. These characteristics may also mean that populations are slow to recover from any over-exploitation (Jones & Kaly, 1995). International conservation status of the species is unclear - it is listed as having a 'Indeterminate' status on the World Conservation Union's *Red List of Threatened Animals* (IUCN, 1994). This category applies to animals known to be 'Endangered', 'Vulnerable' or 'Rare', but there is not enough information available to say which of these three categories is appropriate. In the 1996 IUCN Red List the whale shark's status is still considered to be 'Data Deficient' (IUCN, 1996).

Both Casey *et al.* (1992) and Rose (1996) considered the whale shark to be at potential risk from pelagic fisheries. There are indications that even small traditional fisheries may be unsustainable, with catches from the seasonal fishery in the Philippines declining over recent years, but the reasons for this downward trend are unknown (Anon., 1996; Trono, 1996; Alava *et al.*, in press). Globally, commercial fisheries for this species are limited at present, but may expand from an increased demand for food products. There may be a developing market for whale shark fins, with reports that some may recently have been sold in Hong Kong (Smith, 1996). In the Maldives the limited fishery for liver oil has ceased in recent years, and in June 1995 the Ministry of Fisheries and Agriculture introduced specific legislation banning all fishing for whale sharks (C. Anderson, pers. comm.). This protection was introduced because of the low monetary value of the fishery, the possible serious impact that the fishery may have been having on whale shark stocks, and the possible benefits to both the tuna fishery and tourist industry.

1.6.2 Nature-based tourism

With the world-wide growth of nature-based tourism, recreational snorkelling and scuba diving there has been a steady increase in the number of encounters with whale sharks. In a few locations, such as Ningaloo Reef, the Galapagos Islands, the islands of the Andaman Sea off the west coast of Thailand and the Sea of Cortez and Baja California in the eastern Pacific, where occurrences of whale sharks appear to be predictable, they are increasingly being targeted by commercial tourist operations. These operations provide a rare opportunity for close encounters between humans and large marine fauna, but may result in unknown effects on the shark's behaviour and ecology. The annual aggregation of whale sharks at Ningaloo Reef has become, like the dolphins at Monkey Mia, an internationally known tourism attraction. Since 1993, a nature-based tourist industry has developed in the Ningaloo Marine Park (Figure 1), as this is one of the few opportunities world-wide for people to interact with these animals. Visitors are able to snorkel and dive with whale sharks and this is attracting increasing numbers of both Australian and international tourists to the North West Cape region.

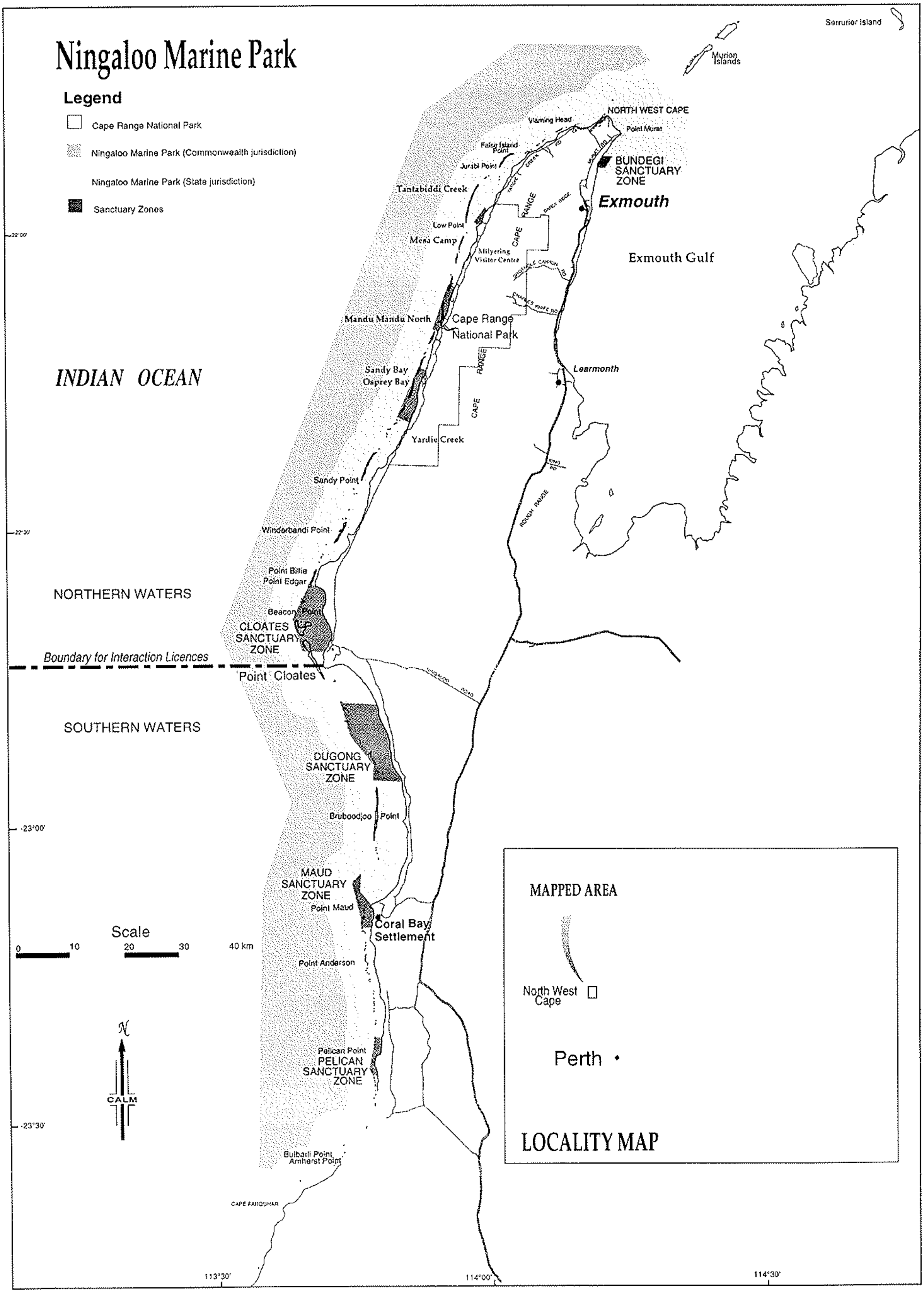


Figure 1: Ningaloo Marine Park

2. MANAGEMENT STRATEGIES

2.1 CALM's statutory responsibility

The Western Australian Department of Conservation and Land Management was established under the *Conservation and Land Management Act 1984* (CALM Act) to fulfil a number of functions. In relation to whale shark interaction in State waters, these include:

- to be responsible for the conservation and protection of flora and fauna throughout the State and in particular to administer the *Wildlife Conservation Act 1950*;

- to manage marine reserves for the purposes of

  "...fulfilling so much of the demand for recreation by the members of the public as is consistent with the proper conservation and restoration of the natural environment, the protection of indigenous flora and fauna and the preservation of any feature of archaeological, historic or scientific interest" (CALM Act);

- to promote and facilitate public recreation, consistent with the CALM Act, on CALM-managed areas; and

- to carry out research in relation to the management of lands and waters, and conservation and protection of flora and fauna.

2.2 Government policy

2.2.1 Marine conservation strategy

A recently published state-wide review of Western Australia, entitled *A Representative Marine Reserve System for Western Australia* (CALM, 1994) stated that marine reserves have several important functions:

> "......marine conservation reserves help protect species and preserve the diversity of life. They may also be a resource for education, recreation and tourism programs..........There is potential for further development of these activities to improve both local quality of life and the potential for commercial tourism but increased use of the natural environment will need increased protection and management." (CALM, 1994).

In November 1994, the Western Australian Government released the *New Horizons in Marine Management* strategy (Government of Western Australia, 1994), which recognised the relationship between the marine conservation reserve system and the tourist industry:

> "Appropriate tourism development will be encouraged to maximise the opportunity for visitors to enjoy marine conservation reserves while at the same time ensuring such development does not threaten the highest conservation values or conflict with other uses in particular zones." (Government of Western Australia, 1994).

2.2.2 Development of nature-based tourism

The State Government has recognised that the development of nature-based tourism can provide significant benefits to the Western Australian community. The *Nature Based Tourism Strategy for Western Australia* (NBTAC, 1997) recognises that by encouraging sustainable nature-based tourism, conservation and tourism development can be integrated, providing an economic incentive for protecting the environment. Also, the provision of quality tourism experiences can help educate and inform visitors, leading to a greater understanding and awareness of the natural environment, and the subsequent growth of a 'conservation ethic'.

Whilst encouraging nature-based tourism development, the Government also has an important role in regulating tourism activities in sensitive natural areas to ensure that the State's natural assets are not threatened. CALM has a key role in fostering and assisting in the growth of nature-based tourism. This can occur through:

- the identification of tourism opportunities;
- the provision of controlled access to the conservation estate;
- the development of quality information, education and interpretative material; and
- monitoring the effects of nature-based tourism.

2.2.3 Sustainable use of marine resources

The primary principle, with respect to management of wildlife, is to ensure that any use is ecologically sustainable and equitable. The concept of sustainability is also an important aspect of the use of marine resources by nature-based tourism and other activities. This is recognised by Government strategies for the implementation of a marine reserve system and for the management of nature-based tourism within these reserves. Sustainable use aims to ensure that the resource remains intact and has long-term viability:

> "Where utilisation occurs, it should be sustainable for the species itself as well as for other components of its ecosystem, based on sound scientific principles, and in the case of fauna, carried out in a humane manner." (CALM, 1992).

2.3 Policy framework

The Marine Parks and Reserves Authority (MPRA) has a statutory obligation to prepare management plans for waters vested in it, and CALM manages those waters in accordance with these management plans. Other forms of planning are also undertaken to assist CALM in achieving its objectives. These include the development of policies for all management activities and the development of issue plans for a range of topics, including the development of wildlife management programs.

Key policies in relation to the management of commercial whale shark tourism in marine reserves are:

- **Policy No. 44 (Wildlife Management Programs),**
  CALM's conservation objective is:

  To conserve the indigenous plant and animal species and environmental processes in natural habitats throughout the State.

  This policy statement sets out the objective to ".. conserve and manage threatened, specially protected, or harvested taxa of flora and fauna and their habitats, threatened ecological communities and other taxa in need of intensive management by the preparation and implementation of written wildlife management programs." This policy statement recognises that some taxa may be exploited by being the subject of non-consumptive use that may necessitate intensive management.

- **Policy No. 18 (Recreation, Tourism and Visitor Services),**
  This policy statement spells out the underlying principles, administrative controls and, where appropriate, operational guidelines and procedures relating to CALM's recreation objective, which is:

  > *To facilitate the public enjoyment of the natural attributes of public lands and reserved waters in a manner that does not compromise conservation and other management objectives.*

  When read in conjunction with the CALM Act and regulations and other related policies, this statement provides the basis for planning and managing for recreation, tourism and associated visitor activities on Department managed lands and waters.

Management of commercial whale shark interaction in marine reserves requires an integration of CALM's conservation and recreation objectives. Encouraging the sustainable development of this type of industry is an excellent example of the mutual benefits that can flow from the integration of conservation and tourism development.

CALM's principal role in whale shark interaction is to manage and regulate the commercial and recreational activities of visitors. However, the level of exploitation of whale sharks associated with this activity requires that a Wildlife Management Program be developed and implemented specifically to ensure that CALM's conservation objective is achieved along with management objectives to promote and facilitate this form of nature-based tourism. This Management Program provides a statement of the administrative, compliance auditing, and research and monitoring measures to be followed to ensure that human/whale shark interactions in marine reserves, with particular reference to the Ningaloo Marine Park, is a sustainable activity that assists CALM in meeting both its conservation and recreation objectives.

2.4 Relevant legislation

CALM administers both the CALM Act and the Wildlife Conservation Act and respective subsidiary legislation. In relation to the management of whale shark interaction in marine reserves, several aspects of this legislation are relevant.

- Whale sharks are wholly protected fauna within all State waters, under the Wildlife Conservation Act.

- Use of marine reserves, including the activities of visitors, is subject to the provisions of the CALM Act and its subsidiary legislation, including the *CALM Regulations 1992* and the *National Parks Authority Regulations*. The CALM Regulations require that commercial activities occurring within conservation reserves (including marine parks and marine nature reserves) be licensed and subject to appropriate terms and conditions.

- The operational 'code of conduct' developed, in consultation with the industry, for the commercial activity licences in the Ningaloo Marine Park is in part also applicable to all other persons who wish to approach whale sharks, by way of the *Wildlife Conservation (Close Season for Whale Sharks) Notice 1996* made under the Wildlife Conservation Act. This notice (Appendix 1) applies to the control of activities of private vessels and swimmers or divers in the proximity of whale sharks, anywhere in State waters, and at any time of the year. It also applies to the control of activities of unlicensed, private vessel operators who wish to participate in whale shark interactions in marine reserves.

Whale sharks are listed as totally protected fish under Regulation 10 of the *Fish Resources Management Regulations 1995* and as such are protected from commercial and recreational fishing under section 46 of the *Fish Resources Management Act 1994* (FRM Act). The FRM Act also allows for the provision of regulations to license *"..persons engaged in aquatic ecotourism for a commercial purpose.."* (section 257(1)(g)). In addition, section 258(w) allows for regulations to "..regulate aquatic ecotourism and other activities that might disturb fish. However, in the event of conflict or inconsistency between the CALM and FRM Acts in a marine reserve, the CALM Act defers to the FRM Act only in relation to commercial and recreational fishing (section 13(3)). The definition of fishing is clearly aimed at activities related to the taking of fish and is separate to aquatic nature-based tourism. Recreational and commercial tourism activities involving human interaction with whale sharks within marine reserves must be managed in accordance with the provisions of the CALM Act.

The *Ningaloo Marine Park Management Plan 1989-1999* (CALM, 1989) became operative on 24 November 1989. The management plan allows for the granting of commercial concessions, consistent with the purpose of the park, for the "..provision of appropriate facilities and services for visitors' use and enjoyment" subject to Departmental policy on commercial concessions (p.29). Currently, whale sharks are not listed as a 'protected animal' under Schedule 1 of the Commonwealth *National Parks and Wildlife Regulations* and therefore have no statutory protection in Commonwealth waters of the Ningaloo Marine Park, other than that provided under the State *Fish Resources Management Regulations 1995*.

2.5 Management objectives

Within the broad conservation and recreation objectives described in section 2.3, CALM has several specific objectives in relation to management of whale shark interactions in marine reserves. From a conservation perspective the primary objective is:

- **to conserve whale shark populations by ensuring that individual sharks, or the group as a whole, are not being subjected to an unacceptable level of disturbance.**

What constitutes an 'unacceptable level of disturbance'? Ecologically, it would be one that significantly changes the normal behavioural patterns of individuals, or the local population, in a way which affects their natural function in the marine environment or which might deter them from returning to a particular location on a seasonal basis. Therefore, management of the interaction must aim to maintain the current population structure and retain population size at least at existing levels.

From a recreation perspective the primary objective is:

- **to facilitate the development of ecologically sustainable whale shark tourism in marine reserves.**

These two primary objectives must be addressed through the development and implementation of a management program. A set of additional objectives must also be considered in the development of management controls. Other factors influencing management include public perceptions, local economic needs, practicability of rules governing the interaction, and the ethics of human interactions with animals. From a human perspective, it is important that the whale sharks continue to visit the Ningaloo Marine Park annually because an increasing number of people are participating in a high quality nature-based tourism experience that has both social and economic benefits. These additional objectives are:

- **to facilitate safe interaction between people and whale sharks by allowing reasonable access within an appropriate 'duty of care';**
- **to raise public awareness and appreciation of whale sharks and broader marine conservation issues;**

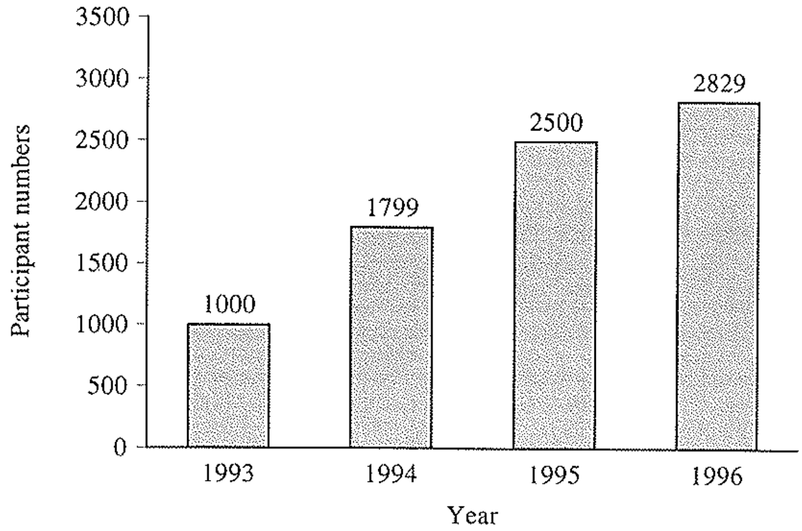
- **to develop and implement a management framework that provides equitable opportunities for commercial operators to deliver a quality experience;**
- **to ensure that whale shark interaction does not adversely impact on other values and users of marine reserves; and**
- **to recoup the costs of managing the interaction, whenever possible and appropriate, from the commercial operators, according to the 'user pays' principle.**

2.6 Development of management controls

Whale shark interaction tours have been operating in the Ningaloo Marine Park since 1989, and until 1992 the scale of these activities was relatively small. By 1993, increased national and international publicity through a series of magazine articles and television documentaries had caused a significant growth of public and commercial interest in diving and snorkelling with these animals. As commercial interaction tours began to develop within the Ningaloo Marine Park it became apparent that whale sharks were becoming the target of considerable tourism interest.

