DRAFT ENVIRONMENTAL ASSESSMENT

GULF OF THE FARALLONES NATIONAL MARINE SANCTUARY
WHITE SHARK RESEARCH PERMIT APPLICATION
FOR PROJECT ENTITLED:
FINE SCALE, LONG-TERM TRACKING OF ADULT WHITE SHARKS

Office of National Marine Sanctuaries
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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1. PURPOSE AND NEED

1. 1 Introduction

The National Oceanic and Atmospheric Administration (NOAA) Gulf of the Farallones National Marine Sanctuary (GFNMS or Sanctuary) consists of an area of 966 square nautical miles (1,279 square miles) of coastal and ocean waters and the submerged lands along and off the coast of northern California (Fig. 1). The sanctuary extends out to and around the Farallon Islands and near shore waters (up to the mean high tide line) from Bodega Head in Sonoma County to Rocky Point in Marin County (Federal Register 2010). The Sanctuary includes Bolinas Bay and Lagoon, most of Tomales Bay, Estero Americano, Estero de San Antonio, and Bodega Bay but excludes Bodega Harbor (Office of National Marine Sanctuaries [ONMS] 2008).

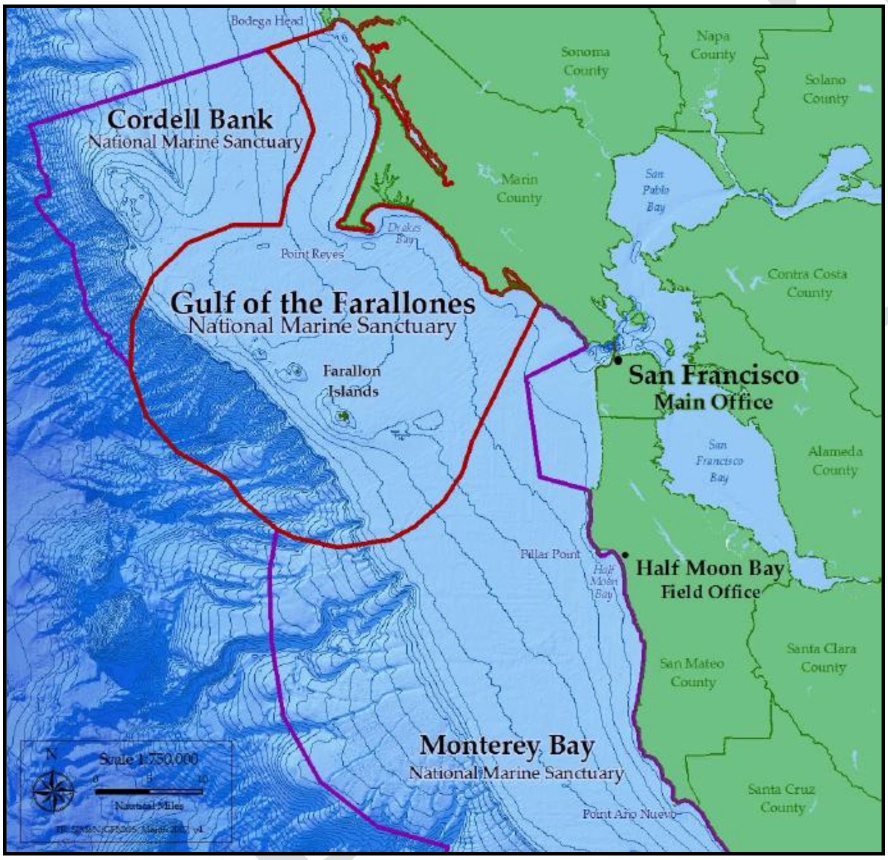

Fig. 1. Boundaries of Gulf of the Farallones National Marine Sanctuary

The Farallon Islands run north westwards from Southeast Farallon Island (SEFI) for approximately five miles. The islands have been protected as part of the Farallon National Wildlife Refuge since 1969 and support the largest and most diverse seabird rookery on the Pacific coast south of Alaska. Each year, hundreds of thousands of seabirds breed on this chain of rocky islands (U.S. Fish and Wildlife Service [USFWS], no date). A vast number of other bird species visit the islands, often many miles outside of their normal ranges. A host of marine mammals, including the threatened Steller sea lion (*Eumetopias jubatus*), either haul out on the islands or cruise nearby. More than a hundred species of fish and several species of marine turtle, including the endangered green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) turtles, swim near the islands (USFWS, no date). The waters surrounding the Farallon Islands are also one area in the northeastern Pacific where adult white sharks (*Carcharodon carcharias*) are known to seasonally aggregate; the other location is Guadalupe Island, off Baja, Mexico.

