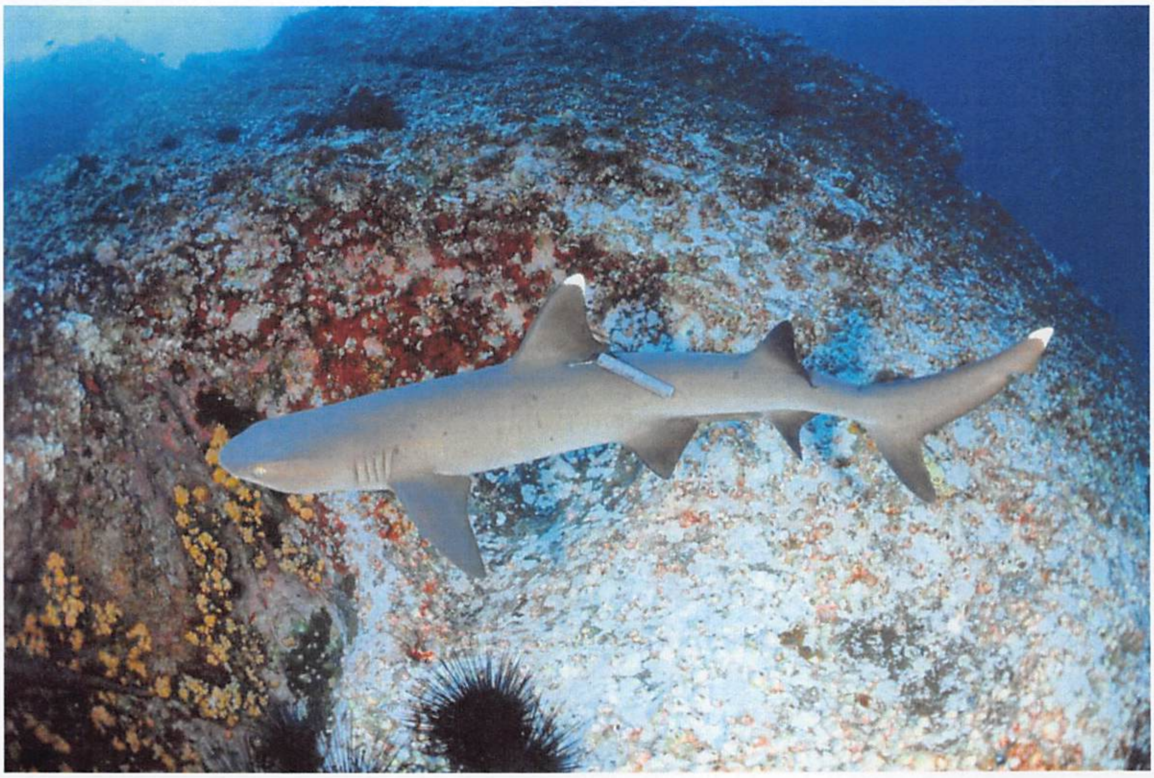
The Revillagigedo Archipelago as critical habitat for migratory sharks and the establishment of a chain of marine reserves in the eastern tropical Pacific

Final Report



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Description of the project

Status of shark populations at the Revillagigedo and other eastern tropical Pacific islands is unknown, although evidence indicates heavy exploitation by fisheries. We propose the first study of sharks in the Revillagigedo and other islands to generate baseline information and to implement management strategies for the conservation of sharks.

Description of the problem

The stocks of predatory fish worldwide are declining dramatically and stocks of these fishes (sharks) have declined by 90% globally (Myers and Worm, 2003). Therefore, it is crucial to manage these stocks in order to conserve them on a global scale. Conservation issues regarding these fishes represent unique and challenging problems since many are found in international waters or migrate between territorial waters of different nations. Traditionally, fisheries management has ignored shark stocks or at best treated them like any stock of bony fishes. Management and regulation have been based on yearly records of catch per unit effort and determining whether they remain unchanged or decrease in successive years – the latter result being followed by a reduction in fishing effort. These management strategies have not been successful in preventing the decline of shark populations (Klimley, 1999). For example, the hammerhead sharks have declined in abundance by 89% since 1986 in the Northwestern Atlantic (Baum *et al.*, 2003) and the same may apply to different parts of the world. Moreover, many species of sharks have very low capabilities to recover from over fishing (Smith *et al.*, 1998) because of their slow growth, late maturity, likely biennial reproduction, and low fecundity (Klimley, 1999). Consequently, FAO countries are committed to developing National Shark Action Plans based on the International Shark Action Plan designed to conserve and recover and ensure sustainable use. These plans are currently in embryonic form in most countries (except USA) due largely to lack of biological information and fisheries monitoring.

An alternative approach to the protection of shark stocks and those of other bony fishes is the creation of reserves or zones, where fishing is prohibited. Size, placement, and spacing are important considerations when creating marine reserves, and conservation actions should consider their impacts on the rest of the local community (e.g. other sharks, tuna, sea turtles) (Baum *et al.*, 2003). Recent theoretical and experimental studies confirm the effectiveness of reserves in sustaining threatened populations and enhancing fisheries (Dayton *et al.*, 2000; St. Mary *et al.*, 2000). However, due to the above mentioned life history properties and heavy predation on immature individuals, sharks may be dependent on the production of large cohorts of young to sustain adult population (Branstetter, 1987). The latter characteristic makes many species of sharks highly vulnerable to fishing pressure and could help to explain the recent declines in their populations. These studies indicate that unique management strategies are necessary for those species with limited recuperation and high vulnerability to fishing pressure (e.g. hammerhead shark). Some of such strategies are (1) setting aside critical habitat (e.g. pupping and feeding grounds) and (2) protecting their reproductive stock (adult mature females) as a top priority (Smith *et al.*, 1998). In addition, sharks are important top predators that may have a strong top-down influence in the structure of communities.

The hammerhead shark is an iconic symbol of the eastern tropical Pacific (ETP), highly valued for tourism due, in part, to its schooling nature (schools reach 200-300 members) originally observed at seamounts in the Gulf of California (Klimley and Nelson, 1981). Since then divers have ventured to these seamounts and other islands in the ETP (e.g. Espiritu Santo, Revillagigedos, Cocos, Galapagos, Malpelo islands), which are now marine reserves and/or World Heritage Sites, to see such aggregations of hammerheads. The status of the hammerhead shark is in the process of being changed from NT (near threatened) to EN (endangered) on the IUCN Red List.