The significance of the whale shark to the conservation objectives of the Ningaloo Marine Park was recognised in CALM's management plan for the State waters of the Park (CALM, 1989), and in the ANPWS management plan for Commonwealth waters of the Park (ANPWS, 1990). However, both of these management plans were developed and implemented before the expansion of commercial tours. Given the increase in whale shark tourism that occurred after 1992, CALM had a clear responsibility to ensure that this nature-based tourist activity was being managed equitably and sustainably. Accordingly, prior to the 1993 season, CALM initiated a trial system of management controls for commercial whale shark interactions. These controls included the licensing, under the Wildlife Conservation Act, of all existing charter vessels operating whale shark tours within the Ningaloo Marine Park. Interim interaction guidelines, developed in consultation with the industry, were implemented to try and minimise any potential negative impacts of the interaction (Appendix II). The industry has expanded steadily since 1993. Figure 2 shows an almost threefold increase in participants in whale shark tours from 1993-1996.

Figure 2: Number of participants in whale shark interaction tours, 1993-1996



(These figures, obtained from CALM records and log book returns provided by the commercial operators, represent cumulative totals of paying passengers, rather than the number of different individuals, as a number of people will have participated on more than one day.)

This rate of growth raises a number of concerns from both conservation and management perspectives. The 'carrying capacity' of this industry is currently unknown and will depend on a thorough understanding of the interaction and the management strategies employed. Impacts of the interaction could possibly include interference with some primary behavioural activity, such as feeding or breeding. Long-term impacts could include habituation to swimmers and vessels. This could result in the animals becoming more vulnerable in areas where they are still actively fished, and also more likely to sustain injuries from being accidentally struck by vessels.

Effective decisions concerning the sustainable management of whale shark tourism need, where possible, to be based on good scientific knowledge, including an adequate understanding of the biology, population dynamics, and ecology of the species. Yet there is currently little known about whale shark population size, distribution and movement patterns, either off Ningaloo Reef or elsewhere in Western Australian waters. The reasons for the aggregation are not yet fully understood and no data are available on movements of the sharks from July to February.

2.7 Licensing of commercial operators

In August 1993, regulations requiring the licensing of all commercial activities within marine reserves came into force. Consequently, prior to the 1994 season whale shark tour operators were issued with commercial tourism licences under the CALM Act. The subsequent development of the licensing structure is shown in Table 1.

Table 1: Licensing of commercial whale shark interactions, 1993-1996

Year	Licensing Structure	Duration of Licences	Licence Charges	Number of Licences
1993	Interaction licences issued for charter vessels, under the *Wildlife Conservation Act 1950.*	12 months, with review after the season.	No fee charged.	16.
1994	Commercial tourism licences issued for charter operators, under the *CALM Act 1984.*	12 months, with review after the season.	Per head/per day charge of $10.	15.
1995	Commercial tourism licences issued for charter operators, under the *CALM Act 1984.* Single vessel per licence.	36 months for northern waters licences, with review after 1997 season. 12 months for southern waters 'developmental' licences.	Per head/per day charge of $15 for adults, $7.50 for children. Pre-season deposit of $750.	15 in total, 13 for northern waters, 2 for southern waters.
1996	Commercial tourism licences issued for charter operators, under the *CALM Act 1984.* Single vessel per licence.	24 months for northern waters licences, with review after 1997 season. 12 months for southern waters 'developmental' licences.	Per head/per day charge of $15 for adults, $7.50 for children. Pre-season deposit of $750.	14 in total, 13 for northern waters, 1 for southern waters.

Prior to the 1995 season, 13 licences were granted for operators to conduct commercial whale shark tours in State waters of the Ningaloo Marine Park north of Point Cloates (Figure 1). These licences expire in December 1997. Two 12 month 'developmental' licences were granted for whale shark tours in State waters of the marine park south of Point Cloates. Before the start of the 1996 season one of these southern waters licences was not renewed, because it was not used during 1995 (a condition of the licence). The second was renewed for a further 12 months.

All whale shark interaction licences are issued as Commercial Tourist Activity Licences under section 101 of the CALM Act and Part V of the CALM Regulations. The licence schedule and conditions, including the code of conduct, are included in Appendix II. Key points of the licensing system are:

- Licences are 'E' Class, issued when there are environmental and/or management reasons for limiting tourist activities.
- Licences are issued to individuals and not for separate charter vessels.
- Licence holders must nominate a primary vessel and a substitute vessel for whale shark tours.
- Only one vessel may be used per licence at any one time.
- Licence holders must abide by the conditions and restrictions contained in the licence schedule, including a code of conduct for interactions with whale sharks.
- Licence holders must indemnify CALM from claims arising from tour activities and carry a minimum of $5 million public liability insurance cover.
- Licence holders must maintain a daily record of all whale shark encounters on log sheets provided by CALM.
- Licence holders must make available a position on their vessel for a CALM officer to monitor licence activities.
- 'E' Class licence charges are linked directly to the level of activity of the licence.
- Current charges are $15.00 per adult/day ($7.50 per child/day) for all paying passengers carried during the season.
- An annual (non-refundable) deposit of $750.00 on these charges must be paid prior to commencing whale shark tours.
- Paying passengers must be issued with a "Whale Shark Experience Pass" provided by CALM.
- Licences not used during the season may be cancelled.
- Licences are not transferable.
- On expiry the current licences will not be automatically renewed. Licence renewals will be part of a competitive licensing system for eligible operators.

2.7.1 Licence renewals

Licences for the northern waters of the park are current to 31 December 1997. The single licence for the southern waters expired in December 1996 and was renewed prior to the 1997 season. All current commercial licences for whale shark interaction will be renewed for 12 months to 31 December 1998 to provide some stability for the existing licence holders in their planning and marketing for the 1998 season. To coincide with this rollover a competitive application process, through formal Expressions of Interest, will be initiated and new licences for 1999 and beyond will be issued prior to the end of 1997. Given both the time required to obtain more information from research and monitoring studies and the need to provide some stability for the commercial operators, a period of 5 years is appropriate for the new licences issued under the Expressions of Interest system.

The selection criteria used during this renewal process will relate to:

- skills and experience in relation to the provision of marine nature-based tours;
- suitability of vessel and other equipment;

- knowledge and understanding of local conditions, environmental processes and management objectives;
- commitment to the provision of quality visitor services; and
- the capacity and willingness to operate within specified codes of conduct appropriate to activities in a protected area.

2.7.2 Licence numbers

The number of licences issued under the Expressions of Interest process will remain at the 1995 level of 15 licences, 13 for the northern waters and 2 for the southern waters. The demand for whale shark interaction licences over and above the existing 14 licences is currently high. Despite this demand, CALM has not added to the number of existing licences to operate whale shark tours in the Marine Park since 1994. Presently, there is no information as to whether the interaction pressure resulting from 14 licences is ecologically sustainable in the long-term. A comprehensive and sustained research and monitoring program is required to determine inter-annual natural variability in the population and whether seasonal fluctuations in whale shark numbers are linked to environmental changes or to increasing tourism pressure. Until there is a better understanding of the effects of the current level of activity on whale sharks, a cautious approach is required in relation to expansion of the industry. The welfare of the whale sharks and the provision of tourism opportunities for the current commercial operators are high priorities. Therefore, the limit on licence numbers is appropriate, and licence numbers will be reviewed, in consultation with the industry, as more information becomes available from research and monitoring studies. The re-issuing of a second licence in the southern waters will assist in the gathering of further information on the abundance, distribution and behaviour of whale sharks in the southern waters of the park.

2.7.3 Licence geographical boundaries

The presence and distribution patterns of whale sharks in the southern parts of Ningaloo Reef are not presently known. In view of the absence of survey data for this area, it had been assumed that there would be substantial similarities between the occurrence of whale sharks in the northern waters around Tantabiddi and their occurrence in the southern areas. Data obtained from one of the two developmental licence holders at Coral Bay suggests that there are marked differences between the southern and northern areas in terms of whale shark occurrence and distribution. The majority of encounters in the southern waters of the marine park appear to occur in a limited area between Point Maud and Point Cloates, usually during May each year. Further data, from aerial surveys and operator interaction records, are required before the potential for any substantial expansion of the industry out of Coral Bay can be determined. Any expansion should be accompanied by increased research and monitoring to determine the spatial and temporal extent of whale shark occurrences.

The geographical boundary for interaction licences was set at Point Cloates on an arbitrary basis and there is currently no justification for this to remain. The prescriptions of both northern and southern waters licences will be altered to remove this restriction, but the point of origin for licensed vessels conducting whale shark interaction tours will remain as Tantabiddi for the 13 northern licences and as Coral Bay for southern waters licences. This will enable licensed live-aboard vessels to interact with any whale sharks they encounter outside of the existing boundary imposed by the licences, should they wish to do so. It will also facilitate the gathering of additional data in the area between Yardie Creek and Point Cloates, an area where currently there is little information on whale shark numbers and distribution patterns throughout the season.

2.7.4 Licence charges

Revenue from 'E' Class licences is used to contribute to management costs, including those resulting from compliance auditing and research and monitoring associated with the licensed activity. The purpose of the levy charged by CALM is made transparent to participants through the issuing of the souvenir quality experience pass. Given the limited scale of whale shark interaction activities at Ningaloo, restricted by the remote location of the event, the licensing structure and the length of the season, it is apparent that the revenue generated from current licence charges is insufficient to wholly fund either short, or medium to long-term research and monitoring. If the extensive funding required for research and monitoring is not available from other sources an increase in licence charges may need be considered. Licence charges will remain at the current level until 31 December 1998, and will be reviewed annually from 1999 onwards.

Management actions

- *All current commercial licences for whale shark interaction in the Ningaloo Marine Park will be renewed for 12 months to 31 December 1998.*

- *Licence renewals will be part of a competitive licensing system for eligible operators.*

- *The competitive application process for new licences for 1999 and beyond will commence during 1997.*

- *Five year licences will be issued by 31 December 1997.*

- *An increase in licence numbers will not be considered until more information is available from research and monitoring studies.*

- *The geographical boundary on existing whale shark interaction licences, currently set at Point Cloates, will be removed.*

- *The licence charges will remain at $15.00 per adult/day, and $7.50 per child/day, until the current licences expire.*

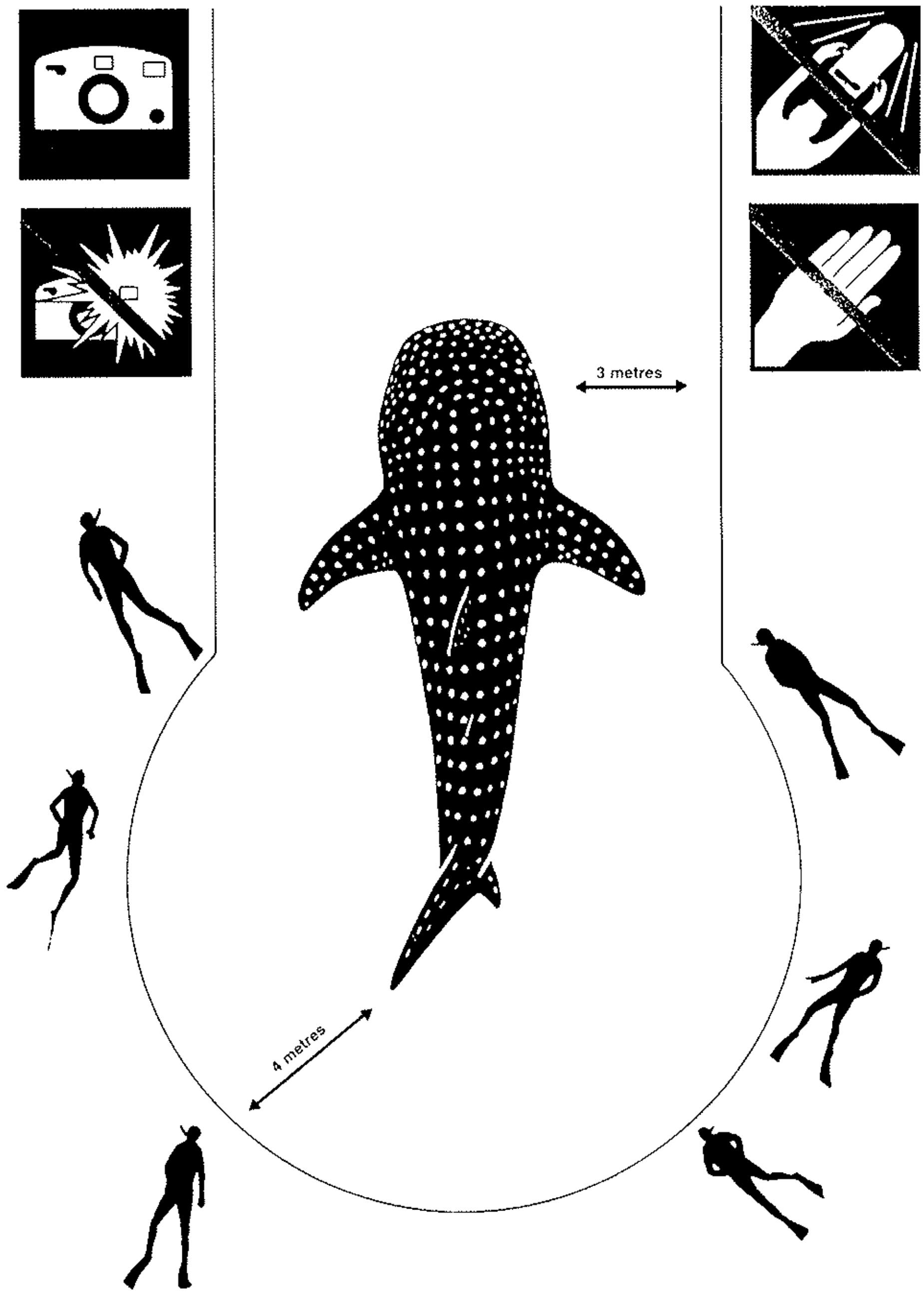
- *Licence charges will be reviewed annually from 1999 onwards.*

2.8 Industry code of conduct

Licence holders are required to abide by a set of interaction rules when conducting their whale shark tours. This code of conduct (Appendix II), banning touching and riding of whale sharks and governing minimum separation distances and maximum number of swimmers, was developed by CALM in consultation with the industry and represents a set of initial rules for vessel operators and swimmers when interacting with the animals. These rules were based on available knowledge, common sense and national whale watching guidelines (ANPWS, 1988). They are designed to be adjusted when additional information becomes available.

From experiential studies of participants (Birtles *et al.*, 1996; Davis & Tisdell, in press) it is apparent that the issues of crowding, number of people in the water and separation distance from the sharks are particularly important in relation to the quality of the in-water experience. Concerns about the maximum number of swimmers permitted in proximity to a whale shark were expressed following the 1995 season. Accordingly, CALM suggested a reduction from 10 to 8, but this was strongly resisted by the industry on commercial grounds. Further consultation with the industry and the results of the 1995 participant survey led to the decision to revise the minimum swimmer/shark separation distance. Originally, the code of conduct required swimmers in the contact zone to stay one metre from the head or body of the shark. Prior to the 1996 season this was altered to three metres from the head or body and four metres from the tail (Figure 3). It was considered that this may benefit both

Department of Conservation and Land Management



Swimming with Whale Sharks – The Code of Conduct

To ensure that you have a safe, enjoyable experience and to prevent the animals from being harmed or disturbed, the following code of conduct applies when interacting with whale sharks:

Swimmers and Divers must not:

- attempt to touch or ride on a whale shark
- restrict the normal movement or behaviour of the shark
- approach closer than 3 metres from the head or body and 4 metres from the tail
- undertake flash photography
- use motorised propulsion

Figure 3: Code of conduct for swimmers

sharks and people alike, by reducing crowding and minimising the risk of accidental contact with the sharks.

The number of swimmers actually in the water with the sharks at any one time is a measure of tourism 'pressure'. The number of people swimming with the sharks has increased each year since 1993 (Figure 2). This means that the operators, within the existing restricted licensing system, have to carry more passengers to cope with the increased 'demand'. Any reduction in the maximum number allowed in the water with a shark at any one time will result in fewer people having the opportunity to swim with the sharks. This would then increase the demand for more licences to be granted. Additional vessels could result in increased disturbance, with an increase in the daily frequency of contact between swimmers and individual sharks, especially on days when whale shark numbers are low. Therefore, maximum number of swimmers permitted in proximity to a whale shark at any one time will remain at 10, until a better understanding of the human/shark interaction exists.

Although the use of SCUBA equipment is currently permitted under the code of conduct, the majority of human/whale shark interaction involves snorkellers rather than divers. Divers often have difficulty keeping up with a fast-swimming shark, making it hard for vessel crews to maintain contact with all the people in a group. There is anecdotal evidence that some individual sharks react adversely when encountering divers on SCUBA, particularly when divers are positioned directly beneath the shark. On some occasions sharks will dive or change direction to actively avoid divers and their exhaust bubbles. A number of operators currently offer whale shark tours with SCUBA, and this option is particularly utilised by photographers keen to get good stills and video footage. Data from future research may indicate whether the use of SCUBA is having a significant impact on the behaviour of individual sharks. If the level of disturbance is determined to be unacceptable, then the code of conduct will be modified to restrict or ban the use of SCUBA for whale shark interaction in the Ningaloo Marine Park.

Licence conditions and the *Wildlife Conservation (Close Season for Whale Sharks) Notice* currently prohibit the use of underwater scooters for all whale shark interactions. Following discussions between CALM and the industry it was recognised that controlled use of scooters is justified to allow disabled access. It is expected that this will only occur on a few occasions throughout a season, and each case is to be assessed on its own merits by the CALM District Manager in Exmouth. Prior written approval is required, with this being given only on medical grounds following an application made at least 24 hours before the event. Procedures and conditions for scooter use will be formulated, to address possible disturbance to the sharks, visitor experience, management enforceability and safety. Conditions of use for underwater scooters, to allow disabled access, will be formulated by CALM , in consultation with the industry, as soon as is practicable.

