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A case study of the Revillagigedo Archipelago

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Can Recreational Diver Surveys Lead to Conservation Action?

A Case Study of the Revillagigedo Archipelago

By Adam D. Baske

11 June, 2008

Introduction:

Often, man's perception of a "pristine" or "healthy" ecosystem relates only to experiences contained in single lifetime. For this reason, many people believe that poorly-studied ocean ecosystems are thriving, when in truth, many face serious threats to their already compromised existence (Jackson 1997). Without an understanding what marine ecosystems looked like before anthropogenic influence, we have no chance of comprehending the scope of change that has been driven by our actions. Recently, several marine scientists have undertaken historical investigations of ecosystems to better understand how certain communities looked in times past, when the stresses from the ever-expanding world population were less severe (Jackson 1997, Sáenz-Arroyo 2003). Such studies are useful not only for illuminating the past, but also for improving marine resource management.

Documenting the "shifting baseline syndrome" (Pauly 1995) in the ocean can involve pouring through old ship logs, photo archives, and personally interviewing persons that hold the historical ecological knowledge of a specific area. This historical methodology has revealed that many marine species were much more abundant in pre-fishing times than previously believed

(Jackson *et al.* 2001, Pitcher 2001). Sáenz-Arroyo (2005) employed “soft science” techniques and incorporated anecdotal evidence in quantitatively assessing the historical grouper populations in the Gulf of California. McClenachan *et al.* (2006) utilized historical sources to examine changes in sea turtle nesting populations in the Caribbean over a period of hundreds of years. Both of these studies exemplify the usefulness of historical data in answering questions for which no quantitative data exist. By seeking out non-traditional data, scientists can look further back in time and more correctly assess the extent of species depletions.

To date, no “shifting baselines” studies have been completed on the eastern Pacific seamounts, such as the Galápagos, Cocos, or Revillagigedo Islands. These islands are similar in many regards. The marine environments abound with large pelagic megafauna – sharks, whales, giant mantas, and tuna. All are marine reserves, and have been for at least 10 years. All have total or partial fishing closures in place. The three island groups also support thriving diving tourism industries which depend on the pelagic megafauna. Finally, the islands support aggressive illegal fishing operations, which threaten the dive-tourism industry as well as the conservation goals of the areas (Cahmi 1995, WildAid 1995, Sea Watch 2001).

My goal was to carefully examine one of these areas, the Revillagigedo Islands, and to determine if the baseline abundance of the elasmobranchs around the islands has shifted using a combination of historical and survey data. Like Cocos Island and the Galápagos, the divers that visit the Revillagigedos pay thousands of dollars to interact with the sharks and mantas. An excerpt from one of the dive operator’s websites exemplifies the importance of the shark and manta populations around the Revillagigedos.

“These islands (the Revillagigedos) have been compared to Galápagos or Cocos in the quality of Big Animal encounters they provide. They have in fact been called "Mexican Galápagos". There are a lot of sharks - huge hammerhead schools, white tips, silver tips, silkys, duskies, galapagos & occasionally tigers. We have counted up to 7 species of shark on JUST ONE DIVE! These islands are famous for unbelievable encounters with Giant Mantas. These winged giants are up to 22 feet across and it is common to be in the water with 5 to 12 of these winged giants at once. This may seem like an exaggeration but it definitely is not! ...[at the Revillagigedos] you have The BEST BIG ANIMAL DIVING ON EARTH!!” (www.solmar.com/solmarv/ May, 2008)

Underwater filmmaker Howard Hall (IMAX® Deep Sea, Shadows in a Desert Sea) has this to say of the archipelago:

“The Revillagigedo Islands are world famous for their enormous manta rays, whale sharks, and spectacular schools of tuna and sharks. Few places on Earth equal the marvels of the Revillagigedo Islands. And no serious sport diver's travels are complete until he has visited these Islands,” (Sea Watch 2001).

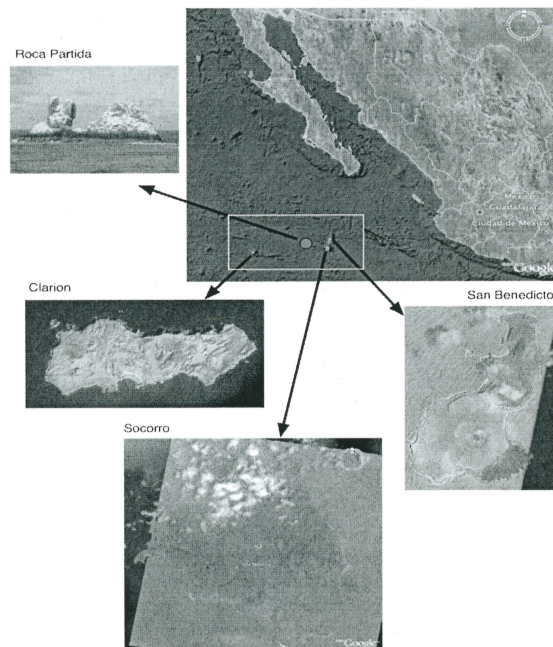
The Revillagigedos are obviously a special place, and are treasured by the dive community. However, anecdotal evidence suggests that shark populations around the islands are severely threatened. Potential consequences of further declines include the loss of dive tourism, which is the only economically sanctioned activity within the marine reserve, and further damage to ocean ecosystems. However, before delving into how the shark abundances have changed around the

islands, I want to provide a brief introduction to these little known islands, and discuss their marine conservation history.

Background:

The Revillagigedo Archipelago consists of four islands, located 250 miles south of the tip of the Baja Peninsula, in the Mexican Pacific (Fig. 1). Three of the islands - Isla Socorro, Isla San Benedicto, and Isla Clarión – support several endemic terrestrial animals, dry forests, and seabird colonies. The small rocky pinnacle of Roca Partida serves only as a temporary home to seabirds. While the terrestrial environment of the Revillagigedos is recognized as a critically endangered eco-region by the World Wildlife Fund, the underwater realm has received little attention from conservation groups.

Figure 1. The Islands of the Revillagigedo Archipelago, Mexico
Images obtained from Google Earth



Since the 18th century, the four islands have had the reputation as shark havens. They are also renowned for the abundances of manta rays, wahoo, and schools of large yellowfin tuna. This combination of biodiversity brought in commercial fishermen, recreational fishermen, and recreational divers starting in the 1960s. Offshore tuna boats commonly topped off their holds around the islands, and San Diego-based long-range recreational boats brought out thousands of fishermen every year to tangle with world-record size yellowfin.

