

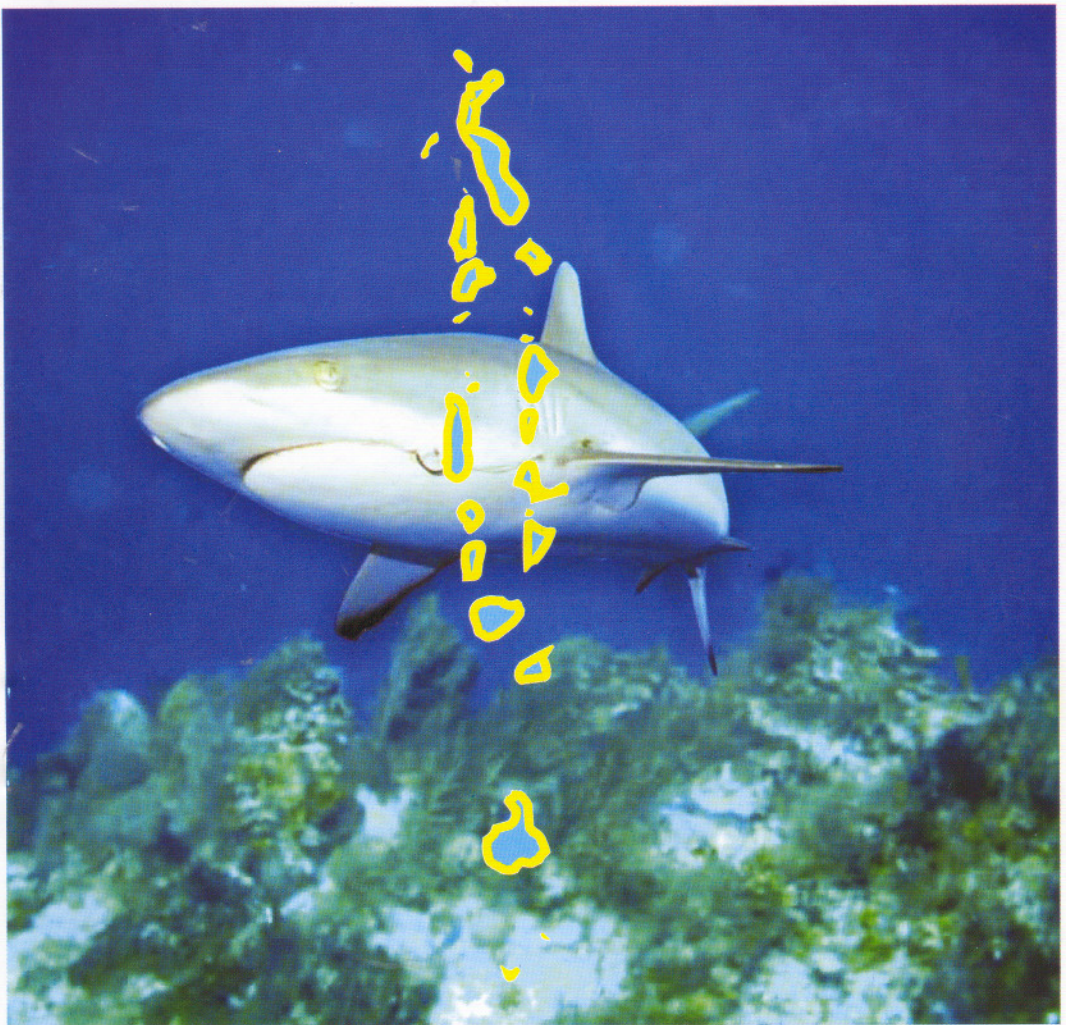


MALDIVES MARINE RESEARCH BULLETIN

A Publication of the Marine Research Centre
Malé, Republic of Maldives

No: 8

10 December 2006



MALDIVES MARINE RESEARCH BULLETIN

The Maldives Marine Research Bulletin is published by the Marine Research Centre of the Ministry of Fisheries, Agriculture and Marine Resources. The Bulletin aims to improve understanding of the Maldivian marine environment and to promote sustainable utilization of marine resources by providing a means of disseminating relevant information. Each issue is dedicated to themes on marine topics, with particular emphasis on fisheries and marine life. Bulletins will include original research results, reviews and manuals. Information published in any Bulletin may be freely used, but the source should be acknowledged. All enquiries should be addressed to:

MMRB - Editorial Board
Marine Research Centre
H. Whitewaves
Malé 20-06
Republic of Maldives

Tel: (+960) 332 - 2242 / 332 - 2328
Fax: (+960) 332 - 2509
Email: info@mrc.gov.mv

Director	Dr. M. Shiham Adam
Editor	Dr. M. Shiham Adam
Editorial Board	Dr. M. Shiham Adam, Mariyam Saleem
Secretary	Ajla Rasheed
Cover design	Ibrahim Faizan

Certificate of Registration	613
Printers	Umeedhee Press Printers & Publishers
Typeset in	Times New Roman 10pt

EDITORIAL

MALDIVES MARINE RESEARCH BULLETIN

VOLUME 8

10 DECEMBER 2006

The Maldives Marine Research Bulletin is published by the Marine Research Centre of the Ministry of Fisheries, Agriculture and Marine Resources. The Bulletin aims to improve understanding of the Maldivian marine environment and to promote sustainable utilization of marine resources by providing a means of disseminating relevant information. Each issue is dedicated to themes on marine topics, with particular emphasis on fisheries and marine life. Bulletins will include original research results, reviews and manuals. Information published in any Bulletin may be freely used, but the source should be acknowledged. All enquiries should be addressed to:

The Maldives Marine Research Bulletin is published by the Marine Research Centre of the Ministry of Fisheries, Agriculture and Marine Resources. The Bulletin aims to improve understanding of the Maldivian marine environment and to promote sustainable utilization of marine resources by providing a means of disseminating relevant information. Each issue is dedicated to themes on marine topics, with particular emphasis on fisheries and marine life. Bulletins will include original research results, reviews and manuals. Information published in any Bulletin may be freely used, but the source should be acknowledged. All enquiries should be addressed to:

The Maldives Marine Research Bulletin is published by the Marine Research Centre of the Ministry of Fisheries, Agriculture and Marine Resources. The Bulletin aims to improve understanding of the Maldivian marine environment and to promote sustainable utilization of marine resources by providing a means of disseminating relevant information. Each issue is dedicated to themes on marine topics, with particular emphasis on fisheries and marine life. Bulletins will include original research results, reviews and manuals. Information published in any Bulletin may be freely used, but the source should be acknowledged. All enquiries should be addressed to:

I would like to thank Dr. Shiham Adam for his advice to the Editorial Committee and for his constructive comments on both the papers. Marie Saleem and Aishah Rasheed deserve special thanks for their effort in all the stages of publishing the contents of MMRB. I would also like to acknowledge the staff of Umeedhee Press dedicated to designing the front page and the layout of the journal. Many thanks go to Aishah Rasheed who helped in all the stages of the publication.

Marine Research Centre
Ministry of Fisheries, Agriculture and Marine Resources
Malé, Republic of Maldives

EDITORIAL

I am delighted to be publishing volume eight of the Maldives Marine Research Bulletin this year. The first paper in this issue concerns the development of sustainable shark diving ecotourism while the second paper presents descriptions of three crabs from Laamu Atoll.

Shark watching by divers is a very important aspect of the tourism product from the Maldives. While the shark watching or shark diving ecotourism is a non-extractive use of the resource, shark fishing is an extractive use that requires strict management from a fishery perspective. Unfortunately sharks are long-lived, sexually mature late and have low reproductive potential, which require very close monitoring for management to be effective. In the Maldives reef sharks have been heavily fished, and as a measure for conflict resolution between fisheries and tourism industries, a 10 year moratorium has been imposed on shark fishing inside and within 12 miles from the atoll rim of seven atolls since 1998. The paper highlights these sensitive issues, carefully arguing for non-extractive sustainable shark diving ecotourism as the way forward to conserve this nationally important resource.

The paper on crabs highlights a commercially important species of crab found in Laamu Atoll along with two other species of poisonous crabs. The paper gives a full taxonomic description of these, including diagrams showing salient features for identification.

I would like to thank Dr. Charles Anderson for his advice to the Editorial Committee and providing constructive comments to both the papers. Marie Saleem and Ajla Rasheed deserve special thanks for their effort in all the stages of publishing this volume of MMRB. I would also like to acknowledge the time Ibrahim Faizan dedicated to designing the front page and fine tuning the crab diagrams. Many thanks go to Aishath Shahinda who helped to do the layout of the publication.

Editor

Development of a Sustainable Shark Diving Ecotourism Industry in the Maldives: Challenges and Opportunities

R. Aidan Martin^{1,2} and Abdul Azeez Abdul Hakeem²

¹ReefQuest Centre for Shark Research, Vancouver, Canada,
email: elasm@shaw.ca

²Banyan Tree Maldives Marine Lab, Vabbinfaru, North Male' Atoll, Maldives,
email: abdul.azeez@banyantree.com

1. SUMMARY

Available data indicate that shark fishing in the Maldives is not sustainable. Populations of reef, pelagic, and deep-sea sharks in Maldivian waters are overexploited by fishers. Due to their value in attracting dive tourists to the Maldives, reef sharks are not permitted to be fished within the Tourism Zone, although illegal fishing for such sharks occurs within the Zone at least occasionally. Whale sharks, which were formerly targeted by small-scale local fisheries, have been protected in the Maldives since June 1995 (Plate 1). Development of shark diving ecotourism offers the Maldives an economically advantageous and ecologically sustainable alternative use of sharks as a living resource, provided proper management is put in place.

Economic comparison of shark fishing versus shark diving in the Maldives indicates that the latter, as a non-consumptive usage of sharks, can ultimately generate greater revenues that spread more fully throughout the local economy and over a longer period than the former. Problems in the shark diving industry in the Maldives and elsewhere include reduction of shark populations, controversy over the effects of shark feeding, variable degrees of client satisfaction, and lack of shark research and monitoring programmes.

Toward development of a sustainable shark diving ecotourism industry in the Maldives, the following steps are recommended: 1) cessation of

reef shark fishing, 2) governmental protection of reef areas where sharks can be reliably encountered by divers, 3) development of shark interaction guidelines intended to increase diver safety and reduce stress on sharks, and 4) development of a dedicated system for monitoring development of the shark diving ecotourism industry and its effects on sharks. To reduce diver-induced stress on reef sharks and whale sharks, recommended interaction guidelines are offered. To increase the standard of service offered by shark diving operators in the Maldives, development of an accredited course for shark diving operators that is complementary to the Ministry of Tourism's existing SharkWatch programme is proposed. In summary, a 6-part Action Plan for development of a sustainable shark diving ecotourism industry in the Maldives is proposed.



Plate 1. Whale Shark (*Rhincodon typus*), photo by R. A. Martin

2. INTRODUCTION

In the early days of recreational diving, intentionally seeking out encounters with sharks was a fringe activity restricted to a few bold undersea pioneers. In the mid-1970s, the motion picture *Jaws* spurred widespread fear and hatred of sharks, often expressed as deliberate hunting and killing of these animals (Ellis 1994). During the 1980s, due largely to well-balanced natural history films on television, public attitudes toward sharks changed from fear and avoidance to curiosity and fascination (authors, pers. obs.). To cater to this new-found fascination, dive operators began to offer organised shark dives. Commercial shark dives were offered sporadically at first and later, as market interest grew, with increasing regularity. By the mid-1990s, shark diving had grown enormously in popularity to become a major global industry, generating hundreds of millions of dollars annually and often featuring a strong educational component (Anderson 2002). Today, shark diving is offered in nearly 40 countries at some 300 recognised dive sites (Carwardine & Watterson 2002; Carwardine 2004).