Commercial whale shark tourism involves dropping generally inexperienced or novice snorkellers, from all age groups and fitness levels, into the potentially hazardous open waters of the reef front. Although CALM has a 'duty of care' in relation to the personal safety of visitors to the Marine Park, primary responsibility for safety of all vessels and people in State waters lies with the Department of Transport (DOT), and with the commercial operators as providers of the tourist activity. Licence holders are required to indemnify CALM from claims arising from whale shark tours and to carry public liability insurance with coverage for the Executive Director. With increasing numbers of people participating in this activity a number of safety issues should be reviewed by the DOT and CALM, in consultation with the industry. These include:

- the use of swimmer check lists;
- escorting of swimmers by qualified staff;
- the wearing of some form of high visibility device by all swimmers;
- drop-off and retrieval of swimmers from both large and small charter vessels; and
- the presence of large tiger sharks in reef front waters.

Interpretive and educational material are a key means of informing participants of the requirements of the code of conduct. Currently, only a limited amount of interpretive and educational material is available on the whale shark phenomenon at Ningaloo Reef, and the interaction industry that has developed around it. Material produced by CALM consists of an operator log book, an information pamphlet (CALM, 1996) and souvenir quality ticket for customers of commercial whale shark tours, Ningaloo Marine Park Notes on whale sharks and a Landscope article (Thomson & Stevens, 1994). The operators have also been supplied with a booklet summarising some of the information available on whale sharks and giving details of the research work carried out at Ningaloo prior to the 1995 season (CALM, 1995). Other material readily available to participants in the industry is a book written by Geoff Taylor on his experiences with whale sharks at Ningaloo Reef over 12 years (Taylor, 1994), and a pictorial souvenir booklet (Aw, 1996). Additional whale shark interpretive/educational material is required to:

- enhance the experience of people interacting with whale sharks by increasing their knowledge and sense of involvement;
- prevent unnecessary harassment of the sharks by ensuring that people are aware of the requirements of the interaction code and of the possible detrimental impacts of touching or crowding the animals;
- provide an accurate, concise and up-to-date summary of the information available globally about whale sharks;
- inform the public of CALM's responsibilities, the conservation and management strategies, and the research and monitoring being undertaken to ensure a sustainable future for the industry; and
- provide material that the commercial operators can utilise to improve the quality of pre-dive briefings, and to enhance their marketing and advertising efforts in developing the industry.

Further Landscope articles would serve to address the same objectives, but could also inform the public about current and future research and monitoring studies. Educational/interpretive material of this type could also be included in a newsletter containing visitor information on all aspects of the parks of the North West Cape.

Management actions

- *A review of the code of conduct will be carried out by CALM, as soon as is practicable.*

- *Safety issues related to the interaction will be reviewed by the Department of Transport and CALM, in consultation with the industry.*

- *Additional whale shark interpretive/educational material will be produced by CALM, as soon as is practicable.*

2.9 Compliance monitoring

2.9.1 On-water surveillance

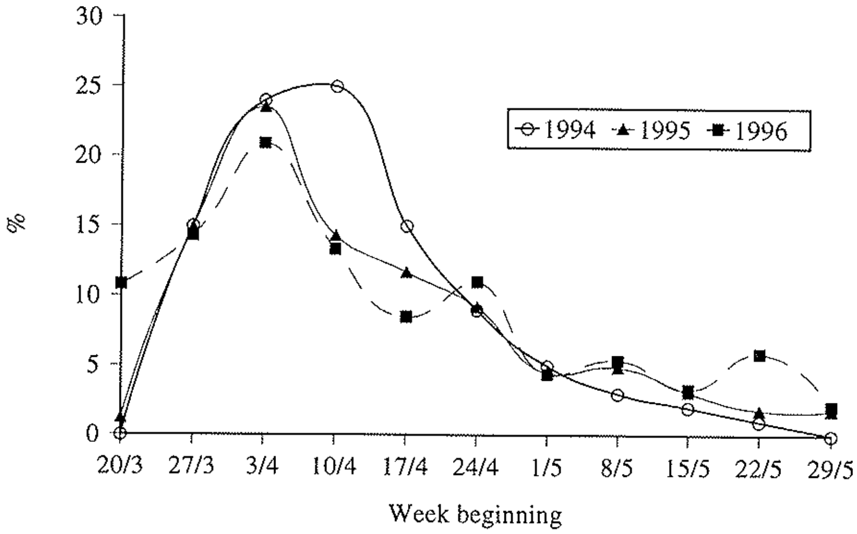
Regulatory surveillance of the on-water activities of commercial and private operators is carried out by CALM Wildlife Officers, using the Department's patrol vessel *Pseudorca II*, and by CALM Exmouth District staff. Australian Nature Conservation Agency (ANCA) officers and suitably qualified volunteers also assist in manning the vessel. In 1995, this surveillance spanned a period of 9 weeks during the season, and this was extended to a 12 week period during the 1996 season. This surveillance is to ensure compliance with the licence conditions. It also assists operators in meeting their obligations and ensures that private operators are complying with the requirements of the

Wildlife Conservation (Close Season for Whale Sharks) Notice. Wildlife Officers have, as an alternative to boat patrols, undertaken opportunistic aerial surveillance of the interaction from industry spotter planes, through the co-operation of Exmouth Air Charter, the company providing spotter planes to the commercial operators.

Patrol vessel-based surveillance of the whale shark industry is used to ascertain whether operators are complying with the requirements of the licence conditions, such as the minimum vessel to shark distance of 30 m and a maximum of 10 people in the water at any one time. CALM officers on the patrol vessel ensure that only one vessel is in contact with a shark at a time, particularly on days when vessel to shark ratios are high. On-water patrolling is currently interspersed with periodic aerial surveillance from industry spotter planes, and with days spent accompanying operators on board their vessels. More effective compliance auditing may be achieved by increasing the frequency of these alternative surveillance methods, in conjunction with continued use of a dedicated patrol vessel. Additionally, consideration will be given to periodic aerial surveillance using a dedicated CALM aircraft. There will be an increase in the number of days on which CALM officers, or trained volunteers, accompany commercial whale shark tours for observation of in-water activities, and to check whether passengers have been issued with experience passes.

Given that the duration of the season is usually from late March to mid May (Figure 4) compliance monitoring will be managed to effectively and efficiently cover the peak and 'shoulder' periods, employing Perth-based staff, Exmouth District staff and appropriate support from Regional staff and trained volunteers.

Figure 4: Weekly percentages of total encounters with whale sharks, 1994-1996



(These data were obtained from log book returns provided by the commercial operators.)

2.9.2 Industry self-regulation

Strategies to promote more industry self-regulation should be investigated. However, a cautious approach is needed in the development of self-regulation to ensure that equitable use of the resource is not compromised. Operators will be encouraged to make more use of appropriately trained in-water spotters, to ensure better compliance with the code of conduct. It is the responsibility of the operators to ensure that the in-water activities of swimmers comply with the interaction code. The requirements of the code are relayed to participants through pre-dive briefings given by the operators and through the distribution of CALM's information pamphlet (CALM, 1996) which provides details of the in-water separation distances and the 'no touching' rule. CALM has provided laminated posters, in English and Japanese, depicting the code of conduct requirements for swimmers, for use in these briefings (Figure 3). The frequency and quality of these pre-dive briefings varies and operators need to be made aware of the importance of providing a thorough explanation of the code of conduct requirements to their customers prior to commencing operations. The introduction of post-tour customer interviews by CALM staff will be assessed.

It is apparent that some individual vessels carry up to 20 passengers and repeatedly drop and rotate smaller groups (4-6) of swimmers, accompanied by an in-water spotter, whilst in contact with a whale shark. This undoubtedly improves quality of experience and customer satisfaction, ensures better code of conduct compliance and could also improve swimmer safety. This has been shown to work within the existing licence conditions, as long as operators are professional and properly staffed.

The industry will also be encouraged to improve the quality of log book returns, which should include formalised recording of practices such as 'hand-balling' of the same shark from vessel to vessel. Licence holders will be reminded that compliance with licence conditions, including the requirement to regularly submit accurate records of their commercial operations, are likely to be important criteria in approval of any future licence applications under a competitive application process. The industry should also continue to take an active role in the review and alteration of the code of conduct, through the proposed Whale Shark Management Advisory Committee (see section 4.2). A carefully developed blend of compliance monitoring and industry self-regulation will ensure an efficient and cost-effective management of the interaction.

2.9.3 Operator log book

A formal licence holder's log book scheme was initiated during the 1995 season. Using daily log sheets operators are required to maintain a record of encounters with sharks whilst they are engaged in commercial whale shark tours in Ningaloo Marine Park. By recording the date, time and location of encounters, and some details of the individual sharks such as size, sex, distinguishing features and behaviour, the industry can assist in the collection of useful observational and management data. Log book records have limitations in deriving valid scientific data, as a result of factors such as:

- the subjective nature of some of the recorded information;
- the use of untrained observers to gather data; and
- the variable accuracy/quality of log sheet returns.

However, log book data, particularly if validated by information from aerial surveys, can indicate the current level of interaction activity by recording the daily number of encounters and the numbers of vessels and people participating in whale shark tours. These data provide information on the status of the industry and any seasonal fluctuations and also provides essential feedback to the commercial operators. Observations of behaviours recorded on the log sheets also assist in identifying any long-term changes in the reactions of whale sharks when approached by vessels and swimmers.

The licence holder log books were extensively redesigned prior to the 1996 season, in an effort to improve the quality and quantity of recorded information, whilst also ensuring that the record sheets are relatively straightforward to complete. The new log sheets (Figure 5) include sections for the recording of GPS co-ordinates for each whale shark encounter. Positional data from the log sheets will facilitate more accurate spatial representation of encounters on a daily, weekly and monthly basis. Collation of these data through a GIS database will enable CALM to prepare data maps showing the spatial and temporal shifts in encounters along the reef front throughout the season. The distribution of encounters at the northern end of the Ningaloo Marine Park for the 1996 season is shown in Figure 6. The operators are required, wherever possible, to record GPS co-ordinates for whale shark

WSL 1099

CALM WHALE SHARK INTERACTION LOG

Date

Vessel	Start time		
Recorder	Finish time		

Number of Passengers	Paying		Other
	Adults	Children	(F.O.C.)

Whale Shark Experience Pass	Pass Numbers	
	From	To

Contact number	Contact time		Position				Shark observations				Number of swimmers	Dive quality
	Start	Total	Sector	Latitude	Longitude	Water depth	Size	Sex	Heading	Behaviour		

Distinguishing features:

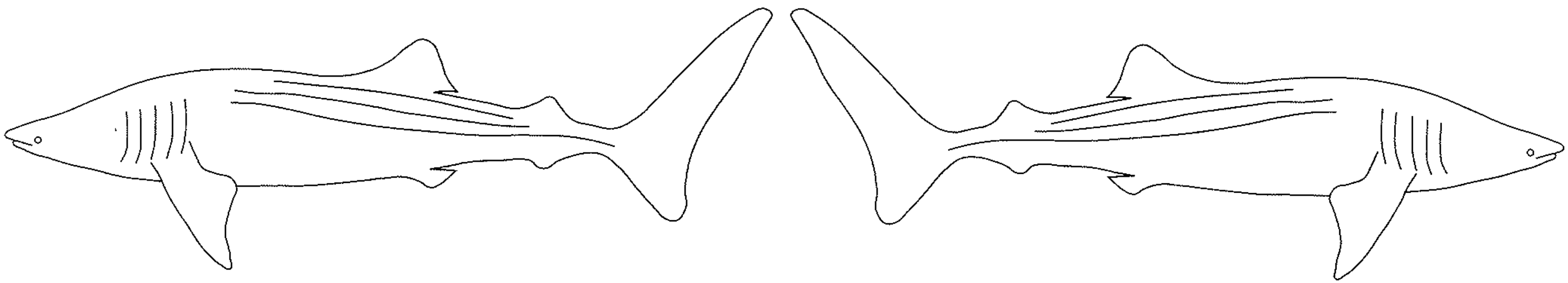


Figure 5: Whale shark interaction log sheet

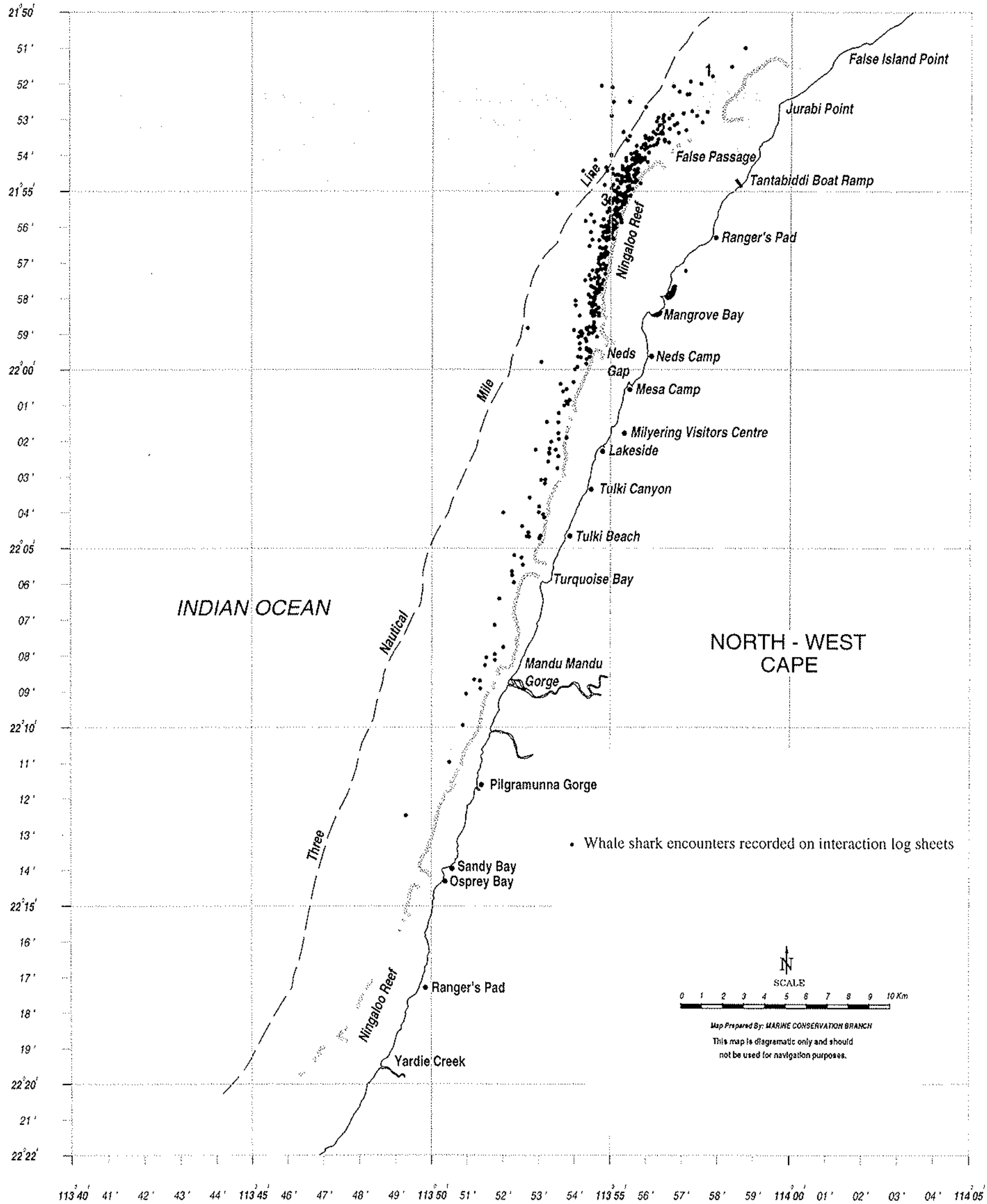


Figure 6: Distribution of whale shark encounters in the northern area of Ningaloo Marine Park during the 1996 season

encounters as the data provide important management information to CALM and valuable feedback to the industry.

Log sheets provide data on the number of days each licence holder has been operating commercial whale shark tours, and the number of paying passengers carried. Auditing of log sheets and passenger tickets provides the means to calculate licence charges due from each operator. Reconciliation of returned log sheets, experience pass ticket stubs and unused ticket books and cross-checks with observations from both on-water and aerial surveillance provides feedback on the accuracy of individual operator's records - i.e. has an operator been out on a particular day carrying paying passengers for whale shark tours and failed to fill out a log sheet or issue experience passes? In order to avoid any loss of important management data and licence revenue a co-ordinated and streamlined compliance auditing records system will be developed for cross-checking of on-water/aerial observations with log sheets submitted by operators.