White sharks may be seen in the Sanctuary at any time but they are most abundant during seasonal aggregations that begin to form near the Farallon Islands in late August (Pyle *et al.*, 1996) and their arrival is timed to coincide with the arrival of juvenile northern elephant seals (*Mirounga angustirostris*). These immature seals are the preferred prey of the white shark at the Farallon Islands (Anderson, 2001). Observations here also indicate that white sharks eat young elephant seals seven times more frequently than they eat other pinnipeds, such as California sea lions (*Zalophus californianus*) and harbor seals (*Phoca vitulina*; Anderson, 2001) but the sharks are also known to feed on whale carcasses (Casey and Pratt 1985; Long and Jones 1996; Dicken 2008).

The advent of electronic tagging technologies in the past decade have allowed researchers to make the surprising discovery that these white sharks leave the Farallon Islands as well as the coastal regions altogether, and disperse into the open ocean from late winter to summer (Boustany *et al*., 2002; Weng et al., 2007; Jorgensen *et al*., 2010). Sanctuary white sharks have been found to share this same pelagic (i.e., offshore/non-coastal) region, termed the Shared Offshore Foraging Area (SOFA) by some researchers and the Café by others, as white sharks from Guadalupe Island (Domeier and Nasby-Lucas, 2008; Jorgensen *et al*., 2010). The SOFA/Café is a vast expanse of ocean located between Hawaii and North America. Some sharks from both the Farallones region and Guadalupe have also been found to travel all the way to Hawaii before returning to their respective adult aggregation sites (Boustany *et al*., 2002; Weng *et al*., 2007; Domeier and Nasby-Lucas, 2008; Jorgensen *et al*., 2010).

Photo-identification records of individual shark visitation patterns to both Guadalupe Island and the Farallon Islands have revealed that males return to these aggregation sites every year (Anderson and Pyle, 2003; Domeier and Nasby-Lucas, 2007). Individual adult white sharks have been found to demonstrate some level of site fidelity to the Farallon Islands, being sighted year after year (Anderson and Pyle, 2003). Mature females differ from the males in that they may not visit their respective adult aggregation site each year but will demonstrate an every-other-year visitation pattern (Anderson and Pyle, 2003; Domeier and Nasby-Lucas, 2007). Female sharks tend to depart the Farallon Islands later than males but it is not known when they arrive (Weng *et al*., 2007). These studies have revealed an unexpected pelagic life history pattern for white sharks that has created new questions that have yet to be answered: Where are adult white sharks, particularly females, when they disappear from the GFNMS? What is the primary reason the females come back to the GFNMS – is it only for foraging or for mating, as well? How much interaction is there between Guadalupe Island and Farallon Islands white sharks? Where are the pupping and nursery grounds for the GFNMS white sharks?

1.2 Background

In September 2009, a one-year permit (GFNMS-2009-004) was issued by GFNMS to Dr. Michael Domeier of the Marine Conservation Science Institute (MCSI). The MCSI is a

California 501(c)3 organization that supports research to help manage, protect and conserve marine resources. This permit allowed for the attraction, capture, handling, examination, tagging and release of up to ten adult white sharks. During the 2009 white shark season, a total of two adult (male) white sharks were tagged and released. An amendment (GFNMS-2009-004-A1) was issued in October 2009 to allow Dr. Barbara Block and authorized personnel working under her GFNMS permit (MULTI-2009-005), to simultaneously install acoustic tags on white sharks that have been attracted and captured pursuant to Dr. Domeier's permit.

In May 2010, the GFNMS received an application from Dr. Domeier to renew his current permit (GFNMS-2009-004-A1) for four years and to tag up to 11 white sharks (3 males and 8 females) to study the long distance, multi-year migration and life history patterns of adult white sharks that seasonally aggregate near the Farallon Islands in the Sanctuary. If implemented, this project would involve tagging a cumulative total of 13 sharks.

The research would be supported by a variety of funding sources, including private foundations and corporations. The Farallon Island research is intended to illustrate the importance of this site for northeastern Pacific white sharks, hopefully identifying the pupping and nursery habitat for the Farallon Island group, and comparing that to sharks tagged at Guadalupe Island, Mexico.