Development of shark ecotourism has been especially rapid in the Asia-Pacific region, where the activity is no longer restricted to scuba divers but also draws snorkellers as well as boat- and shore-based observers (Anderson 2002). In the Maldives, 16 shark diving sites have been established on six atolls within the tourism zone and is utilised by at least 39 local resorts (Carwardine & Watterson 2002); six of these sites are not protected (Figure 1). Even at existing protected dive sites, proper enforcement is not in place. Shark species most commonly observed by divers and snorkellers in the Maldives include the Grey Reef Shark (*Carcharhinus amblyrhynchos*; Plate 2), Blackfin Reef Shark (*C. melanopterus*; Plate 3), Whitetip Reef Shark (*Triaenodon obesus*; Plate 4), Scalloped Hammerhead (*Sphyrna lewini*), Tawny Nurse Shark (*Nebrius ferrugineus*), Zebra Shark (*Stegostoma varium* = *S. fasciatum*; Plate 5), and whale shark (*Rhincodon typus*) (Anderson 2002; Carwardine & Watterson 2002). Reef sharks are present at most shark dive sites in the Maldives year-round, while whale sharks are most commonly seen at Ari, Baa, and Dhaalu atolls and are sporadic at other sites (Carwardine & Watterson 2002).

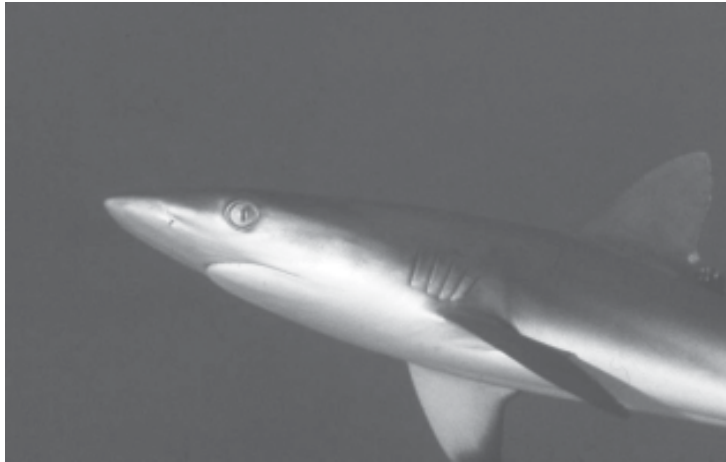


Plate 2. Grey Reef Shark (*Carcharhinus amblyrhynchos*), photo by
R. A. Martin



Plate 3. Blackfin Reef Shark (*Carcharhinus melanopterus*), photo by
R. Gardner

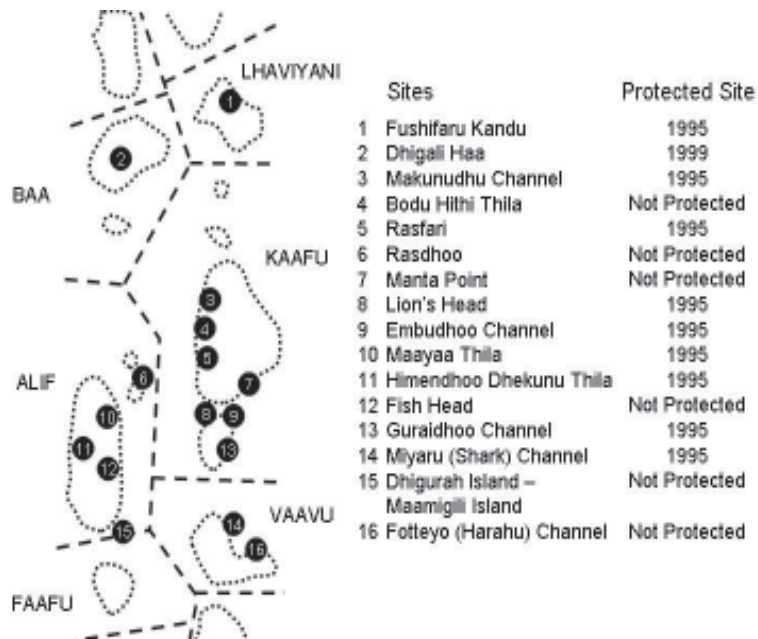


Figure 1. Location of 16 established shark diving sites in the Maldives and their status (data from Carwardine & Watterson 2002 and M. Shiham Adam, pers. comm.).



Plate 4. Whitetip Reef Sharks (*Triaenodon obesus*), photo by K. Smith



Plate 5. Zebra or Leopard Shark (*Stegostoma varium*), photo by R. A. Martin

Sharks are generally slow-maturing, long-lived animals featuring a low reproductive rate that suggests a low mean rate of natural mortality (Camhi et al. 1998). For example, Grey Reef Sharks mature at an age of 7-7.5 years, live at least 25 years, and produce 1-6 pups after a year-long gestation (Compagno et al. 2005). Many reef shark species are apparently resident throughout their lives, inhabiting well-defined home ranges through which they move in highly predictable ways (Nelson & Johnson 1980; McKibben & Nelson 1986; Nelson 1990). This combination of features renders reef sharks highly vulnerable to even moderate levels of fishery mortality. The long-term effects of depletion of shark populations are incompletely known, but are likely to be far-reaching throughout the ecosystems of which these predators are an integral part (Stevens et al. 2000).

Sharks are commercially fished in the Maldives via gillnet, handline and longline for fins, meat, and jaws (Anderson & Ahmed 1993; Anderson & Waheed 1999; Anderson & Hafiz 2002). In addition, shark liver oil is still used in the Maldives as a traditional sealant and water-proofing treatment for boat hulls. Whale shark were traditionally fished in the Maldives for their liver oil but have been protected by national fisheries regulation since June 1995 (Anderson & Ahmed 1993; Camhi et al. 1998). In a recent government-commissioned socio-economic assessment, it was concluded that reef shark stocks in the northern atolls of the Maldives have already been grossly overfished (McMaster Elliot & Partners 2002). Currently, reef shark fishing in the Maldives is permitted only in 13 atolls outside the Tourism Zone (A. Naseer, pers. com.). Despite this restriction, some artisanal shark fishing does occur within the tourism zone. For example, in March 2004, the authors visited Dhangethi, in Ari Atoll, where they saw numerous reef shark jaws for sale in various island shops and examined the catch of a local shark fishing boat that had just docked with freshly cleaned reef shark jaws in the hold. Fish Head, in Ari Atoll, was one of the most famous shark diving sites in the Indian Ocean; the removal of about 20 Grey Reef Sharks in the early 1990's resulted in sufficient reduction in shark sightings that dive operators, unable to guarantee shark encounters, have suspended or greatly reduced frequency of visits (Anderson & Waheed 1999). Thus, reef shark fisheries in the Maldives are in direct conflict with the economically important diving tourism industry (Anderson 2002; Anderson & Ahmed 1993; Anderson & Waheed 2001).

Development of a sustainable shark diving industry in the Maldives is feasible. But developing a responsible shark diving industry depends

upon balancing the multitudinous needs of divers and other ocean users against impacts on sharks and the local marine ecology (Carwardine 2002). Many problems and controversies surround the shark diving industry, especially relating to using bait to attract sharks (Brylske 2000). This paper draws on published literature and the authors' informal interviews with shark divers and shark dive operators to: 1) summarise the economics of shark fishing versus shark ecotourism in the Maldives; 2) examine common problems in the development of shark ecotourism in other regions; and 3) propose solutions to said problems as they might be implemented in the Maldives toward development of a sustainable local shark diving industry.

3. ECONOMICS OF SHARK FISHING VS. SHARK DIVING

Artisanal shark fishing has a long and rich tradition in the Maldives (Anderson & Ahmed 1993). FAO data on landings have only become available since about 1970, but show a marked (>5x) increase in reported landings from the early 1990s onward (Figure 3). This increase corresponds with the widespread rise in Asian affluence and concomitant increase in commercial demand for shark fins. Three main types of shark fishery are conducted in the Maldives, all propelled by export demand: 1) an offshore longline fishery for pelagic oceanic sharks, processed for salt-dried meat (for export to Sri Lanka) and dried shark fins (for export to east Asian markets); 2) a predominantly bottom-set gillnet and handline fishery for reef sharks, processed for salt-dried meat and dried fins for export; and 3) a vertical longline fishery for deep demersal sharks, processed for squalene-rich liver oil for export to Japan (Anderson & Hafiz 2002). Anderson & Ahmed (1993) estimated that in 1992, export earning from all three commercial shark fisheries was about US\$1.2 million. The pelagic shark fishery has expanded in recent years while the deep-sea shark resource has been overexploited and the fishery has collapsed. The fishery for reef sharks has been heavily exploited in recent years, although the status of their stocks is difficult to assess in the absence of CPUE data (Anderson & Hafiz 2002). It has been estimated that, in 1992, the total monetary value of a single processed (fins, meat, and jaws) Grey Reef Shark to a Maldivian fisherman was about US\$32 (Anderson & Ahmed 1993). Although some small (maximum length ≤ 1.5 m) tropical reef sharks exhibit relatively rapid juvenile growth and early maturation and may be able to resist a moderate level of fishing pressure, the sustainability of

larger, slower-growing reef sharks is highly doubtful (Nichols 1993). The global IUCN conservation status of selected tropical reef sharks is presented in Table 1.

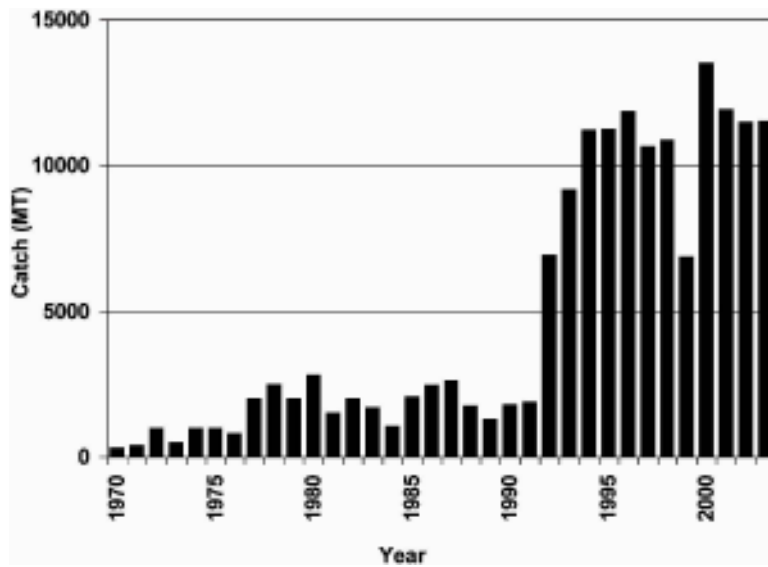


Figure 3. Shark catch by year from the Maldives (1970-2003), based on FAO Fishery Statistics data.

Table 1: Global IUCN conservation status of selected tropical reef sharks taken in commercial shark landings that are also important to dive ecotourism in the Maldives (data from Compagno et al. 2005).

Species	Common Name	Status
<i>Nebrius ferrugineus</i>	Tawny Nurse Shark	Vulnerable
<i>Stegostoma varium</i>	Zebra Shark	Vulnerable
<i>Rhincodon typus</i>	Whale Shark	Vulnerable, CITES II
<i>Galeocerdo cuvier</i>	Tiger Shark (Plate 6)	Near Threatened
<i>Carcharhinus albimarginatus</i>	Silvertip Shark	Not Evaluated
<i>Carcharhinus amblyrhynchos</i>	Grey Reef Shark	Near Threatened
<i>Carcharhinus melanopterus</i>	Blackfin Reef Shark	Near Threatened
<i>Triaenodon obesus</i>	Whitetip Reef Shark	Near Threatened
<i>Sphyrna lewini</i>	Scalloped Hammerhead	Near Threatened

Sharks are a major draw attracting diving tourists to the Maldives and are important to its overall economy (Anderson & Ahmed 1993; Anderson 2002; Anderson & Hafiz 2002). Anderson & Ahmed (1993) estimated that, in 1992, shark watching by dive tourists generated direct diving revenues of US\$ 2.3 million. Further, they estimated that a single average-sized Grey Reef Shark living at a shark diving site had a mean monetary value of US\$3,300 per annum – some 100 times as much as the same shark dead in a boat. A dead shark can be sold only once; in contrast, Grey Reef Sharks are apparently resident on discrete parts of a given reef and may live up to 18 years after reaching maturity (Nelson & Johnson 1980; Compagno et al. 2005), and thus can be ‘sold’ over and over to new batches of diving tourists. Therefore, a single Grey Reef Shark living at a dive site, over the course of its adult life, could (at 1992 prices) generate nearly US\$60,000.