Management actions

- *The frequency of each of the available surveillance methods will be manipulated to provide the most efficient and effective combination for monitoring compliance.*

- *Periodic aerial surveillance will be undertaken using an aircraft dedicated to compliance monitoring.*

- *Sufficient Exmouth District and Pilbara Regional staff and resources will be allocated to ensure effective and efficient compliance monitoring during peak and shoulder periods of the season.*

- *A co-ordinated compliance monitoring records system will be developed.*

- *Strategies to facilitate greater industry self-regulation will be investigated, in consultation with the industry.*

3. RESEARCH AND MONITORING

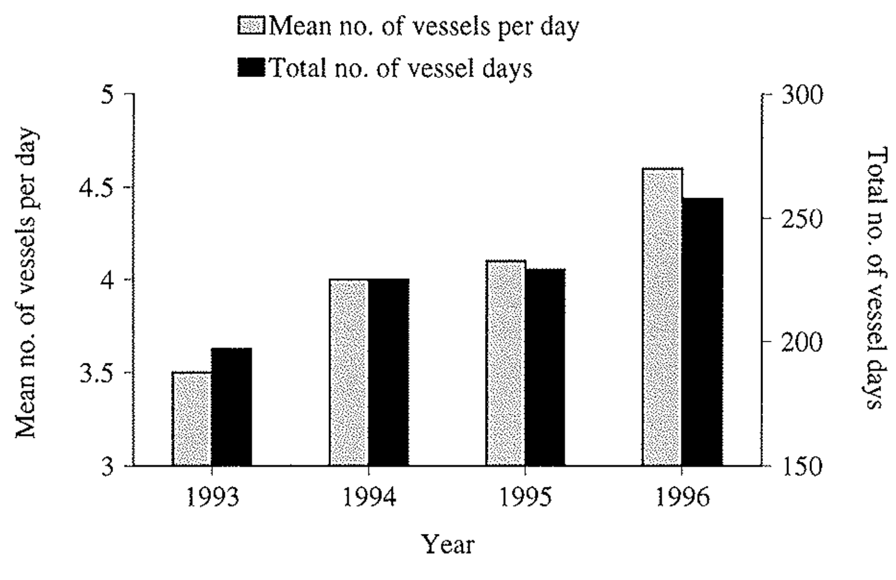
The accessibility of the seasonal aggregation of whale sharks at Ningaloo Reef provides an excellent opportunity for researchers to undertake studies of this rarely encountered and poorly understood shark. Initial research efforts lacked clearly defined objectives and were often hampered by limited scientific knowledge and resources. Dedicated and sustained research of whale shark biology and ecology should seek to provide information to managers in order to minimise possible detrimental impacts of tourism pressure. As suggested by Wolfson (1986), researchers studying whale sharks should "move beyond the purely descriptive natural history approach and design and implement sustained programs of investigation, using the most advanced equipment and techniques that are amenable to statistical treatment."

In developing a scientifically objective research and monitoring program, there are a number of factors to be considered, including ethical, technical and logistical issues. Research should be of a non-invasive nature if at all possible, and must not cause the animals unnecessary stress. The large size, free-swimming epi-pelagic nature, and sporadic appearance of whale sharks makes study of these animals intrinsically difficult and creates numerous technical and methodological problems. As has been seen with cetacean research, the time required and complexity of programs examining any large marine animal have to be considered at the design stage. There are problems in initiating further research in an area where a whale shark watching industry is already in place. Attempts to investigate the population size and structure may suffer from sample size and range problems. Serious population studies require large sample sizes and this is a major problem when working with rarely encountered species, especially if individuals cannot be captured or restrained. Accurate morphometric data and samples for age/growth determination (such as vertebral centra) can usually only be obtained from restrained or dead animals. Research and monitoring studies must be properly designed and have access to the necessary resources to ensure that their objectives are achieved.

3.1 Objectives

Whale sharks within the Ningaloo Marine Park are being exposed to increasing pressure from commercial tourism. A comparison of mean number of vessels operating per day and total number of vessel days for an 8 week period from the last 4 seasons (Figure 7) reveals this upward trend. It follows that in seasons when there are fewer sharks present on the reef front the level of pressure on individual animals will increase sharply. Whether this increased pressure will have any detrimental impacts on individual sharks or on the group as a whole is not currently known. In the short-term, there could be changes in behaviour. If the area is important for some primary activity, such as feeding or breeding, this could have a significant impact on movement patterns and population dynamics of the species. Currently there is no information upon which to judge sustainability of the present level of use, or to regulate the intensity and nature of contact relative to the proportion of the population accessible for tourism. It is impossible to predict the numbers of whale sharks in this area from year to year, a factor important for industry planning and customer satisfaction. Until more information is available from research and monitoring studies about possible impacts, a precautionary approach to management must be adopted.

Figure 7: Mean number of vessels operating per day and total number of vessel days for the same 8 week period, 1993-1996



(These data were obtained from CALM records and log book returns provided by the commercial operators.)

Therefore, there is a requirement for further information from research and monitoring studies. These studies should have the following objectives:

- **to provide baseline information on the natural spatial and temporal variability in whale shark numbers;**
- **to identify links between seasonal changes in physical and biological parameters and inter-annual population variability;**

- **to provide baseline information on whale shark behaviour and movement patterns;**
- **to monitor the levels of tourism pressure and to establish what proportion of the whale shark population at Ningaloo Reef is subject to this pressure;**
- **to determine whether increased tourism pressure causes any short or long-term impacts; and**
- **to determine factors affecting participant in-water behaviour and quality of experience.**

Short and long-term studies addressing these objectives should, if properly designed, provide information that can be used to determine whether the initial controls on the interaction in the Ningaloo Marine Park are adequate, or if they require modification.

3.2 Population monitoring

A key factor in sustainable management of whale shark/human interactions is a clear understanding of the population dynamics of whale sharks. Until both intra- and inter-annual variability in abundance and distribution are known, it will be impossible to identify any long-term impacts. Therefore, monitoring studies have to establish an independent and repeatable series of population counts. Reliable estimates of whale shark population size at Ningaloo Reef are difficult to obtain. In the past there has been no standardised collection of data. If segregation by age occurs, which appears to be the case, sightings in the area are not a random sample of population. Habituation to boats may occur, which also negates random sampling. A sufficient sample size is also required. At present it is impossible to fix the spatial boundaries of the population, as there is no indication where the sharks may migrate.

3.2.1 Tagging

Conventional tag-recapture techniques have been utilised for studies of shark population size, age and growth, and migratory movements. These studies have been characterised by large numbers of individuals tagged, quite low percentage of returns, irregular return times, and often a lack of necessary information such as accurate measurements of returned individuals (Nelson, 1990). Tagging of this nature may be inappropriate for population monitoring of whale sharks at Ningaloo Reef, for the following reasons:

- a requirement for physical contact with as many individuals as possible;
- the difficulty of obtaining accurate measurements of the sharks;
- data on population size and individual returns can be obtained using non-invasive techniques such as aerial surveys and photo-identification; and
- data on migratory movements can be obtained from telemetry studies.

It could be difficult to initiate a large scale tagging program given the current level of commercial whale shark tourism. Dart tagging would have to be done either before swimmers were allowed in the water with a shark, which might react to the interference by diving and avoiding further contact, or alternatively after interactions were completed for the day. Tagging prior to allowing swimmers in the water with a shark could jeopardise a successful interaction or reduce the quality of the experience for paying passengers on commercial vessels, a very undesirable situation for the operators. Obtaining tag details from returns would require further disturbance - swimmers would have to approach the shark closer than the minimum separation distance laid down in the interaction code of conduct.

Whale shark tagging studies are being carried out by the Shark Research Institute in South Africa, Mozambique (A. Gifford, pers. comm.) and the Seychelles (D. Rowat, pers. comm.). These projects are being undertaken in association with selected commercial dive-boat operators who are taking people out to swim with the animals. The shark is first sexed, sized and then tagged before the tour party are allowed to swim with the animal. Further information from this study may reveal whether dart tagging compromises commercial interaction with whale sharks by reducing contact times.

3.2.2 Aerial surveys

Aerial surveys were conducted along Ningaloo Reef between February and May in 1990, 1991, and 1992. These observations were primarily aimed at identifying whale shark seasonality, and linking shark numbers, distribution and movements to coral spawning episodes (Taylor, 1996a).

During the 1994 season, whale shark and commercial operator vessel numbers at the northern end of the Ningaloo Marine Park were recorded by aerial survey (Osborne & Williams, 1995). This monitoring, conducted over a seven week period covering the peak of the season, collected data from area searches using the industry spotter planes. The objectives of this study were to estimate the availability of sharks within the area covered by commercial operations, and to measure the proportion of commercially available sharks potentially affected by human interaction.

The surveys were carried out using an area search technique. The commercial interaction area was divided into sectors which were periodically searched to record: (1) number of 'commercial' sharks (those in shallow enough water to be accessible to commercial tour vessels); (2) number of sharks in contact with vessels, and (3) the number of vessels not in contact with a shark. The index of resource size was then calculated as the average number of sharks per sector division and the index of industry pressure was stated as being equivalent to the proportion of sharks which were in contact with commercial vessels per sector division (Osborne & Williams, 1995).

This monitoring program showed that the industry is an efficient one - the use of spotter planes ensures that vessels have a high probability of locating and making contact with any sharks within the area of commercial operations. More importantly, it established some baseline values for the proportion of sharks actually in contact with commercial vessels, for both peak and shoulder periods of the season. These estimates of the proportion of whale sharks in contact with the commercial vessels provides a useful method of monitoring the scale and efficiency of the industry. This preliminary study indicates that aerial survey may be the most effective method to monitor resource size and industry pressure.

Unfortunately, as a result of a lack of reliable aerial survey data from the industry spotter planes in 1995, no meaningful comparisons can be made with the results of the 1994 preliminary study. Comparisons between commercial vessel log sheet returns and these data, for the same periods, show that the aerial returns often only represent between 10-35% of actual vessel activity. A significant proportion of the aerial sheets were often not completed until well after the actual flights, and data do not appear to have been provided for more than 50% of the spotter plane flights. The difficulties of recording consistent and accurate information have compromised the availability and standard of data obtained from the industry spotter planes.

Whilst the spotter planes may be a low cost option for obtaining data, independent observers are probably necessary to improve the accuracy of the data obtained from these flights. However, even if data recording is transferred from the pilot to an observer there are limitations in using the spotter planes to obtain data on shark abundance and contact rates. Given that CALM cannot regularly place observers into the aircraft that the industry charters for spotting whale sharks, data collection is sporadic. The use of a number of different observers, including CALM and ANCA staff and volunteers, results in variable data quality and makes quality control difficult. Observers sitting in the right-hand seat of the aircraft have a very restricted view as the pilot usually banks to the left-hand side to keep located sharks in view as he directs vessels in towards them. On days when the frequency of sharks in sectors close to the northern end of the reef is high spotter planes will often not be required to check sectors further south. Therefore, accurate data on the number of sharks available for interaction will not be obtained for those days.

A comprehensive and sustained aerial survey program needs to be initiated as a high priority. This should have two objectives:

- to monitor inter-annual spatial and temporal variability in whale shark numbers throughout the waters of the Marine Park; and
- to establish what proportion of the whale shark population at Ningaloo is subject to human interaction.

Independent aerial surveys would enable CALM to quantitatively monitor whale shark numbers and distribution from season to season, and to calculate periodic index values for both the proportion of the whale shark population subject to interaction pressure, and the level of tourism pressure by recording data on shark contact rates. It would also serve to confirm the accuracy of data collected from the commercial operator log book scheme. Aerial observation is also a possible method for monitoring any changes in behaviour of whale sharks due to the presence of vessels or swimmers. Behaviour prior to contact and any changes during and after contact, such as extended dive times, changes in swimming speed and direction, could be recorded by observers or possibly by using video cameras.

Survey design and field protocol of a comprehensive and sustained aerial survey to monitor whale shark population size and distribution have to be tested with a preliminary study, the design of which should incorporate standard guidelines for distance sampling techniques (Buckland *et al.*, 1993). This pilot study will establish appropriate spatial and temporal scales and examine the suitability of field methods and data handling techniques. Costs for a dedicated aerial survey of this nature are likely to be considerable.

There are indications from operator log sheet data of an increased number of encounters with whale sharks in the southern waters of the park, between Point Maud and Point Cloates, during May each year. This often coincides with a decrease in whale shark numbers at the northern end of the reef (CALM, unpublished data). Aerial surveys of the entire length of the reef should be undertaken at least twice a week during the peak and shoulder periods of the season. Outside the season a much lower frequency of flights would be required, perhaps one every 2-3 months. These flights could fulfil a number of other functions, including compliance monitoring and observations of other marine wildlife such as cetaceans, dugongs, turtles and tiger sharks. Once a long-term data set has been compiled, fluctuations in population size and distribution can be compared with, and perhaps correlated to, changing environmental parameters.

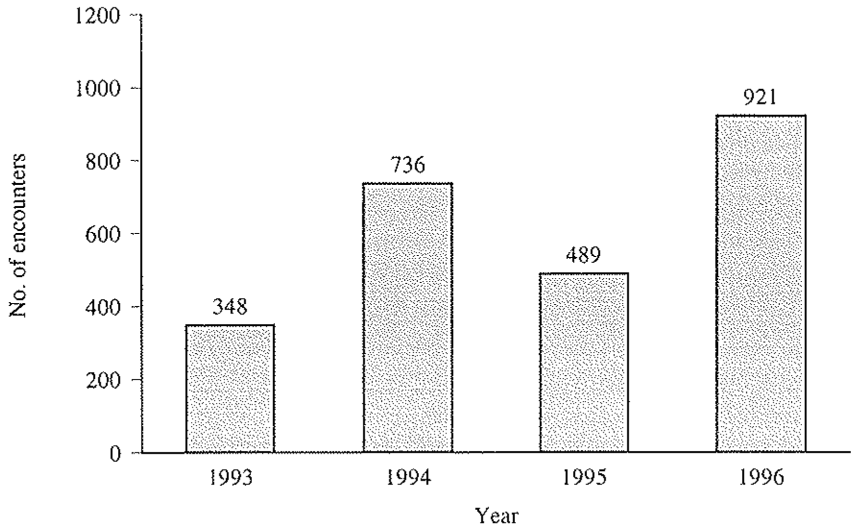
3.3 Environmental research

The significance of any changes in whale shark behaviour, abundance and distribution has to be examined. Are these changes a consequence of human interaction or are they natural fluctuations governed by variation in the animal's environment? There is a critical need to understand the reasons for the aggregation phenomenon at Ningaloo Reef. Monitoring of environmental parameters is very important, especially given the complexity of processes in marine ecosystems, and the lack of information about natural variability in the waters between the reef front and the continental slope.

There are indications of significant inter-annual variability in the number of whale sharks that congregate at Ningaloo Reef in March and April each year. Initial observations, from boat searches and aerial surveys carried out between 1985 and 1992, suggest that there may be spatial variability in the location of the aggregation (Taylor, 1996a). Temporal patterns in whale shark abundance have also to be understood before there can be accurate assessment of the results of monitoring studies established to detect short or long-term impacts. The possible causes of this natural variation must also be investigated, as significant correlation may exist between seasonal changes in environmental parameters and whale shark numbers, distribution and behaviour.

It has been postulated that the autumn aggregation of whale sharks at Ningaloo Reef is linked to high levels of productivity associated with mass synchronous coral spawning events (Taylor, 1994). Taylor has also put forward a hypothesis that the apparent decline in whale shark abundance from 1985 to 1990 could be related to the mass destruction of coral along the reef by the gastropod mollusc *Drupella cornus,* and consequent reduction in biomass of coral spawn (Taylor, 1996a). Unfortunately, it is not possible to examine whale shark numbers pre- and post- 1990, as a result of the use of different search methodologies and a lack of comparable data. However, the number of encounters recorded on commercial operator log sheets from 1993-1996 (Figure 8), which probably gives an indication of the number of sharks present on a seasonal basis, suggests that there may be substantial inter-annual variation in whale shark numbers in the northern area of the reef. If the high number of encounters reported for the 1994 and 1996 seasons represents a 'recovery' of the population from pre-1990 levels it is unlikely that this is related to a parallel recovery of corals and increase in spawn biomass. Such large scale recovery of coral communities could only take place over decadal time scales.

Figure 8: Number of whale shark encounters, 1993-1996



(These figures, obtained from CALM records and log book returns from the commercial operators, represent the total number of encounters and do not take into account multiple encounters with the same shark by different vessels, either on the same day or on different days.)

Inter-annual variability in the whale shark population may be associated with transient upwelling events. It is well established that the process of upwelling can supply cold, nutrient-rich water to the surface, resulting in increased phytoplankton production and a subsequent increase in zooplankton abundance. Upwelling usually occurs along the eastern boundaries of most oceans as a result of prevailing wind direction being towards the equator, which produces equator-ward surface currents that are steered offshore due to the Coriolis force (Pearce, 1991). This results in a geostrophic adjustment flow of deeper, colder water to the surface adjacent to the coast and if this water is rich in nutrients an increase in primary productivity can occur.

Despite favourable equator-ward winds, there is no evidence of persistent, large scale upwelling off Western Australia (Pearce, 1991). It is believed that the presence of the south-west flowing Leeuwin Current is the major reason for this lack of upwelling. However, there are indications that weak, episodic upwelling events do occur off the North West Shelf. These pulses of colder water, lasting several weeks, occur in the summer months and are associated with high nutrient levels (Holloway *et* *al.*, 1985). The upwellings are believed to result from north-east flowing currents. The seasonal weakening and occasional localised reversal of the normally southward-flowing Leeuwin Current is thought to be due to reduced wind stress resulting from the predominantly south-west winds that occur between September and March. Often these winds alone are not strong enough to reverse the south-west currents but merely retard them (Holloway & Nye, 1985). The upwelling events were strongest in summer, when the Leeuwin Current is weakest and most variable.

The Leeuwin Current, which flows along the shelf break, is believed to be primarily driven by a steric height (sea level) gradient along the Western Australian coastline which is generated due to the inter-connection between the Indian and Pacific Oceans through the Indonesian Archipelago (Godfrey & Ridgway, 1985). It flows all year round but exhibits seasonality with strongest flows occurring between April and August. The Current flows weakest from October to March, due to the strong northwards wind stress created by the prevailing south-westerly winds. It has also been suggested that the strength of the Leeuwin Current is linked to the occurrence of El Nino-Southern Oscillation (ENSO) events (Pearce, 1991). During ENSO years there is a decreased along-shore steric height gradient along the Western Australian coastline that results in a weaker Leeuwin Current (Pattiaratchi & Buchan, 1991). This weakening of the Current may allow northward winds to cause more frequent coastal upwelling, especially during the summer months when northward wind stress is increased.