This Environmental Assessment (EA) is included as part of the decision-making process by the NOAA Office of National Marine Sanctuaries (ONMS) whether to permit continued white shark attraction so that white sharks may be captured, tagged and released. The request is detailed under the Proposed Action in Section 2 of this EA. The EA is also used to determine whether the effects of the proposed project are "significant" (as defined by 40 Code of Federal Regulations [CFR] Section 1508.27) and therefore, require an environmental impact statement, or are not significant, and would thus involve the preparation of a finding of no significant impact or FONSI.

Dr. Domeier, the principal investigator of the proposed project, is a recognized researcher, who served as Chairman to the recent International White Shark Symposium held in Hawaii in February 2010. He has published peer-reviewed papers on a variety of topics and species (Appendix A), including four journal articles describing aspects of an 11-year study of adult white sharks at Guadalupe Island, Mexico. These white shark papers outline seasonal migratory behavior, scavenging preferences, diving behavior, habitat use, and a unique photographic method for identifying individual white sharks. In total, Dr. Domeier has deployed more than 500 pop-up satellite tags, 78 of these on white sharks. He has also surgically implanted over 100 electronic tags (both acoustic and archival tags) on marlin, white seabass, giant sea bass, bluefin tuna, tiger sharks, kelp bass, California sheephead, goliath grouper and California halibut. He has attached near real-time satellite transmitters, the type of tag that would be used for this project in the GFNMS, on dozens of marlin and white sharks (Domeier, unpubl. data).

1.3 Purpose of the Proposed Action

The purpose of the proposed continuation of research that was started in 2009 is to improve GFNMS understanding of the full migratory cycle of white sharks that seasonally visit the Sanctuary in order to improve sanctuary management of white sharks.

1.4 Need for the Proposed Action

The need for the proposed research is to obtain scientific data that enables protection of white sharks that seasonally aggregate in the GFNMS and to facilitate ONMS engagement in efforts to protect the full range of white shark habitat. The proposed activity would provide long-term tracking data from a cumulative total of 13 adult white sharks.

Biological questions regarding the migratory cycle of female white sharks are important for the long-term conservation and management of this species in the eastern Pacific. The study is designed to determine the location of females during their years of absence from the Sanctuary, as well as identify the pupping and nursery regions for Sanctuary white sharks. Secondary goals include collection of genetic material for ongoing studies of population structure and analyses of blood hormone levels to better understand the reproductive biology of the white shark.

1.5 Public Involvement and Coordination

The initial attempts to catch and tag two sharks in the GFNMS were problematic – the first shark tagged in October 2009 was hooked not in the mouth as intended but in the esophagus. Although the research team tried to remove the entire hook, it had to be cut near the eye of the hook with most left in the shark. The hook was cut in this manner so that it would slide out of the esophagus and be expelled. The second tagging proceeded without incident but the public and members of the other research teams studying white sharks in the region were concerned that the shark had died and that the tagging was being conducted primarily for a National Geographic television program. Questions were raised regarding sub-lethal effects to the captured sharks (e.g. possible crushing of organs, effects on any pregnant females, and changes in migratory behavior) and whether the techniques used, the location in the Sanctuary, and the sample sizes were appropriate for the biological questions.

In response to these concerns, GFNMS initiated an independent review to assess the status of the white sharks tagged last year under the permit issued to Dr. Domeier. The reviewers are employees of the National Marine Fisheries Service and have expertise in shark behavior, husbandry and/or health. The review addressed four specific sets of questions regarding the fate of the tagged sharks and recommendations for improvements. Information from that review was included in the drafting of this document and will be available on the GFNMS website.
The draft EA will also be provided to the public through a 15-day review period. This will allow the public an opportunity to comment on the activity proposed, which would be considered as part of the decision process related to the permit application for this project. The public comment period will allow review by other federal and state agencies as well as the public and individuals on the GFNMS Sanctuary Advisory Council (SAC). The SAC serves as a liaison to the community regarding Sanctuary issues and acts as a conduit, relaying the community's interests, concerns, and management needs to the Sanctuary. SAC members represent public interest groups, local industry, commercial and recreational user groups, academia, conservation groups, government agencies, and the general public.

1.6 Regulatory Review Criteria

1.6.1 Sanctuary Protections for White Sharks

In March 2009, the Sanctuary implemented regulations prohibiting white shark attraction and approach (http://sanctuaries.noaa.gov/management/fr/73_fr_70488.pdf). The requirements at 15 CFR Section 922.82(a)(13) specifically state that it is unlawful to attract a white shark in the Sanctuary; or approach within 50 meters (164 feet) of any white shark within the line approximating two nautical miles (2.3 miles) around the Farallon Islands. Further, Section 922.81 defines "attract or attracting" as the conduct of any activity that lures or may lure any animal in the Sanctuary by using food, bait, chum, dyes, decoys (e.g., surfboards or body boards used as decoys), acoustics or any other means, except the mere presence of human beings (e.g., swimmers, divers, boaters, kayakers, surfers).