Plate 6. Tiger Shark (*Galeocerdo cuvier*), photo by N. Hammerschlag

Revenues generated by shark diving in the Maldives have likely increased substantially since 1992. Anderson & Ahmed (1993) estimated there were 76,800 shark-dedicated dives conducted in the Maldives during 1992. According to official Ministry of Tourism (MOT) statistics, 212,000 tourists visited the Maldives in 1992 and 485,000 in 2002 (Anderson & Waheed 2001; Ministry of Tourism 2003). If the number of shark dives has remained proportionate to the number of tourists, there were approximately 175,700 shark dives conducted in the Maldives during 2002. At an average cost of US\$42 per dive, direct revenue generated by shark diving in the Maldives during 2002 was about US\$7.4 million.

But such calculations tell only part of the story. When vacationing divers visit a tourist destination such as the Maldives, they do much more than dive. They stay at hotels or resorts, dine in restaurants, go on cultural tours, buy souvenirs, and partake of numerous other activities that have the desirable effect of injecting income into many parts of the host nation's economy. Thus, the indirect value of a live shark at a shark dive site is many times that of its direct value to – and the benefits spread far beyond – the local dive industry. Small wonder that, in 1995, 15 popular dive sites (of which 9 are or were renowned for their sharks) within the tourism zone were declared marine protected areas (Anderson & Hafiz 2002). And, in

1998, shark fishing was banned within the Tourism Zone (Anderson & Waheed 2001).

Where they can be reliably encountered (at least seasonally), whale sharks may be even more valuable than reef sharks to the local dive industry and regional economy. It has been estimated that, during the 2005 season, the whale shark ecotourism industry at Ningaloo Marine Park, Western Australia, injected a total of some US\$12 million into the local economy (B. Norman, pers. com.). These are impressive earnings for a three-month, seasonal ecotourism industry. In the Maldives, whale sharks can be reliably encountered at three atolls year round although a six-month season exists from June to November. During this period, whale sharks are seen on 50% of dedicated safari boat trips at Baa and Dhaalu atolls and 80% of trips from Ari Atoll. Collectively, these three atolls are served by 50 safari boats, which average 400 divers/snorkellers per week at a cost of US\$60 per diver. During the 6-month peak season, whale shark watching at these atolls generates some US\$31.2 million per annum in direct revenues. As with reef shark ecotourism, whale shark ecotourism in the Maldives generates several times this amount each year in indirect revenues from food, accommodation and transport.

The authors would like to stress that we feel sharks have intrinsic value as wildlife and should be protected as part of the shared natural heritage of all the world's people. However, we appreciate that the economic value of sharks as a living resource is a powerful incentive for their conservation. There is every reason to believe that shark diving ecotourism, if properly managed, is sustainable (Anderson 2002; Carwardine & Watterson 2002; Carwardine 2004; Topelko & Dearden 2005). In addition to providing a purely economic incentive for non-consumptive shark exploitation, shark diving ecotourism has the potential to generate other positive effects, including promoting shark conservation as well as reportage by shark diving participants of illegal fishing activities to local authorities and observations of shark behaviour and ecology to interested researchers (Anderson 2002). However, care must be taken to anticipate and alleviate possible negative impacts of shark diving ecotourism on shark behaviour, habitats, and ecology (Walker 2002; Compagno et al. 2005). Toward the goal of responsible development of shark diving ecotourism in the Maldives, it is worth examining problems encountered in developing shark diving ecotourism elsewhere.

4. COMMON PROBLEMS IN SHARK DIVING INDUSTRY

Shark diving ecotourism should be bound by the general principles and ideals of ecotourism (Table 2). Certain aspects of shark diving ecotourism are controversial, creating public relations and (ultimately) economic problems for the industry. Of these, by far the most controversial is the issue of attracting sharks via bait (Brylske 2000; Stafford-Deitsch 2000; Carwardine & Watterson 2002; Carwardine 2004; Topelko & Dearden 2005). One of the earliest shark feeding ventures was established in the Maldives in the early 1970's. In North Male' Atoll, Herwarth Voightman gained considerable fame for feeding sharks by mouth: he trained Grey Reef Sharks to take fish held by the tail between his teeth. After several near accidents and abrasions, Voightman switched to less exhibitionistic methods of shark feeding (Topelko & Dearden 2005). Such stunts, which are reminiscent of lion tamer acts, do not foster respect for sharks as wild animals. Even without such showboating, shark feeding stimulates much controversy.

The main arguments for and against shark baiting in shark diving ecotourism are summarised in Table 3. In response to critics who claim shark baiting for dive ecotourism endangers people, sharks, and the local marine ecology, in January 2002, the Cayman Islands banned feeding sharks underwater or chumming them from boats (Carwardine 2004). Also in January 2002, Florida became the first American state to prohibit divers from feeding sharks; in June 2002, Hawai'i became the second state to ban shark feeding (Carwardine 2004). These reactions are strictly precautionary and seem excessive, given that, 1) injuries to shark feeding participants are extremely rare and those few that have occurred were limited exclusively to 'shark wranglers' (feeders) rather than tourists, and 2) the closest confirmed shark attack to any established shark feeding site was some 160 km away (Perrine 1998; Carwardine 2004). Opponents to bans on shark baiting claim that such laws are a triumph of fear over reason and point out that it is hypocritical for a government to declare it illegal to bait sharks in order to observe them while perfectly legal to bait them to hook and kill them (J. Stafford-Deitsch, pers. com.). Although baiting sharks prolongs encounters with them and may not inevitably produce deleterious effects, these are in our opinion insufficient reasons to promote the practice.

Table 2: Five general principles of ecotourism and their rationale (adapted from Holling 1991; Lindberg & Hawkins 1993; Lindberg et al. 1993; McLaren 1998)

Principle	Rationale
Support conservation of natural resources	The founding principle of ecotourism is to increase tourism to areas of special natural value, beauty and interest in a way that contributes to the conservation of those areas. Without nature, there can be no nature-related tourism; mechanisms must be established for revenues and profits generated by a successful ecotourism enterprise or industry to support conservation efforts.
Environmentally sensitive	Careful consideration must be given to site selection and preparation, carrying capacity and limits of acceptable change, construction materials, energy production and consumption, water quality and usage, and waste generation and treatment. Construction projects should incorporate, whenever practical, alternative energy, water and waste treatment systems into construction projects – not only do they yield specific benefits to the project, but they can serve the educational mission of providing practical examples of the benefits of sustainable technologies.
Culturally sensitive	Ecotourism must be sensitive to the traditions, needs, lifestyles and expectations of local communities. It must include local communities in the planning and implementation process, and involve them in the product and its management, it must generate new and appropriate economic opportunities and benefits, and it must never result in the denigration of local cultural traditions.
Good business decisions and management	Ecotourism initiatives need to be creative, attractive, and marketable, with realistic expectations for economic benefit; thorough and conservative business plans, economic feasibility studies, marketing plans and financial projections are essential. It is important that the private business sector be included in ecotourism planning and implementation as well, as they bring valuable perspective and expertise to the process. Ecotourism is at its core a business enterprise with a higher social purpose; it is a customer-oriented, customer-driven business. If ecotourism development does not have a sound financial basis it will fail, and the opportunity for benefit will disappear.
Dedicated educational emphasis	Ecotourism is fundamentally about far more than destination development. The concept is predicated on visitors leaving the destination more cognisant of and sensitive to the conservation and resource management issues than when they arrived. This is part of what this kind of tourist is looking for – an interactive and often adventurous learning and entertainment experience that personally exposes them to an intimate cross-section of the destination.

Table 3: Summary of arguments for and against use of bait to attract sharks for dive ecotourism.

Arguments Against Shark Baiting	Arguments For Shark Baiting
<p>Baiting sharks reduces their natural fear of humans, teaches them to associate or depend upon people with hand-outs of food, increases their aggressiveness toward and likelihood to attack people</p>	<p>Sharks are very wary of humans in the water and do not approach closely or remain in the area long without the inducement of bait; sharks are opportunistic and learn quickly but there is no evidence that feeding sharks causes them to depend upon hand-outs from humans, increases their aggressiveness toward or likelihood to attack people; shark attack case histories attest that incidents are rare accidents, most of which have little or nothing to do with feeding</p>
<p>Feeding sharks unnatural foods is injurious to their health</p>	<p>Sharks baited for observation are typically offered scraps of fishes and other marine animals that are waste of seafoods caught locally for human consumption and of species that form a natural part of local sharks' diet; there is no evidence that such bait is in any way unhealthy for sharks; use of artificial foods or 'exotic' bait species is scrupulously avoided by reputable dive operators</p>
<p>Feeding sharks concentrates them unnaturally and causes long-term deleterious changes in the local marine ecosystem</p>	<p>Shark aggregations at feeding sites are temporary, after which they disperse and there is no evidence that their local populations are permanently increased as a result of feeding; reputable shark diving ecotour operators do not foster local fisheries specifically to support their need for bait and scrupulously avoid using bait from endangered or threatened species; quantities of bait used are typically very small compared to fish offal jettisoned overboard by fishermen since time immemorial and there is no evidence that shark feeding causes significant or long-term negative changes in the local marine environment</p>

On general principle, we believe that feeding sharks is never a good practice. It is far preferable that divers encounter sharks without baiting. Baiting presents a misleading conception of shark behaviour, largely limited to active or violent competition for food concentrated in a small area. In our experience, encounters in the wild with sharks that are relaxed and have not been artificially stimulated by food rank among the most serene, aesthetic, and serendipitously thrilling of underwater experiences. During such encounters, more subtle aspects of shark behaviour can be observed, including natural predation, social interactions and even courtship. It is certainly possible for divers to encounter sharks in un-baited contexts, provided their local populations are relatively intact. On a recent exploration of Dhaalu Atoll, one of us (RAM) encountered 26 Whitetip Reef Sharks during a 52-minute un-baited dive on the Velavaru house reef. At nearby Nilandhoo Kandu, Grey Reef Sharks are often attracted by squeezing an empty mineral water bottle underwater. Such a technique would take advantage of sharks' natural curiosity, although shark response would be expected to attenuate over repeated exposures. Underwater encounters with sharks under such un-baited contexts minimise impact on both sharks and the local marine environment, affording opportunities to observe and interact with sharks under more natural conditions.

Opportunities for divers to interact with sharks in the wild generate a number of positive consequences. These include: 1) increasing the value of sharks as living resources and create an ecologically and economically viable alternative to fishing for them; 2) creating opportunities for divers to appreciate the charisma, grace and beauty of sharks as well as to learn more about their biology and behaviour; and 3) inspiring divers to act as a potent public relations force on behalf of sharks, to promote widespread appreciation for them as wildlife worthy of human respect, admiration and conservation. The authors feel that the positive aspects of shark baiting, responsibly conducted for ecotourism purposes, outweigh the supposed – and largely unsubstantiated – negative impacts. However, we feel that the lack of conduct guidelines for shark baiting by dive operators and lack of interaction guidelines for shark diving ecotourists creates unacceptably elevated risks of: 1) accidental injury to participants and/or sharks; 2) driving sharks away from heavily dived areas; 3) interrupting shark courtship, mating, and pupping behaviours; and 4) degrading critical shark habitats. These issues must be addressed if a sustainable shark diving ecotourism industry is to be developed in the Maldives.