This current probably has a significant effect on the hydrology of Ningaloo Reef, particularly at the northern end where the shelf break is only 10km offshore. There is evidence of episodic pulses of cold water occurring immediately adjacent to the reef. Simpson & Masini (1986) found temperature anomalies in the Ningaloo Reef lagoon that involved water temperatures being depressed 1 or 2°C below seasonal values for a duration of 2 to 3 days. They concluded that these anomalies, one of which was recorded over 3 days in December 1985, were probably caused by advection of a mass of cold water from the open ocean over the reef crest into the lagoon. As the lagoon is tightly coupled to the open ocean through a rapid flushing process (Hearn *et al.*, 1986), Simpson & Masini (1986) believed that these temperature anomalies indicated that upwelling occurs in the immediate vicinity of the reef. This is consistent with the rapid onset and decay of the anomalies within the lagoon. Hearn *et al.* (1986) suggested that these temperature anomalies may result from upwellings onto the shelf in the vicinity of the Ningaloo Reef tract caused by internal breaking waves. The likely causes and frequency of such events are unknown, and detailed studies are required to answer such questions.

Transient upwelling during the summer months may result in nutrient enrichment, an increase in phytoplankton productivity, and a subsequent increase in zooplankton biomass. This cycle of events could take weeks or months, resulting in increased food supply for whale sharks during the autumn, before the Leeuwin Current begins to flow strongly over the winter months. The occurrence of swarms of tropical krill (*Pseudeuphausia latifrons*) along the reef front in March and April (Taylor & Grigg, 1991) would be consistent with upwelling and an increase in primary productivity. Sightings of whale sharks have been made in other locations , such as the Western Pacific (Iwasaki, 1970), the Galapagos (Arnbom & Papastavrou, 1988), and the Maldives (Anderson & Ahmed, 1993), where upwelling and localised increases in primary productivity are known to occur.

The sporadic nature of these upwelling events could perhaps account for the apparent inter-annual variability in whale shark numbers at Ningaloo Reef. The frequency and strength of transient upwellings along the shelf break in this region may be affected by ENSO events. During non-ENSO years a strongly flowing Leeuwin Current may hinder the development of conditions favourable for transient upwelling. Tropical cyclones may also play an important role in nutrient enrichment of surface layers. An upwelling beneath the eye of the storm may cause some vertical mixing of deeper cold water to the surface, where it is advected and mixed onto the shelf in the weeks and months following the cyclone (Holloway *et al.*, 1985). Given that two or three cyclones can occur on the North West Shelf each summer this may be a significant source of nutrients to shelf waters. These infrequent events could possibly be one of the causes of inter-annual variability in whale shark abundance at Ningaloo Reef.

Baseline studies are necessary to monitor the physical and biological oceanography of shelf waters in the vicinity of Ningaloo Reef. Information on shelf dynamics and nutrient supply will facilitate an understanding of the patterns of primary productivity and how these may be linked with phenomena such as the annual aggregation of whale sharks off the reef front. Measurement of a range of physical and biological parameters as part of a sustained research program is integral to the process of assessing whether seasonal fluctuation in the whale shark population is a consequence of natural variability, or whether it is due to tourism pressure. Detecting transient upwellings and examining any correlation between increases in primary productivity and spatial and temporal patterns in whale shark numbers, distribution and behaviour should be a primary objective of long-term environmental monitoring in the Ningaloo Marine Park and adjacent waters.

Data on water temperatures and chlorophyll concentrations of the surface layers from the reef front to the shelf break can be compared with seasonal population counts of whale shark numbers. Simpson & Masini (1986) demonstrated that there is very close agreement between mean weekly water temperatures in the lagoon, measured by temperature loggers, and ocean surface temperatures inferred from satellite imagery. This is particularly true for the northern sector of the Ningaloo Reef tract where the shelf is narrow and therefore there is better contact between lagoonal and oceanic waters. Surface water temperatures from the ocean in the region of the shelf break, measured from NOAA-AVHRR (Advanced Very High Resolution Radiometer) satellite data, can be expected to reveal intrusions of cold water to surface layers. This information, combined with chlorophyll concentration data also acquired from satellite imagery (SeaWiFS project - Sea viewing Wide Field-of-view Sensor), should point to episodes of upwelling and nutrient enrichment. These data need to be carefully analysed on a weekly, monthly, seasonal and annual basis.

Comparative plankton sampling covering areas of known whale shark aggregation and adjacent waters could provide data on spatial and temporal variability in food supply. It could also reveal information on optimal foraging behaviour and whether the animals are selecting habitat based on higher food abundance. In the short-term, telemetry studies of whale shark movements and diving patterns need to be accompanied by concurrent data on the hydrology and productivity of the surrounding waters.

3.4 Interaction monitoring

3.4.1 Behavioural study

In February 1995, a two year whale shark research project commenced at Ningaloo. This project, funded by a grant under the Australian Postgraduate Awards (Industry) Scheme and sponsorship from CALM and sectors of the whale shark tourism industry, is being undertaken by a M.Phil. student under the joint supervision of Professor Ian Potter (Fish Research Group, Murdoch University) and Dr John Stevens (Division of Marine Research, CSIRO). The research was established around a set of objectives related to human activities around the sharks and the potential impacts from tourism pressure.

The primary objectives of this project are:

- to define a repertoire of whale shark behaviours under natural (i.e. control) and unnatural (i.e. tourism pressure) conditions;
- to identify behaviours that can be utilised as measurement parameters to assess the impact of tourism pressure; and

- to determine if morphological characters can be used to identify individual whale sharks, and to examine the methodologies for establishing a photo-identification database.

Subsidiary objectives of this project are:

- to contribute to a photo-identification database;
- to review CALM's whale shark code of conduct; and
- to investigate options for industry self-regulation.

Over the last two seasons the student has been able to determine and record a preliminary repertoire of behaviours including eye rolls, diving and banking, changes in swimming speed, degree of mouth opening and coughing/gill flushing (B. Norman, pers. comm.). This repertoire may increase as more observations are made. Essentially these observations are being carried out to determine any gross differences in individual whale shark behaviour between situations when vessels and swimmers are, and are not, present. The collection of these behavioural data has been facilitated by the use of an underwater video. Comparative analysis of the behaviour of individual sharks on several occasions is particularly relevant, especially when visitor numbers and separation distances vary.

One major difficulty with this observational study is the lack of 'true' control situations. The student gathers behavioural data by accompanying commercial whale shark tours and limited opportunities exist to observe whale sharks in completely 'natural' conditions (i.e. not exposed to any tourism pressure). Even when the student gets a rare opportunity to swim alone with a shark it can be argued that interaction stimuli are still present, and its behaviour may be affected by recent contact with swimmers and vessels. Observational data of whale sharks under totally 'natural' conditions will be difficult or impossible to collect. Data from 'control' areas, such as Christmas Island or the Coral Sea, where whale sharks are not exposed to the same levels of tourism pressure, are required for comparison with data from areas, such as the Ningaloo Marine Park, where human activities may have altered their behaviour, distribution and movements. Careful statistical analysis of data from impacted and control situations will be required before any valid conclusions can be drawn.

This behavioural research should be viewed as an initial study necessary to establish good baseline information and to identify appropriate behavioural indices that can be utilised to examine any long-term changes in shark behaviour resulting from tourism pressure. It may also facilitate the identification of influence parameters, such as the frequency and duration of encounters, maximum number of swimmers and minimum separation distances, that can be altered through regulation to reduce or remove impacts. The 1995 whale shark season was characterised by low numbers of sharks, with the number of encounters recorded by the industry falling from 736 in 1994 to 489 in 1995 (Figure 8). The duration of this project was extended to incorporate the 1997 season, to build on the limited data collected in 1995.

3.4.2 Photo-identification

Individual identification of whale sharks is critical to examining the potential impacts of human interaction. It allows for behavioural assessments of individual animals before, during and after human contact. A key question for behavioural studies is whether individual sharks are repeatedly exposed to human interaction pressure. Initial studies suggest that individuals can be identified through scars, deformities and marking patterns behind the gill slits, and that these distinctive patterns can be used as a repeatable method of identifying individuals (Taylor, 1994; B. Norman, pers. comm.).

The establishment of a central, comprehensive photo-identification library will provide information relating to shark return rate, length of stay and movements whilst at Ningaloo Reef. A review of the methods for the establishment of a photo-identification library has been carried out as part of the behavioural study, and the initial results suggest that digitisation, computer storage of images and matching by eye may be the most suitable and cost-effective techniques (B. Norman, pers. comm.). Once sufficient material has been accumulated it may be possible to apply image analysis and statistical techniques to identify individual whale sharks. In addition, it has to be ascertained whether the pattern of lateral markings alters with age, and whether there are any significant differences in the patterning of the head between males and females, as suggested by Taylor (1994). Photographs of the genital area will facilitate collection of accurate sex ratio data.

A photo-identification library will assist in estimates of population size by recording seasonal re-sightings, and in the determination of the average proportion of whale sharks exposed to the interaction. It will also reveal whether sharks encountered at Ningaloo Reef are re-sighted in other areas, giving some indication of movements along the Western Australian coastline, and possibly further afield. It may take several years before definitive results are available from such a library, but it is important that reliable identification methodologies and a comprehensive set of baseline data are established. Taylor's extensive photographic records of individual sharks at Ningaloo, covering the last decade, will be an important contribution to a central photo-identification database.

3.5 Movement patterns

The duration of the whale shark aggregation at Ningaloo Reef and where they are before, during and after the season are questions of major importance to CALM and to the industry. Are they not regularly seen at other times of the year because they have either moved offshore into deeper water, or have left the area entirely? Their occurrence at Ningaloo may be part of a large scale migratory pattern. A better understanding of movement patterns will assist in a broader definition of the appropriate spatial and temporal boundaries for management of the interaction. There are a number of different techniques that could be utilised to obtain further information on the movements and migratory patterns, including:

- acoustic telemetry;
- archival tagging;
- satellite tracking; and
- sightings database.

A discussion of the suitability of each of these techniques is included in Appendix III. Researchers from the CSIRO Division of Marine Research and Murdoch University received funding from the Commonwealth Department of Tourism (National Ecotourism Program) to carry out further tagging and tracking studies of whale sharks at Ningaloo Reef. This research, carried out in April 1997, included the use of acoustic telemetry, archival tagging and satellite tracking to determine short, medium, and long-term movements and behavioural patterns. Unfortunately, the research team was unsuccessful in their attempts to attach satellite tags to whale sharks during this project.

3.6 Participant surveys

During the 1994 season, a pilot study to examine recreational aspects of the whale shark industry was carried out by researchers from the Centre for Coastal Management at Southern Cross University and the CRC Reef Research Centre at James Cook University. Through the use of participant surveys, information on the quality of experience, visitor satisfaction and in-water behaviour when in contact with the sharks, and benefits to the regional tourism industry were collected. Full scale surveys were conducted during the 1995 and 1996 seasons.

This research has produced information crucial to decisions concerning the management of the whale shark industry, including data on factors that may influence impact upon the animals (Birtles *et al.*, 1996; Davis & Tisdell, in press; Davis *et al.*, in press). The surveys have also produced information on the desires of users and their willingness to pay for a quality experience and this is important to the commercial operators in the management and marketing of their whale shark tours. Data obtained from these and further surveys will be invaluable in the formulation of future management strategies. Further surveys of participants need to be undertaken for the continual monitoring of visitor satisfaction and behaviour as the interaction industry grows and develops. This will provide essential feedback about the extent to which CALM's code of conduct rules are being followed, the effects of any changes to these rules on visitor behaviour and quality of experience, and the efficacy of educational/interpretive materials. This research could be extended to focus on the social 'carrying capacity' of the industry, and to consider economic issues such as the importance of the whale shark 'icon' in attracting tourists to Exmouth, and impacts on the local economy from the whale shark industry compared to other forms of tourism.

3.7 Additional research studies

There are a number of other research projects that could be undertaken on whale sharks at Ningaloo Reef. A summary of these additional studies is given in Appendix III. The research and management objectives outlined in section 3.1 provide broad criteria to prioritise research projects. In assessing future research proposals higher priority may have to be assigned to studies that yield information which leads to the modification of management controls to minimise or reduce any human impacts on the sharks.

3.8 Management issues

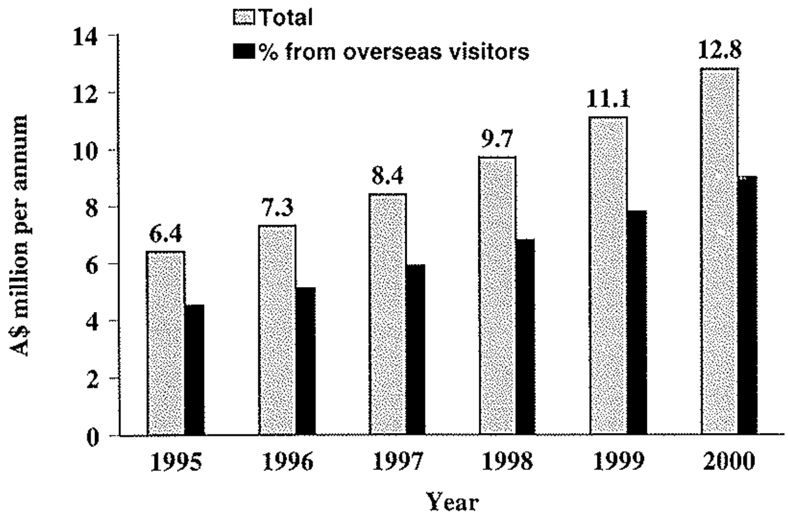
3.8.1 Funding

Small scale funding to cover short-term priorities may be available through various state and federal funding schemes. Larger grants could be accessed from agencies such as Environment Australia and from other Government sources such as the National Tourism Development Program (NTDP). Funding for postgraduate research students may be available from federal bodies such as the Department of Education, Employment and Training (DEET) and the Australian Research Council (ARC). There may be a possibility of attracting funding through international organisations such as the World Conservation Union (IUCN Species Survival Commission's Shark Specialist Group) and the World Wide Fund for Nature (WWF). Research proposals to attract funding from international organisations would have to cover co-ordinated projects involving research on whale sharks at several locations in the Indo-Pacific region.

Corporate sponsorship is another possible source of research funds. The whale shark industry, whilst still relatively small, has one of the highest profiles of all of the state's nature-based tourism activities. The seasonal nature of the industry, relative isolation of the location and the high cost of whale shark tours have all served to keep participant numbers low. Those visitors, however, are willing to pay for a high quality experience, and the benefits from the industry are spread through many parts of the local economy. It has been estimated that mean expenditure by participants in whale shark tours was of the order of A$3,198 per person in 1995 (including travel costs within Australia), and based on 2,000 participants this translated to a primary injection of funds to the economy of approximately A$6.4 million (D. Davis, pers. comm.). During the 1997 season there were an estimated 2,640 whale shark tour participants which translates to an industry 'value' of A$8.4 million. If the annual 15% rate of growth seen from 1995 to 1997 is repeated over the next three years it is estimated that there will be approximately 4,000 participants by the year 2000. Taking the 1995 mean expenditure figure of A$3,189 per participant the industry's value to the local and regional economy will be in the order of

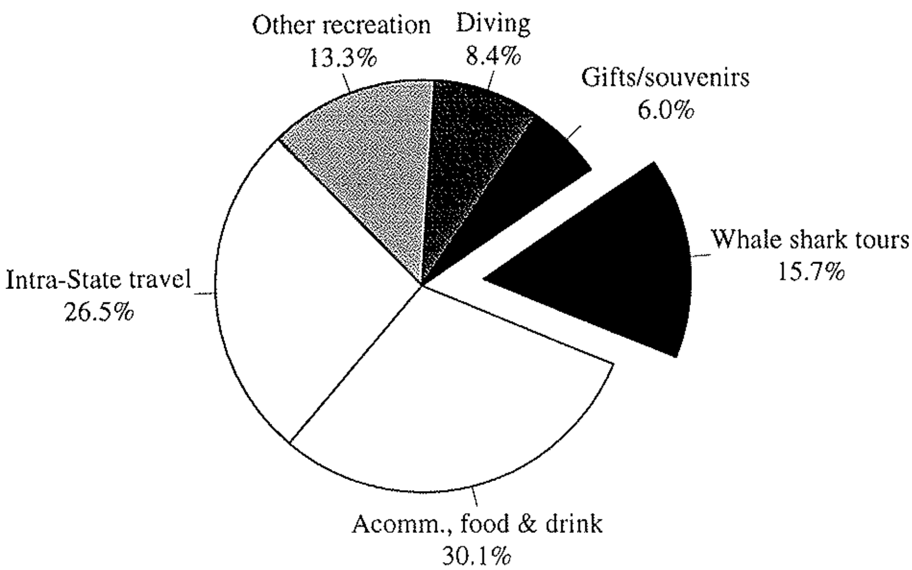
A$12.8 million by the turn of the century (Figure 9). In 1995, it was estimated that expenditure on whale shark tours comprised only 16% of the total expenditure by visitors who came to Western Australia to participate in the interaction (Figure 10) (D. Davis, pers. comm.). Undoubtedly, the financial benefits from this industry flow on to other regions in the state and throughout Australia. Overseas visitors made up 65% of the total number of whale shark participants in 1995, and 76% in 1996 (D. Davis, pers. comm.). The national and international profile of the activity is apparent from many articles about the whale sharks of Ningaloo in newspapers and magazines world-wide. The industry is actively promoting itself through national and international marketing efforts.