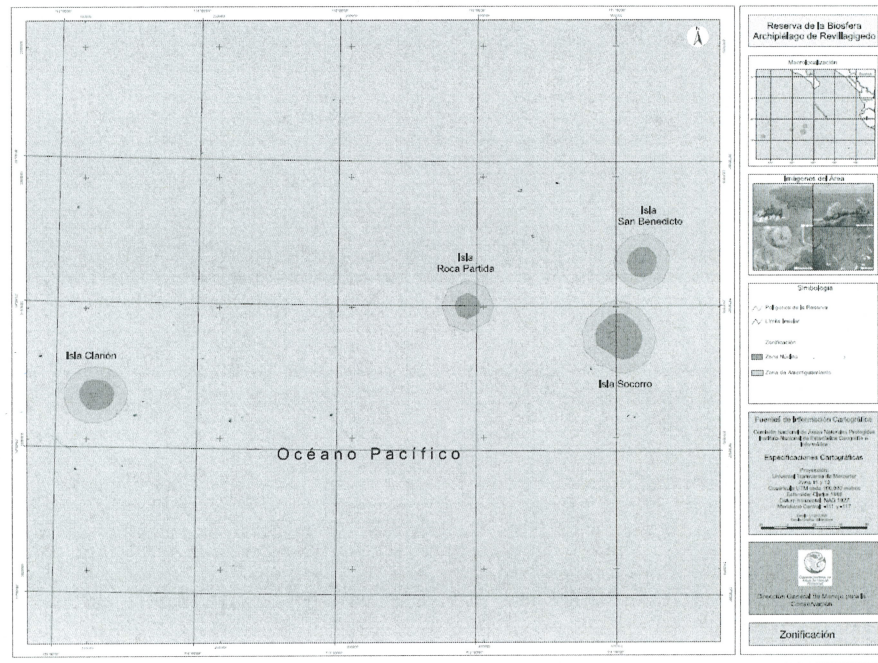
As commercial fishing efforts ramped up in the 1980s and 1990s, both the diving and recreational fishing communities sought some sort of regulation from the Mexican government. At that point, the only way to get an area protected was by presidential decree, however, neither the American recreational fishing fleet, nor the dive operators had the political power to make that happen.

The situation took a turn in 1994, due to the efforts of the small non-governmental organization (NGO), Sea Watch. On February 14, 1994, Sea Watch's vessel, the Ambar III, shot video of a Mexican fishing boat hauling in their nets adjacent to Isla San Benedicto. Two of the giant mantas that the divers on the Ambar III had been riding the previous day were torn to shreds by the monofilament net. The fishing boat simply discarded the damaged net, along with the mantas, onto San Benedicto's reef. The vessel then pulled in its longline which had hooked dozens of reef sharks. Because of the low value of the fins and meat, the dead sharks were cut loose.

On the same day, and also caught on video, another Mexican fishing vessel harpooned two giant mantas. The animals spanned 20 feet across and weighed about one ton. The fishermen cut the wings off of the mantas with axes. The footage from Sea Watch made it to the Mexican media in a matter of days. The story was featured on Guillermo Ortega's Mexican TV news-magazine, *Al Despartar*, which has an audience of over 58 million Latinos. The St. Valentines Massacre, as the manta slaughter became known as, made headlines in the US as well, with coverage on the CBS Evening News and CNN. Within two months, the Giant Pacific Manta was put Mexico's endangered species list; making the killing of one in the Revillagigedos punishable with a \$10,000 fine (Sea Watch 2008).

As a result of the Mexican media exposing the commercial slaughter of manta rays in the shallows of San Benedicto Island to the Mexican public, a Presidential Decree granted the islands biosphere reserve status on June 4, 1994, only four months after the incident. This created a "Core Zone" extending 6 miles out from each island in which no fishing could occur, as well as a "Buffer Zone" which allowed for limited fishing from 6 to 12 miles from the islands (Fig. 2) (Decree 1994). However, because of the rapidity of the process, no time was spent on developing a management plan or enforcement strategy. Thus no agency was certain about who should do what, resulting in continued exploitation by the Department of Fisheries. The Revillagigedos Archipelago Biosphere Reserve was a "paper park" from the beginning, and continued in this form for many years.

Figure 2: Protected Zones of the Revillagigedo Archipelago Biosphere Reserve



The 1994 decree establishing the biosphere reserve banned fishing activity in the “Core Zone” extending six miles from the shore of all four islands. Unfortunately, the islands are over 200 miles the nearest town, so little monitoring or enforcement from local communities or Mexican agencies was possible. To make matters worse, no management plan existed for the area, even though it was called for in the 1994 decree (Decree 1994). A clear management plan would have set regulations and made concessions for the enforcement of the biosphere reserve’s boundaries. The dive boats and recreational boats in the area regularly documented illegal fishing activity, and sent proof to the proper authorities, but little ever resulted (McGettican 2008). The only possible way to monitor and enforce the regulations of these isolated islands was with the help of the Navy, which supports a station with about 60 men on Socorro Island. However, the Navy has no fisheries enforcement authority under Mexican law.

Not surprisingly, no real enforcement occurred in the biosphere reserve for the first eight years of its existence (Peterson 2005). Some fishing boats even had permits to fish in the area, which illustrated the tensions between the Fisheries Department and other government agencies (Kira 2002). These realities upset the NGOs that fought hard for its protection. As a result, the NGO Sea Watch brought the minister in charge of the islands, Secretary Santiago Creel, out to witness the destruction incurred by illegal fishing. Two weeks later, all fishing activities (recreational and commercial) were banned out to 12 miles from the islands (Sea Watch 2008). More importantly, the Navy came on board to aide in the enforcement of the fishing ban (Kira 2002). Soon after the 2002 fishing ban was enacted, a Mexican Navy officer commented, “It was never made clear to us before that [the biosphere decree] is the law. Now, we know. Regardless of whatever may have been done in the past by questionable officials, we are now enforcing the law,” (Kira 2002). To prove their seriousness, the Navy stationed a frigate ship and two speed boats at Socorro Islands.

However, illegal fishing persisted (McGettigan 2008), and the area still had no comprehensive management plan. What was the effect of these factors on the marine animals in the area that sustained the tourism industry? My objective was to determine if the shark and manta populations in the waters surrounding the Revillagigedo Archipelago Biosphere Reserve were sustained over the years to see what effect, if any, the protected status had on elasmobranch numbers. Moreover, I wanted to qualitatively show how the baseline of abundances has shifted using sailing logs from the 18th century, testimony from the first divers to visit the islands, and accounts from visitors in 2008.

Methodology:

Historical Evidence:

The University of California San Diego Library provided two historical ship logs with information relating to the sharks of the Revillagigedo Archipelago. More recent information was collected by interviewing commercial fishermen, recreational fishermen, recreational spearfishermen, professional underwater photographers, and recreational SCUBA divers.