Another factor important to the development of sustainable shark diving ecotourism is client satisfaction. Informal interviews with shark diving ecotourists (hereafter referred to as shark divers) indicate that their primary motivations for seeking out encounters with sharks are: 1) a desire for adventure; 2) interactions with sharks as charismatic marine wildlife; and 3) photography or videography. Such interviews also reveal that, in general, shark divers fit a highly desirable socio-economic profile: they include both men and women, range in age from adolescent to post-retirement (roughly normally distributed, with some 80% between 25 and 40 years of age), are typically well educated (at least some college education), affluent (significant discretionary income and taking a foreign vacation at least once a year), and research travel destinations thoroughly (via dive magazines, guidebooks, and the internet) before committing to a holiday package.

This socio-economic and motivational profile of shark divers agrees well with that of divers in general visiting the Maldives (Salih 2000). Although no official statistics are available on the country of origin of dive tourists in the Maldives, it is likely that they represent a subsection of nationalities of all tourists visiting the Maldives (with the possible exception of visitors from India and China, who tend to be underrepresented among divers).

According to official MOT statistics, between January and April 2003, total tourist arrivals in the Maldives was 216,392 (an increase of 23.5% over the same period in 2002) and six nationalities were responsible for 78.8% of total tourist arrivals in the Maldives (Table 4). All six of these are first world nations, featuring a wealthy, well-educated populace. Thus, visitors to the Maldives in general and shark divers in particular are affluent, sophisticated and knowledgeable travellers whose holiday expectations and desires must be anticipated and accommodated.

Table 4. Nationality of tourist arrivals in the Maldives, January to April 2002 versus January to April 2003 and % change (Ministry of Tourism 2003).

Country of Origin	Arrivals Jan-Apr 2002	Arrivals Jan-Apr 2003	% Change	% Total Tourist Arrivals Jan-Apr 2003
Italy	47,223	66,273	40.3	30.6
United Kingdom	28,456	31,887	12.1	14.7
Germany	20,634	25,822	25.1	11.9
France	14,023	20,921	49.2	9.7
Switzerland	12,446	12,912	3.7	6.0
Japan	11,982	12,819	7.0	5.9

For all their variety, one characteristic unites all shark divers: a deep and abiding fascination with sharks. Informal interviews conducted by the authors indicate that divers in general, and shark divers in particular, are fairly knowledgeable about shark biology and behaviour by the time they arrive at their tourist destination. However, they continue to be curious about sharks and are always eager to learn more. Although the staff members of many dive operations are themselves divers, in our appraisal, their knowledge of shark biology and behaviour is not appreciably greater – and in many cases considerably less advanced – than that of shark divers. If the Maldives wishes to develop its reputation as a premier shark diving ecotourism destination, it must address the needs of knowledgeable and discriminating shark divers in an intensely competitive marketplace.

Another problem facing the Maldives in development of a sustainable shark diving ecotourism industry is the lack of a shark research and monitoring programme. Such a programme would require some care in setting up and will need some initial investment. But, once established, it could become largely self-funding, providing on-going monitoring of the growth of the shark ecotourism industry as well as changes in the species composition, abundance, ecology and behaviour of local sharks. One way in which monitoring growth of the ecotourism industry has been

accomplished elsewhere is through park user fees. It is well established that terrestrial ecotourists visiting national parks in Costa Rica do not mind paying park usage fees if they are confident that their contribution supports local research, education and conservation efforts (L. Rose, pers. com.). There is some evidence that shark ecotourists feel no different from terrestrial ecotourists in this regard. For example, operators offering shark dives in Beqa Lagoon, Fiji, collect a marine park fee of US\$15/diver/day. This revenue goes toward monitoring operator and shark diver conduct at this site as well as conducting basic research on the reef sharks utilising Beqa Lagoon. Informal interviews with shark ecotourists who had recently dived at Beqa Lagoon revealed that all were happy to pay the *per diem* because their funds were going toward supporting local shark research and conservation; some interviewed were repeat visitors who were proud that they could see improvements in research and conservation efforts, which they attributed partly to their support through park fees (J. Brunnschweiler, pers. com.). But Beqa Lagoon is a single, discrete sharkwatching site. In contrast, shark diving sites in the Maldives are distributed over such a large geographical area, it may be impractical to collect park user fees such as are charged at Beqa Lagoon.

5. PROPOSED MANAGEMENT OF SHARK ECOTOURISM IN MALDIVES

If the Maldives wishes to develop its reputation as a premier shark diving ecotourism destination, two main strategies seem prudent: 1) preserve healthy populations of reef and whale sharks of interest to shark divers, and 2) develop a standardised, government-sanctioned accreditation course for dive operation staff that provides a minimum standard of demonstrable expertise in the biology and behaviour of sharks. By implementing these strategies, the Maldives can ensure it continues to have enough sharks to draw shark divers and can offer a high level of quality assurance with respect to the service offered by shark diving operators.

Traditionally, the dive industry has been largely self-regulating. It is very much to the industry's credit that training has been standardised and accident rates are low compared with many other outdoor sports (Mountain 1996). Although certifying agencies, dive instructors and individual divers are uniformly pro-conservation, it seems unwise to leave development of standard shark ecotourism practices entirely to the dive

industry. Sharks are wildlife and, as such, fall under the management and protection of governments as a natural resource. Because sharks are also important to the tourism industry in the Maldives (Anderson 2002; Anderson & Ahmed 1993; Anderson & Waheed 2001), we respectfully suggest that the Ministry of Fisheries Agriculture and Marine Resources (MOFAMR) co-operate with MOT toward developing a well monitored and managed shark ecotourism industry in the Republic. By combining the scientific and resource management experience of the former with the tourism monitoring experience and economic resources of the latter, sharks in the Maldives can be protected as a shared birthright of all Maldivians.

With respect to developing a sustainable shark ecotourism industry in the Maldives, the remoteness of the nation is a double-edged sword: it has protected sharks from extensive population depletions that have occurred in more accessible regions, but it also limits recreational visitation to tourists with the financial means to do so. If the Maldives is to pursue development of its shark ecotourism industry, encounters with sharks must occur reliably. Otherwise, shark ecotourists will simply choose to go elsewhere, where shark encounters are more likely, taking their much-needed tourist dollars with them.

Logically, the first order of business should be to stop all shark fishing in the Maldives. Admittedly, this is much easier said than done. Despite the logistical and social hurdles, we propose that the government ban on reef shark and whale shark fishing in the Tourism Zone should be extended to all Maldivian waters, on the grounds that these animals are far too valuable to the ecology and economy of the Maldives to be sold-off at so many pennies a kilogram. MOFAMR data show clearly that reef shark populations in the Maldives are overexploited (Anderson & Ahmed 1993; Anderson & Waheed 2001; McMaster Elliot & Partners 2002). The government of the Maldives has not heavily invested into shark fishing (Topelko & Dearden 2005). By discontinuing shark fishing and switching to shark ecotourism as a sustainable, non-consumptive alternative, the Maldives stands to avoid the known and unknown negative impacts of depleting shark populations and gain significant long-term ecological and economic benefits.

A wholesale switch from consumptive to non-consumptive shark exploitation in the Maldives such as we propose carries inherent social consequences. For example, small-scale shark fishers typically have a

long history of fishing and often lack the interest, knowledge, skills, or equipment to benefit from local development of ecotourism industry (Topelko & Dearden 2005). However, fishermen who know local waters and have boat handling experience can be an invaluable asset to ecotourist diving ventures (authors, pers. obs.) and, as has been demonstrated in southeastern Peru, ecotourism also creates jobs for non-skilled workers (Groom et al. 1991). Since not all sectors of a community can benefit equally from shark ecotourism development, care must be taken to minimise wealth disparity that can be exacerbated by development of this new industry (Stonich 1998). One possible way to accomplish this might be socially-assisted education in various aspects of the tourism industry. The switch from shark fishing to shark ecotourism will likely be difficult for adults who have worked as fishers their entire lives, but it promises a better and sustainable future for their children. Such a switch from consumptive to non-consumptive use of wildlife is analogous to poachers becoming wardens in African game parks.

5.1 Operator Quality Control

Since the beginning of tourism within its borders, the Maldives has allowed a rather *laissez-faire* approach to development of diving operations in the Maldives. However, as described, shark divers are typically very knowledgeable and discriminating tourists. Accreditation of ecotourism operators in other venues has helped earn the trust and business of ecologically and socially responsible ecotourists (Wearing & Neil 1999). Thus, if the Maldives wishes to establish itself as a world-class shark ecotourism destination, some system of operator accreditation seems prudent. The governmental agencies best positioned to set standards for and monitor such accreditation are MOT and MOFAMR. Development of such an accreditation program will not be easy. But the rewards include a uniformly high level of quality assurance with respect to the service offered by shark diving operators and an international reputation as a world-class shark ecotourism destination. In addition, revenues generated by course tuition for this accreditation programme can help support monitoring and, if necessary, policing of the shark ecotourism industry. In this way, the Maldives cannot only build its own shark ecotourism industry in a sustainable manner, but also show the way to other nations that may be developing, or are considering developing, their own.

A detailed syllabus of a standardised accreditation course for shark ecotourism operators is beyond the scope of the present paper, but general topics that should be included in any such training programme include:

- Ecotourism ideals
- Code of conduct
- First aid
- Solving common tourist problems (sunburn, seasickness, snorkelling, photographic, or video equipment malfunction, etc.)
- Shark identification
- Shark interaction guidelines
- Shark biology and behaviour
- Local marine ecology
- Local culture

In addition, a standardised pre-shark diving briefing should be developed. The specific points raised for any particular dive site would vary somewhat, but in general should include the following:

- Dive safety & logistics
 - o State experience rating of dive & confirm all participants are suitably experienced
 - o Record buddy team composition, entry and exit times
 - o State type of dive (natural observation, baited dive, drift dive, deep dive, etc.)
- Dive site review, including
 - o Map of site
 - o Maximum depth
 - o Maximum time
 - o Buddy separation procedures
 - o Entry and exit logistics
 - o Safety procedures
- Dive conduct
 - o Types of sharks likely to be seen and what to expect of their behaviour
 - o Shark interaction guidelines
 - o Guidelines to minimise environmental impact

5.2 Interaction Guidelines

In any shark diving ecotourism venture, care must be taken to avoid imposing unnecessary stress on sharks. Such stress cannot only create situations that are dangerous for divers but can change the behaviour of sharks in ways that compromise their ability to survive. For example, in March 2004, the authors had opportunity to observe interactions among whale sharks, safari boats, and snorkellers at south Ari Atoll. Typically, a single whale shark at the surface was converged upon by three to four dive dhonis, each spilling 15 to 20 snorkellers into the water next to the hapless animal. In every case, the besieged shark was clearly stressed by the onslaught, suspending its feeding glides along the surface to dive precipitously along the outer reef face and disappearing from view. As foraging success and reproductive success are intimately linked (Arnold 1986; Clutton-Brock 1988; Grafen 1988; Riechert 1992), such interruptions of a shark's feeding behaviour may ultimately negatively impact its reproductive fitness. To increase safety of diving ecotourists and reduce stress they impose on sharks, recommended guidelines for diving with reef sharks and their desired effects are provided in Table 5 and species-specific guidelines for diving with whale sharks and their desired effects are provided in Table 6.

Table 5. Recommended reef shark interaction guidelines for shark divers and their desired effects.