Figure 9: Estimated value of whale shark tourism to the Western Australian economy, 1995-2000



(These estimates are based on a 15% annual rate of growth, a mean expenditure per participant of A$3,189 and an overseas visitor figure of 70% - Davis D., pers. comm.)

Figure 10: Estimated breakdown of expenditure by participants in whale shark tourism, 1995



(These figures are based on a 1995 mean expenditure per participant of A$3,189 - Davis D., pers. comm.)

Due to the high profile and cosmopolitan nature of this industry potential sponsors do not necessarily have to be those with commercial concerns in the Exmouth region. Japanese tourists make up the bulk of overseas visitors (D. Davis, pers. comm.). Therefore, there are a number of potential corporate sponsors who could possibly be interested in large scale and long-term funding of whale shark research. The benefits to the sponsor include association with the conservation of this little known and spectacular animal, and the sustainable development of a high profile nature-based tourism activity in the Ningaloo Marine Park. There would be excellent publicity opportunities for any research sponsors.

A co-ordinated approach is essential for any future funding proposals for whale shark research and monitoring studies. All projects should be well-designed, fit within an agreed overall framework, address stated research priorities, and must be clearly relevant to the management objectives of this program. The potential benefits to the industry and the local and regional economies must also be emphasised.

3.8.2 Licensing and reporting

Communication between CALM and whale shark researchers is essential. This should take place not only during the initial stages of project design and funding application, but also whilst the research is being carried out and after project completion. This can be achieved through the Management Team (section 4.1) and also through the use of research licences. Researchers are also required to provide reports outlining the results of their work. Copies of all publications and theses generated from whale shark research at Ningaloo must be lodged with CALM.

It is essential that all future research is co-ordinated by the Management Team, with full and open communication between all parties involved. The requirement for all researchers to apply for a research licence before commencing any studies in the marine park ensures that CALM will be kept fully informed of all proposed whale shark research. It also ensures that all proposed projects can be carefully scrutinised to check whether they meet certain criteria, and that results will be passed back to CALM shortly after completion of the research.

3.8.3 Industry involvement

Long-term research and monitoring of whale sharks in the Ningaloo Marine Park will require the involvement and co-operation of the commercial operators. Industry support is a key factor in applied studies examining possible impacts of the interaction, and in-water behaviour and perceptions of participants in the activity. Reliable information about the extent to which the code of conduct rules are being followed can only be gathered with the co-operation of whale shark tour operators. Cross-matching of whale shark photographs taken by visitors with previously identified individuals in a central photo-identification database relies to some extent on the active co-operation of the operators and their staff. The commercial operator log book scheme relies solely on the accurate input of data from the licence holders.

The importance of research and monitoring studies in providing information vital to on-going management of the activity and to its future development on a sustainable basis, has to be impressed on the industry. It is essential that the industry is kept fully informed of any projects, and the reasons for any such work should be fully explained to them. Feedback of results and conclusions is very important, especially if it concerns issues that affect the licence holders on-water operations, and the management and marketing of their whale shark interaction tours.

3.8.4 International collaboration

There is a need for communication and collaboration between scientists involved in whale shark research world-wide. This is particularly important given its cosmopolitan distribution, the lack of basic knowledge of the animal, the patchy and unpredictable nature of its occurrence, and the inherent difficulties in carrying out research on whale sharks. As the species may be highly migratory, research and management of human interactions takes on global dimensions. Long-term studies of the animals in areas where they may have been exposed to a high degree of tourism pressure (such as Ningaloo Reef) and other locations, such as Christmas Island, the Coral Sea, South Africa and Mozambique, where interaction is limited could allow a comparative experimental approach to behavioural studies. A large scale of information transfer has to be promoted. This will allow researchers to keep an open mind to the full range of possibilities when addressing research problems.

Research priorities are closely linked with the objectives of management, and workshops could enable consultations between all groups involved - management agencies, commercial operators, the scientific community, conservation bodies, private vessel operators and the general public. It is recommended that a whale shark research workshop is held within the next two years. Participants should include overseas researchers currently involved in whale shark studies, as well as Australian scientists involved in past and current projects at Ningaloo Reef.

3.9 Research and monitoring recommendations

- *A long-term monitoring program should be undertaken to determine the extent of inter-annual variability in the whale shark population of the Ningaloo Marine Park.*

- *A suitable technique for monitoring resource size and tourism pressure should be determined over the next two seasons.*

- *Long-term monitoring of physical and biological parameters should be undertaken to examine possible links between environmental parameters and whale shark population fluctuations in the Ningaloo Marine Park.*

- *Research to study behavioural patterns and movements of whale sharks within the Ningaloo Marine Park and in surrounding waters should be continued.*

- *A central whale shark photo-identification database should be established as a priority.*

- *Research to study large scale migratory patterns of whale sharks should be undertaken.*

- *Participant surveys should be regularly carried out, in collaboration with the industry, to monitor experiential and economic aspects of human/whale shark interactions.*

- *A whale shark research workshop should be held within the next two years.*

4.0 IMPLEMENTATION AND REVIEW

4.1 CALM Management Team

A CALM Management Team will be established to implement and review the Management Program. This team should be comprised of:

- Exmouth District Manager, or delegate (Chairperson);
- Wildlife Protection Section representative;
- Marine Conservation Branch representative; and
- Parks, Policy and Tourism Branch representative.

This Management Team should report to the Pilbara Regional Manager, and the Corporate Executive of CALM, once a year by 31 December. The terms of reference of the Management Team will be to:

- review the previous season in relation to management objectives and performance criteria;
- assess monitoring results;
- schedule management operations for the following season, including budget and staffing requirements;
- make recommendations on further research and monitoring; and
- prepare a report to the Pilbara Regional Manager and the Corporate Executive.

Review of the Management Program will examine two criteria:

- success in terms of achieving the objectives and meeting performance criteria; and
- overall cost-effectiveness.

The key issue in determining whether management of whale shark interaction has been successful is to ensure that the conservation and recreation management objectives are in fact measurable (i.e. they should have performance criteria). One stated objective of this program is that whale shark populations must be maintained at least at existing levels. In order to evaluate the success of management in achieving this aim it is necessary to establish baseline monitoring to measure current population size and inter-annual variability. It will also be necessary to have an understanding of how seasonal changes in the environment may affect whale shark abundance and distribution. This can only be gained through long-term research and monitoring studies.

The efficiency and cost effectiveness of the program can be assessed through the preparation of costing and budgets for management operations, and for research and monitoring studies. Aspects such as the proportion of licence revenue to be allocated for surveillance activities, appropriate staffing levels, frequency of monitoring activities and funding for long-term research studies all need to be considered. Any cost or resource shortfalls or areas where savings could be made in future operations, need to be brought to the attention of the Corporate Executive through the report prepared by the Management Team. Allocation of resources, however, has to be considered in the context of Departmental priorities and resource levels.

As additional information becomes available from research and monitoring studies it should be possible to ascertain if existing industry controls are appropriate or whether they need to be modified. Research and monitoring studies should make it possible to identify most of the 'influence' parameters that can be altered to reduce or eliminate any impacts on individual whale sharks. These may include:

- **Vessel characteristics**
  - Type (mono-hull, multi-hull)
  - Size
  - Engine (outboard, inboard, sail)
- **Swimmer characteristics**
  - Snorkel or SCUBA
  - Motorised propulsion
- **Vessel behaviour**
  - Course and speed variation

- **Intensity of influence**
  Number of vessels
  Number of swimmers
  Proximity of vessels and swimmers
  Duration of encounter
  Frequency of encounters

Revised controls should have the effect of altering one or more of these variables to ensure that precautionary thresholds are not exceeded and participant quality of experience is maximised. For example, a reduction in vessel numbers and/or frequency of encounter would have the effect of reducing the intensity of influence on the sharks, as measured from index values obtained from aerial monitoring.

4.2 Management Advisory Committee

Consultation between the relevant agencies and the industry is central to the effective management of commercial whale shark interaction in the Ningaloo Marine Park. A Whale Shark Management Advisory Committee, comprised of representatives from CALM, the industry, the local community and relevant agencies is required to provide an open forum for discussion of the licensing structure, the industry code of conduct, safety and other issues relating to management of the interaction. As well as providing advice to CALM, the Management Advisory Committee will also be responsible for providing feedback to licence holders on logbook data and the progress of research and monitoring studies. To facilitate this there should be annual post-season meetings of the Committee.

4.3 Application of the Management Program

There are indications that whale sharks occur in inshore waters all along the western and north-western coasts of Western Australia. Apart from the seasonal aggregation at Ningaloo Reef, there appear to be accumulations of whale sharks, during the summer months, along the coast north from Kalbarri to Dirk Hartog, Bernier and Dorrier Islands on the edge of Shark Bay, and around the Montebello Islands. There are recent reports of whale shark sightings around the Houtman Abrohlos Islands and as far south as Rottnest Island and Geographe Bay. Presently, there is no information on the migratory patterns of the species and it is not possible to determine whether any of these occurrences involve the same individuals moving north and south along the coastline. In the last few years there has been increased interaction with whale sharks, by private vessels, in the waters around Dirk Hartog Island and there has been some interest in developing commercial whale shark tours out of Kalbarri.

If individual whale sharks undertake large scale migrations they could be exposed to spatially and temporally separated incidents of human interference. Any detrimental impacts from these interactions could be cumulative, affecting the animals directly or altering their natural behaviour. Whale sharks are protected within all State waters under the Wildlife Conservation Act and the activities of both commercial tours and private vessels and swimmers interacting with the animals are controlled, at any time of the year, under the *Wildlife Conservation (Close Season for Whale Sharks) Notice 1996* (see section 2.4). It is appropriate, therefore, for the management objectives and controls, as well as the research and monitoring strategies, to be applied wherever relevant (and modified where necessary), in existing and future CALM Act marine reserves. The management principles detailed in this Wildlife Management Program are also recommended for whale shark interaction in State waters outside marine reserves.

Management actions

- *A CALM Management Team will be established to implement the Wildlife Management Program.*

- *The Management Program will be subject to annual review by the Management Team.*

- *A Whale Shark Management Advisory Committee, comprised of representatives from CALM, the Department of Transport, and representatives from the industry and local community will be established to provide advice to CALM.*

- *The management objectives and controls, and the research and monitoring strategies detailed in this Management Program will apply, with appropriate modifications, in all CALM marine reserves wherever relevant.*

REFERENCES

Alava, M.N.R., Yaptinchay, A.A.S.P., Dolumbalò, E.R.Z. & Trono, R.B. (in press). Fishery and trade of whale sharks and manta rays in the Bohol Sea, Philippines. In: *Proceedings of the International Seminar and Workshop on Shark and Ray Biodiversity, Conservation and Management*, Sabah, Malaysia, 7-10 July 1997. Department of Fisheries - Sabah, IUCN Species Survival Commission's Shark Specialist Group.

Anderson, R.C. & Ahmed, H. (1993). The shark fisheries of the Maldives. Ministry of Fisheries and Agriculture, Republic of Maldives, Food and Agriculture Organisation of the United Nations, 76 pp.

ANPWS (1988). Whale watching guidelines. Australian National Parks and Wildlife Service, Commonwealth of Australia, Canberra, pamphlet.

ANPWS (1990). Ningaloo Marine Park (Commonwealth Waters) Plan of Management. Australian National Parks and Wildlife Service, Commonwealth of Australia, Canberra, 31 pp.

Anon. (1955). Marine fishes of Karachi and the coasts of Sind and Makran. Ministry of Food and Agriculture (Central Fisheries Department), Government of Pakistan Press, Karachi, 4-5.

Anon. (1961). Whale sharks - Gulf of Aden. *Marine Observer*, **31 (192)**: 64-65.

Anon. (1962). Whale shark - Arabian Sea. *Marine Observer*, **32 (195)**: 17.

Anon. (1989). Baby shark causes a stir in the Middle East. *New Scientist*, **Sept. 9, 1989**: 8.

Anon. (1996). Report on the preliminary investigation on the whale shark (*Rhincodon typus*) fishery in Bohol Sea, Philippines. Unpublished report, World Wide Fund for Nature (WWF) - Philippine Program, 27 pp.

Arnbom, T. & Papastavrou, V. (1988). Fish in association with whale sharks *Rhiniodon typus* near the Galapagos Islands. *Noticias de Galapagos*, **46**: 13-15.

Aw, M. (1996). Ningaloo Reef - Australia's best kept secret of the Sea. Pictorial souvenir booklet, Tony Medcraft, Whale Shark Adventures, Degon Pty Ltd, Exmouth, Western Australia.

Bass, A.J. (1978). Problems in studies of sharks in the south-west Indian Ocean. In: *Sensory Biology of Sharks, Skates and Rays*, eds. Hodgson, E.S. & Mathewson, R.F. U.S. Government Printing Office, Washington D.C.: 45-594.

Baughman, J.L. (1955). The oviparity of the whale shark, *Rhineodon typus*, with records of this and other fishes in Texas waters. *Copeia*, **1955 (1)**: 54-55.

Beckley, L.E., Cliff, G., Smale, M.J. & Compagno, L.J.V. (1997). Recent strandings and sightings of whale sharks in South Africa. *Environmental Biology of Fishes*, **50**: 343-348.

Birtles, A., Cuthill, M., Valentine, P. & Davis, D. (1996). Incorporating research on visitor experiences into ecologically sustainable management of whale shark tourism. *Proceedings of the Ecotourism Association of Australia, National Conference, Alice Springs,* 1995, eds. Richins, H., Richardson, J. & Crabtree, A.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake, J.L. (eds.). (1993). Distance sampling: Estimating abundance of biological populations. Chapman & Hall, London, 446 pp.

Cailliet, G.M. & Tanaka, S. (1990). Recommendations for research needed to better understand the age and growth of elasmobranchs. In: *Elasmobranchs as living resources: Advances in the biology, ecology, systematics, and the status of the fisheries.*: NOAA Technical Report, U.S. National Marine Fisheries Service, **90**: 505-507.

Cailliet, G.M., Uchida, S., Laurendine, W. & Brennan, J. (1986). Structure and growth zone formation from captive Okinawan whale sharks (*Rhincodon typus*). Abstract of unpublished paper, Victoria, B.C. Available from author, Moss Landing Marine Laboratory, PO Box 450, Moss Landing, CA 95039, USA.

CALM (1989). Ningaloo Marine Park Management Plan 1989-1999. Department of Conservation and Land Management, Perth, 74 pp.

CALM (1992). A Nature Conservation Strategy for Western Australia. A Draft for Public Comment. Department of Conservation and Land Management, Perth, 130 pp.

CALM (1994). A Representative Marine Reserve System for Western Australia. Report of the Marine Parks and Reserves Selection Working Group. Department of Conservation and Land Management, Perth.

CALM (1995). The whale sharks of Ningaloo Reef. A booklet of interpretative materials for guides and tour operators in the whale shark interaction industry. Department of Conservation and Land Management, Perth, unpublished report, 32 pp.

CALM (1996). Experiencing whale sharks in Ningaloo Marine Park. A guide for passengers of commercial tours. Department of Conservation and Land Management, Perth, pamphlet.

Casey, J.G., Connett, S.M.H., Compagno, J.L.V., Stevens, J.D., Oulton, G. & Cook, S.F. (1992). The status of pelagic elasmobranchs: concerns and commentary. *Chondros*, **3** (**4**): 3-6.

Chang, W.B., Leu, M.Y. & Fang, L.S. (1997). Embryos of the whale shark, *Rhincodon typus*: early growth and size distribution. *Copeia*, **1997** (**2**): 444-446.

Chen, G.C.T., Liu, K.M., Joung, S.J. & Phipps, M.J. (1996). TRAFFIC report on shark fisheries and trade in Taiwan. In: *TRAFFIC [East Asia] report on shark fisheries and trade in the East Asian region*, comp. Phipps, M.J., TRAFFIC East Asia, Taipei.

Clark, E. (1992). Whale sharks. Gentle monsters of the deep. *National Geographic*, **182** (**6**): 123-138.

Clark, E. & Nelson, D.R. (1997). Young whale sharks, *Rhincodon typus*, feeding on a copepod bloom near La Paz, Mexico. *Environmental Biology of Fishes*, **50**: 63-73.

Compagno, L.J.V. (1973). Interrelationships of living elasmobranchs. In: *Interrelationships of fishes*, eds. Greenwood, P.H., Miles R.S. & Patterson, C. Academic Press, New York: 49-51.

Compagno, L.J.V. (1984). FAO Species Catalogue. Vol. 4, Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1 - Hexanchiformes to Lamniformes. *FAO Fisheries Synopsis*, **125**: 209-211.

Davis, D.C. & Tisdell, C. (in press). Managing marine tourism resources in Ningaloo Marine Park, Western Australia. *Proceedings of the 1996 World Congress on Coastal and Marine Tourism*, Honolulu, Hawaii, 19-22 June, 1996.

Davis, D., Banks, S., Birtles, A., Valentine, P. & Cuthill, M. (1997). Whale sharks in Ningaloo Marine Park: managing tourism in an Australian marine protected area. *Tourism Management*, **18** (**5**): 259-271.

Devadoss, P., Nammalwar, P., Srinivasan, P.V. & Srinivasarangan, S. (1990). Instances of landings of whale shark *Rhineodon typus* in Indian coastal waters. *Marine Fisheries Information Service, Technical and Extension Series*, **102**: 18-20.

Dingerkus, G. (1985). Interrelationships of Orectolobiform sharks (Chondrichthyes: Selachii). *Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes.* Eds. Uyeno, T., Arai, R., Taniuchi, T. & Matsuura, K., Ichthyological Society of Japan, Tokyo. 1986, 227-245.