The whale shark is the world's largest fish, reaching sizes of up to 15 m. However, relatively little is known about this highly migratory, plankton-feeding giant. Whale sharks appear at islands of the Eastern Tropical Pacific at different times of year – they appear in the south of Galapagos in March and migrate to the northern islands where they remain between July and November. In Revillagigedo sightings are sporadic and could occur at any time of the year. It is not known whether the same individuals are migrating between the islands, or why. Whale sharks are listed on Appendix 2 of the Convention on Highly Migratory Species, Appendix 2 of CITES, which restricts their international trade, and are listed as VU (vulnerable) on the IUCN Red List.

One of the problems, however, is that the sharks must be protected over an extensive spatial corridor at multiple sites, and their abundance may be affected by fishing pressure both as direct catch and by-catch at only one or two unprotected sites. For that reason, it is essential to create marine reserves and marine protected areas around all seamounts and islands, which they inhabit along their migration route. It is clear that the worldwide populations of hammerhead shark and its associated species (other pelagic migratory fishes and sharks) are at a critical point as shown by several recent studies (Myers and Worm, 2003), and that immediate and specific actions should be taken to prevent their complete decline and extinction.

Importantly, the hammerhead shark populations of the ETP may be spatially linked. For example, a single hammerhead shark, carrying a satellite tag, moved from the Gulf of California southwards to the Revillagigedo Islands over a period of a week (S. Jorgensen, Stanford University, pers. comm. 2005). More recently, three hammerhead sharks tagged in the northern Galapagos with ultrasonic signature transmitters, moved from the Galapagos to Cocos Island and back (Hearn et al. 2008), and another hammerhead tagged in Malpelo Island, Colombia moved from Malpelo to Cocos and then to Galapagos (Bessudo et al., unpubl data). Another hammerhead tagged with a satellite tag moved from the northern Galapagos away into international waters with a heading in the direction of Clipperton island, but transmissions stopped a third of the way there (Ketchum et al., unpubl data). All of these examples indicate that sharks are capable of migrating great distances over short periods and, most importantly, may be able to migrate throughout the whole extent of the ETP.

Recent observations indicate that schools of hammerhead sharks at Malpelo Island, a protected area with relatively little fishing, are small (20-30 individuals per group), far smaller in size than schools observed at a seamount in the Gulf of California in 1979 (>500 members; Klimley and Nelson, 1981), and this may be a consequence of fishing pressure not in Colombia, but in other places such as Clipperton, Revillagigedo, or Marias islands, where directed fisheries on sharks are intense. Hence, fisheries in the northern eastern tropical Pacific, i.e., Revillagigedo, Clipperton (Figure 1) might be impacting the populations of sharks in the whole ETP, thus it is highly important to study the shark populations at these islands.

In recent years, a multi-national project was established to protect and conserve migratory marine species in the ETP known as the Eastern Tropical Pacific Seascape (ETPS). Most recently, researchers from different countries in Central and South America started to share scientific information about the movements of sharks in the ETPS within a research group called Migramar (www.migramar.org). It is possible that sharks move between the islands of the ETPS and the northern part of the ETP, and if in fact this movement is discovered, a northerly extension of the ETPS will be proposed (Figure 1).

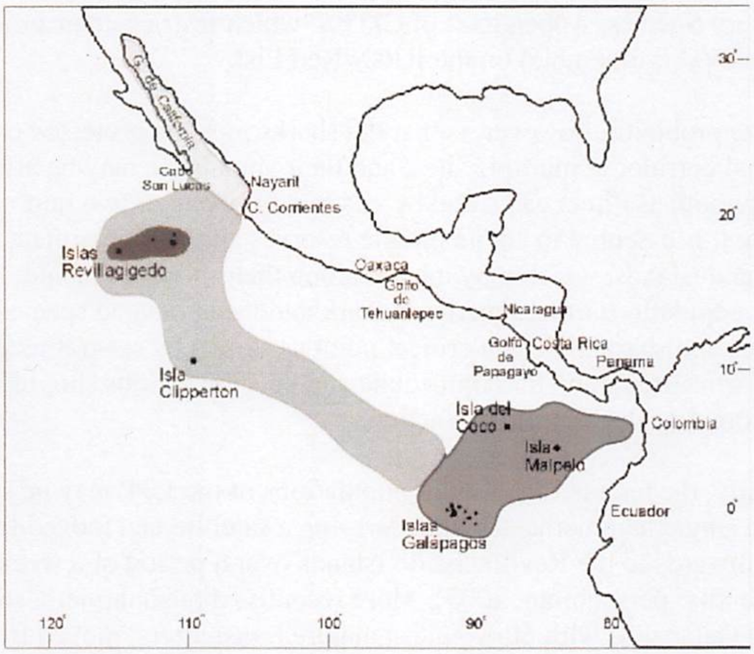

Figure 1. The Eastern Tropical Pacific Seascape Corridor (dark gray) and the proposed extension of the corridor (medium gray, light gray, and black).

Description of the solution and activities

We propose (1) a telemetric study of hammerhead and whale sharks to determine their movement patterns, connectivity and residency and 2) a shark censusing program to examine population size and dynamics in the Revillagigedo Archipelago and other islands in the eastern tropical Pacific. This information is necessary to understand the behavior, ecology, and population state and dynamics of sharks, which will constitute baseline information to implement a management strategy for the conservation of sharks in the region. Hence, the seed funding requested would be used for the following objectives:

1. Analyze daily movements of individual hammerhead and whale sharks and determine the degree of residency at each island.
2. Examine movements of hammerheads and whale sharks between islands to establish connectivity and migratory routes or corridors.
3. Determine the existence of connectivity with the southern ETP to ascertain the existence of long-distance migratory corridors in the ETP.
4. Determine shark population size and dynamics.

Tasks

We will accomplish the following: (1) Deploy and maintain listening stations at the Revillagigedos, Clipperton, Marias and Gulf of California, (2) tag sharks, (3) download data and redeploy listening stations, (4) undertake periodic visual censuses by divers to obtain an index of relative abundance, (5) analyze data and prepare a final report for ICF, and (6) publish findings in peer-reviewed international journals.