Guidelines	Desired Effect		
	Reduce effects on shark behaviour	Reduce or limit shark stress	Increase Diver Safety
Shark divers must:			
Dive within their experience level			•
Dive with a buddy			•
Wear mask, fins, snorkel & preferably a wetsuit			•
Carry fluorescent safety flag or tube			•
Avoid wearing contrasting clothing or equipment that hangs loosely			•
Avoid swimming with sharks at dawn and dusk			•
Before diving, buddy teams must review:			
Entry site and method			•
Dive plan should include: Dive site layout, Current speed and direction, Planned course, Maximum depth, Maximum duration			•
Buddy separation procedures			•
Exit site and method			•
During a shark dive, divers must:			
Always:			
If diving from a boat, make sure it is not too far away from the dive site			•
Enter the water as quietly & splash-free as possible	•	•	•
Swim in smooth, rhythmic manner, avoiding excessive hand or fin movements	•	•	•
Never:			
Snorkel or dive in open water without a boat nearby			•
Splash excessively on the surface	•		•
Snorkel or free-dive with marine mammals where sharks may be encountered			•
Swim, or allow themselves to be swept, farther from the reef than they can return within 2 minutes			•
Disturb sharks that appear to be courting or mating	•	•	•
Disturb or damaging the reef environment			•
Touch, corner, or chase any shark, no matter how small or harmless it may appear	•	•	•
Follow or flash photograph any shark that appears to be swimming strangely	•	•	•
Spearfish in the presence of sharks or remain in an area where others are doing so	•		•

Table 6: Whale shark interaction guidelines for whale shark ecotourism operators, boaters and divers, modified from Western Australia’s Coast and Land Management (CALM) whale shark operators’ code of conduct.

Guideline	Desired Effect			
	Reduce effects on whale shark behaviour	Reduce whale shark / boat collisions	Reduce or limit whale shark stress	Increase Snorkeller Safety
Low speed (maximum 15 kph or 8 kn)				
Minimum operator approach distance 30 m				
No other vessels within 400 m				
Operator vessel contact duration limited (maximum 90 minutes)				
Operator vessel in contact with a whale shark must fly a standardised pennant or flag indicating so				
Operator vessel in contact with a whale shark must fly a diver flag and deploy a current line whenever snorkellers are in the water				
Boaters				
Low speed (maximum 15 kph or 8 kn)	•			
Minimum operator approach distance 30 m	•	•		
No other vessels within 400 m	•	•	•	•
Operator vessel contact duration limited (maximum 90 minutes)	•	•	•	
Operator vessel in contact with a whale shark must fly a standardised pennant or flag indicating so	•			•
Operator vessel in contact with a whale shark must fly a diver flag and deploy a current line whenever snorkellers are in the water				
Low speed (maximum 15 kph or 8 kn)	•			
Minimum operator approach distance 30 m	•	•		
No other vessels within 400 m	•	•	•	•
Operator vessel contact duration limited (maximum 90 minutes)	•	•	•	
Operator vessel in contact with a whale shark must fly a standardised pennant or flag indicating so	•			•
Operator vessel in contact with a whale shark must fly a diver flag and deploy a current line whenever snorkellers are in the water				•
Snorkellers				
Snorkellers only (no scuba or DPVs)	•		•	
Limit number of snorkellers in water at one time (maximum = 6)	•		•	•
Snorkellers must not approach whale sharks closer than 5 m	•		•	•
Snorkellers must not duck dive in front of whale shark pectorals	•		•	•
Snorkellers must not conduct flash photography in front of shark pectorals	•		•	•
Snorkellers must remain in 2-person buddy teams at all times when in the water, at least one of whom carries an inflatable dive signal			•	•

5.3 Expansion of Existing SharkWatch Programme

In 2003, MOT developed its SharkWatch programme. The main objectives of this program were to better understand the nature and extent of the shark diving industry in the Maldives as well as monitor the types and numbers of sharks observed. To accomplish this, the Ministry developed a standardised SharkWatch form, which it distributes to dive operators in the Maldives. A locally-based biologist has published an excellent illustrated guidebook (Anderson 1992) that provides additional information on the identification and general biology of sharks in the Maldives.

The accreditation course we suggest above would better equip dive operators to monitor growth of the shark ecotourism industry in the Maldives, monitor local shark population trends, and provide observations on shark ecology and behaviour important to wise management of sharks as a living resource. The proposed course would complement MOT's existing SharkWatch programme, amplifying and extending it into a potent shark monitoring and research program. Development of more detailed forms, to be filled out by accredited shark ecotourism operators, could provide a great deal of useful tourism marketing and ecological management information in a reliable and cost-effective way.

Information generated by the expanded version of the SharkWatch programme we propose includes:

- Monitor growth of the shark ecotourism industry in the Maldives
- Monitor socioeconomic characteristics and satisfaction levels of shark diving tourists
- Monitor impacts of shark ecotourism on shark species composition and relative abundance
- Enable more efficient targeting of shark ecotourist advertisement budget
- Monitor seasonal and other changes in shark species and abundance in the Maldives
- Increase shark ecotourist satisfaction by enabling them to observe shark species and behaviours of particular interest
- Provide information on shark ecology and behaviour important to management of the shark ecotourism industry and of interest to shark researchers world-wide.

Knowledge of the ecology of Maldivian sharks of importance to shark ecotourism is presently inadequate for management purposes. The expanded SharkWatch programme we propose can also help fill in critical knowledge gaps through collection of basic data by accredited shark ecotourism operators and their clients. More specialised information on growth of the shark ecotourism industry and basic ecology of sharks in the Maldives could be obtained through dedicated research projects conducted by Maldivian and visiting scientists experienced in the collection, analysis, and reportage of such data. Recommended research that could be conducted in the Maldives that would be relevant to managing local sharks as an ecotourism resource is outlined in Table 7.

Table 7. Recommended research on sharks and effects of shark ecotourism industry in the Maldives.

<p>Basic Research on Sharks (conducted away from shark dive sites)</p>
<p>Effects of Dive Ecotourism on Sharks (conducted at shark dive sites)</p>

How revenues generated by shark diving ecotourism spread through various sectors of the Maldivian economy is inadequately known. Similarly, how information generated by the proposed expanded version MOT's SharkWatch programme is cycled from where it is collected to where it is employed to monitor development of the shark diving industry in the Maldives and its effects on shark populations is unknown. A model for the likely flow of revenue and information generated by the proposed shark diving ecotourism industry in the Maldives is presented in Figure 4.

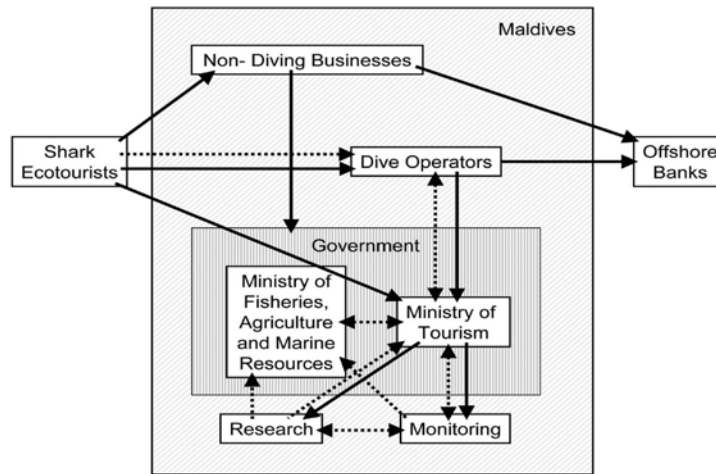


Figure 4. Hypothesised flow of shark ecotourist-generated dollars (solid lines) and information (dotted lines) useful for monitoring shark ecotourism and its impacts in the Maldives.

6. CONCLUSIONS

Shark diving ecotourism in the Maldives has great potential to be economically lucrative and ecologically sustainable, provided adequate management steps are taken. The foregoing analysis is based on the best available information about shark exploitation in the Maldives and best practices exhibited by the shark diving industry elsewhere. Our suggested strategy for improving operator quality control, adopting safe shark interaction guidelines, and expanding the MOT's existing SharkWatch programme are founded in the guiding principles of ecotourism and our combined experience in shark behaviour, marine education and conservation. Toward development of a sustainable shark diving ecotourism industry in the Maldives, we propose the following 5-part Action Plan:

- 1) Stop all existing shark fisheries in the Maldives. Shark fisheries in the Maldives are clearly unsustainable and stopping them limits the harm this activity imposes on development of shark diving ecotourism as a sustainable alternative in the Republic.
- 2) Identify all present and likely future shark diving ecotourism sites and a) have these areas declared national marine parks, protected by appropriate restrictions against longline or net fishing and other activities likely to negatively impact shark populations or the local ecology, and b) monitor development of the shark ecotourism industry at these sites and its effects on local shark ecology.
- 3) Develop a standardised, MOT- and MOFAMR-accredited course for shark diving ecotourism operators along the lines of that proposed here, including all teaching, support, and industry-monitoring materials.
- 4) Administer the shark diving ecotourism course so that at least one dive master or instructor is properly trained and certified from each tourist operation that wishes to offer the MOT- and MOFAMR-approved SharkWatch programme; operators thus certified should apply every four (4) years for renewal of their status as MOT- and MOFAMR-accredited shark ecotourism operators, based on their participation in monitoring the shark

diving ecotourism industry in the Maldives and its effects on local shark ecology.

- 5) Advertise the Maldives as a world-class shark diving ecotourism destination, offering well managed, socially and ecologically sustainable shark diving opportunities for the discriminating traveller, complete with a certification system allowing them to identify MOT- and MOFAMR-accredited SharkWatch members.
- 6) Incorporate units on the importance of sharks to the economy and marine ecology of the Maldives into the 8th through 10th year Fisheries Science component of the national GCSE curriculum, since children of the Maldives are the future stakeholders of the marine and other resources of their nation.

The Maldives should not allow offshore businesses to control development of shark diving ecotourism within its borders. By taking control of shark diving ecotourism within its territorial waters and taking every reasonable precaution that the industry develops in a sustainable way, the Government of the Maldives can help protect sharks as an important natural resource. By using part of the funds generated by shark diving ecotourism in the Maldives toward protecting sharks, improving standards of shark diving ecotourist safety and service, and reinvesting a proportion of tourist dollars into monitoring the Maldives' shark ecotourism industry and its effects on shark populations, the Maldives can serve as an example to other nations developing or considering developing sustainable shark diving ecotourism industries of their own. Perhaps most importantly, by protecting sharks occurring within its territorial waters, the Government of the Maldives can ensure that the economic and ecological benefits of shark diving ecotourism will be available to future generations of Maldivians.

7. ACKNOWLEDGEMENTS

We thank Mr. K.P. Ho, Chairman of Banyan Tree Hotels and Resorts (Singapore) and F. Huet, former Area General Manager of Banyan Tree Maldives, for their generous support of our on-going shark research, education, and conservation efforts through the Banyan Tree Maldives Marine Lab. Thanks to the Banyan Tree Maldives Marine Lab staff, for logistical support in the field. We also thank Dr. A. Naseer, of Ministry of Fisheries, Agriculture and Marine Resources and Dr. M. Shiham Adam and Ms. M. Saleem of the Marine Research Centre (Male'), Dr. C. Anderson, J. Stafford-Deitsch of the Shark Trust, B. Norman of Murdoch University, Dr. P. Dearden of University of Victoria, L. Rose of Duke University, J. Brunnschweiler of University of Zurich and Dr. C. Harvey-Clark of University of British Columbia, who offered helpful suggestions for strengthening this paper. Thanks also to N. Hammerschlag, R. Gardner, and K. Smith for generous use of their photographs.