To implement these new Sanctuary regulations, GFNMS initiated the White Shark Stewardship Project; the goal of which is to protect and conserve the white shark population that utilizes the Sanctuary (http://farallones.noaa.gov/eco/sharks/sharks.html).

Permitting for research and education purposes is an important component of the White Shark Stewardship Project. ONMS may issue a permit for activities that are otherwise prohibited, provided the Superintendent considers the following factors described in 15 CFR Section 922.83:

- The applicant meets professional and financial qualifications;
- The methods proposed are appropriate;
- The activity is compatible with the protection of Sanctuary resources and qualities;
- The activity is compatible with Sanctuary values;
- It is necessary to conduct the project within the Sanctuary; and,
- The expected end value furthers Sanctuary goals and outweighs the potential adverse effects on its resources and qualities.

The activities that may involve attracting or approaching white sharks and may require a permit would fall into one of three types:

Activity Type	Permit category
Educational Filming for Broadcast Media	Education
Educational Tourism	Education
Science	Research

When a proposed project involves activities with multiple objectives, ONMS will determine the most appropriate permit category; however, the entire project will be evaluated according to the regulatory review criteria identified above and in 15 CFR Section 922.83.

Extending the current ONMS research is necessary for MCSI to continue to conduct the white shark tagging activities in Sanctuary waters. The purpose of the EA is to determine whether significant environmental impacts could result from the proposed action. The EA is also an analysis document that will be part of the decision-making process for the permit, which will include comments from other agencies and the public.

1.6.2 Other Protections for White Sharks

White sharks are federally protected under the Magnuson-Stevens Fishery Conservation Act. In the Exclusive Economic Zone off of Washington, Oregon and California, white sharks are managed by the Pacific Fishery Management Council, which is one of eight regional fishery management councils established by the Magnuson-Stevens Fishery Conservation Act to manage commercial and recreational fisheries (16 U.S.C. 1801-1883). The Council manages about 119 species of salmon, groundfish, coastal pelagic species (sardines, anchovies, and mackerel), and highly migratory species (tunas, sharks, and billfish). The Council's Highly Migratory Species ishery Management Plan prohibits the commercial fishing of white sharks. If fishers should catch white sharks they must be released immediately unless other provisions for their disposition are established, including for scientific study (http://www.pcouncil.org/wp-content/uploads/HMS_FMP_Aug09.pdf).

The white shark has been protected in all State waters off of California since January 1994 but the "take" of white sharks, which includes the capture, mark and release of any animal, can be allowed through a scientific collecting permit issued by the California Department of Fish and Game (Title 14 California Code of Regulations, Section 650).

White sharks are not designated as a federal endangered or threatened species under the Endangered Species Act but they are listed under Appendix II of the Convention on International Trade of Endangered Species (CITES). CITES is an international treaty that requires any participating member-state (of which the United States is one) to implement a fishery management plan (as described above) prior to conducting commerce in white shark products. Species listed in Appendix II of CITES are those that may become endangered if their trade is not regulated (http://www.nmfs.noaa.gov/ia/intlagree/cites.htm).

White sharks are listed as vulnerable on the Red List of Threatened Species by the International Union for the Conservation of Nature and Natural Resources (Fergusson, Compagno and Marks, 2005; www.iucnredlist.org/apps/redlist/details/3855/0).

A particular challenge for white shark management efforts is that this species is highly migratory and with a trans-boundary migratory life history; moving between national and international waters, and between the waters of adjacent states before returning to major aggregation sites (Wildlife Conservation Society, 2004).

1.7 Scope of this Environmental Assessment

Section 1 of this EA primarily includes the background on the Sanctuary, a brief description of the proposed activity, and the purpose and need of the project. Section 2 details the activity that is being proposed and the alternatives that are being considered. This includes the "No Action" Alternative. Section 3 provides a description of the environmental conditions at the proposed study site. Section 4 describes the environmental consequences of the proposed action. Section 5 provides a list of preparers and Section 6 contains the citations used in this document.

2. DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

2.1 Conduct a study using Smart Position and Temperature Tags on white sharks in the GFNMS (Alternative 1)

The applicant proposes to capture and affix near real-time satellite transmitters to the dorsal fin of three male and eight female white sharks around the Farallon Islands over a four-year period. This would be in addition to the two sharks already tagged with satellite transmitters in 2009. The sharks would be captured by hook-and-line, raised from the water on a large hydraulic platform and tagged before being released. Once tagged, data would be collected and monitored over the next four to six years with the use of the ARGOS satellite array, a collection system for studying and protecting the environment. Results of the proposed study would be disseminated to the Sanctuary via reports, and to the scientific community via peer-reviewed publications.

The following sections provide the methodologies proposed as well as methods that were considered and evaluated but were determined to not be viable for the research project as proposed.

2.1.1 Methods for White Shark Attraction and Feeding

A large research vessel would be used for travel and living quarters for the duration of the proposed field work. The timing of the research and the number of days the vessel would be at the island would be dependent upon the weather and the presence or absence of sharks. Once anchored, the research vessel would remain stationary for up to a week, moving only when wind or current direction deemed it necessary. The vessel that is proposed to be used is a 128-foot decommissioned Bering Sea crabber but the final vessel could be different depending on contract negotiations. The capture methods, hydraulic lift system and other components; however, would all function the same as described regardless of the vessel chosen.

A smaller capture boat (approximately 20 to 25 feet) would be used to follow and tire the sharks. The sharks may be baited from either the large ship or the small boat.

White sharks would be attracted by baiting a large circle hook with salvaged marine mammal carcass (obtained via an existing NOAA Marine Mammal Protection Act “Letter of Authorization;” Appendix B). Two methods have been considered and evaluated to prevent the sharks from swallowing the hook. The options labeled as “proposed method” are the ones that are preferred for use in this study.

Surface Baiting (Option 1: method considered)

The baited hook would be held within four feet of the surface with either a plastic float or an outrigger extended from the boat (refer to Section 2.1.4 for more information). Fishing near the surface would minimize the chance of the shark swallowing the hook since the shark must turn away from the surface immediately after taking the bait and in doing so tension is immediately placed on the hook via the floating buoy, preventing it from being swallowed. The hooked sharks would then be tired with floating buoys affixed to the line, prior to being lifted from the water for tag attachment.

Baiting with Preventer or Blocker Attachment (Option 2: proposed method)
A gut hook "preventer" has been devised that could theoretically eliminate the chance of hooking a white shark in the stomach or throat. This preventer-rig would consist of a length of ¾-inch PVC positioned in the fishing rig just above the hook. The PVC would be long enough so that it cannot pass into the shark's mouth, thereby preventing the hook from lodging anywhere but in the mouth. Crimps and ties would be used to prevent the rig from sliding up and down the leader. Such a device has not been tested on white sharks; however, a similar concept has been successfully used in the field by a shark fishing charter operation from Ocean City, Maryland (http://www.bigsharks.com/thisweek.htm). The company has been experimenting with this type of rig to prevent sharks from swallowing the baits, ensuring that the sharks are hooked in the mouth (Fig. 2). According to their website, good success has been achieved with the Blocker rig and this has generated interest from biologists and marine managers. There are current plans by a graduate student to conduct more formal trials with this rig to determine its ability to eliminate gut-hooking without sacrificing capture rate.

Fig. 2. A blocker-type of device to better ensure that white sharks are hooked only in the mouth.

White sharks may shy away from hooks rigged with the preventer or Blocker, causing a reduction in fishing success but sharks hooked while using either of these devices would likely be hooked only in the mouth. The use of the preventer rig would also allow fishing to occur more than four feet below the surface, since the device alone would prevent deep hooking. However, neither device has been tested on white sharks in the Farallones.

Under either option, after the sharks are hooked, they would then be tired with floating buoys affixed to the line, prior to being lifted from the water for tag attachment.

2.1.2 Methods for Tagging Eight Females and Three Males

Capturing and Releasing More Than Three Males (Option 1: proposed method)
The number of sharks proposed to be tagged (11 total; 13 cumulative from the two already tagged in 2009) is a small sample size that was chosen in a precautionary manner to obtain initial data that would help guide future research. The small sample size is too small to be statistically rigorous but it can provide important information on an animal in which relatively little is known.

The sample size proposed for males (three) is small since the research gains would not be as significant as what can be learned from tagging the eight females. Male sharks have demonstrated a one year migration cycle that has been successfully documented with other tagging methods. By including a small number of males in the proposed study, this would allow a comparison to similarly tagged males at Guadalupe Island.

Given the poor water visibility at the Farallones, it would be very difficult to target only females. Thus, the sex of the shark probably would not be known until after it is hooked. Because the females are the most important part of this study, once the first three male sharks are tagged, then any other males caught would be released without tagging but they would still need to be raised from the water to remove the hook. Care would be taken to pull the bait away from obvious males, once the three male tags have been deployed.