Retrospective Survey:

The Revillagigedos have no consistent scientific monitoring programs in place for its marine ecosystems. Likewise, no fishing records are available that indicate anything about the shark catches from around the islands. For these reasons, I developed a sociological survey that targeted the only consistent user group of the islands marine environment – the recreational dive community. Under the guidance of Dr. John H. Evans of the UCSD Dept. of Sociology, I developed a bias-minimizing retrospective survey consistent with the discipline's standards for instrument design as outlined in Survey Research Methods by Earl Babbie (1998).

The first step in developing the survey was meeting with the various dive operators and professional underwater photographers who have worked in the area who possess the Local Ecological Knowledge of the marine environment surrounding the islands. I call this team of people the Focus Group. The Focus Group offered insights on the various species of sharks, on the specific dive sites, and on the divers themselves that visit the Revillagigedo Islands. Using this information, I created a draft survey that addressed the following concerns:

Length: Since I could not offer any incentives to take the survey, I had to make it short so to encourage participation. I kept the survey to one page of 12-point font.

Language: The questions had to be clear and unambiguous. To do this, I kept the questions short, direct, and used vernacular terms. I also used bold font for especially important words.

Respondent's Competency to Respond: The focus group meetings revealed to me that the divers that visit the Revillagigedo Islands are very experienced and knowledgeable about shark identification. The dive boats that service the islands also educate their passengers about shark identification.

Recall Bias: People cannot perfectly recall the past, and for this reason, the survey could not totally eliminate this bias. To reduce this bias, I chose a specific dive site that is very memorable for its abundance of sharks – Roca Partida. I also only asked people to comment on their two most memorable experiences – their first visit to Roca Partida, and their most recent.

Dive Profile: People have been diving on Roca Partida for over 30 years. The Focus Group convinced me that divers at Roca Partida consistently go down to 100' and work their way up to the surface over the course of one hour. Thus, most dives on Roca Partida over time, though not exactly the same, have been very similar.

Avoiding Biased Terms: The wording in the survey could not indicate a certain position. A biased survey solicits biased responses. In this case, I did not want to indicate that shark

populations had changed one way or another, over the years. I simply used language in the survey introduction that reflected my interest in tracking elasmobranch abundances over time.

Diver Preferences: Not all divers look at the same thing. I was interested only in the shark and mantas of the area, but not all divers may be paying attention to those animals. A study of the divers that visit the Revillagigedos revealed that divers spend 97% of their time observing the pelagic megafauna (Sala and Sánchez-Ortiz 2006), which supports the idea that divers are specifically looking for the animals I was interested in.

IRB Application: As part of a university study that involves surveying the public, I had to apply for approval through the Institutional Review Board (IRB). In this document, you specify: the target audience, any dangers posed to them by the survey, and draft Consent Form. In this case, consent was assumed if a person filled out a survey after reading a short introduction. The introduction also functioned as a tool with which I framed the project in a bias-minimizing fashion.

I sent out the draft surveys for a pretest in January, 2008. I received feedback from the boat captains and Divemasters currently working in the area. After incorporating their suggestions, I was ready to distribute the survey, starting in February, 2008. The final version of the survey can be found in Appendix 1.

Survey Distribution:

I distributed the survey to as many past divers as possible through a variety of venues. To collect current information about the Roca Partida elasmobranch abundances, one of the dive operators (the Solmar V) distributed the survey to its clients. In order to reach out to past divers, I employed a variety of strategies. I attended local meetings, called dive shops that ran trips to the islands, contacted dive magazines, emailed professional underwater photographers, and created an online version of the survey.

I created the online version of it through a free online surveying service (www.freeonlinesurvey.com). This allowed me to email the survey out to past divers and post it on online forums. Respondents simply filled in the blanks and clicked “Submit”, and the results were immediately sent to my account. Responses were solicited on a variety of websites, email list-serves, and electronic newsletters. See Appendix 2 for a full list of venues on which I made the Roca Partida Shark and Manta Survey available.

Results:

Historical Documentation of the Shifted Baseline:

Were the waters of the Revillagigedos always shark-laden? They certainly have that reputation today, both from fishermen and SCUBA divers. Few historical sources that document anything about the Revillagigedos exist, let alone documents relating to the shark abundances. I was only able to find two historical accounts – one from 1793 and another from 1889 – that mention the sharks of the Revillagigedos.

In 1793, Captain James Colnett sailed to the Revillagigedos twice, and gives detailed accounts of the visits in his published ship log, entitled “Voyage to the South Atlantic and Round Cape Horn.” The purpose of the voyage was to scout out potential ports of call where the British whaling fleet could reprovision and come in for repairs if necessary. He paid special attention to the resources available at each island he visited – both terrestrial and marine. Below are his accounts of the marine fish of the Revillagigedo Islands:

“Sept. 24 – at nine A.M. we saw Rocka Partida, on our weather bow, which has the appearance of a sail...At Rocka Partida was a prodigious quantity of fish, but we caught only few, as the sharks destroyed our hooks and lines, and no one on board, but myself, had ever before seen them so ravenous. One of our men, reaching over the gun-whale of the boat, a shark of eighteen or twenty feet in length, rose out of the water to seize his hand,” (pg. 89)

Colnett’s ship, the *Rattler*, sailed to the mainland for a month, before returning to Isla Socorro in December so the crew could recover from scurvy. As the word *socorro* in Spanish, means “supply”, Colnett thought the island may be an ideal port for ships to re-provision after months at sea. Here is what he had to say about the abundance of fish from around the island.

“The fish we took were land-crabs, sea crabs, craw-fish...To these may be added cod, rays, eels, and all those that are usually taken in tropical latitudes...But with all this abundance of fish, it is a matter of some difficulty to obtain them, from the number and size of the sharks, who very frequently seized the whole of our prey, before we could draw them out of the water,” (pg. 118).

One may ask the question if the shark situation was similar in other locations, considering it was over 200 years ago. Captain Colnett scouted other islands that are currently known for their high shark abundances. He mentions the sharks in the Galápagos in one sentence, “The deep water fish, were of every kind,...sharks were in great abundance,” (pg. 58). Likewise, he spends little time discussing the sharks around the Cocos Islands: “Fish were in great abundance, but would not take the bait, which we attributed to the great number of sharks off this island,” (pg. 71). In the 1790s, the Revillagigedos exhibited a remarkably high abundance of large sharks. So high, in fact, that one of the world’s most traveled sea captains of the time dedicated several sentences of the ship’s log to sufficiently warn future visitors of the situation.