8. REFERENCES

- Anderson, R. C. (1992) *Divers' Guide to Sharks of the Maldives*. Novelty Printers & Publishers, Male'. 64 pp.
- Anderson, R. C. (2002) Elasmobranchs as a recreational resource. pp 46-51. In: S. L. Fowler, T. M. Reed and F. A. Dipper (eds) *Elasmobranch Biodiversity, Conservation and Management*. Occasional Paper, IUCN Species Survival Commission, No. 25.
- Anderson, R. C., and H. Ahmed (1993) *The shark fisheries in the Maldives*. Ministry of Fisheries and Agriculture, Male', and FAO, Rome. 73 pp.
- Anderson, R. C., and A. Hafiz (2002) Elasmobranch fisheries in the Maldives. pp 114-121 In: S. L. Fowler, T. M. Reed and F. A. Dipper (eds) *Elasmobranch Biodiversity, Conservation and Management*. Occasional Paper, IUCN Species Survival Commission, No. 25.
- Anderson, R. C. and A. Waheed (1999) Management of shark fisheries in the Maldives. In: R. Shotten (ed) *Case Studies of the Management of Elasmobranch Fisheries*. FAO Fisheries Technical Paper, 378 (2): 367-401.
- Anderson, R. C. and A. Waheed (2001) The economics of shark and ray watching in the Maldives. *Shark News*, 13: 1-3.
- Arnold, S. J. (1986). Laboratory and field approaches to the study of adaptation. pp. 157-179 In: M. E. Feder and G. V. Lauder, (eds). *Predator-Prey Relationships: Perspectives and Approaches from the Study of Lower Vertebrates*. University of Chicago Press. Chicago.
- Brylske, A. (2000) Fish feeding, part 1: the controversial shark dive. *Dive Training*, 10(12): 28-40.
- Camhi, M, S. Fowler, J. Musick, A. Bräutigam and S. Fordham (1998) Occasional Paper, IUCN Species Survival Commission, No. 25: 1-39.
- Carwardine, M. (2004) *Shark*. BBC Books. London. 168 pp.

- Carwardine, M. and K. Watterson (2002) *The Shark Watcher's Handbook*. BBC Worldwide Ltd. London. 287 pp.
- Clutton-Brock, T. H. (1988). Reproductive success. pp. 472-485 In: T. H. Clutton-Brock, ed. *Reproductive Success: Studies of Individual Variation in Contrasting Breeding Systems*. University of Chicago Press. Chicago.
- Compagno, L.J.V., M. Dando and S. Fowler (2005) *Sharks of the World*. Collins. London. 368 pp.
- Ellis, R. (1994) *Monsters of the Sea*. Alfred A. Knopf. New York. 323-358.
- Grafen, A. (1988). On the uses of data on lifetime reproductive success. pp. 454-471 In: T. H. Clutton-Brock, ed. *Reproductive Success: Studies of Individual Variation in Contrasting Breeding Systems*. University of Chicago Press. Chicago.
- Groom, M. J., R. D. Podolsky and C. A. Munn (1991) Tourism as a sustained use of wildlife: a case study of Madre de Dios, southeastern Peru. pp 393-412 In: J. G. Robinson and K. H. Redford (eds) *Neotropical Wildlife Use and Conservation*. University of Chicago Press. Chicago.
- Holling, D. (1991) *A Guide to Earthtrips: Nature Travel on a Fragile Planet*. Living Planet Press. Los Angeles. 209 pp.
- Lindberg, K. and D. E. Hawkins (eds) (1993) *Ecotourism, a Guide for Planners and Managers, Volume 1*. The Ecotourism Society. North Bennington. 175 pp.
- Lindberg, K., M. E. Wood and D. Engledrum (eds) (1993b) *Ecotourism, a Guide for Planners and Managers, Volume 2*. The Ecotourism Society. North Bennington. 244 pp.
- McKibben, J. N. and D. R. Nelson (1986) Patterns of movement and grouping of gray reef sharks, *Carcharhinus amblyrhynchos*, at Eniwetak, Marshall Islands. *Bulletin of Marine Science.*, 38: 89-110.

- McLaren, D. (1998) Rethinking Tourism and Ecotourism. Kumarian Press. West Hartford. 182 pp.
- McMaster Elliot and Partners (2002) Regional Development Project Northern Development Region Kulhudhufushi shark fisheries review. Draft report for Ministry of Planning and National Development and the Asian National Bank. 32 pp.
- Ministry of Tourism (2003) Tourism Statistics 2002. Ministry of Tourism, Republic of Maldives. 54 pp.
- Mountain, A. (1996) The Diver's Handbook. New Holland Press. London. 160 pp.
- Nelson, D. R. (1990) Telemetry studies of sharks: a review, with applications in resource management. NOAA Technical Report. NMFS, 90: 239-256.
- Nelson, D. R. and R. H. Johnson (1980) Behavior of the reef sharks of Rangiroa, French Polynesia. National Geographic Society Research Reports, 12: 479-499.
- Nichols, P. V. (1993) Sharks. Pp 285-327 In: A. Wright and L. Hill (eds) Nearshore Marine Resources of the South Pacific. Institute for Pacific Studies, Suva, and Forum Fisheries Agency, Honiara. Singapore.
- Perrine, D. (1998) Letters to the editors: responses to "Diving with elasmobranchs – a call for restraint". Shark News, 12: 1-2.
- Riechert, S. E. (1992). Spiders as representative 'sit-and-wait' predators. pp. 313-328 In: M. J. Crawley, ed. Natural Enemies: the Population Biology of Predators, Parasites and Diseases. Blackwell Scientific. London.
- Salih, A. (2000) Divers' perception in the Maldives. Unpublished report to Ministry of Tourism. 41 pp.

- Stafford-Deitsch, J. (2000) *The Identification, Behaviour and Natural History of the Sharks of Florida, the Bahamas, the Caribbean, the Gulf of Mexico*. Trident Press. London. 95 pp.
- Stevens, J. D., R. Bonfil, N. K. Dulvy and P. A. Walker (2000) The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science*, 57: 476-494.
- Stonich, S. C. (1998) Political ecology of tourism. *Annals of Tourism Research*, 25: 25-54.
- Topelko, K. N. and P. Dearden (2005) The shark watching industry and its potential contribution to shark conservation. *Journal of Ecotourism*, 4: 108-128.
- Walker, T. I. (2002) Review of fisheries and processes impacting shark populations of the world. pp 220-229 : In S. L. Fowler, T. M. Reed and F. A. Dipper (eds) *Elasmobranch Biodiversity, Conservation and Management*. Occasional Paper, IUCN Species Survival Commission, No. 25.
- Wearing, S. and J. Neil (1999) *Ecotourism: Impacts, Potentials, and Possibilities*. Butterworth-Heinemann. Oxford. 163 pp.

Notes on a Commercially Valuable Crab *Scylla serrata* (Forskäl, 1775) and two Poisonous Crabs, *Zosimus aeneus* (Linnaeus, 1758) and *Platypodia granulosa* (Rüppell, 1830) from Laamu Atoll, Maldives

A. Anand^{1,2}, S.G. Wesely² and S. Satheesh²

¹Science Head of Department, Maavashu School, L.Maavah, Laamu Atoll, Republic of Maldives, email: anandjey06@ yahoo.co.in & anandjey@hotmail.com

²Department of Zoology, Scott Christian College, Nagercoil, Tamil Nadu, 629001, India.

1. ABSTRACT

As per the collections made by the first author, the carcinological fauna of Laamu Atoll comprises more than one hundred species of brachyuran crabs. Of these, three species are highly interesting: *Scylla serrata*, *Zosimus aeneus* and *Platypodia granulosa*. The former species is commercially significant and the latter two species are highly poisonous. *S. serrata* is found abundantly in Kunahandhoo and Hithadhoo islands of Laamu Atoll. Recently, two males were caught from the sea grass bed of Maavah. Several specimens of *Z. aeneus* were collected from the reef-front of Maavah, and *P. granulosa* was found inside the holes of the boulders scattered in the intertidal area of the northern side of the jetty of Maavah. All the three species are described in detail in this paper with figurative keys.

2. INTRODUCTION

The genus *Scylla* comprises three species and one genera: *S. serrata*, *S. tranquebarica*, *S. oceanica* and *S. serrata* var. *paramamosain* (Estampador 1949). Generally, these species inhabit mangrove areas and estuaries (Chahpgar 1957). All these species have a wide distribution throughout the Pacific and Indian Oceans from Tahiti, Australia, and Japan to South Africa (Hill 1975; Keenan et al. 1998).

These species fetch a high market price owing to their meat quality and larger size. Species of *Scylla* are mostly marketed alive and the current demand far exceeds the supply. At present, the main markets are Taiwan Province of China, Hong Kong and Singapore. They always command high prices, ranging from US\$ 5 to US\$ 10 per Kg (Ng 1998). During 1994-95, more than 1,800 tonnes of frozen/ canned crabmeat valued at Indian Rupees (Rs.) 2,290.9 million were exported by India, and in 1995-1996, live mud crab export was 1,635 tonnes valued at Rs.167.1 million (Kathirvel et al. 1997).

Aside from the commercially valuable species, there are some that are highly poisonous and toxic. To date six species of crabs have been identified as extremely toxic. These species are *Zosimus aeneus*, *Lophozozymus pictor*, *Atergatis floridus*, *Demania cultripes*, *Platypodia granulosa* and *Demania toxica*. Toxins that make these species poisonous are saxitoxins, palytoxins and tetrotoxins (Ng 1998).

Saxitoxins are neurotoxic alkaloids and rapidly cause death after paralyzing skeletal muscles and then leading to respiratory arrests (Skulberg 1999). Saxitoxin is, by mass, 1,000 times more potent than cyanide and fifty times stronger than curare (Hackett et al. 2004). Palytoxin has produced ciguatera-like symptoms in humans that have eaten mackerel in Hawai'i (Katiriciođlu et al. 2004). Tetrotoxins are similar to saxitoxins and consists of a positively charged guanidine group made up of three nitrogen atoms and a pyrimidine ring (Katiriciođlu et al. 2004).

Generally these poisons are produced by microalgae (Carmichael et al. 1998; Ferreira et al. 2001), and these poisons are filtered from water as food by shellfish that are eaten by the crabs. These poisons accumulate as algal toxins to the levels that can be lethal especially to land vertebrates and reach the body of humans through the food chain (Shumway 1989; Ragelis et al. 1984; Katiriciođlu et al. 2004).

Studies on the brachyuran assemblages of Laamu Atoll (E 3° 2' and N 1°54'), Maldives, show that *S. serrata* is found in the mangroves of Hithadhoo and marshy areas of Kunahandhoo and Maavah (Figure 1). Maldives is a country that depends on tourism and has several resorts of high standards. Some of these resorts are visited by Chinese communities from Malaysia, Singapore, Taiwan and Hong Kong, where the *Scylla* meat



Figure 1. Map of Laamu Atoll

is regarded as a delicacy (Chen 1990; Harvey 1990). Thus the Maldives may be benefited, if the *S. serrata* stock found around Hithadhoo and Kunahandhoo islands is accurately assessed and well managed to ensure sustainable harvests. Since the taxonomy of the genus *Scylla* is ambiguous, the present paper elaborates the diagnostic features of *S. serrata*.

All the poisonous species of crabs are xanthids and brightly coloured, and several human deaths have been attributed to them (Ng 1998). Therefore, it is essential to avoid them for consumption purpose. For the same reason, everyone should be aware of the identification features of these species. Considering this, the present paper is *au fait* with the diagnostic features of *Z. aeneus* and *P. granulosa*. Moreover, information on the presence of two poisonous species of crabs in Laamu Atoll is certainly a contribution to knowledge. The present paper provides diagnoses and taxonomic notes for these three interesting species of crabs along with relevant figures. The taxonomically significant characters are given in italics.

3. MATERIALS AND METHODS

The mangroves of Hithadhoo is interspersed with patches of mangrove vegetation, brown muddy sand and white sand. Numerous fiddler crab burrows (*Uca tetragonon* and *U. chlorophthalmus*) are found on the brown muddy sand. Generally, *S. serrata* burrows are located under the roots of *Rhizophora mucronata* and *Burquiera* sp plants (Figure 2). In Kunahandhoo and Maavah the same species was collected from the sea grass bed.



Figure 2. The burrow of *Scylla serrata*

The reef front of Maavah receives full impact of powerful waves. Different sized boulders encroach this site. However, the collection site of *Z. aeneus* (outer edge of reef front) is free from boulders and very shallow for a few meters.

The northern side of the jetty of Maavah is characterised by a sand dune. This sand dune is intertidal and totally exposed during spring low tides. Several fragmented pieces of algal mats and boulders are ubiquitously scattered in this area. The holes of these boulders harboured *P. granulosa* and the rocks were broken by hammer and chisel to collect the specimens.

