Diver Eco-Tourism and the Behavior of Reef Sharks and Rays – an Overview

Phillip S. Lobel

Boston University, Biology Dept., Boston, MA 02215.
plobel@bu.edu

Abstract

This paper addresses the issue of the expanding tourist dive industry that is focused on seeing sharks and other elasmobranchs. The two competing approaches involve baiting and feeding sharks and rays versus natural observations without feeding. In terms of shark feeding dive operations, there are two main questions: 1) How safe are divers on tourist operations that attract sharks and rays using bait? 2) How is the fish's behavior and ecology being affected by this interaction? The broader issue is: what is the best practice in terms of conservation and ecology? I offer some observations on shark behavior and suggestions for future scientific research.

Keywords: bait, diving, elasmobranchs, feeding, safety, scuba, tourist

Introduction

Dive destinations compete vigorously to attract recreational scuba divers to their resorts. One major attraction for any dive site is the reliability of seeing big fishes and especially sharks and rays. This raises interest in scientific questions about fish behavior, as natural resource managers need to know basic information concerning home range and habitat usage in order to best define the boundaries for a marine protected area. Other behavioral questions such as how the fish habituate (or not) to scuba divers depends both on the behavior as well as the movement patterns of the species. Such information is also important to safety considerations regarding tourist's interactions with wildlife underwater. This is also a question for scientific divers (and AAUS) who may undertake to study these sharks attracted by the tour.

This paper is an overview based upon my research on the movement patterns of the grey reef shark, *Carcharhinus amblyrhynchos*, in the Pacific Ocean. The purpose is to highlight the research questions and practical applications as well as to initiate discussion of the diver safety questions.

Diving with sharks, skates and rays is a main attraction for diving tourists worldwide. Consequently, the economic success of any local diving tourism industry can be dependent on the reliability of seeing sharks and rays up close. Some locations, such as Blue Corner, Palau, have natural aggregations of sharks that are not fed by divers. At other locations (e.g., Bahamas, Fiji, Tahiti) dive operations attract sharks and stingrays using bait operators (Brunnschweiler and Earle, 2006). These operations allow divers to watch underwater as the divemasters hand feed these fish (Figures 1, 2, 3). Baiting is a highly controversial practice, and there have been several instances of divers being bitten and even killed. Of course, every location and dive operation has its own unique set of circumstances and operating procedures. Successful shark feeding operations do best where they have individual sharks that are regular visitors and can be 'trained.' There is always concern by the dive guides when unfamiliar sharks come into a hand-feeding arena (Lobel, personal observation).
Figure 1. Shark feeding tourist dive in Fiji, bull shark, *Carcharhinus leucas*. Photo credit: Phillip S. Lobel.

Figure 2. Shark feeding in Tahiti with tourists lined up along a rope. Photo credit: Phillip S. Lobel.
As we all know, sharks are in danger due mainly to fishing for fins and as by-catch in other fisheries. The shark fin fishery is a global threat that has to be acted upon by most local governments to protect species in their legal territorial waters. The nation of Palau has lead Earth's nations by enacting pioneering legislation backed up by effective law enforcement to protect sharks in its territorial waters. This is great, but the scientific data are completely lacking to evaluate whether this will save sharks only locally. In other words, do reef sharks move offshore at some times, and thereby become vulnerable to open seas fisheries?

A grey reef shark with a tangled lure (figure 4) was swimming at Blue Corner, Palau (Lobel, personal communication). The fishing line was stainless steel and the stainless hook with lure attached was imbedded in her jaw. This female grey reef shark was very thin and gradually looked worse over time until she disappeared from Blue Corner. This is an obvious risk to the animal because she may well not survive; it is also a risk to divers if this shark becomes aggressive, and a risk to the local economy by losing 'watchable' wildlife.

Figure 3. Tourists wading with large stingrays in Tahiti. Rays were attracted by bait.

Photo credit: Phillip S. Lobel.

Figure 4. *Carcharhinus amblyrhynchos*, Grey reef shark with a fishing lure at Blue Corner, Palau.

Photo credit: Phillip S. Lobel.
In terms of elasmobranch behavior, we need to know the home range of individual sharks and rays in order to better determine the size of marine protective areas. These same data allow for estimating the predictability of observing the animals for site-specific ecotourism. For these studies, tracking sharks using acoustic tags is the most feasible methodology. One of the key issues, however, is determination of the best method for tagging a shark that will cause the least harm to the animal (Skomal et al., 2007). This is an especially relevant concern given that research in the USA is governed by permits from the Institutional Animal Care and Use Committee (IACUC).