Gaertner, D, Pagavino, M. & Marcano, J. (1996). Use of generalized linear models to investigate the fishing strategies of tuna purse seiners, in presence of floating objects in the western Atlantic Ocean. *Aquatic Living Resources*, **9** (**4**): 305-323.

Garrick, J.A.F. (1964). Additional information on the morphology of an embryo whale shark. *Proceedings of the United States National Museum*, **115 (3476)**: 1-7.

Godfrey, J.S. & Ridgway, K.R. (1985). The large scale environment of the poleward-flowing Leeuwin Current, Western Australia: longshore steric height gradients, wind stresses and geostrophic flow. *Journal of Physical Oceanography*, **15**: 481-495.

Government of Western Australia. (1994). New Horizons in Marine Management. November, 1994.

Gruber, S.H. (1977). The visual system of sharks: Adaptations and capability. *American Zoologist*, **17**: 453-469.

Gudger, E.W. (1938a). Four whale sharks rammed by steamers in the Red Sea region. *Copeia*, **1938 (4)**: 170-173.

Gudger, E.W. (1938b). Whale sharks struck by fishing boats off the coast of lower California. *California Fish and Game*, **24**: 420-421.

Gudger, E.W. (1940). Whale sharks rammed by ocean vessels. How these sluggish leviathans aid in their own destruction. *New England Naturalist*, **7**: 1-10.

Gunn, J.S., Whitelaw, A.W., Davis, T.L.O., Bailey, K. & Itano, D.G. (1992). Tuna tagging in the Coral Sea. *Australian Fisheries*, **51**: 22-24.

Gunn, J.S., Polacheck, T., Davis, T.L.O., Sherlock, M. & Betlehem, A. (1994). The development and use of archival tags for studying the migration, behaviour and physiology of southern bluefin tuna, with an assessment of the potential for transfer of the technology to groundfish research. *ICES C.M. Mini Symposium on Fish Migration.* Paper No: **21**.

Gunn, J.S., Stevens, J.D. & Davis, T.L.O. (in preparation). Preliminary observations on the short-term movements and behaviour of whale sharks (*Rhincodon typus*) at Ningaloo Reef, Western Australia. *Copeia.*

Hanfee, F. (1997). Trade in sharks and shark products in India. World Wide Fund for Nature (WWF)-India/TRAFFIC-India. Avenash Datta, New Delhi, 50 pp.

Hearn, C.J, Hatcher, B.G., Masini, R.J. & Simpson, C.J. (1986). Oceanographic processes on the Ningaloo Coral Reef, Western Australia. Centre for Water Research, The University of Western Australia, Environmental Dynamics Report **ED-86-171**, 79 pp.

Hoffman, W., Fritts, T.H. & Reynolds, R.P. (1981). Whale sharks associated with fish schools off south Texas. *North-East Gulf Science*, **5 (1)**: 55-57.

Holloway, P.E. & Nye, H.C. (1985). Leeuwin Current and wind distributions on the southern part of the Australian North West Shelf between January 1982 and July 1983. *Australian Journal of Marine and Freshwater Research*, **36**: 123-137.

Holloway, P.E., Humphries, S.E., Atkinson, M. & Imberger, J. (1985). Mechanisms for nitrogen supply to the Australian North West Shelf. *Australian Journal of Marine and Freshwater Research*, **36**: 753-764.

IUCN (1994). The Red List of Threatened Animals. The World Conservation Union (IUCN), Gland, Switzerland.

IUCN (1996). The Red List of Threatened Animals. The World Conservation Union (IUCN), Gland, Switzerland.

Iwasaki, Y. (1970). On the distribution and environment of the whale shark, *Rhincodon typus*, in skipjack fishing grounds in the western Pacific Ocean. *Journal of the College of Marine Science and Technology, Tokai University*, **4**: 37-51.

Jones, G.P. & Kaly, U.L. (1995). Conservation of rare, threatened and endemic marine species in Australia. In: *The State of the Marine Environment for Australia. Technical Annex: 1. The Marine Environment.* eds. Zann, L.P. & Kailola, P. Ocean Rescue 2000, Department of the Environment, Sport and Territories, Canberra, 183-191.

Joung, S.J., Chen, C.T., Clark, E., Uchida, S. & Huang, W.Y.P. (1996). The whale shark, *Rhincodon typus*, is a livebearer - 300 embryos found in one 'megamamma' supreme. *Environmental Biology of Fishes*, **46** **(3)**: 219-223.

Karbhari, J.P. & Josekutty, C.J. (1986). On the largest whale shark *Rhincodon typus* Smith landed alive at Cuffe Parade, Bombay. *Marine Fisheries Information Service, Technical and Extension Series*, **66**: 31-35.

Kaikini, A.S., Rao, V.R. & Dhulkhed, M.H. (1959). A note on the whale shark *Rhincodon typus* Smith, stranded off Mangalore. *Journal of the Marine Biological Association of India*, **4** **(1)**: 92-93.

Klimley, A.P. & Brown, S.T. (1983). Stereophotography for the field biologist: measurements of lengths and three-dimensional positions of free-swimming sharks. *Marine Biology*, **74**: 175-185.

Kukuyev, E.I. (1996). The new finds in recently born individuals of the whale shark *Rhiniodon typus* (Rhiniodontidae) in the Atlantic Ocean. *Journal of Ichthyology*, **36** **(2)**: 203-205.

Last, P.R. & Stevens, J.D. (1994). Whale sharks. In: *Sharks and rays of Australia.* CSIRO Australia: Chapter **18**: 142-143.

Leu, M.Y., Chang, W.B. & Fang, L.S. (1997). The success of keeping a baby whale shark from its fetal stage in Taiwan. In: *Proceedings of the Fourth International Aquarium Congress Tokyo*, pp. 109-111. Tokyo: Congress Central Office of IAC '96.

Liu, K.M., Chen, C.T. & Joung, S.J. (in press). Preliminary estimate of the whale shark catch in Taiwan. In: *Proceedings of the International Seminar and Workshop on Shark and Ray Biodiversity, Conservation and Management*, Sabah, Malaysia, 7-10 July 1997. Department of Fisheries - Sabah, IUCN Species Survival Commission's Shark Specialist Group.

Mahdi, N. (1971). Additions to the marine fish fauna of Iraq. *Iraq Natural History Museum Publication*, University of Baghdad, **28**: 5.

Martin, A.R., Kingsley, M.C.S. & Ramsay, M.A. (1994). Diving behaviour of narwhals (*Monodon monoceros*) on their summer grounds. *Canadian Journal of Zoology*, **72**: 118-125.

Melville, R.V. (1984). Opinion 1278. The generic name *Rhincodon* A. Smith, 1829 (Pisces): conserved. *Bulletin of Zoological Nomenclature*, **41** **(4)**: 215-217.

McCann, C. (1954). The whale shark *Rhineodon typus* (Smith). *Journal of the Bombay Natural History Society*, **52** **(2/3)**: 326-333.

McConnell, B.J., Chambers, C. & Fedak, M.A. (1992). Foraging ecology of southern elephant seals in relation to the bathymetry and productivity of the Southern Ocean. *Antarctic Science*, **4** **(4)**: 393-398.

Muller, K. (1995). East of Bali: from Lombok to Timor. Periplus Travel Guides (ed. Pickell, D.), Periplus Editions, Hong Kong, pp. 154-159.

Myrberg, A.A. Jr. (1991). Distinctive markings of sharks: Ethological considerations of visual function. *The Journal of Experimental Zoology Supplement*, **5**: 156-166.

NBTAC (1997). Nature Based Tourism Strategy for Western Australia. Report of the Nature Based Tourism Advisory Committee. Western Australian Tourism Commission, Perth, 32 pp.

Nelson, D.R. (1990). Telemetry studies of sharks: A review, with applications in resource management. In: *Elasmobranchs as living resources: Advances in the biology, ecology, systematics, and the status of the fisheries.* NOAA Technical Report, U.S. National Marine Fisheries Service, **90**: 239-256.

Osborne, S. & Williams, M.R. (1995). Monitoring of whale shark tourism in Ningaloo Marine Park by aerial survey. Department of Conservation and Land Management, Perth, Western Australia, unpublished report, 16 pp.

Pai, M.V., Nandakumar, G. & Telang, K.Y. (1983). On a whale shark, *Rhineodon typus* Smith landed at Karwar, Karnataka. *Indian Journal of Fisheries*, **30 (1)**: 157-160.

Pattiaratchi, C.B. & Buchan, S.J. (1991). Implications of long-term climate change for the Leeuwin Current. *Journal of the Royal Society of Western Australia*, **74**: 133-140.

Pearce, A.F. (1991). Eastern boundary currents of the southern hemisphere. *Journal of the Royal Society of Western Australia*, **74**: 35-45.

Priede, I.G. (1984). A basking shark (*Cetorhinus maximus*) tracked by satellite together with simultaneous remote sensing. *Fisheries Research*, **2**: 201-216.

Ramachandran, A. & Sankar, T.V. (1990). Fins and fin rays from whale shark (*Rhiniodon typus* Smith). *Fishery Technology*, **27 (2)**: 138-140.

Rau, G.H., Mearns, A.J., Young, D.R., Olson, R.J., Schafer, H.A. & Kaplan, I.R. (1983). Animal $^{13}C/^{12}C$ correlates with trophic level in pelagic food webs. *Ecology*, **64 (5)**: 1314-1318.

Reid, G.K. (1957). External morphology of an embryo whale shark, *Rhincodon typus* Smith. *Copeia*, **1957 (2)**: 157-158.

Rose, D.A. (1996). An overview of world trade in sharks and other cartilaginous fishes. TRAFFIC International, Cambridge, United Kingdom. 106 pp.

Roth, A. (1986). Sharks: Recent advances in captive biology. *Freshwater and Marine Aquarium*, **9 (5)**: 57-59.

Satyanarayana Rao, K. (1986). On the capture of whale sharks off Dakshina Kannada coast. *Marine Fisheries Information Service, Technical and Extension Series*, **66**: 22-29.

Seshagiri Rao, C.V. (1992). On the occurrence of whale shark *Rhiniodon typus* along the Kakinada coast. *Marine Fisheries Information Service, Technical and Extension Series*, **116**: 19.

Silas, E.G. (1986). The whale shark (*Rhiniodon typus* Smith) in Indian coastal waters: Is the species endangered or vulnerable? *Marine Fisheries Information Service, Technical and Extension Series*, **66**: 1-19.

Silas, E.G. & Rajagopalan, M.S. (1963). On a recent capture of a whale shark (*Rhincodon typus* Smith) at Tuticorin, with a note on information to be obtained on whale sharks from Indian waters. *Journal of the Marine Biological Association of India*, **5 (1)**: 153-157.

Simpson, C.J. (1991). Mass spawning of corals on Western Australian reefs and comparisons with the Great Barrier Reef. *Journal of the Royal Society of Western Australia*, **74**: 85-91.

Simpson, C.J. & Masini, R.J. (1986). Tide and seawater temperature data from the Ningaloo Reef Tract, Western Australia, and the implications for coral mass spawning. Department of Conservation and Environment, Perth, Western Australia, Bulletin **253**, 18 pp.

Smith, A. (1828). Descriptions of new, or imperfectly known objects of the animal kingdom, found in the south of Africa. *South African Commercial Advertiser*, Nov. 5, **3 (145)**: 2.

Smith, A. (1829). Contributions to the natural history of South Africa. *Zoological Journal*, **16**: 443-444.

Smith, A. (1849). In: *Illustrations of the zoology of South Africa. Vol. 4. Pisces.* Smith, Elder Co., London.

Smith, H.M. (1925). A whale shark (*Rhineodon*) in the Gulf of Siam. *Science*, **62**: 438.

Smith, J.L.B. (1967). Pugnacity of the whale shark, *Rhincodon*. *Copeia*, **1967 (1)**: 237.

Smith, R. (1996). In deep water. *Time* magazine, **January 8**: 30-36.

Smith, T.G. & Martin, A.R. (1994). Distribution and movements of belugas, *Delphinapterus leucas*, in the Canadian high Arctic. *Canadian Journal of Fisheries and Aquatic Science*, **51**: 1653-1663.

Southwell, T. (1912/13). Notes on the fauna of the Ceylon pearl banks. *Ceylon Administration Reports. Pt. IV. Education, Science and Art. Appendix I*, **Marine Biology**: E44.

Stevens, J.D. (1994). Whale sharks at Ningaloo Reef, northern Western Australia. *Chondros*, **5 (3)**: 1-3.

Stretta, J. & Slepoukha, M. (1983). Analysis of biotic and abiotic factors associated with tuna schools. *Proceedings of the ICCAT Conference on the International Skipjack Year Program.* Eds. Symons, P.E.K., Miyake, P.M. & Sakagawa, G.T. International Commission for the Conservation of Atlantic Tunas, Madrid, 1986: 161-169.

Sudhakara Rao, G. (1986). Note on the occurrence of the whale shark *Rhincodon typus* Smith off Veraval coast. *Marine Fisheries Information Service, Technical and Extension Series*, **66**: 30.

Taylor, G. (1994). Whale sharks, the giants of Ningaloo Reef. Angus & Robertson, Sydney, 176 pp.

Taylor, J.G. (1996a). Seasonal occurrence, distribution and movements of the whale shark, *Rhincodon typus*, at Ningaloo Reef, Western Australia. *Marine and Freshwater Research*, **47**: 637-642.

Taylor, J.G. (1996b). Whale shark population study. Preliminary report on whale shark research undertaken in 1995. Department of Conservation and Land Management, Perth, unpublished report, 16 pp.

Taylor, J.G. (1997). Whale shark population study. Report on whale shark research undertaken in 1996. Department of Conservation and Land Management, Perth, unpublished report, 5 pp.

Taylor, G. & Grigg, G. (1991). Whale sharks of Ningaloo Reef. Australian National Parks and Wildlife Service, Commonwealth of Australia, Canberra, unpublished report, 20 pp.

Taylor, L.R., Compagno, L.J.V. & Struhsaker, P.J. (1983). Megamouth - a new species, genus, and family of lamnoid shark (*Megachasma pelagios*, family Megachasmidae) from the Hawaiian Islands. *Proceedings of the Californian Academy of Science*, **43**: 87-110.

Thomson, C. & Stevens, J. (1994). A whale of a shark. *Landscope*, **10 (2)**: 28-34.

Trono, R. (1996). Philippine whale shark and manta ray fisheries. *Shark News*, **7**: 13.

Uchida, S., Toda, M. & Kamei, Y. (1990). Reproduction of elasmobranchs in captivity. In: *Elasmobranchs as living resources: Advances in the biology, ecology, systematics, and the status of the fisheries.* NOAA Technical Report, U.S. National Marine Fisheries Service, **90**: 211-237.

van Rooij, J.M. & Videler, J.J. (1996). A simple field method for stereo-photographic length measurement of free-swimming fish: merits and constraints. *Journal of Experimental Marine Biology and Ecology*, **195**: 237-249.

Wamukoya, G.M., Mirangi,J.M. & Ottichillo, W.K. (1996). Report on the marine aerial survey of marine mammals, sea turtles, sharks & rays. *Kenya Wildlife Service Technical Series Report No. 1*, 22 pp.

Wolfson, F.H. (1983). Records of seven juveniles of the whale shark, *Rhiniodon typus*. *Journal of Fish Biology*, **22 (6)**: 647-655.

Wolfson, F.H. (1986). Occurrences of the whale shark, *Rhincodon typus*, Smith. *Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes.* Eds. Uyeno, T., Arai, R., Taniuchi, T. & Matsuura, K., Ichthyological Society of Japan, Tokyo. 1986, pp. 208-226.

Wolfson, F.H. (1987). The whale shark, *Rhiniodon typus*, Smith 1828, off Baja California, Mexico (Chondrichthyes: Rhinodontidae). *Memorias Del V Simposium de Biologica Marina, Universidad Autonouna de Baja California Sur*, **5**: 103-108.

Wolfson, F.H. & Notarbartolo di Sciara,G. (1981). The whale shark, *Rhiniodon typus* Smith 1828, an annotated bibliography. *Atti della Societa Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano*, **122 (3-4)**: 171-203.

Wright, E.P. (1870). Six months at the Seychelles. *Spicilegia Zoologica, Dublin*, **1**: 64-65.

Zhang, H., Song, X., Li, Y., Wang, W., Wang, S., Su, X., Li, P., Sung, J. & Yang, Z. (1988). A study of anti-tumoral activity of liver oil emulsion of *Rhincodon typus*. *Journal of Marine Drugs, Haiyang Yaowu*, **7 (4)**: 3-5.

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APPENDIX I

Wildlife Conservation (Close Season for Whale Sharks) Notice 1996

WILDLIFE CONSERVATION ACT 1950

WILDLIIFE CONSERVATION (CLOSE SEASON FOR WHALE SHARKS) NOTICE 1996

Made by the Minister under section 14 (2) (a).

Citation

1. This notice may be cited as the *Wildlife Conservation (Close Season for Whale Sharks) Notice 1996.*

Object of this notice

2. The object of this notice is to allow limited interaction between humans and whale sharks in State waters, while protecting whale sharks from disturbance and molestation, by setting out acceptable approach distances, etc., for vessels, swimmers and divers when in proximity to a whale shark, and to prevent some other activities that may disturb whale sharks.

Interpretation

3. (1) In this notice -

"contact vessel" means a vessel, and any tender vessel accompanying the vessel, within a contact zone,

"**contact zone"** means the area within a radius of 250 metres of any whale shark that is in State waters;

"**whale shark"** means the fauna *Rhincodon typus.*

(2) It is the responsibility of the person in charge of a vessel to comply with a requirement placed on that vessel by this notice.

Declaration of a close season

4. (1) Subject to clauses 5 to 14, a close season is declared in respect of whale sharks in all State waters.