To collect *S. serrata*, their burrows were identified and dug out. Small specimens were collected using a type of net employed by Maldivian fishermen to handle bait fish in masdhonis (fishing boats). Using the same net, crabs of the species *Z. aeneus* were collected during the spring low tides from the outer edge of the reef front.

Voucher specimens have been deposited at the Marine Research Centre (MRC), Malé, Maldives. They include a single male specimen of *S. serrata*, several specimens of *Z. aeneus* (both sexes) and a single male specimen of *P. granulosa*.

4. PORTUNIDAE

***Scylla serrata* (Forskäl, 1775)**

Cancer serratus, Forskäl 1775, p.90
Scylla serrata De Haan 1833, p. 44; Barnard 1950, p.160.

Carapace transversely ovate, convex, *smooth* and microscopically granulated; grooves defining the regions are shallow except for *the H-shaped deeper gastric groove* (Plate 1a). The anterolateral borders cut into eight equal size teeth excluding the external orbital angle, *and these teeth project obliquely outwards* (Plate 1a). The front has *six sharp teeth* including the external orbital angle. *All teeth are more or less in line with each other* (Plate 1b). The antero-external angle of basal antennal segment not appreciably produced, the flagellum thus standing in the orbital hiatus. The basal segment of antenna produced into a small lobule at antero-external angle; the antennules fold obliquely. The ischium of external maxillipeds longer than broad; the anterior border of merus externally produced; the palp articulates on the anterointernal border of merus;

exognath long and terminates with a flagellum (Plate 1c).

The chelipeds are ponderous, powerful and inflated. Two somewhat sharp spines are located at the distal upper margin of palm, and another spine is situated at the carpal articulation. Fingers are strong, incurved and pointed at its tip; the proximal end of the pollex of right cheliped has two teeth, arranged sideways, the adjacent three teeth are larger and molariform, these are followed by two medium-sized and four smaller teeth. The proximal end of movable finger has a big molariform tooth followed by four medium-sized teeth, the distal end is provided with seven small-sized teeth. *The outer surface of palm has polygonal markings* (Plate 1d). *The carpus has two sharp smaller outer spines* in its far end and a bigger inner spine (Plate 1e); merus has three spines in front and two spines behind.

The ambulatory legs are slender and long. Both the dorsal and ventral margins of the two distal segments of the first three ambulatories are thickly fringed with hairs, whereas the upper margin of ischium and either of the upper and lower margins of the three distal segments of the last ambulatory are furnished with hairs; all the surfaces of the distal segments of the first three ambulatories are costate; the two distal segments of the last pereopod are typically paddle shaped.

Male abdominal segments 3 to 5 completely fused together, immovable; the telson rounded at its tip; the suture between the two distal segments is oblique and the suture between the penultimate segment and the preceding segment is almost straight; the outer margin is surrounded with short hair (Plate 1f).

G₁ (First male gonopod) is stout, slightly sinus and its distal part bends outwardly (Plate 1g); G₂ (second male gonopod) shorter, distal segment thin, bilobed at the tip.

Carapace olive green in colour, outer surface of palm green with marbled pattern, last pair of legs marbled both in males and females.

Note:

The taxonomy of the four species of *Scylla* has been terribly confused. These taxonomical problems are discussed by Fushimi and Watanabe (2000) in detail. In this paper, the F.A.O Key written by Ng (1998) is followed. As per the key, it is confirmed that the species found in Hithadhoo and

Kunahandhoo islands of Laamu atoll is *S. serrata* and this species fully agrees with the figure of *S. serrata* published by Ng et al. (2001).

Specimen: MRC-CR-0001/06; Male, Carapace: L 9 cm, W 13cm; collected from Maavah, mangrove, sea grass (*Cymodocea* sp) bed.

5. XANTHIDAE

Subfamily: Zosiminae (Alcock, 1898)

Zosimus aeneus (Linnaeus, 1758)

Zosimus aeneus Dana 1852; Sakai 1976 pp.402 & 403, pl.143

Carapace broad, regions well defined, *tuberculated, and the tubercles are larger in the anterior one third* (Plate 2a); front narrow being one fifth of the greatest width found between the last two anterolateral teeth of either sides; bilobed, obliquely deflexed; *anterolateral border well crested* and divided into *four well separated lobes* excluding the external orbital angle, of which *the last tooth is dentiform* (Plate 2a); either supra and infra orbital angles are not in contact with each other, leaving the flagellum of antenna to articulate in the orbital hiatus; antennule folds transversely; ischium of the external maxilliped longer than broad; merus quadrate, a somewhat deeper, longitudinal groove nearer to the internal margin; inner margins of ischium and merus fringed with thick band of hair; the palp articulates at the anterointernal border of merus; exognath moderately broad and terminates with a flagellum.

Chelipeds symmetrical; *outer surfaces of palm, carpus and merus rugose; upper surfaces of palm and merus crested* (Plate 2b); carpus with a blunt internal spine; fingers are black in colour; cutting edges of both of the fingers with a few prominent teeth; two fingers contact at the tip leaving a narrow gap; *fingers are slightly hollowed at the tip* (Plate 2b).

All the ambulatory legs are depressed; anterior borders of merus, ischium, propodus and the lower border of merus sharply cristiform (Plate 2c). Dactylus spine tipped.

The abdominal segments three to five fused together; the posterior portion of penult diverges; the telson rounded at the tip (Plate 2d).

Specimen: MRC-CR-0002/06; Male, Carapace: L 4.1 cm, W 6.1 cm; Female, Carapace: L 5.2 cm, W 7.9 cm; collected from the Reef front of Maavah

***Platypodia granulosa* (Rüppell, 1830).**

Xantho granulosis Rüppell 1830, p.24

Platypodia granulosa Rathbun 1906, p.845

Carapace transversely oval, convex, regions well defined and subdivided into many lobules by deep grooves, *and the surfaces of these lobules coarsely granulate* (Plate 3a). Front little more than one third of the greatest width of carapace; obliquely deflexed, bilobed, notched and slightly emarginated in the middle line; its outer border sinous, not separated from the inner orbital angle by a definite notch; the anterolateral border *well crested* and divided into four lobes by *faint sutures* (Plate 3a). Of these lobes, the first lobe is confluent with the external orbital angle and the last one is the smallest of all. Ischium of the third maxilliped longer than broad; merus sub quadrate, and its anterior corner of the outer margin slightly produced; a concavity nearer to the internal margin; the palp articulates in the anterior border of the internal margin of merus; exopod broad and terminates with a flagellum; ischium, merus, exopod and carpus studded with granules.

Chelipeds sub equal; *outer margin of the palm of major cheliped with coarsely granulate lines* (Plate 3b); size of the granules are smaller in the lower half of the same margin; *the superior border with a beaded crest* (Plate 3b), the internal margin with smaller granules; *the tips of fingers acuminate* (Plate 3b); fingers close with a small gap; outer border of carpus coarsely granulate, and its internal border with two blunt spines; *the superior border of merus crested.*

All the ambulatories are depressed. First two ambulatories are sub equal, the third pair is little longer than these, the last pair is the shortest. *The upper borders of meri, carpi and propodi and the lower borders of the meri of all the ambulatories cristate* (Plate 3c); all the margins of the distal segment with velvety hairs.

The abdominal segments three to five fused together; the penultimate segment rectangular; telson rounded at the tip (Plate 3d).

Specimens: MRC voucher number: MRC-CR-0003/06; Male, Carapace: L 1.8 cm, W 2.4 cm; The specimen was collected from the intertidal region of lagoon of Maavah.

6. DISCUSSION

Scylla tranquebarica and *S. olivacea* are more closely associated with mangroves and *S. serrata* prefers oceanic waters (Ng 1998). However, so far *S. tranquebarica* and *S. olivacea* have not been observed in the mangrove of Hithadhoo.

Table 1 illustrates the Indo-Pacific distribution of the six species of poisonous crabs. As far as poisonous crabs are concerned, all of the species excepting *Demania cultripes* and *D. toxica* have been reported from Japan and the adjacent seas (Sakai 1976). However, trend of the latest checklist may be different. The checklist of the brachyuran crabs of Taiwan includes all the six toxic species (Ng et al. 2001). In the mean time, the checklist of the brachyuran crabs of Phuket and western Thailand (Ng and Davie 2002) documents *A. floridus*, *P. granulosa*, *L. pictor* and *Z. aeneus*. The checklist of the crustaceans and pycnogonids of Marinas (Gustav et al. 2003) comprises the records of *A. floridus*, *L. pictor* and *Z. aeneus*.

In a monograph dealing with the brachyuran crabs of the Gulf of Mannar (Jeyabaskaran et al. 2000), the existence of *A. floridus* and *Z. aeneus* has been reported.

A. floridus, *P. granulosa* and *Z. aeneus* have been reported from Andaman and Nicobar islands (Deb and Rao 1993 and Sankarankutty 1962). As per the above cited checklists, it becomes evident that *A. floridus* and *Z. aeneus* are distributed throughout the Indo-Pacific region. Therefore, the presence of one of the common species *Z. aeneus* in the Maavah Island reef system is not surprising. However, it is interesting to note that the other common species *A. floridus* is absent. Borradaile (1906) reports the presence of *P. granulosa* in the Maldives.

Table 1. Distribution of the toxic species of crabs in the Indo-Pacific region.

	Location	Poisonous species of crabs present
1.	Japan and adjacent seas.	<i>Zosimus aeneus</i> , <i>Lophozozymus pictor</i> , <i>Atergatis floridus</i> , and <i>Platypodia granulosa</i>
2.	Taiwan.	<i>Zosimus aeneus</i> , <i>Lophozozymus pictor</i> , <i>Atergatis floridus</i> , <i>Demania cultripes</i> , <i>Platypodia granulosa</i> and <i>Demania toxica</i> .
3.	Phuket and Western Thailand,	<i>Zosimus aeneus</i> , <i>Lophozozymus pictor</i> , <i>Atergatis floridus</i> , and <i>Platypodia granulosa</i>
4.	Marinas.	<i>Zosimus aeneus</i> , <i>Lophozozymus pictor</i> and <i>Atergatis floridus</i> .
5.	Gulf of Mannar.	<i>Zosimus aeneus</i> and <i>Atergatis floridus</i> ,
6.	Andaman and Nicobar.	<i>Zosimus aeneus</i> , <i>Atergatis floridus</i> and <i>Platypodia granulosa</i>
7.	Laamu Atoll, Maldives.	<i>Zosimus aeneus</i> and <i>Platypodia granulosa</i>

7.ACKNOWLEDGEMENTS

The authors wish to thank Dr. P. J. Hogarth, York University, England for spending his precious time to confirm the identification of the species being reported in this paper and also for reviewing this paper. We thank Dr. M. Shiham Adam, Executive Director of Marine Research Centre (MRC) and Mr. Ali Waheed, former Deputy Director of MRC for their assistance in various ways. We are grateful to Mr. Hassan Shakeel, Deputy Director of MRC, Ms. Zaha Waheed, Deputy Director of Ministry of Fisheries, Agriculture and Marine Resources, and Ms. Asiyath Abbas, Assistant Librarian of MRC for their help and encouragement. We are grateful to Mr. V. Edwin Joseph, Technical Officer, CMFRI, Cochin, India for providing necessary references. With a sense of gratitude, we note that the monograph written by Dr. R. Jeyabaskaran et al. (2000) has been provided to the first author by Dr. S. Ajmal Khan, Professor, Centre of Advanced Studies in Marine Biology, Parangipettai, India.