Methods

1. Use of ultrasonic tags

Signature transmitters emit uniquely pulsed ultrasonic signals that identify a particular tagged individual, have a life of three to five years, and are detected by automated monitors (or listening stations) moored at different sites. We will affix signature transmitters to 20 hammerhead and 5 whale sharks in the Revillagigedo Archipelago by free diving (or SCUBA or rebreather diving) into the schools of sharks and attaching them with a pole spear (or spear gun) (Figure 2) . A dart mounted in an applicator needle mounted at the end of the pole spear (see Figure 2) will be inserted into the dorsal musculature of an adult shark to affix the tag, which is attached to the dart by a short monofilament leader. Alternatively, hammerhead sharks may be caught by hook and line and tagged in the water (see Figure 2). Sharks caught with hook and line will be brought alongside the vessel, lead into a canvass sling lifted so that the sides keep the shark immobile, and then the boat will be moved forward slowly so that water flows through the mouth and gills and the shark can respire. Sharks will be tagged in the water by holding it with the hook leader on one end and a rope noose placed around the caudal peduncle. Prior to release, the hooks will be carefully removed from the shark's mouth. This whole procedure, from retrieval from the long line to release should not take longer than 3-5 minutes.

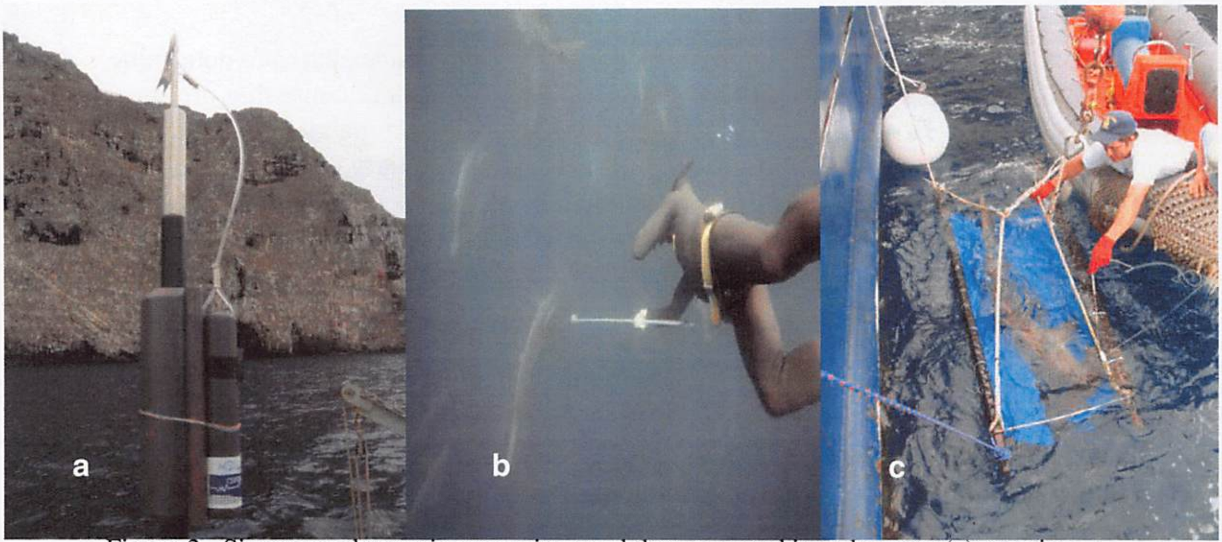

Figure 2. Signature ultrasonic transmitter and dart mounted in pole spear (a), tagging by free-diving (b), and tagging by placing shark caught by hook and line in sling (c).

2. Use of automated listening stations

Automated listening stations or monitors will be used to detect fish tagged with the signature transmitters and to monitor their behavior (see Klimley *et al.*, 1998, for review of technology). These devices are moored at a location where fishes aggregate such as the peak of a seamount or an escarpment of an oceanic island (Figure 3), and register whenever tagged fish swim by within the range of detection of the monitor. The automated monitors recognize an individual shark carrying a transmitter by its unique signal and store the date and time of detection and a numeric code in an electronic memory. After a period of time (typically, several months) the monitor can be removed from the water, attached to a computer, and interrogated for records of fish attendance at the site. Monitoring devices have typically a limited detection range of 500 meters, but this reception range is sufficient to record the presence of tagged sharks in the vicinity of the monitor. They have been successfully used in the past to record the residence of hammerhead sharks (Klimley, 1988a, b) and yellowfin tuna (Klimley *et al.*, 2003) at Espiritu Santo Seamount in the Gulf of California – the latter for a period exceeding two years, as well as for studying in the Galapagos, Cocos, Malpelo and Coiba islands in central and south America. We will deploy ten listening stations at the Revillagigedo Islands (four at Socorro, two at Clarion, two at San Benedicto Island, and two at Roca Partida), six at Tres Marias Islands (two at San Juanico, two at Maria Madre, and two at Maria Cleofas), two at Clipperton Atoll, and four in the Gulf of California (two at El Bajo Espiritu Santo and two Gorda Banks). The monitors will be placed judiciously near aggregations or schooling sites at each island, and will record the seasonal residence times of the sharks, due to their behavioral affinity to school at prominent topographic features (e.g. seamounts, ridges). The tagging of the sharks and deployment of the listening stations will be carried out from two commercial dive boats, the 116' dive boat (Nautilus Explorer), and the 110' dive boat (Sea Escape), which visits the Revillagigedo Islands on a regular basis from November thru April of each year. The Nautilus explorer also makes an annual trip to Clipperton in April. The owner of the boat (M. Lever) as does the owner of the Sea Escape (F. Aguilar) will provide two-three spaces for the research team on several trips to accomplish the tagging and the deployment of listening stations. The deployment of listening stations in the Gulf of California will be performed from a 80' dive boat (Don Jose) owned by Baja Expeditions and long time supporters of research and conservation efforts in the Gulf. The placement of monitors in the Marias Islands will be carried out with the support of the Mexican navy base located at Isla Maria Madre.