In 1889, the U.S. Fish Commission’s vessel, The Albatross, surveyed the islands. On March 2, A.B. Agassiz wrote this of the marine life of the Revillagigedos:

“We had only been fishing a short time when many sharks appeared about us and did much damage to our gear... sharks were exceedingly abundant and troublesome, and the utmost care had to be exercised to prevent their carrying away our gear”

Records from spear fishermen and SCUBA divers have documented abundant sharks around the Revillagigedos from the late 1970s to the early 1990s. Marty Snyderman, a professional underwater photographer, provided me with the earliest account diving at Roca Partida, dating back to 1977. “One of the only dives I ever aborted was my first dive on Roca Partida. A silky shark attacked a triggerfish, and the place went off. Silky, Galapagos, Silvertip, White tip, and

scalloped hammerheads frenzied. I'm talking of seeing over 500 sharks within minutes. I was just saying to myself 'Dear Jesus, don't get clobbered.'

More detailed quotes that point at the shifted baseline are listed in Appendix 2. All suggest the same story. The sharks started disappearing in the 1990s. Regardless of this trend, recreational divers still flock to the islands to see the sharks and mantas. Below is an account from a diver's trip out to Roca Partida in April of 2008. The customer preformed three dives on Roca Partida, and provided me with a detailed account of each.

"Dive 1: We saw a few silky and galápagos sharks in the distance. We hung near the rock on this dive to see the white tip reef sharks chilling in crevices on the rock at about 45 feet below the surface. There were 2 crevices with approximately a dozen sharks and 2 huge lobsters hanging out... We saw a couple of manta rays gliding below us."

"Dive 2: We saw a different manta ray than the one on the first dive. We both saw 2 huge yellow fin tuna (6+ feet) swim by us. We didn't see hammerheads but several divers saw a small school (7-13) near the rock. We saw a very large Galapagos shark twice on this dive and some more white tip sharks swimming below us."

"Dive 3: We saw a very large galápagos shark immediately when we hit the water... In addition, we saw a good size silvertip shark that made the hairs stand up on the back of your neck. We also saw a couple of white tips swimming around. We saw one manta on this dive," (Black Personal Interview 2008)

Survey Results:

Between February 20, 2008 and June 6, 2008, 129 usable data points were collected. Table 1 summarizes from where the responses were solicited, and the number of responses from a generalized list of venues. See Appendix 3 for a detailed list. Overall, the web proved to be the most important tool for soliciting responses, as 63% of completed surveys were completed online. Within all of the web-based responses, most of those came through personal email contact (26) and through the electronic newsletter sent out by one of the dive operators that services the Revillagigedos (30). The same dive boat that posted a link to the survey on their website also agreed to hand out a paper version of the survey to their customers, on-location, which provided 44 surveys describing the current state of shark and manta observances at Roca Partida.

Table 1: Distribution of Survey Respondents

Venue	Responses	Percent of Total
Dive Boat	44	34%
Web Based	81	63%
Magazine	2	1.5%
Meetings	2	1.5%

Responses ranged from 1977 to 2008. The average number of dives completed by respondents was 2,341, with a median of 1,000, which confirmed the assumption that the islands attracted highly experienced divers. The individual responses for the total number of elasmobranchs

observed on a typical dive at Roca Partida were plotted against the year of those observations (Figure 3). The resulting downward trend had a highly significant regression ($p < 0.001$), with a slope of -4.29 sharks/year.

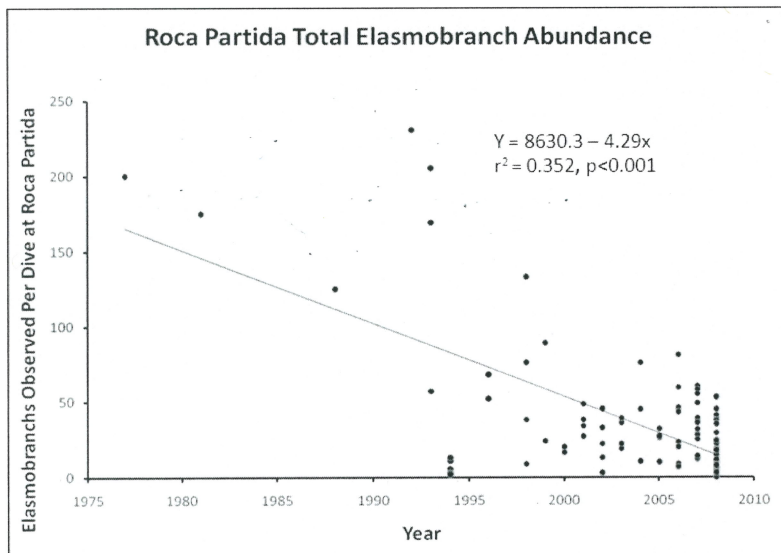


Figure 3: Number of Elasmobranchs Observed per Dive at Roca Partida (with best-fitting linear relationship). n = 129.

To examine how elasmobranch abundances at Roca Partida had changed since the establishment of the Revillagigedo Archipelago Biosphere Reserve, I plotted only those data points after 1994 (Figure 4). Again, a highly significant ($p < 0.001$) downward sloping regression resulted, which a slope of -3.45 sharks/year.

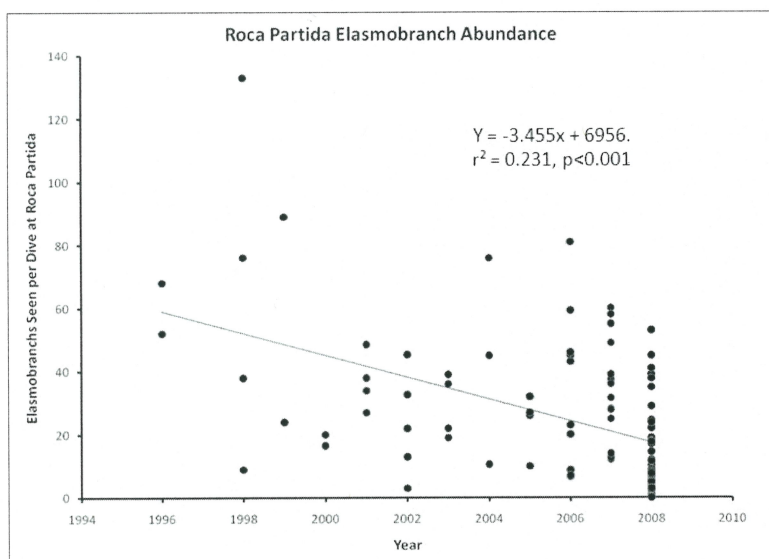


Figure 4: Roca Partida elasmobranch abundances since the Revillagigedo Archipelago Biosphere Reserve was established (plotted with best-fitting linear relationship). n = 115.

I then split the “Total Elasmobranchs” into three easily identifiable groups: 1) Pelagic sharks (Galapagos, silky, silvertip, and scalloped hammerhead), 2) resident sharks (white tip reef sharks), and 3) Mantas, to examine if all groups followed the same trend (Figures 5, 6, and 7).