(2) The close season is for the period commencing on the day on which this notice is published in the *Government Gazette* until the day on which this notice is cancelled or this clause is varied by a notice under section 14 (2) (b) of the Act,

Restriction on number of vessels in or near contact zone

5. (1) A vessel must not enter a contact zone if another vessel is in the contact zone.

(2) If a vessel is in a contact zone and a second vessel is within 400 metres of the relevant whale shark, any other vessels must maintain a distance of at least 400 metres from that whale shark.

Restriction on period in contact zone

6. A contact vessel must not remain in the same contact zone for longer than 90 minutes.

Restriction on vessel speed in contact zone

7. (1) Subject to subclause (2), a contact vessel must not exceed 8 knots in a contact zone.

(2) If, for reasons of safety, a contact vessel must exceed 8 knots in a contact zone, that vessel must leave the contact zone as soon as is practicable.

Proximity of contact vessel to whale shark

8. A contact vessel must at all times maintain a distance of at least 30 metres from the nearest whale shark.

Direction of approach

9. If swimmers or divers are to enter the sea from a contact vessel to view a whale shark, the contact vessel must approach a whale shark from the opposite direction of travel to the whale shark's direction of travel.

Physical contact with whale sharks prohibited

10. Subject to clause 12, a person must not touch or ride on, or attempt to touch or ride on, a whale shark.

Proximity of swimmers or divers to whale shark

11. Subject to clause 12, a person in the sea must at all times maintain a distance of at least:

(a) 3 metres from the head or body of a whale shark, when approaching a whale shark from any direction; and
(b) 4 metres from the tail of a whale shark, when approaching the tail from any direction.

Exception when authorized under the Act

12. Clause 10 and 11 do not apply to a person who is authorized under the Act to make physical contact with a whale shark, if that contact is in accordance with the authorization (eg. *authorized under a scientific licence).*

Motorized swimming or diving aids, and other aids, prohibited

13. (1) A person must not use a submersible motorized or otherwise powered swimming or diving aid in a contact zone.

(2) A person must not use any device capable of towing or carrying a person, that is towed behind a vessel, in a contact zone.

Other taking, etc., of whale sharks prohibited

14. (1) A person must not capture, disturb, molest or take in any other way, a whale shark unless that person does so in accordance with this notice and the *Wildlife Conservation Act 1950,* or unless it is lawful for that person to do so -

(a) under the *Fish Resources Management Act 1994; or*
(b) under the *Conservation and Land Management Act 1984.*

(2) To the extent that this notice and the *Wildlife Conservation (Fauna of Ningaloo Marine Park) Notice 1992** are inconsistent, this notice prevails.

[Published in Gazette of 17 July 1992 at p. 3388-9]*

P. G. FOSS, Minister for the Environment

APPENDIX II

Commercial Whale Shark Interaction Licence: Schedule and Code of Conduct

CONSERVATION AND LAND MANAGEMENT ACT 1984 (SECTION 101)
CONSERVATION AND LAND MANAGEMENT REGULATIONS 1992 (PART 5)

LICENCE

This licence is not valid without the signature of the Executive Director or his delegate

The Executive Director of the Department of Conservation and Land Management hereby grants to:

Approved Vessel:

....

Substitute Vessel:

....

....
Licence holder

a licence for the period	1 January 1995 *Commencement Date*	to	31 December 1997 *Expiry Date*

to enter upon and use land within the

Ningaloo Marine Park north of Point Cloates,
for Tours from Tantabiddi
....
Approved Areas

in order to operate

Whale Shark Interaction Tours
....
Approved Activities

subject to the provisions of the Conservation and Land Management Act 1984, and all subsidiary legislation made under it and to the conditions and restrictions set out in Schedule 1 attached.

....
Executive Director Date

CONSERVATION AND LAND MANAGEMENT ACT 1984 (SECTION 101)
CONSERVATION AND LAND MANAGEMENT REGULATIONS 1992 (PART5)
LICENCE TO ENTER UPON AND USE LAND IN ORDER TO CONDUCT GUIIDED TOURS, INSTRUCTIONAL
COURSES AND LEISURE ACTIVITIES - SCHEDULE

Licence Number: ....

Expiry Date: ....

SCHEDULE 1

1. The licence holder must abide by the conditions and restrictions as set out in the "General Licence Conditions" dated July 1994 as varied from time to time by the Executive Director.

2. The licence holder must prepare, keep and preserve a full record of operations indicating, on a daily basis and in a form approved by the Executive Director, details of whale shark sightings and the number of passengers carried during the operation of the licence, and

   (a) make this record available to the Executive Director on request; and

   (b) submit a copy of the record of operations to the Exmouth CALM office, at weekly intervals during the operation of the licence, for the licence activities conducted during the previous week.

3. In consideration for the licence, the licence holder must pay to the Executive Director

   (a) a charge of $15.00 per adult per day and $7.50 per child (under the age of 16) per day for all paying passengers carried during the operation of the licence between 11 March and 9 June (inclusive) each year, payable on or before 10 July for each year of the licence period; and

   (b) an annual (non-refundable) deposit on these charges of $750.00 on or before 31 January for each year of the licence period. Note that this deposit will be deducted from the amount payable under Condition 3 (a), and represents the minimum annual licence charge payable.

4. Upon payment of the deposit required under Condition 3 (b), the Executive Director will issue to the licence holder passenger validation tickets for the purposes of Condition 6. At the completion of each whale shark season, all unused passenger validation tickets must be returned to the Executive Director on or before 10 July each year. The difference between the number of tickets issued and the number of tickets returned will be used to assist calculation of the amount payable under condition 3 (a).

CODE OF CONDUCT - COMMERCIAL WHALE SHARK INTERACTION TOURS (NINGALOO MARINE PARK)

5. The licence holder must ensure that interactions occur during daylight hours only.

6. The licence holder must ensure that each paying passenger is issued a passenger validation ticket appropriate to their age group, to be supplied by the Executive Director, for each day, or part thereof, that the passenger spends on a whale shark interaction tour conducted by the licence holder, and that each ticket issued is validated as required by the Executive Director.

7. The licence holder must co-operate with the Department of Conservation and Land Management (CALM) in gathering and providing any data which may be required for research and management purposes.

8. The licence holder must complv with all directions issued to him by an officer designated under the CALM Act 1984 as amended.

9. The 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.

10. The licence shall be displayed in prominent position on the vessel specified on the licence.

11. The licence holder must ensure that all due care is taken to avoid stressing or injuring whale sharks and interaction activities are to cease immediately any stress or injury is apparent.

12. The licence holder must ensure that activities authorised under the licence are conducted each year of the licence period. If the licence is not used to a reasonable extent. as determined by the Executive Director, the Executive Director may cancel the licence.

13. The licence not transferable, The licence holder must explain to prospective purchasers of a business operation that involves the operation of the licence that the licence is not transferable, and that the prospective purchaser would be required to make application to the Executive Director to obtain a new licence to continue the licensed activities conducted by the licence holder.

"Licensed vessel" means the vessel nominated on the licence as the vessel to be used by the licence holder to carry out the licensed activities.

"Exclusive contact zone" means all waters within a 250 metre radius of any whale shark.

"Swimmer" includes divers, snorkelers and any other persons in the water within the exclusive contact zone.

EXCLUSIVE CONTACT (EXCLUSION) ZONE

14. Only one licensed vessel is to operate within the exclusive contact zone at any one tune. All other vessels are to use boat power as necessary to avoid any encroachment into an exclusive contact zone occupied by another vessel.

15. The first vessel to encroach within an exclusive contact zone will be deemed to be "in contact" with a whale shark, regardless of the position of any spotter aircraft. Other vessels should attempt to locate other sharks, with the exception that the second vessel to arrive at the exclusive contact zone may queue to have access to the shark by maintaining a minimum distance of no less than 250 metres from the contacted shark. All other licensed vessels are to maintain a distance of at least 400 metres from the contacted shark.

16. A licensed vessel may remain "in contact" with a whale shark for a maximum of ninety (90) minutes. Swimmers from the licensed vessel may remain in the water with a shark for a maximum of sixty (60) minutes from the time of first entry. into the water.

17. In the event that two (2) or more whale sharks are within a 250 metre radius of each other the limit of one vessel "in contact" still applies until the sharks separate by more than 250 metres, in which case each shark will have its own exclusive contact zone.

18. In the event that two (2) or more whale sharks with swimmers "in contact" from separate vessels close to within 250 metres of each other, skippers must co-operate to ensure the safety of their swimmers and the sharks.

LICENSED VESSELS AND THEIR TENDERS

19. The vessel nominated by the licence holder to be the licensed vessel must not be nominated as the licensed vessel to be used by another licence holder.

20. The licence holder must nominate a principal vessel to be used during the operation of the licence, and may nominate a substitute vessel to be used only in the event that the primary vessel is unavailable. The substitute vessel may be a vessel nominated as the licensed vessel to be used by another licence holder, only where unavailability of the primary vessel is for mechanical reasons.

21. Licensed vessels will be restricted to a maximum of one diving tender in addition to the licensed vessel.

22. Licensed vessels and diving tenders must not approach within thirty (30) metres of a whale shark and shall move at a slow speed (8 knots or less) when within an exclusive contact zone.

23. Licensed vessels and tenders may only approach whale sharks from ahead of the shark's direction of travel and must drop swimmers into the water no less than thirty (30) metres ahead of the shark.

24. Licensed vessels must clearly display one (1) dive flag (International Code Flag 'A') and one "whale shark" flag of a design approved by the Executive Director to indicate when swimmers are in the water and must maintain radio contact with other approaching vessels to advise that diving/shark interactions are in progress.

SWIMMERS

Licence holders must ensure that the "in water" activities of swimmers comply with the following:

25. Swimmers must treat all whale sharks with caution and at all times recognise that while they appear to be "gentle giants" they are wild animals that can inflict serious injury if they, strike a swimmer with their body, tail or fins.

26 Swimmers must not touch a whale shark under any circumstances and must maintain a minimum distance of at least three (3) metres from the head or body of a shark and four (4) metres from its tail.

27. Swimmers must not attempt to block a whale shark from its chosen direction of movement.

28. Swimmers must not undertake flash photography.

29. The number of swimmers in the water with a whale shark at any one time is limited to a maximum of ten (10).

30. The number of swimmers to be carried by a licensed vessel is limited to a maximum of twenty (20) unless otherwise endorsed on the licence.

31. Swimmers must not use dive scooters or any other motorised propulsion aid.

CAUTION: **Whale sharks are normally gentle but are capable of inflicting injury or death, particularly if harassed or distressed.**

32. The licence will not be automatically renewed upon expiry of the licence period. The licence holder should expect that licence renewal will be subject to a competitive application process, following a full review of licence activities and numbers.

INDEMNITY

33. The Licence Holder hereby indemnifies the Executive Director from and against liability for all actions, suits, demands, costs, losses, damages and expenses (hereinafter called "claims") which may be brought against or made upon the Executive Director or which the Executive Director may pay, sustain, or be put to by reason of damage to property or injury to persons (including death) caused by or arising in any way out of the conduct of the Licence Holder on any lands or waters managed by the Department of Conservation and Land Management ("CALM") or generally as a result of the presence of the Licence Holder, or the Licence Holder's agents or clients on lands or waters managed by CALM and for the purpose of this indemnity the Licence Holder shall at all times during the period of the licence maintain a policy of public liability insurance in the names of the Licence Holder and the Executive Director to the extent of their respective rights and interests for a sum of not less than 5 million dollars ($5,000,000) to cover claims to which this indemnity applies made against the Executive Director or the Licence Holder AND SHALL LODGE WITH THE EXECUTIVE DIRECTOR proof of the insurance policy with the interest of the Executive Director noted thereon and shall on demand by the Executive Director produce evidence of current premiums required under the policy having been paid.

I confirm that I have read and will comply with the conditions and restrictions above.

....

Licence Holder Date

APPENDIX III

Additional Research and Monitoring Studies

Whale shark movements and migratory patterns

There are a number of different techniques that could be utilised to obtain further information on whale shark movements and migratory patterns, including:

- acoustic telemetry;
- archival tagging;
- satellite tracking; and
- sightings database.

Telemetry usually involves the attachment of an electronic device on to the animal. This could be a disturbance and tagging-induced artifactual behaviours have been documented in sharks (Nelson, 1990). However, telemetry tagging can be utilised to collect some of the data traditionally accomplished by conventional tagging, and has the major advantage that it does not rely on physical contact with a large number of animals.

Acoustic telemetry

Acoustic telemetry has been widely used to study movement patterns in free-ranging sharks (Nelson, 1990). Details of horizontal and vertical movement patterns, tidal phase and diel activity cycles, and the influence of environmental factors such as prey location, water salinity and depth, bottom topography and thermal strata can be obtained using this technology. Acoustic tags have already been successfully used to track whale sharks at Ningaloo Reef over short periods. Further ultrasonic tagging will reveal more information about the shark's short-term movements. It will also enable comparisons to be made between shark movements during human interactions and movements when undisturbed. Acoustic tracking can also be utilised to maintain contact with individual sharks whilst other devices, such as satellite transmitters, are being attached. The placement of acoustic listening posts on the sea floor in the area where the sharks were originally tagged would allow automated monitoring of the time of arrival and departure of sharks from the area on a continual basis.

Archival tagging

Archival or 'smart' tags have successfully been used to study the behaviour and migration of southern bluefin tuna (Gunn, *et al.* 1994). Six were attached to whale sharks at Ningaloo Reef in 1994, and the retrieval of one of these after 24 hours provided valuable information on short-term horizontal movements and diving patterns (Gunn, *et al.*, in preparation). Further archival tagging should be carried out, as the more tags deployed increases the chances of retrieving one or more in future seasons at Ningaloo Reef, or possibly from other locations. The suitability of the attachment method and the need to take full records of the tagged sharks are issues that need to be addressed in any further archival tagging work.

Satellite tracking

Satellite-linked UHF radio packages have successfully been utilised to record the medium and long-term movements and diving patterns of a number of large, free-ranging marine animals, including southern elephant seals (McConnell, *et al.*, 1992), narwhals (Martin, *et al.*, 1994), and belugas (Smith & Martin, 1994). The basking shark was the first marine animal successfully tracked using a satellite-based data collection and location system (Priede, 1984). For the last three years whale sharks have been tracked using satellite transmitters in the Sea of Cortez, Gulf of California (S. Eckert, pers. comm.). These transmitters are providing data on animal location, depth and the temperature of the surrounding water. These studies have revealed that whale sharks are good subjects for satellite tracking and the researchers have been able to track individuals for periods of more than 12 months.

Sightings database

There are numerous anecdotal reports of whale shark sightings along the coastline of Western Australia. Many of these reports are unconfirmed and details on exact time, date, location of sighting, number of sharks seen, behaviour etc., are often unavailable. In order to collect and collate accurate data, a central sightings database should be established. Records could be collected through the use of standard record sheets, distributed to various users of the marine environment - local and state management agencies, the oil and gas industry, commercial shipping, fisheries, defence, dive operators, private vessels, recreational divers and snorkellers, aerial sight seeing tours, etc.

Additional Studies

There are a number of other research projects that could be undertaken on whale sharks off Ningaloo Reef. In assessing future research proposals higher priority may have to be assigned to studies that yield information which leads to the modification of management controls to minimise or reduce any human impacts on the sharks.

Morphometrics, growth rates and ageing

It is possible that accurate underwater measurements of whale sharks could be made at a distance using stereophotography. This technique produces paired photographs that can be utilised to accurately determine overall shark length (Klimley & Brown, 1983; van Rooij & Videler, 1996). Stereophotography, combined with photogrammetry analysis using advanced CAD (computer aided design) software programmes, can produce a three-dimensional image of a subject which can be processed to reveal information on a range of morphometric parameters. Several pairs of stereo photographs of whale sharks at Ningaloo Reef were taken during the 1995 season (P. Baker, pers. comm.) and it is hoped that they will be suitable for analysis by computerised photogrammetry. This method may offer a remote and accurate method of measuring body size, that has several advantages - it can be done in-water with minimal disturbance to the animal, and parameters can be measured without distortions that often result when a large marine animal is measured out of the water.

If stereophotography and image analysis photogrammetry are suitable methods for recording and analysing whale sharks dimensional data (including clasper length in males) it may be possible to collect information on individual variation in growth rate by monitoring the morphometrics of individual sharks identified through a central photo-identification database. Age and growth rate data may also result from further study of dead stranded animals or from specimens from fisheries.

Tissue sampling

Samples of muscle and other tissues have been used in biochemical studies of a variety of marine animals to examine population genetics, diet and trophic level, and presence of biological pollutants. Mitochondrial DNA sequence analysis (karyotyping or gene mapping) has promise as a technique to investigate intra-specific phylogenetics of geographically separated populations. Researchers at the Hubbs-Sea World Research Institute and the University of Florida are conducting a global genetic survey of whale sharks to examine geographic relationships using molecular genetic analyses of DNA extracted from tissue samples (B. Stewart, pers. comm.). The trophic levels of several shark species, including the planktivorous basking shark, has been assessed from analyses of stable carbon isotope levels from muscle samples (Rau *et al.*, 1983). It has been hypothesised that predictable rates of protein accumulation in tissues could be used as an age-determination technique for marine animals such as sharks (Cailliet & Tanaka, 1990).

Whilst it may be possible to obtain tissue samples from living whale sharks (perhaps in conjunction with telemetry tag attachment), obtaining statistically valid sample sizes would be difficult, and could result in an unacceptable level of disturbance for the whale sharks at Ningaloo Reef. Priority should therefore be assigned to research that is minimally intrusive and does not result in increased stress for the animals.

Function of markings

More information regarding the possible roles of the whale shark's pigmentation pattern may be revealed by behavioural studies of the animal and by collation of photographic records of individual markings in a central database.