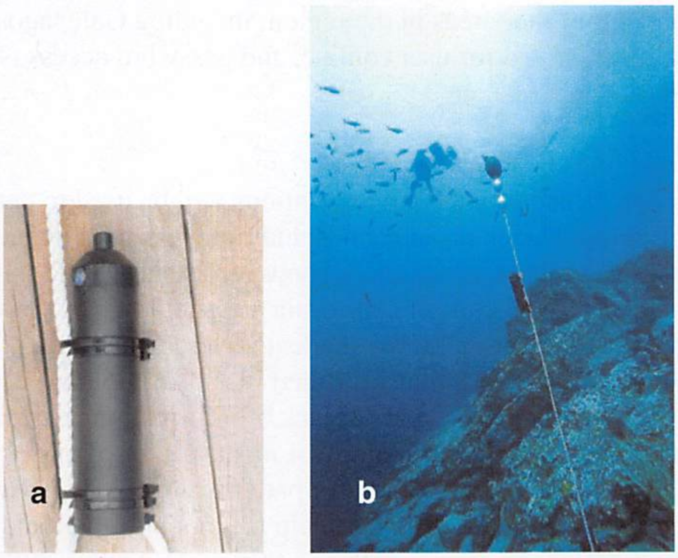

Figure 3. Underwater receiver (a) and moored listening station (b).

Automated listening stations have also been used in a large number of studies of the movements of fishes in various localities. They have recently been used to describe the spatial interrelationships among multiple members of the assemblages of pelagic fishes at a seamount in the southern Gulf of California (Klimley *et al.*, 2003) and to identify the spawning sites of green sturgeon in the Sacramento River, California (J. Heublein, San Francisco State University, pers. commun.). This technology has also been utilized to examine school fidelity and homing synchronicity of yellowfin tuna at fish aggregation devices (FADs) off Oahu, Hawaii (Klimley and Holloway, 1999) and for the estimation of home ranges of juvenile blacktip sharks in Tampa Bay, Florida (Heupel *et al.*, 2004), among other applications. Most recently, listening stations have been deployed at different islands of the ETPS (see Fig. 1), such as the Galapagos, Cocos, Malpelo, and Coiba islands. Therefore, it is essential that additional listening stations be placed at the Revillagigedo and other islands or the northern boundary of our proposed extension of the ETPS (see Fig. 1), to be able to monitor and track sharks throughout the whole ETP region, from Mexico to Ecuador. Based on this knowledge, managers from Ecuador, Colombia, Panama, Costa Rica, and Mexico can establish a chain of marine reserves and enact collaborative legislation to protect threatened marine predators like the scalloped hammerhead shark as well as other important members of the open ocean assemblages such as tunas and billfishes.

3. Censusing

Visual censuses will be carried out at tourist dive sites and the receiver locations. Pairs of divers are asked to hang in mid-water (approximately 15-20 meters depth) with their backs to the coastline, and to identify and count all sharks seen on a 30 minute drift dive or on a slow swim in one direction when there is no current. Dive guides will be trained during the cruise and asked to carry out censuses throughout the year. The scientific team will carry out censuses on each visit to receiver locations. The census data will be entered into an online database at www.migramar.org, which collects visual census data for sharks for other areas in the region, including Galapagos, Cocos and Malpelo. Reports are generated for users online, and password access is given to those requiring more detail

Significance of study

Coded ultrasonic beacons and listening stations will be used to determine daily residence habits of individual sharks at each island (intra-island movements), the connectivity in terms of movements of sharks between islands (inter-island corridors), and if sharks move north to the Gulf of California or south to Cocos or Galapagos Islands. There are two major obstacles for sharks to overcome in order to restore the once abundant local fauna, namely, (1) an uncontrolled illegal fishery that is reducing the abundance pelagic fish assemblages, and (2) lack of information regarding important aspects of the ecology and population biology of most species of large predatory fishes, particularly on their movements and migratory patterns within and between offshore islands. During the initial phase we intend to help fill this informational void by using the hammerhead shark as a focal species (explained above). In a relatively short period of time (two years), we will gather enough tag detections to establish the level of residency at the islands and the degree of interconnectivity between them throughout the Archipelago.

We will determine whether interchange occurs between the Revillagigedo's shark population and those farther northward in the Gulf of California and those farther southward in Clipperton or even more southerly in the Cocos and Galapagos Islands. This will be accomplished by comparing records of shark attendance from the listening stations deployed in all of these localities. All of this information will provide the necessary background knowledge that will serve as a basis for implementing a management strategy (i.e., the accurate specification of a corridor of reserves) that ideally will result in the recovery of stocks of pelagic fishes at the Revillagigedo and other ETP islands, and linking management and conservation efforts along a conservation corridor or extension of the ETPS (see Fig. 1).

Results

Deployment of listening stations

We deployed 18 (VR2W, Vemco, Halifax) receivers during different times from 2008 to 2011 (Table 1) at several locations in the Gulf of California, Mexican Pacific, and Eastern Tropical Pacific (Figure 4). All underwater receivers were set for the first time at all the locations, except El Bajo, San Benedicto and Roca Partida, where other researchers had placed them previously. The last time a receiver was placed at El Bajo was in the late 90's. All receivers at the Revillagigedos, except the ones at Clarion, were recovered during cruises in November 2010, April and May 2011 to download several months of information. The receivers at Clipperton were recovered during a cruise in May 2011. The receivers at Islas Marias and Cabo Pulmo will be recovered at the end of 2011. Our plan is to maintain the receivers for five years at all the locations and retrieve information once or twice a year.

Table 1. Sites, depths, and dates of deployments of eighteen underwater receivers.
*Dates are of the first deployment. All receivers at the Revillagigedo Islands and Clipperton have been replaced in April and May 2011.