Selectively Capturing Only Females (Option 2: method considered)

A method to selectively fish for females, by pulling the bait away from males, was considered. Male and female sharks can be discerned via the presence or absence of enlarged and elongated pelvic fins, called claspers. Males possess claspers, used for mating, whereas females do not. Given the poor water visibility at the Farallones, and the fact that the claspers are often tucked beneath the shark and therefore not visible, it is not be possible to target only females with 100 percent accuracy. As a result, the sex of some sharks would not be known until after they are hooked.

2.1.3 Tag Type

Fin Mounted SPOT tags (Option 1: proposed method)

Smart Position and Temperature (SPOT) tags (http://www.coml.org/edu/tech/study/spot1.htm) are specifically designed for obtaining multi-year precision tracks from adult white sharks. The satellite transmitter on the tag is activated when the tag exits the water, thus the best location to affix a SPOT is the tip of the dorsal fin, which requires the shark to be captured, temporarily restrained while the tag is attached and then released. Once the shark is released, the SPOT tag gives near real time, high resolution position data whenever and wherever the shark is at the surface with its dorsal fin out of the water (i.e., their positions are not dependent upon moored receivers).

Fig. 3. White shark SPOT tag (refer to Fig. 11 for scale).

The tag measures approximately six inches long, one inch wide and 0.75 inches thick (Fig. 3). It is designed to function for four to six years before the batteries expire. A total of 23 white sharks have been SPOT tagged by Dr. Domeier's research team. Of these, 19 were tagged at adult aggregation sites (17 at Guadalupe Island and two at Southeast Farallon Island) and four were juveniles captured in southern California.

This project has seen an evolution of the tag itself, since the first version was deployed at Guadalupe Island and three of those first four failed to work properly; however, all of these sharks have been re-sighted at the island in subsequent years. The remaining tagged sharks from Guadalupe are still providing data for the last two and three years since tagging occurred (M. Domeier, pers. comm.).

The SPOT tags are useful in confirming one-year migration cycles but the primary benefit is in providing multi-year data for tagged individuals. Having SPOT tagged males from both Guadalupe Island and the Farallon Islands would provide researchers with an opportunity to observe the relative proximity of tagged sharks in the offshore habitat, and thereby allow conclusions as to the degree of interaction between sharks from these two locales. SPOT tags can also provide high resolution data on local movements in the central California region, providing local movement data that is not possible with any other technology.

Pop-up Satellite Archival Tags (Option 2: method considered)

Over the past eleven years, researchers have deployed nearly 80 Pop-up Satellite Archival Tags (PSAT) on white sharks off Guadalupe Island, Mexico, and a similar number of these tags off Central California (see Domeier and Nasby-Lucas, 2008 and Jorgensen *et al*., 2010). PSATs are affixed to the sharks by attracting them alongside the research vessel and then harpooning a plastic or metal dart into the musculature near the dorsal fin. The dart is affixed to a short monofilament or wire leader (approximately seven inches in length) and the other end of the leader is attached to the tag.

PSATs are designed to systematically record pressure, temperature and ambient light levels until they detach from the animal on a pre-programmed date. PSATs come off via a corrodible link that is activated by onboard software. Once the tag detaches, the dart and leader remain in/on the fish. PSATs are relatively easy to deploy, since the shark does not need to be captured; however, these tags do not give very precise geolocation estimates, and due to limited battery life, they typically do not provide tracks in excess of one year. The relatively short lifespan of PSAT tags prevents the documentation of adult female white shark migration patterns; PSATs are sufficient; however, to study the male white sharks since the data obtained show that they have one-year migration cycles (Anderson and Pyle, 2003; Domeier and Nasby-Lucas, 2007; Weng *et al*., 2007; Domeier and Nasby-Lucas 2008). The accuracy of PSAT position estimates can also vary from 30 miles to several hundred miles because the light-based geolocation estimates are affected by the time of year, with equinox periods introducing the most error. SPOT tags provide much more precise location estimates, sometimes within 300 feet. PSAT tags also leave a dart in the active swimming muscle and have the potential for drag. PSAT tags do provide, however, detailed temperature and depth preference data that cannot be collected via a SPOT tag.