8.REFERENCES

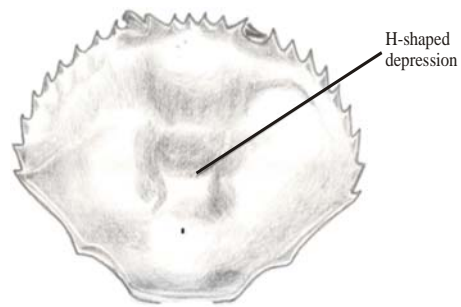
- Alcock, A. 1898. Materials for a carcinological fauna of India .3. The Brachyura Cyclometopa. Part 1.The family Xanthidae. *Ibid*, **67 (1):** 67-223.
- Barnard, K.H. 1950. Descriptive catalogue of South African Decapod Crustacea. *Annals of South African Museum*, **38:** 160, 201 & 210.
- Borradaile, L.A. 1906. Marine Crustaceans. Fauna and Geography of the Maldive and Laccadive Archipelagos. part I & II . Cambridge Univ.Press.
- Carmichael, W.W., Beasley, V.R., Bunner, D.L., Eloff, J.N., Falconer, I.R., Gorham, P., Harada, K.I., Krishnamurthy, T., Yu, M.J., Moore, R., Rhinehart, K., Runnegar, M., Skulberg, O.M. and M. Watanabe. 1998. Naming of cyclisheptapeptide toxins of cyanobacteria (blue –Green algae).*Toxicon*, **26:** 971-973.
- Chahpgar, B.F. 1957. On the marine crabs (Decapoda: Brachyura) of Bombay State. *Journal of Bombay Natural History Society*, **54:** 399-439.
- Chen, L.C.1990. Aquaculture in Taiwan. Fishing News Books, Oxford.
- Dana, J.D. 1852. Crustacea. United States Exploring Expedition during the years 1838-1842, under the command of Charles Wilkes, U.S.N., **13:** 1-685, pt.1, Atlas (1855), **13:** pls.1 –96.

- Deb, M. and G.C. Rao. 1993. A check-list of the brachyuran crabs (Crustacea: Decapoda) of Bay Islands. Journal of Andaman Science Association, **9 (1&2)**: 25-34.
- Estampador, E.P. 1949. Studies on *Scylla* (Crustacea: Portunidae). 1. Revision of the genus. Philippine Journal of Science, **78(1)**: 95-108.
- Ferreira, F.M.B., Soler, J.M., Fidalgo, M.L. and P.F.Vila. 2001. PSP toxins from *Aphanizomenon Flos-aquae* (cyanobacteria) collected in the Crestuma-Lever reservoir (Duro River, northern Portugal). Toxicon, **39**: 757-761.
- Forskäl, P. (1775). Descriptions Animalium, Avium, Amphibiorum, Piscium, Insectorum, Vermium: quae in Itinere orientali observavit. Petrus Forsskål. Post Mortem Auctoris edidit Carsten Niebuhr. Hafniae: 1-164.
- Fushimi, H. and S. Watanabe. (2000). Problems in species identification of the mud crab genus *Scylla* (Brachyura: Portunidae). In: C. Christian, T. Tamaru, C.S. Tamaru, P.J. McVey and K. Ikuta (Eds). Spawning and Maturation of Aquaculture Species. UJNR Technical Report, **28**: 9-13. University of Hawai'i Sea Grant College Program.
- Gustav P., Kropp, R., Ng, P.K.L. and L.G., Eldredge. 2003. The Crustaceans and Pycnogonids of the Mariana Islands. Micronesica, **35-36**: 502, 504 & 506.
- Haan, W. De, 1833-1850. Crustacea, in: de SIEBOLD, P.F.de(Ed).Fauna Japonica, Lugduni, Batavorum. 11& 44.
- Hackett, J.D., Anderson, D.M., Erdner, D.L. and D., Bhattacharya. 2004. Dinoflagellates: A remarkable evolutionary experiment. American Journal of Botany, **91(10)**: 1523-1534.
- Harvey, M., 1990. Mud crab culture in Thailand. INFOFISH international (FAO, Kuala Lumpur) **6**: 53-54.
- Hill, B.J., 1975. Abundance, breeding and growth of the crab *Scylla serrata* (Forskäl) in two South African estuaries. Marine Biology, **32**: 119-126.
- Jeyabaskaran, R., Khan, S.A. and V. Ramaiyan. 2000. Brachyuran crabs of Gulf of Mannar. Centre of Advanced Studies in Marine Biology, Annamalai University, Parangipettai: 1 - 99, pl.52 & 56.

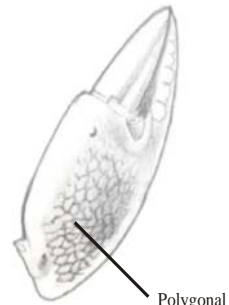
- Kathirvel, M., Srinivasagam, S., Gosh, P.K. and C.P. Balsubramanian. 1997. Mud crab culture. Central Institute of Brackish Water Aquaculture Bulletin, **10**: Central Institute of Brackishwater Aquaculture, I.C.A.R., Chennai.
- Katiriciođlu, H., Akin B.S. and T. Atici. 2004. Microalgal toxin(s): Characteristics and importance. African Journal of Biotechnology, **3(12)**: 667-674.
- Keenan, C.P., Davie, P.J.F. and D.L. Mann. 1998. A revision of the genus *Scylla* de Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidea). Raffles Bulletin of Zoology, **46(1)**: 217-245.
- Linnaeus, C. 1758. Systema Naturaw per Regna tria Naturae, secundum Classes, Orderes, Genera, Species, cum Characteribus, Differentiis, Synonymis, Locis, Id.**10**: 1-824.
- Ng, P.K.L. 1998. Cephalopods, crustaceans, holothurians and shark In: K. E. Carpenter and V. H. Niem (Eds) .The living marine resources of the Western Central Pacific. FAO species identification guide for fishery purposes. Food and Agriculture Organization of the United Nations, Rome, **2**: 1047 -1050.
- Ng, P.K.L., Wang, C-H., HoHo, P. and H-T. Shih. 2001. An annotated checklist of brachyuran crabs from Taiwan (Crustacea: Decapoda) In: Ying- Tzung Xhien (Ed). National Taiwan Museum Special Publication Series, National Taiwan Museum, Taipei, Taiwan, Republic of China, **11**: 1-78.fig.5 e & f.
- Ng, P.K.L. and P.J.F. Davie. 2002. A Check List of the Brachyuran Crabs of Phuket and Western Thailand. In: N. Bruce, M. Berggren and S. Bussarawit (Eds). Phuket Marine Biological Centre Special Publication, **23(2)**: 375.
- Ragelis, E.P. 1984. Ciguatera seafood poisoning: Overview. In E.P. Ragelis (Ed). Seafood toxins, 25-36. American Chemical Society Symposium Series no 262 , Washington, D.C., USA.
- Rathbun, M.J. 1906. The Brachyura and Macrura of the Hawaiian Islands.- Bulletin on the United States Fish Commission. **23** (for 1903), Washington: 845.
- Rüppell, E. 1830. Beschreibung und Abbildung von 24 Arten kurzschwänziger krabben, als Beitrag zur Naturgeschichte des Rothen Meeres.Frankfurt: 1-28, pl.1-6.

- Sankarankutty, C. 1962. On Decapoda Brachyura from the Andaman and Nicobar Islands: 2. Family Xanthidae. *Journal of Marine Biological Association of India*, **4** (1): 121-150.
- Sakai, T. 1976. Crabs of Japan and the adjacent seas. Kodansha, Tokyo.
- Shumway, S.E. 1989. Toxic algae: a serious threat to shellfish aquaculture. *World Aquaculture*, **20**: 65-74.
- Skulberg, O.M., 1999. The biological nature of cyanotoxin-types and effects. ICRO-UNESCO workshop and training course notes. Pannon Agricultural University, Hungary.

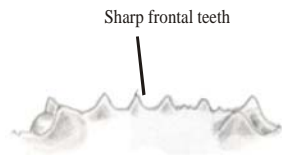
Plate - 1 (*Scylla serrata*)



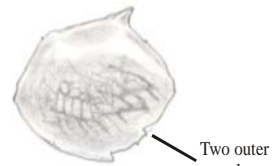
a. Carapace



d. the right claw



b. Frontal view



e. The carpus of right cheliped



c. The external maxilliped

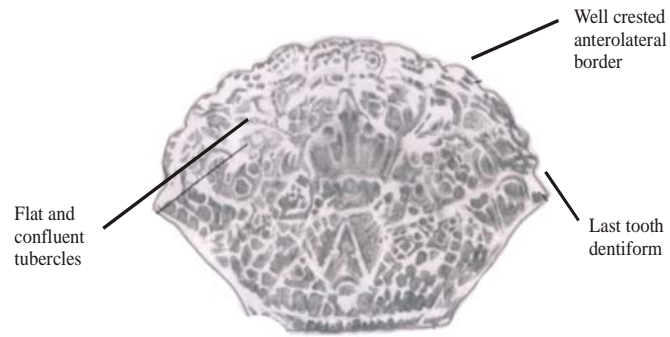


g. The first male gonopod

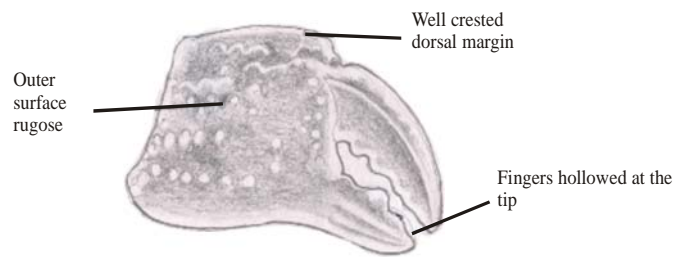


f. The abdomen of male

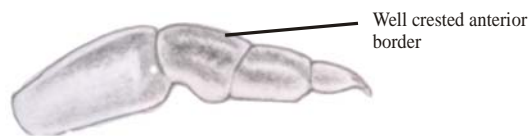
Plate - 2 (*Zosimus aeneus*)



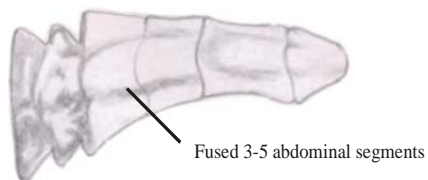
a. Carapace



b. The finger of the major claw

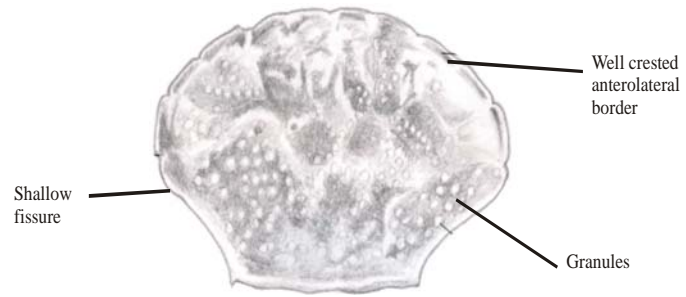


c. The first ambulatory leg

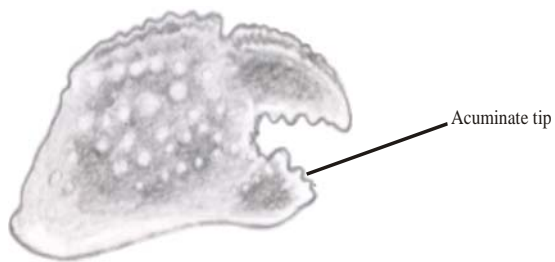


d. The abdomen of male

Plate -3 (*Platypodia granulosa*)



a. Carapace



b. The major claw



c. The first ambulatory leg



d. The abdomen of male

MALDIVES MARINE RESEARCH BULLETIN VOL. 8

CONTENTS

Editorial..... 1

Development of a Sustainable Shark Diving
Ecotourism Industry in the Maldives: Challenges
and Opportunities..... 2

R. A. Martin and A. A. A. Hakeem

Notes on a Commercially Valuable Crab *Scylla serrata*
(Forskäl, 1775) and two Poisonous Crabs, *Zosimus*
aeneus (Linnaeus, 1758) and *Platypodia granulosa*
(Rüppell, 1830) from Laamu Atoll, Maldives..... 38

A. Anand, S.G. Wesely and S. Satheesh

ISBN: 99915-56-09-5