No	Site/Island	Depth (m)	First deployment date*
1	Cabo Pearce, Socorro	28	8-Apr-09
2	South atoll, Clipperton	34	14-Apr-10
3	Northeast atoll, Clipperton	36	17-Apr-10
4	West side, Roca Partida	40	22-Apr-10
5	El Cañon, Sn Benedicto	30	23-Apr-10
6	Petit Boiler, Socorro	40	26-Apr-10
7	Punta Tosca, Socorro	29	26-Apr-10
8	Roca O'Neal, Socorro	18	15-Nov-10
9	Three fathoms, Clarion	12	19-Nov-10
10	Roca Piramide, Clarion	12	19-Nov-10
11	Roca Monumento, Clarion	24	19-Nov-10
12	Maria Cleofas, Marias	23	28-Nov-10
13	Isla San Juanico, Marias	20	29-Nov-10
14	Cantil, Cabo Pulmo	16	29-Mar-11
15	Tinajitas, Cabo Pulmo	11	29-Mar-11
16	Barracas, Cabo Pulmo	13	13-Apr-11
17	Los Frailes, Cabo Pulmo	10	25-Apr-11
18	El Bajo Espiritu Santo	25	9-Jun-11

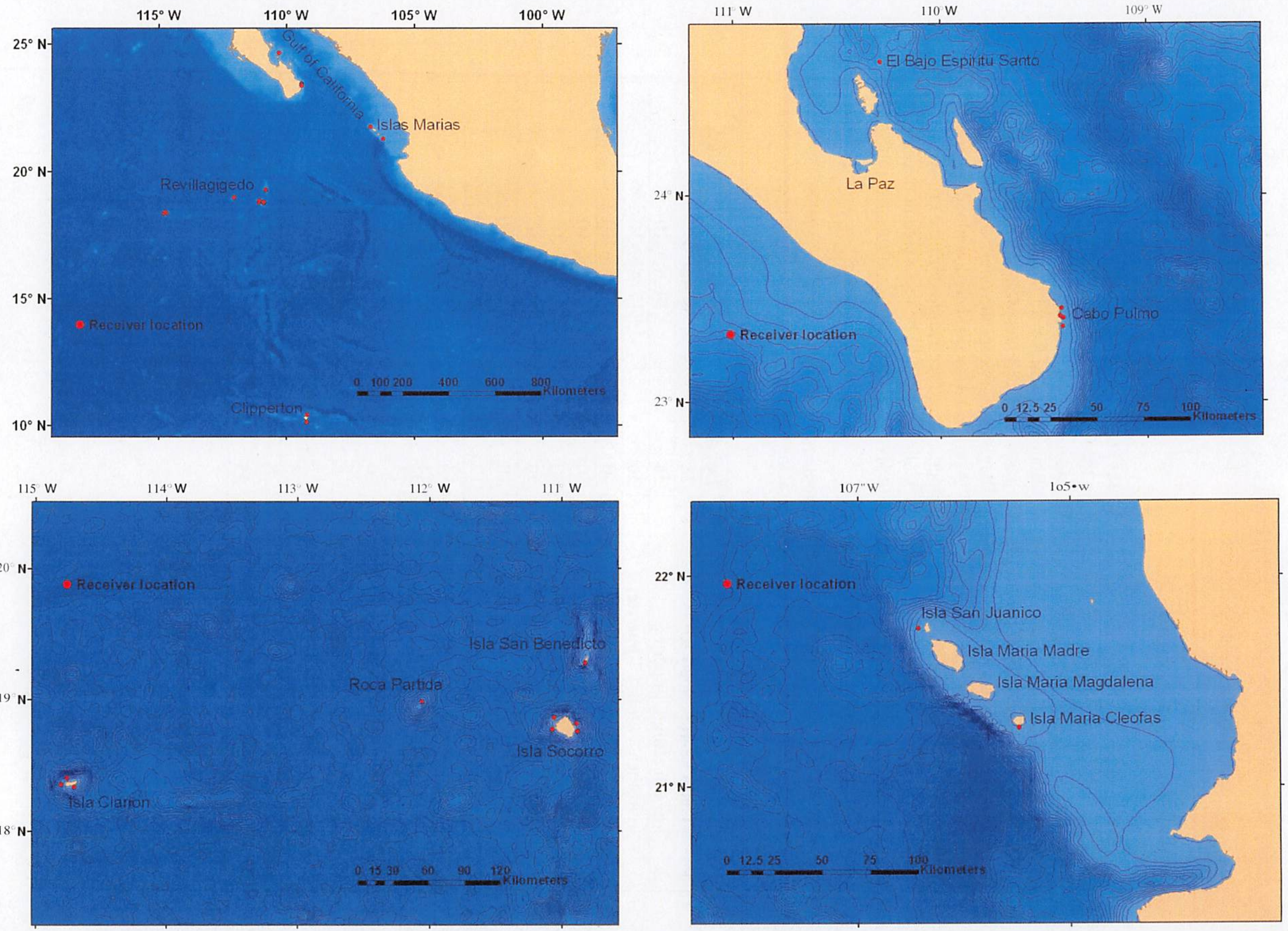

Figure 4. Locations of deployment of undetwater receivers

Tagging of sharks

We placed 44 ultrasonic transmitters (V16, Vemco, Halifax) on six different species of sharks (tigers, silkies, hammerheads, Galapagos, silvertips, and whitetip reef sharks) at the Revillagigedo Archipelago. Thirty-eight of the transmitters were pingers and six had pressure sensors to study the depth distribution of different species of sharks at Roca Partida, which were placed on white-tip reef, Galapagos, silvertip, and dusky sharks (Figure 5). We also deployed four ultrasonic tags on one silky, two Galápagos, and one silvertip at Clipperton Atoll. No whale sharks were tagged because they were not seen during the three tagging expeditions to the Revillagigedo and Clipperton islands.

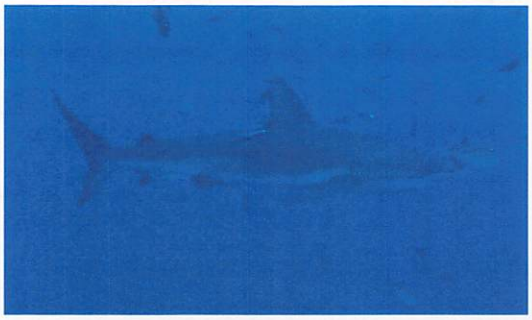

Figure 5. Galapagos shark with external ultrasonic transmitter

Records of detections at the array

Our single receiver at San Benedicto detected the movements of one tiger and a Galapagos shark that have resided at this island continuously for five months, from November 2010 to April 2011 (Figure 6). The only silky tagged at this island was recorded only twice in December 2010 and March 2011.