The sharks proposed to be SPOT tagged in the GFNMS could possibly be double-tagged with PSATs as a method to assess the fate of the sharks if the SPOT tags were to fail. For example, three of those first four SPOT tags deployed at Guadalupe Islands failed to work properly although all of those sharks were re-sighted at the island in subsequent years. During the early stages of the white shark SPOT tagging program at Guadalupe Island, some PSAT tags were attached to individuals that were also tagged with a SPOT, which was done to ensure that the fate of the shark would be known even in the event of a SPOT tag failure. Since the second generation SPOT tags have proven to be reliable and effective, PSATs are no longer necessary to use in conjunction with SPOT tagging because the PSATs do not provide enough additional meaningful data to justify the cost. Furthermore, the failure rate of PSAT tags is known to be quite high.

Towed SPOT tags (Option 3: method considered)

Another configuration of SPOT tag exists that is designed to be towed behind the animal. These tags can be attached without capturing the shark but they employ a large metal spearhead (four inches in one study on whale sharks by Hsu *et al*., 2007) that is harpooned into the dorsal musculature. The tags were then attached by more than 30 feet of tow line made of one millimeter diameter multi-strand stainless steel. Such tags have been used on whale sharks and basking sharks but only three deployments have resulted in tracks that exceeded one year (Hsu *et al*., 2007; Eckert and Stewart, 2001). It is likely that the drag induced by the tag causes the tether to break or perhaps the dart pulls out of the flesh.

These towed tags may also result in long term deleterious impacts. In addition to the large, sharp metal spearhead that is intended to remain in the shark's active swimming muscle, the device is attached with a long tether that could cause entanglement or injury. Furthermore, whale and basking sharks are filter feeders, not active predators. The visual and/or audible signal that results from the trailing tag could hinder a white shark's ability to ambush prey.

Towed tags also have more induced drag than PSAT tags. The towed tags are designed to plane up and away from the fish so that they surface and transmit when the animal is near the surface. To "fly" up in the water column, these tags must use directional drag, whereas PSAT tags are designed to simply trail straight behind the fish with as little drag as possible. These types of towed SPOT tags could be tried but there are other uncertainties that come with this method as to its potential effects. The tag itself, based on limited long-term success on whale sharks, may not provide the level of consistent data that is otherwise expected from the proposed SPOT study.

Acoustic tags (Option 4: method considered)

Acoustic tags transmit an underwater sound signal or "ping" that identifies the individual tagged fish to acoustic receivers (or hydrophones) that have been attached to the seabed. Acoustic tags have multi-year battery capability and can be attached by harpooning them into free-swimming sharks. They are similar to the PSAT, in that the acoustic tags are attached via a tether and dart, but they differ in that they remain attached to the shark indefinitely. Over time the tag can become encrusted in biofouling organisms and cause injury to the shark as the tag and associated fouling community constantly rub against the side of the shark.

One of the main drawbacks to using acoustic tags is that they provide data only from locations where the acoustic receivers have been deployed and, therefore, cannot give any indication of the shark's location while it is swimming more than 500 meters (1,640 feet) from the receiver (see Domeier, 2005, for review of methods).

2.1.4 Capture

Safely capturing, tagging and releasing adult white sharks has involved the development of special tools and capture methods. The methods that are described below have been developed to minimize the risk of serious injury or death to the sharks.

These methods have also been used to capture, SPOT-tag, and release 23 white sharks (4 were juveniles from southern California), the largest of which were females exceeding 17 feet in length, and all have survived as indicated by satellite tag transmissions and re-sightings.

Customized Circle Hook (Option 1: proposed method)

The hook and line have to be sufficiently large to withstand the pressure exerted against the tackle by a shark that may weigh in excess of two tons. A 3/8-inch nylon rope would be used as the mainline and a braided stainless steel cable would be used for the leader to prevent the shark from parting the line with its teeth. The wire leader braided into nylon rope or covered in rubber, which is intended to reduce abrasion to the shark's skin, would then be attached to a large hook. A customized circle hook (Fig. 4) has been developed specifically for this task. A circle hook design was chosen because it is designed to lodge in the corner of the jaw and has been proven to cause a significantly lower incidence of internal injury than a conventional J-hook (Domeier *et al*., 2003; Prince *et al*., 2007; Graves and Horodysky, 2008), although comparative studies between the proposed hook and a J-hook of comparable size have not been conducted.

Hooks used for SPOT tagging white sharks are 13 inches long by seven inches wide, with a five-inch gap between the point and the shank. This sized hook has already been used to capture 19 white sharks from approximately 11 to 18 feet in length that were SPOT-tagged in California and Mexico. The four juveniles were caught with the largest commercially available circle hook (as shown in the center of Fig. 4). The ratio of hook to body size is within the norm for hook-and-line fishing. Smaller hooks would be prone to bending and the gap may not be large enough to accommodate the thick jaw. The hooks are also manufactured to exacting circle hook specifications and are made of a steel alloy that is designed to rust, rather than resist corrosion, in the event that some or the entire hook must be left in the shark.