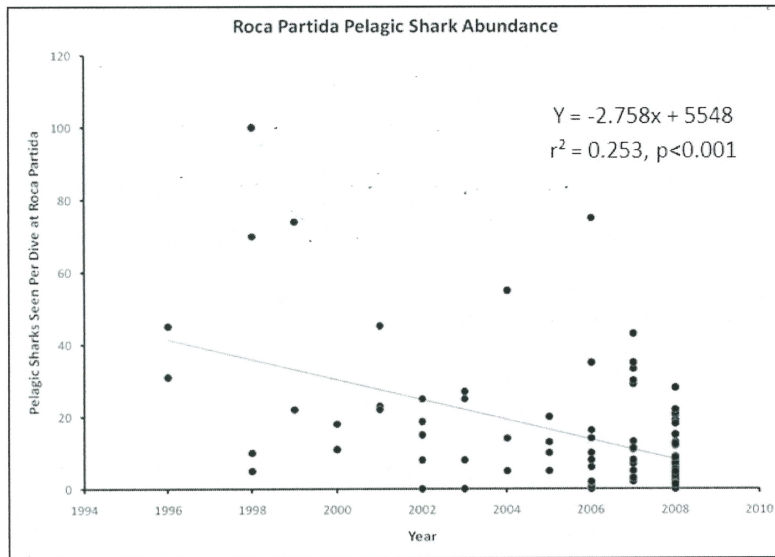


Figure 5: Pelagic shark abundances (Galapagos, silky, silvertip, and scalloped hammerheads) observed at Roca Partida since 1995 (with best fitting linear relationship). n = 115.

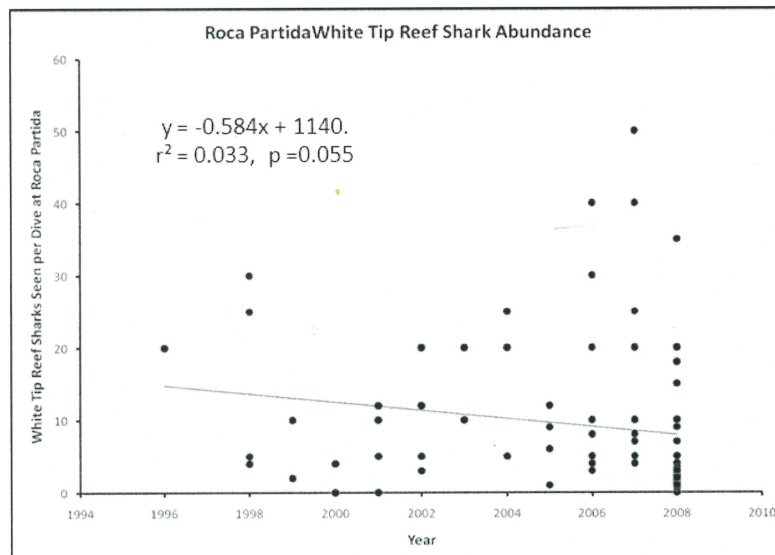


Figure 6: White tip reef sharks abundance observed at Roca Partida since 1995 (with best fitting linear relationship). n = 114.

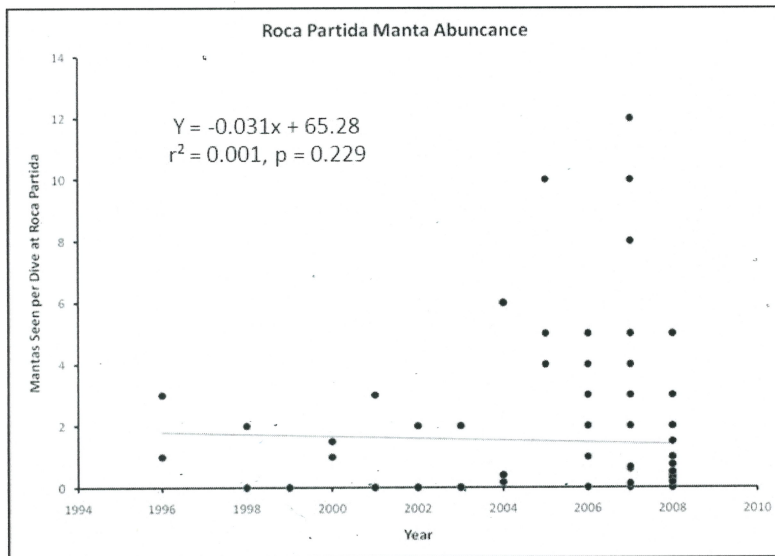


Figure 7: Manta abundance observed at Roca Partida since 1995 (with best fitting linear relationship). n = 115.

The only significant trend found in these three groups was the downward trend of observed pelagic sharks at Roca Partida ($p < 0.001$). Neither white tip reef shark nor manta abundances have changed significantly since the establishment of the biosphere reserve in 1994.

Discussion:

Overall, the results from the survey support the oral records, and offer a coarsely quantified estimate of change over time. From the anecdotes, dating back to the 18th century, it was apparent that the baseline abundances of sharks had shifted, and the survey data provided a more detailed examination of these claims, dating back to 1977. The trend line on the data suggests a highly significant ($p < 0.001$) downward trend in shark abundances, and estimates that divers are seeing 4.3 fewer sharks per year at Roca Partida, however, we must recognize the caveats and limitations of the survey before discussing the results in further detail.

Caveats/Limitations of survey:

The survey violates some of the technical assumptions of modeling with statistical inference, however this is justified because no other methods to measure shark populations in the 1980s exist. Many biases remain in the data, which is why I am reluctant to claim specific changes in terms of percentages or other definitive terms. Specifically, I want to address randomness, systematic bias, recall bias, seasonality.

Ideally, a sociological survey represents a random sample from a sample universe. The only way to obtain such a sample would be by obtaining a list of all past divers to the islands, which does not exist. I attempted to obtain a list of all divers that have visited the islands on the two dive boats servicing the area. Understandably, the owners were not willing to give out personal information about their clients. Without this list, I was left with only one option – to solicit as many responses as possible using the phone, email, and an online version of the survey. Although the samples were not collected from a random sample, I believe they were solicited in such a way that reduced systematic response bias.

This sampling strategy was unlikely to create systematic biases because of the question format and framing. I had no conservation-spin associated with the survey. I simply asked for their help in reconstructing the shark and manta abundances at Roca Partida. I claim that people were equally likely to fill out the survey, no matter how many sharks they saw on their last trip there. Indeed, I received responses from people who saw zero sharks, and responses from divers who saw hundreds. All of the divers who visit the islands go to see the sharks and mantas. They spend thousands of dollars to do so, which makes it logical to infer that these people are

interested in sharks. If they are interested in sharks, then they are equally likely to want to participate in a shark study regarding a location they had visited, no matter how many they saw on a particular dive trip.