The unifying scientific question in terms of understanding how dive operations may or may not be impacting sharks and rays and the associated diver safety issues is whether the individual sharks and rays are local residents and thus able to learn and habituate to divers. Alternatively, if these sharks and rays rarely reside for long-term in the same areas, then they are much less likely to become accustomed to a site-specific feeding dive. I base this on my own experiences, especially with the grey reef shark *Carcharhinus amblyrhynchos*. I have observed that sharks unfamiliar with divers are more aggressive (Figure 5) and less predictable than those that have habituated to the presence of divers, such as we now see in numerous marine protected areas such as Blue Corner, Palau, and Shark Reef Marine Reserve, Fiji.

![Grey reef sharks](image)

**Figure 5.** Grey reef sharks can be aggressive when first encountering scuba divers, but they habituate to the presence of divers to the point that they ignore flash photography and bubbles (photo Fanning Atoll, 1974). Photo credit: Phillip S. Lobel.

**Methods and Results**

My research has examined the movement patterns and reproduction of the grey reef shark, *Carcharhinus amblyrhynchos*, at two locations in the Pacific Ocean: Johnston Atoll and Palau. The objective was to determine whether this shark species exhibited any measurable degree of local site fidelity, or if they just wandered widely and haphazardly. At Johnston Atoll, the local question concerned the degree of exposure to individual sharks that were found in reef habitats contaminated with PCBs and dioxins. At Palau, the local question concerned if and how far individual sharks wander beyond the boundaries of the marine protected area at the Blue Corner dive site.
The overall aim of this research was to address both conservation and scientific issues. The basic issues are:

- Socio-economic issues
  - Marine Protected Area – how big?
  - Fisheries prohibitions – on what scale?
  - Making the case for conservation based on solid science and applied economics
    - How much is a shark worth to ecotourism?
    - Are individuals resident longtime?
    - Do scuba divers adversely affect a shark's behavior?

- Scientific questions
  - Behavioral ecology, natural history of a top predator
    - Home range: hunting and feeding habits- orientation to spawning fishes?
  - Trophic ecology: Bioaccumulation of contaminants and ciguatera

Observation of Reproduction

One aspect of shark biology that is easy for scuba divers to note is the relative abundance of males and females. It is also simple to note if females have been recently mated or appear pregnant. Male and female sharks are easily distinguished by the presence of claspers on the males (Figures 6, 7). A recent mating event can be recognized by scars on a female (Figure 8) that result from the male biting and holding her during copulation (Whitney et al., 2004). Fresh mating wounds are clearly recognizable on females of many species of elasmobranchs (Pratt, 1979; Kajiura et al., 1999; Jensen et al., 2002; Porcher, 2005). It is a little more difficult to assess pregnancy in sharks, but females in advance gestation are much 'fatter' than others (Figures 9, 10). Pregnant female grey reef sharks have been observed to gather in aggregations in shallow water away from their usual territory (Economakis and Lobel, 1998).

Figure 6. Male grey reef shark showing claspers. Photo credit: Phillip S. Lobel.
Figure 7. Female grey reef shark, no claspers. Photo credit: Phillip S. Lobel.

Figure 8. Female grey reef shark showing mating scar and torn pectoral fin. Photo credit: Phillip S. Lobel.
The Acoustic Bracelet Tag

We developed a new method of tagging sharks that was minimally physically intrusive. The design is to have the tag fall off (by corrosion) after the battery lifetime of the tag has ended. Sharks were captured by baited hook, promptly tagged and released. An acoustics bracelet tag was banded onto a shark's caudal peduncle (Figure 11) and tracked by underwater loggers (Figure 12) strategically deployed at up to 16 locations. The bracelets were made of stainless fishing lure braid and were crimped with non-stainless crimps. These last about 15 months in seawater jars in the laboratory. In
addition to the acoustic bracelet tag, several of the sharks were also equipped with the National Geographic Cittercam camera system (Figure 13, Skomal et al., 2007).

Figure 11. The newly developed acoustic bracelet tag on the shark's caudal peduncle. Photo credit: Phillip S. Lobel.

Figure 12. Diver deploying underwater acoustic loggers for recording passage of sharks that have been tagged in Palau. Photo credit: Phillip S. Lobel.
The study of grey reef sharks at Johnston Atoll began in 1983 with acoustic tracking during 1999 to 2003. The long-term study at Johnston Atoll included detailed census surveys of females (most being pregnant) in shallow water aggregations and acoustic tracking. Johnston Atoll was a military base with extensive chemical and nuclear operations since the 1930s (Lobel, 2003; Lobel and Lobel, 2008). Johnston Atoll had no tourists and relatively few divers. Palau, in contrast, is a sport diver Mecca with as many as 300 divers per day at Blue Corner. The Palau study was from 2003 to 2006.