At Punta Tosca, Socorro, one silvertip and one tiger tagged have resided continuously, particularly the silvertip, at this location for five months (Figure 7). Two silkies tagged also at this site have been recorded sporadically at different times. Other sharks detected at this site were the four tigers tagged at Cabo Pearce, which have been recorded for 4-5 months.

At Cabo Pearce, Socorro, four tigers and three silvertips tagged here have been recorded at the site (Figure 8). The tigers have been detected more sporadically at this location during 3-5 months, whereas the silvertips have resided continuously during five months.

At Roca Partida, the single silvertip tagged with a sensor transmitter resided continuously at this location during five months (Figure 9). Another silvertip and a Galapagos shark were detected for that length of time, but less constant. Another Galapagos stayed at this location for 3 months. Of the 15 silkies tagged at this island, eleven were detected sporadically and only one was detected continuously at this site. Two of these were tracked with a satellite transmitter on another study.

Considering the overall number of detections, the east side of the island received more hits than the west indicating a possible hotspot of sharks specifically located at this side of Roca Partida.

At Clipperton Atoll, we detected a silky shark that had been tagged four months earlier at Wolf Island, Galapagos. It subsequently returned to Galapagos, performing a round-trip of 4400 km (Figure 10).

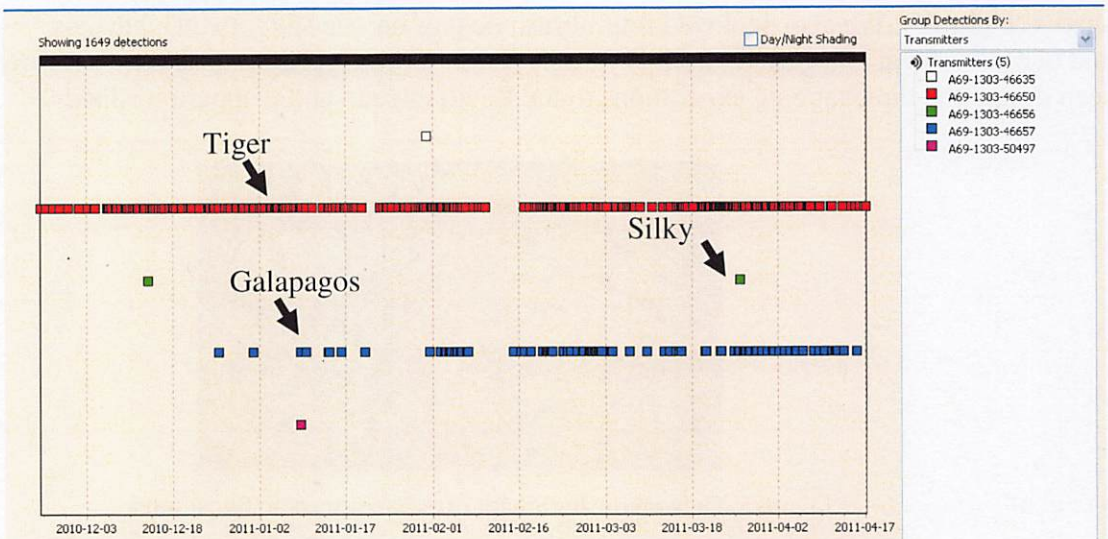

Figure 6. Record of detections of sharks at El Cañon, San Benedicto from November 2010 to April 2011

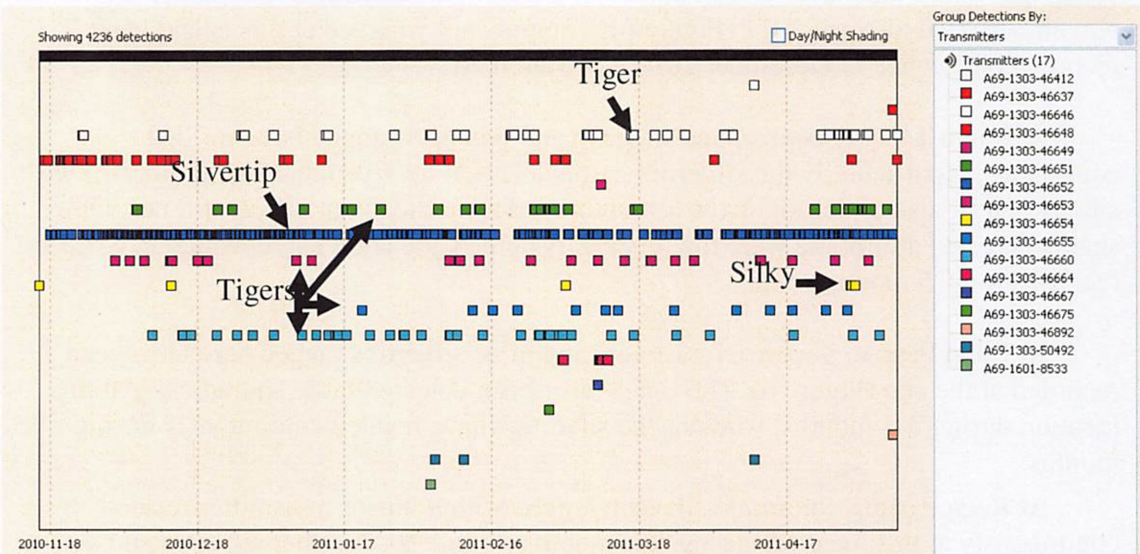

Figure 7. Record of detections of sharks at Punta Tosca, Socorro from November 2010 to April 2011