The fact that respondents cannot remember the past in perfect detail introduces recall bias into the results. As time from the present increases, so does this bias. There is no way to eliminate this bias. However, it is worth mentioning that the few data points I have from before 1994 are from extremely experienced divers and professional underwater photographers. These are people who make a living out of diving, who can easily identify various types of sharks and provide relatively accurate estimate of numbers.

Another factor that could not be accounted for was seasonality. Some people claim that different types of sharks migrate seasonally to the Revillagigedos, while others disagreed with that claim. No studies have been done on the seasonal variability in shark abundances off of the Revillagigedos, but seasonal variability in elasmobranch populations has been noted in other parts of the world, so the claim should not be discounted. The scale of my analysis was not able to pick up seasonal variations, however, if the dive operators continue to distribute the survey to their clients, this question could be partially addressed. However, dive boats only visit the islands from November to May, to avoid the hurricane season, which would leave a five-month window with no information.

I agree that the results contain some amount of the above biases. I did all that I could in terms of bias reduction in the creation and distribution phase of the experiment, however it is impossible

to control for all of the biases. We need not discredit the results, which simply reflect the nature of the retrospective surveying; rather, we should embrace the methodology and improve upon it to gain insights into the poorly studied past of our marine systems.

Effectiveness of the Biosphere Reserve:

All marine reserves should have their effectiveness regularly evaluated to determine if their management strategy needs to be modified and to examine if enforcement measures are adequate to fulfill the goals of the area. However, many lack the resources and tools to do so. Developing a retrospective survey for the dive community may offer a low-cost way of completing this necessary task. Over the course of seven months, I was able to provide a semi-quantifiable program evaluation on the effectiveness of the Revillagigedo Archipelago Biosphere Reserve in protecting sharks and mantas.

In terms of the data, the 1994-to-present regression models have an advantage beyond modeling change after the law was changed. In two cases (Total Elasmobranchs and Pelagic Sharks) I still found declines even after the most suspect data points were eliminated (the pre-1994 data points are the most likely to have recall bias, and are also where the greatest problem with heteroskedasticity is found). This suggests that the biosphere reserve is not adequately protecting those resources. However, no significant trend was observed for the white tip reef sharks and manta rays over that same time period (Figures 4, 5, and 6). These findings bring up many questions that demand further investigation.

Was the decline in pelagic sharks at Roca Partida a local or global phenomenon? What would be the best course of action for reversing the trend? Was the \$10,000 fine imposed on killing manta rays actually protecting them, or was it the fact that their meat got such a low price on the market? Were white tip reef sharks protected because their fins are of relatively low value or because their life history keeps them relatively close to the protected islands? Some of the questions will never be answered, while others demand further study.

Local vs. Global?

We cannot say for certain that the lack of proper protection from illegal fishing operations has driven the decline in pelagic sharks. Both dive operators that service the Revillagigedos blame the Mexican government for not offering sufficient enforcement for the commercial fishing ban. Since the biosphere reserve was established in 1994, both boats have caught countless vessels fishing illegally with long lines and gillnets. It is apparent that the islands have not been adequately protected, but it is not clear if the local illegal fishing has caused the decline in pelagic sharks, or if the Roca Partida survey simply illuminates a global problem on a small scale.

Pelagic shark populations have been declining globally in recent decades. In the Gulf of Mexico, it is estimated that silky and oceanic white tip populations are down at least 90% since the 1950s (Baum and Myers 2004). Populations of various oceanic and coastal sharks in the northwest Atlantic are estimated to have declined by 40–89% since the late-1980s (Baum *et al.* 2003). In 2008, the IUCN – World Conservation Union Red List criteria were used to evaluate the status 21 oceanic pelagic shark and ray species. Of those, 16 were declared Threatened or Near

Threatened (Dulvy *et al.* 2008). In all of these cases, high-seas fishing mortality is thought to have driven the declines.

Many of the species found in the waters of the Revillagigedos spend significant portions of their lives outside the boundaries of the Biosphere Reserve, and could easily be caught in long lines, gillnets, or purse seines in the poorly regulated and monitored high-seas industrial fisheries. Perhaps the decline in sharks observed at Roca Partida simply reflects this widely-recognized global phenomenon, driven primarily by the demand for shark fins in Southeast Asia (Clarke *et al.* 2006). The only way to address the question would be to effectively enforce the fishing ban in the Revillagigedo Archipelago Biosphere Reserve over a period of 10 – 20 years, while monitoring changes in shark populations inside and outside the reserve. Sharks are slow-growing, late-maturing animals which means recovery timetables would be much longer than for most other finfish. A more effective solution, which more pointedly addresses the problem, would be a global ban on the practice of shark finning accomplished by national laws, while attempting to reduce demand in the Asian shark fin market.

The location of the Revillagigedos and their distance from one another make it extremely difficult to enforce the fishing ban. However, this year the Mexican government took several progressive steps to keep the fishermen out. Mexican fishing vessels that venture more than 100 miles from shore are required to have a GPS tracking system installed, which will be monitored by fisheries officers. Additionally, the staff at the Navy station on Socorro Island was recently trained on how to better handle fisheries violations (Sanchez personal interview 2008). The

news is promising, and we can only hope that Mexico, as well as other countries that oversee open-ocean seamounts, will protect these hotspots of marine abundance and biodiversity.

Apparent Successes:

Neither the manta nor white tip reef shark populations as observed by divers at Roca Partida have changed according to a significant trend since 1994. Can this be attributed to the outstanding management of marine resources? It is unlikely, considering the fact that the dive boats regularly witness fishing operations taking place within the reserve. More likely, the life histories of these animals, combined with their relatively low market value have protected them. White tip reef sharks are commonly seen laying in caves and nestled against the seamount. In order to catch them, fishing gear would have to be deployed dangerously close to Roca Partida. Additionally, white tip reef sharks have relatively smaller fins compared to their pelagic cousins, making fishing for them a financially less attractive risk.

A similar argument can be made for manta rays. Their meat has a low-market value, and would take up considerable space in the holds of fishing vessels. However, unlike the white tip reef sharks, the mantas have had additional protections since 1994. Since then, there has been a \$10,000 fine associated with the killing of a manta in the Revillagigedo Archipelago Biosphere Reserve. The fine has never been imposed on fishermen, so it is unknown if the low-value of the manta meat or the possibility of fines has protected them.

Applications to Similar Areas

Converting the anecdotal evidence into a quantified estimate of change is a small step for improving conservation efforts and raising awareness. However, I am hopeful that I have created a tool that can be applied to other areas that are equally treasured by the dive community. Both Cocos Island and the Galápagos would be ideal locations to carry out similar studies.