The Study of Sharks at Johnston Atoll: Pollution and Ciguatera

The answer to the question about how far and wide a reef shark may roam also has major implications to pollution impact studies and remedial pollution cleanup actions. The consequence of the decisions to clean up a site or 'remediate in place' also have economic implications as the price tag for clean-up is always in millions of dollars. In our case study at Johnston Atoll, a central Pacific Ocean U.S. Department of Defense installation, cleanup requirements are based upon an evaluation of potential ecological impact, particularly to top-level carnivores and other threatened or endangered species. Our studies addressed this issue by studying sharks as well as contaminants in potential prey fishes and in the marine sediments that prey fauna consume while feeding (Lobel and Lobel, 2008).

On another tangent that is interesting scientifically, one of the long time questions in animal behavior can be paraphrased as 'what makes a good fish go bad?' It is well known that certain contaminants that accumulate in the tissues of an animal can affect that animal's behavior. Lead and mercury can cause learning abnormalities and could lead to abnormal behavior, perhaps even increased aggression ('mad as a hatter'). The impact of the mix of other chemicals in the ocean, both pollutants and natural, is really unknown. We are particularly interested in the effects of the natural phenomenon of ciguatera on the survivorship and behavior of fishes. Ciguatera is a natural toxic phenomenon that is pervasive on tropical marine reefs. Sharks are well known to be top-level carnivores and have been shown to have high levels of ciguatera in some areas at some times. We have been evaluating the impacts from military contamination on reefs from these several perspectives.
The objective of the study at Johnston Atoll was to determine where sharks ranged relative to underwater sites contaminated with Agent Orange, dioxins, PCBs, and plutonium from nuclear weapons detonations. At Johnston Atoll, we found concentrations of contaminants in shark tissue samples that were much higher than expected. The levels were of concern because if the sharks were feeding randomly throughout the entire atoll, it would imply a greater environmental impact from the contaminants than if, on the other hand, the sharks were homebodies. If the sharks were individually very site specific and were staying on a particular local reef area, then their feeding perhaps could be focused on where there were contaminated reef fish (such as on adjacent reef to the Navy pier, the old Loran station and the former Herbicide Orange storage site.. If that was the case, individuals may be impacted but not necessarily a significant portion of the overall population of the atoll.

The Study of Sharks in Palau

Scuba divers worldwide come to Palau to see and photograph sharks. The abundance and diversity of shark species that can be seen on any given day guarantee the economic survivorship of Palau's ecotourism diving industry. But more than that, Palau provides an educational product that introduces sharks as wondrous animals to those watching films in theaters, in schools and on TV. It is fair to state that the reliability of filming sharks in Palauan waters attracts film crews from all international venues. These films show sharks in their natural habitat, and help audiences appreciate their positive role in the coral reef ecosystem.

Specifically, we do not yet know if the common reef sharks seen by divers every day at such famous dive locations such as Palau's Blue Corner, are resident or migratory. We do not know if these same sharks may at some time in their life cycle venture far out into international waters. If they do, they could become easy prey to high seas fisheries legally operating in international waters. More complicated, is the legal prosecution of captured fishing boats found, for example, within Palau's sovereign waters with shark fins aboard. These boats can claim that the fins were taken legally in international waters and not within Palau's protected economic zone. The law enforcement case can only be made if the boats were actually witnessed fishing in restricted waters OR if science can demonstrate beyond a reasonable doubt that the species of sharks in the boat could only be found and caught inside of the protected exclusive economic zone.

Palau's Blue Corner is arguably one of the best diving sites in the world, where divers come to specifically see sharks. Are these the same sharks they are seeing on a daily basis? How do the sharks react to the people? And, as a dive master for tourists, are there things you can do that would make it easier for people to see the sharks and be less intrusive to them? The scientist needs to answer the question about where different shark species spend their time. Are the so-called 'reef sharks' really restricted to only coastal coral reefs? Can these 'reef sharks' migrate between Pacific Islands such as from Palau to Yap to Guam? These questions remain to be answered.

Discussion

Data obtained, so far, indicate that the grey reef sharks are highly site resident for extended periods of time from weeks to months, but that they also range elsewhere (at least outside of the range of the acoustic logger array) for some time periods and then later return. Analysis of these data is in progress, and will be presented in forthcoming research papers.
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References