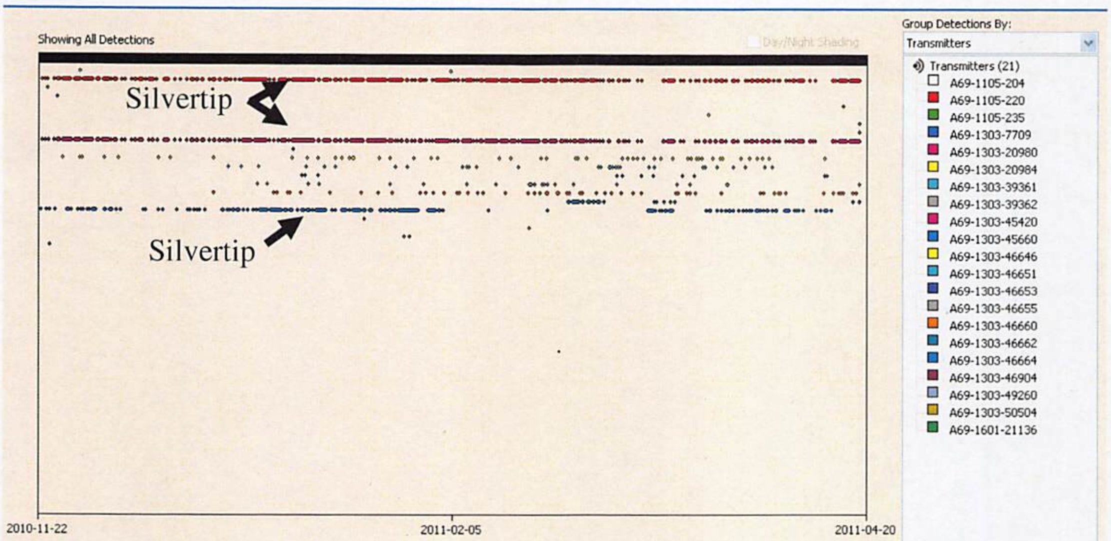

Figure 8. Record of detections of sharks at Cabo Pearce, Socorro from November 2010 to April 2011

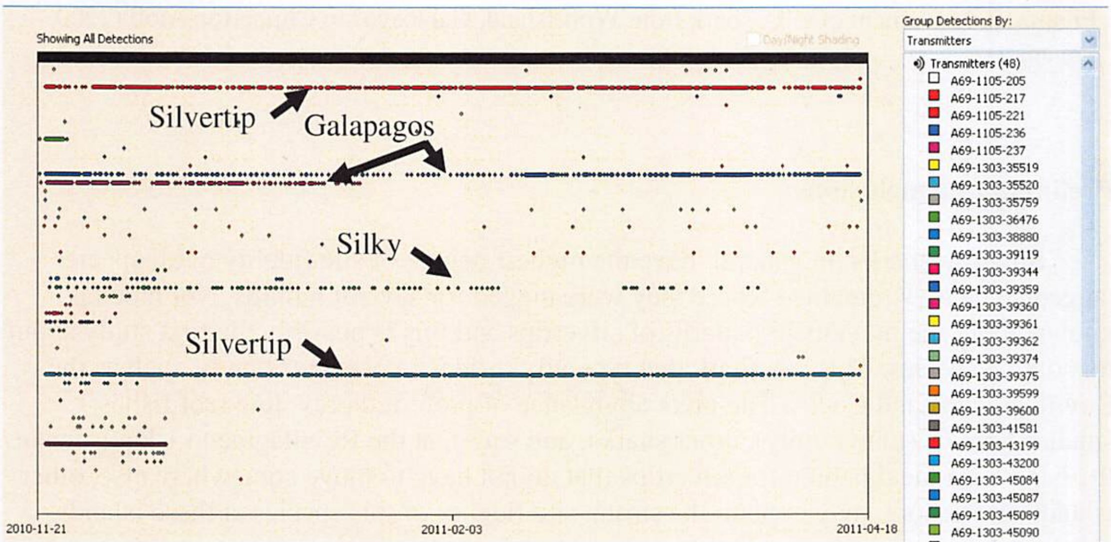

Figure 9. Record of detections of sharks at Roca Partida from November 2010 to April 2011

Figure 10. Movement of silky shark from Wolf Island, Galapagos to Clipperton Atoll (2200 km apart)

Preliminary conclusions

Silvertip sharks, in general, have the highest degree of site fidelity of all species tagged since they remained where they were tagged for several months. Not much is known about the movement patterns of silvertips and this is possibly the first study about this on the species. This is a shark that typically resides in oceanic islands, such as the Revillagigedos and Cocos. The great abundance of preferred prey, like reef fishes, smaller tunnids (tuna family), other sharks, and squid, at the Revillagigedo Islands make the islands an ideal habitat for silvertips that do not have to move somewhere else, other islands or offshore, may explain the strong site fidelity of this species at these islands.

Tiger sharks, on the other hand, also had a high degree of site fidelity, but most of all, were resident to Socorro, San Benedicto, and Cocos islands where they move in different areas near these islands. These results are very different from other tracking studies of the same species but at another group islands in the Pacific: Hawaii. Here tigers reside for much shorter periods of time and return to the islands after weeks, months and even years. The Hawaiian tigers move rapidly from a location to maximize their foraging success. Perhaps the tigers at the Revillagidedos and Cocos have developed other foraging strategies in an area with less number of islands and wide expanses of water between the few islands in the ETP. Their constant presence at the northern part of Socorro may coincide with the presence of abundant prey such as sea turtles that nest on the beaches of this part of the island.

Silkies are the least resident of all species studies and perform long-distance movements from the Revillagigedos to the Gulf of California as we have seen on another study using satellite tags. This is the first study of silkies in the ETP and one of the few using telemetry on this species. The high mobility of this species is demonstrated by a silky tagged at Galapagos and recorded again at Clipperton and then moving back to Galapagos. These examples of long-distance movements of silkies are evidence of a high degree of connectivity throughout the extent of the ETP.

The high levels of residency that we found for several species of sharks at the Revillagigedo Archipelago demonstrates the need of better protective measures around this group of islands. On the other hand, the long-distance movements of silky sharks are evidence of a great degree of connectivity throughout the extent of the ETP, underpinning the need of multinational marine protected areas or seascapes.

Future work

More tagging efforts on sharks in the future will provide more information on their movement and habitat use, and the use of genetic analysis will help determine the population structure in the region. Also, the censusing of sharks and other pelagics will be implemented in the near future with the dive companies that visit Revillagigedo, Clipperton, and the islands in the Gulf of California to determine their abundance and changes in time.

Community contribution

This project will generate baseline information for the conservation and management of sharks in the Revillagigedo Archipelago and other islands and seamounts of the ETP. This is a crucial undertaking to avoid the likely possibility of local extinctions of sharks in the region. The Revillagigedo Islands are currently a protected area, declared by the Mexican government in 1994 (Diario Oficial, 1994), but enforcement is minimal and management nil. Our efforts will help the Mexican government manage and set aside important marine reserves in the Mexican Pacific. Our findings will be published in peer reviewed international journals as well as in magazines and other publications for the general public.