These islands groups attract a similar array of pelagic megafauna as the Revillagigedo Archipelago. Both are marine reserves, and have total or partial fishing closures in place. And, like the Revillagigedos, anecdotal evidence of shifted baselines in shark abundances abound in the literature (Cahmi 1995, WildAid 2007), while quantified accounts of change do not yet exist. According to the conservation group WildAid, both the Galápagos and Cocos Islands support aggressive illegal fishing operations, mostly driven by the demand for shark fins. Documenting the degree of decline in shark abundances around these islands over the last few decades could provide similar insights into their conservation and management. For this reason, I compiled a list of dive operators and conservation groups that work in those (Appendix 4) areas to which I will send a 2-page newsletter, highlighting the key points of this study, as well as how to create a bias-limiting retrospective survey, and how to most effectively solicit responses from the diving community.

Conclusion:

The entire process, from survey development, to survey distribution, to the analysis of the results proved to be a very educational process; both for me, as well as for the future of marine

conservation. Retrospective surveys can provide useful information about the past as long as biases are addressed and minimized.

In the case of the Revillagigedos, the surveys indicated that the decline in total elasmobranchs observed at Roca Partida over the last 30 years was driven by the decline of pelagic sharks starting in the mid-1990s. I hypothesize that this trend was driven by local and high seas fisheries targeting shark fins, though it is impossible to say if local or high-seas fisheries are responsible, as the islands have received inadequate protection from commercial fishing.

The best course of conservation action would be to enforce a global shark finning ban, and to better manage elasmobranch resources on the high-seas. As this is unlikely to happen in the near future, the Mexican government should put a fine on the killing of sharks in the Revillagigedo Archipelago Biosphere Reserve - like it did for manta rays in 1994 - in addition to its current efforts to curb illegal fishing in the reserve.

I believe that the technique of surveying the recreational diving community can prove useful in documenting the shifted baseline of marine organisms in other highly visited areas. Specifically, I recommend carrying out similar surveys in the Galápagos and Cocos Island. Doing so would not only illuminate how our poorly-studied marine systems have changed over time, but could also provide a tool for continued monitoring, and offer valuable information for marine resource managers.

Acknowledgments:

I would like to sincerely thank all of the divers that participated in taking the survey. This project could not have happened without the goodwill and generosity of the diving community. I am also thankful to Jose Luis Sanchez, the owner of the Solmar V, who agreed to distribute the surveys to his clients and was also instrumental in the survey creation. Marty Snyderman, one of the first divers to frequent the islands contributed many photographs and colorful stories, as did Mike McGettigan, the founder of the non-profit group Sea Watch. Lastly, thank you to my advisers: Dale Squires, Stuart Sandin, and John Evans.

Appendix List:

1. Survey and Consent Form
2. List of survey venues and responses
3. Quotes from Spearfishermen
4. Names and addresses to send newsletter document

Appendix 1: Survey and Consent Statement Distributed between Feb. and June, 2008

2008 Roca Partida Shark and Manta Survey

I, Adam Baske, am a graduate student at the University of California, San Diego and am interested in shark and manta ray abundances at Roca Partida, in the Revillagigedos Biosphere Reserve. I am undertaking a study that will continue from January 2008 until May 30th, 2008. There will be approximately 250 participants in this study.

You have been asked to take part because I would like to learn about shark and manta ray abundances from the people, like yourself, who have observed the animals in their natural habitat. If you agree to participate in this study, I will ask you a series of questions related to your most recent trip to Roca Partida, in the Revillagigedos, and, if applicable, your first trip there. Please feel free to look at your logbooks when answering these questions. The entire survey should only take 5 minutes. You will be free to skip any question you do not wish to answer and you may terminate this survey at any time. If you have any more questions or research related problems you may contact Adam Baske at the Center for Marine Biodiversity and Conservation at UCSD at 619-846-4442.

If you agree to participate, please fill out information on the blanks provided on the following page.

UCSD Human Research Protections Program Disclaimer

Your participation in this study is entirely voluntary. There is a slight risk that the data you provide could be subject to a loss of confidentiality. These risks are minimal, as no data you provide could personally identify you as a participant in this study. All data will be kept on a password protected computer and only researchers involved in this project will be able to view this data.

You may call the UCSD Human Research Protections Program at 858-455-5050 to ask about your rights as a research subject or to report research-related problem

2008 Roca Partida Shark and Manta Survey

Approximate number of total dives in your lifetime: _____

What is the date of your most recent dive trip to Roca Partida (month and year)? _____

Approximately how many dives did you complete on Roca Partida on that trip? _____

On your **most recent** dives on Roca Partida, please estimate the numbers of the various types of sharks and rays you saw on a **typical** dive (not the best). For less commonly seen species, estimate how often you would see one. For example: If you saw one whale shark over the course of ten dives, you would write "1/10".

Whale sharks _____

Silky sharks _____

Hammerhead sharks _____

Silvertip sharks _____

White tip reef sharks _____

Manta rays _____

Galapagos sharks _____

Other sharks (specify) _____

If you have made only one trip to Roca Partida, please stop here.

What is the date of your first dive trip to Roca Partida (month and year)? _____

On that **first trip** to Roca Partida, please estimate the numbers of the various types of sharks and rays you saw on a **typical** dive (not the best). For less commonly seen species, estimate how often you would see one. For example: If you saw one whale shark over the course of ten dives, you would write "1/10".

Whale sharks _____

Silky sharks _____

Hammerhead sharks _____

Silvertip sharks _____

White tip reef sharks _____

Manta rays _____

Galapagos sharks _____

Other sharks (specify) _____

Thank you very much for taking the time to complete the survey.

Appendix 2: Venues on which the Roca Partida Shark and Manta Survey was presented

Venue	Distribution Method	# of Responses
Solmar V	Onboard	44*
Solmar V electronic newsletter	Web	30
Personal Email	Web	26
Divebums list-serve	Web	6
Wetpixel Forum	Web	4
Scuba Forum	Web	2
Scuba Board Forum	Web	3
Shark Diver International Blog	Web	2
San Diego Oceans Foundation Newsletter	Web	4
Ocean Enterprises Newsletter	Web	1
YouTube®	Web	2
MySpace®	Web	1
California Diving News	Magazine	2
San Diego Underwater Photographers Society	Meeting	2
American Assn. of Underwater Scientists	Meeting	0
San Deigo Council of Divers	Meeting	0
Total		129

**More Responses Pending*

Appendix 3: Anecdotes from Spearfishermen and Underwater Photographers

Dr. Terry Maas: Terry is a world champion free diver, underwater hunter and photographer and has written several books on free diving. He has been diving the Revillagigedo Islands for 19 years and has personally spent over 1000 hours in the water.