We created an NGO (Pelagios-Kakunjá) based in La Paz, Mexico to continue with the long-term study of sharks and other pelagic fauna of the Revillagigedo and Mexican Pacific. We will seek additional grants to support our studies and conservation efforts. Additional support and funding is provided by Fins Attached: Marine Research and Conservation, a non-profit organization based in Colorado Springs, USA, www.finsttached.org.

Personnel

James Ketchum. UC Davis, Ph.D. James has worked extensively in the Revillagigedo Islands and the Gulf of California, where he conducted his Bachelor's and Master's thesis research, respectively. He participated in the first telemetric studies of sharks in Malpelo Island, Colombia, and the Galapagos Islands. His Ph.D dissertation is on the movements and habitat use of hammerhead sharks and the design of marine reserves in the Galapagos Islands.

Mauricio Hoyos-Padilla. Centro Interdisciplinario de Ciencias Marinas (CICIMAR), Ph.D. Mauricio has worked with several species of sharks, using a wide variety of telemetric techniques in the Caribbean, Gulf of California, and Isla Guadalupe, Mexico. His Ph. D. dissertation is on the movements and behavior of white sharks of Guadalupe Island.

Felipe Galvan-Magaña. CICIMAR, PhD, Professor, Fisheries Biologist. Felipe has published more than 30 scientific articles on the biology of fishes and sharks. He has extensive knowledge of the pelagic fishes of the Gulf of California and tropical eastern Pacific, and has collaborated on multiple projects about the ecology and population biology of sharks and rays.

Alex Antoniou. Fins Atached, PhD. Alex is the founder and executive director of Fins attached: Marine Research and Conservation whose mission is to conduct research, promote conservation and provide education for the protection of marine ecosystems. Much of the research is focused on sharks. He has worked with numerous species of sharks including the whale shark, scalloped hammerhead, white shark, silvertip, and Galapagos shark.

Peter Klimley. UC Davis, Ph.D, Adjunct Professor. Pete has published nearly 60 scientific articles and two books on the ecology and behavior of sharks and tunas. He has extensive experience utilizing coded-ultrasonic tags and automated monitors with pelagic fishes, publishing half a dozen articles on this topic. He is the author of the most recent review (see Klimley *et al.*, 1998) of the technology.

Alex Hearn. UC Davis, Ph.D, Project Scientist. Alex is a fisheries specialist with six years of research experience in the Galapagos Islands, including telemetric studies with sharks and lobsters, and population dynamics of commercially important marine species in the Galapagos Marine Reserve. With over 500 dives around the Galapagos archipelago, Cocos and Malpelo islands he has an in-depth knowledge of the eastern tropical Pacific marine environments.

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References

Baum, J.K., R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, and P.A. Doherty. 2003. Collapse and conservation of shark populations in the Northwestern Atlantic. *Science* 299:389-392

Branstetter, S. 1987. Age, growth and reproductive biology of the silky shark, *Carcharhinus falciformis*, and the scalloped hammerhead, *Sphyrna lewini*, from the Northwestern Gulf of Mexico. *Environmental Biology of Fishes* 19:161-173

Dayton, P.K., E. Sala, M.J. Tegner, and S. Thrush. 2000. Marine reserves: parks, baselines, and fishery enhancement. *Bulletin of Marine Science*, 66:617-634

Hearn, A., J. Ketchum, G. Shillinger, P. Klimley, and E. Espinoza. 2008. Programa de investigación y conservación de tiburones en la Reserva Marina de Galápagos. Reporte Anual 2006-7. Fundación Charles Darwin, Santa Cruz, Galápagos, Ecuador 114p.

Heupel, M.R., C.A. Simpfendorfer, and R.E. Hueter. 2004. Estimation of shark home ranges using passive monitoring techniques. *Environmental Biology of Fishes*, 71:135-142

Ketchum, J.T., and H. Reyes-Bonilla. 2001. Taxonomía y distribución de los corales hermatípicos (Scleractinia) del Archipiélago de Revillagigedo, México. *Revista de Biología Tropical*, 49:803-848.

Klimley, A.P. 1999. Sharks beware. *American Scientist*, 87: 488-491.

Klimley, A.P., and S.B. Butler. 1988a. Immigration and emigration of a pelagic fish assemblage to seamounts in the Gulf of California related to water mass movements using satellite imagery. *Marine Ecology Progress Series*, 49:11-20.

Klimley, A.P., S.B. Butler, D.R. Nelson, and A.T. Stull. 1988b. Diel movements of scalloped hammerhead sharks (*Sphyrna lewini* Griffith and Smith) to and from a seamount in the Gulf of California. *Journal of Fish Biology*, 33:751-761.

Klimley, A.P., and C. Holloway. 1999. Homing synchronicity and schooling fidelity by yellowfin tuna. *Marine Biology*, 133: 307-317.

Klimley, A.P., S.J. Jorgensen, A. Muhlia-Melo, and S.C. Beavers. 2003. Movements of yellowfin tuna (*Thunnus albacares*) to and from Espiritu Santo Seamount in Gulf of California. *Fisheries Bulletin*, 101: 684-692.

Klimley, A.P and D.R. Nelson. 1981. Schooling of scalloped hammerhead, *Sphyrna lewini*, in the Gulf of California. *Fishery Bulletin*, 79:356-360.

Klimley, A.P., J.E. Richert, and S.J. Jorgensen. 2005. The home of blue water fish. *American Scientist*, 93:42-49.

Klimley, A.P., F. Voegeli, S.C. Beavers, and B.J. Le Boeuf. 1998. Automated listening stations for tagged marine fishes. *Marine Technology Journal*, 32: 94-101.

Myers, R.A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. *Nature* 423:280-283

Orellana, C. 2004. Tropical seascape corridor planned-Dispatches. *Frontiers in Ecology and the Environment* 2:116-122

Smith, S.E., D.W. Au, and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. *Marine and Freshwater Research* 49:663-678

St. Mary, C.M., C.W. Osenberg, T.K. Frazer, and W.J. Lindberg. 2000. Stage structure, density dependence and the efficacy of marine reserves. *Bulletin of Marine Science*, 66:675