“During my 19 years, I have noted a steady and dramatic decline in sea life in the archipelago...I remember swimming with thousands of wahoo. These curious fish often approach us from long distances. ...Currently, I am lucky to see 10 small fish in an entire day, whereas in 1984, I would see 20 large fish with every breath hold dive..We have refined our knowledge of the local islands, which allows us to hunt the very best areas. In spite of our increased knowledge, we see fewer fish each passing year. The large tuna are missing, and the small are fewer. While I still see a number of sharks, their populations are down 50% and it is very common to find them with mouth injuries from a hook in their mouth.”

Mike McGettigan: Founder of Sea Watch ardent fisherman and free diver. He has been going to the Islands since 1977 and has made over 130 trips there.

“When I got there 25 years ago, it was terrifying to get into the water. You would often be surrounded by several hundred sharks and up to 100 wahoo would be visible within your range of sight. Tuna schools miles long would swim by until you were tired of watching them. The tuna were decreasing every year, even back then. There was heavy commercial seiner pressure in those days near the Islands.”

Gerald Lim: Gerald has been freediving for twenty years and I have been diving the Revillagigedo Islands for the past ten years. He has spent over 1000 hours in the water there over that period of time.

“In the 20 years of freediving around the world, I have never seen as unique and incredible diving as at the Revillagigedo Islands. The Islands have a variety of big animals like whales, marlin, yellowfin tuna, giant mantas and dolphin unequaled anywhere in the world. That was then! In the last 5 years there has been a dramatic decrease in hammerhead and Galapagos sharks”

Howard Hall: His career as an underwater natural history film producer, cinematographer, still photographer and writer began in the early 1970's... The winner of six Emmy Awards, Howard has worked on over one hundred underwater film projects... In 1994 he directed the IMAX 3D feature, *Into the Deep* and in 1998 he directed the IMAX film, *Island of the Sharks*, which was an enterprise of Howard Hall Productions and was produced by Michele Hall.

“I was there during the making of a Wild Kingdom film in the early 1980’s... We saw an enormous school of hammerheads with what were either dusky, large silky, or Galapagos sharks mixed in by the dozen. The swarm of sharks was so large that it looked on our side-scan sonar like a separate rocky pinnacle rising up next to Partida. The requiem sharks (whatever they were) started peeling out of the swarm and buzzing us aggressively... The only other time I was there was in March, 2002. I looked through my log. We saw two silky sharks on two or three dives.”*

Source: Sea Watch. 2001. Revillagigedo Islands – State of the Fisheries.

***Howard Hall quote from personal email exchange, 5 May, 2008.**

Appendix 4: Names and Addresses to Receive “State of the Sharks: Revillagigedo Archipelago” Newsletter

Dive Operators:

Agressor I and II (Galapagos and Cocos)
209 Hudson Trace
Augusta, GA 30907 USA

Nauti Diving (Galapagos)
Charles Darwin Avn, Puerto Ayora
Galapagos Ecuador
info@galapaguide.com

Sky Dancer (Galapagos and Cocos)
Peter Hughes Diving Inc.
15291 NW 60 Ave., Suite 201
Miami Lakes, FL 33014

Solmar V (Revillagigedos)
PO Box 529
Topanga, CA 90290

Undersea Hunter (Cocos)
PO Box 025216, Dept. 314
Miami, FL 33102-5216
USA

Government Officials:

Eliecer Cruz
Director, Galapagos National Park
Parque Nacional Galapagos
Puerto Ayora, Isla Santa Cruz
Galapagos Islands, Ecuador

Carlos E. Narro Flores (Regional Director of Revillagigedo Archipelago Biosphere Reserve)
Edificios Cabañas, Edificio D Int. 4
Calle El Pescador esq. Camino Viejo a San José
Cabo San Lucas, Los Cabos, B. C. Sur
C. P. 23450 MEXICO

Director
Cocos Island Marine and Terrestrial Conservation Area
Ministerio del Ambiente y Energía de Costa Rica,
Apartado 10104,
San José, Costa Rica

Conservation Groups:

Charles Darwin Foundation, Inc.
407 N. Washington Street, Suite 105
Falls Church, VA 22046 U.S.A.

Friends of Cocos
Apto. 276-1005, Barrio Corazón de Jesús, Costa Rica
Yamuny, Avenue 10, 125 m Sur Building.
La Harinera del Consejo Nacional de Producción, 3th floor

Galapagos Conservancy
407 North Washington Street, Suite 105
Falls Church, VA 22046-3436
Galapagos Conservation Trust

Greenpeace
702 H Street, NW
Washington, D.C. 20001

Greenpeace
75 Arkansas St.
San Francisco, CA 94107

Iemanya Oceanica
5776-D Lindero Cyn Rd. #373
Westlake Village, CA 91362

Iemanya Oceanica
Paseo Álvaro Obregón #1665
Int. 309. C.P. 23000 Colonia Centro
La Paz, B.C.S. Mexico
Oceana
1350 Connecticut Ave., NW
5th Floor
Washington, D.C. 20036 USA

Oceana -- Monterey
99 Pacific Street, Suite 155C
Monterey, CA 93940
Phone: 831-643-9266

Ocean Conservancy
1300 19th Street, NW
8th Floor
Washington, DC 20036

Ocean Conservancy
116 New Montgomery Street
Suite 810
San Francisco, CA 94105
Phone: 415-979-0900

Pronatura Noroeste, A.C.
Calle Décima #60 (esquina Ryerson) Zona Centro
Ensenada, Baja California CP 22800 Mexico

PROTEMA (Cocos)
Tibas, San Jose
Costa Rica 1203-1100

ReefQuest Marine Projects
P.O. Box 48561
595 Burrard Street
Vancouver, British Columbia (BC)
V7X 1A3 Canada

Robert Bensted-Smith
Director, Charles Darwin Station
Puerto Ayora, Santa Cruz
Galapagos Islands, Ecuador

Shark Alliance
c/o Oceana, Rue Montoyer,
39 | 1000 Brussels, Belgium

Bite-Back Shark & Marine Conservation
40 Piper Road
Kingston upon Thames
KT1 3EX
UK

Sea Shephard Conservation Society
P.O. Box 2616
Friday Harbor, WA 98250 (USA)

Sea Watch
Mike McGettigan
P.O. Box 11679
Portland, OR 97211

Shark Campaign
5 Derby Street
London
W1J 7AB
United Kingdom

Shark Research Institute
P.O. Box 40
Princeton, NJ 08540

WildAid - San Francisco
744 Montgomery Street
Suite 120
San Francisco, CA 94111

WildAid - Galapagos Islands, Ecuador
Calle Las Fragatas
Puerto Ayora
Santa Cruz Island
Galapagos Islands, Ecuador

World Wildlife Fund
c/o Steve Cox
1250 Twenty-Fourth Street, N.W.
P.O. Box 97180
Washington, DC 20090-7180

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