Of the 19 adult sharks captured for SPOT tagging 14 were hooked in the corner of the mouth, three were hooked in the upper jaw and one was hooked in the esophagus. The entire hook was removed from all but two sharks. Only a portion of the hook was removed from the shark that was hooked in the esophagus and an entire hook was left in the left corner of the mouth in 2007. Based on the tag's signal, the esophagus-hooked shark caught in the GFNMS in 2009 survived and resumed its normal seasonal migration pattern (Fig. 5). The 2007 shark that had been caught near Guadalupe Island and had the hook left in its mouth was re-sighted in 2008 and 2009 with the hook missing and the wound completely healed (Fig. 6).

Fig. 4. Circle hooks (left and center) compared to J-hook (right). The hook shown on the far left in the picture is proposed to be used for this project whereas the center hook is the largest that is commercially available.

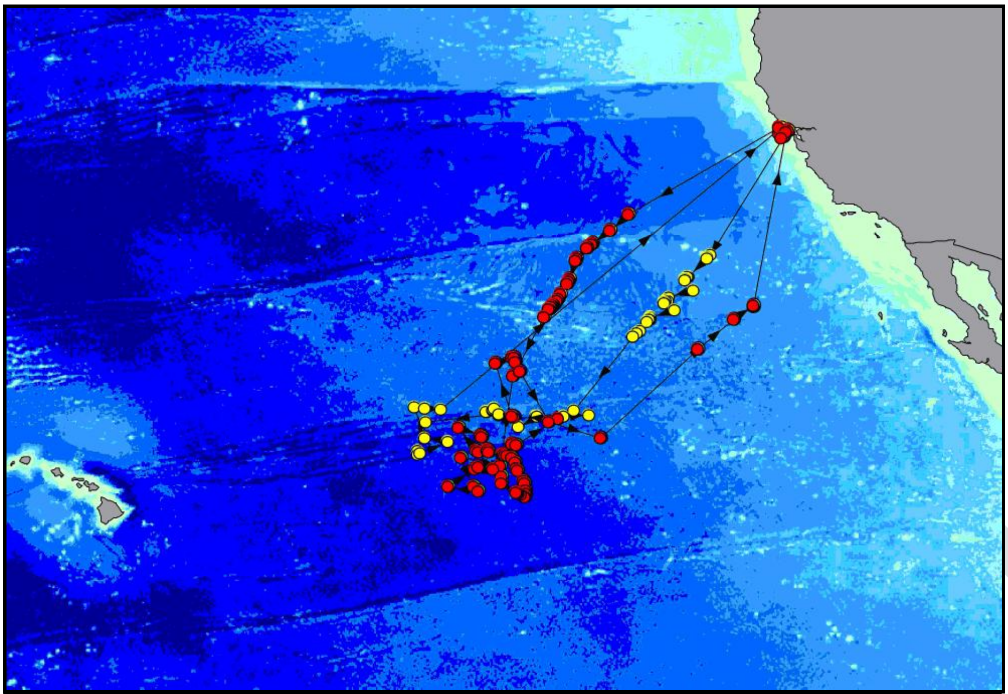

Fig. 5. Satellite tracks of the two white sharks SPOT tagged in 2009 at the Farallon Islands. Arrows indicated direction of travel. As of August 2010, both sharks had returned to Drakes Bay (Domeier, unpublished).

Fig. 6. Shark photographed one year after tagging; hook had remained in left corner of the mouth but is now gone with no visible sign of injury or scarring. The SPOT tag is on the right side of the dorsal fin but the bolt pattern is barely visible on the left side.

Smaller Circle Hook (Option 2: method considered)

Smaller hooks were considered because if the hook placement is somewhere other than the corner of the mouth, a smaller hook may have less probability of interacting with sensitive areas due to its length and gap size (e.g., the distance between the shaft and the barb). However, no other researcher has ever captured sharks as large as those caught at the Farallones or Guadalupe Island. Dr. Ramon Bonfil's white shark tagging studies are often cited as examples to landing these sharks with much smaller hooks. In 2006 he hooked many sharks but they all straightened the hooks except on the last day of his study when two of the smaller hooks were wired together to make a stronger hook. A 15-foot immature female was captured but it took so long to bring the shark in that it was exhausted to the point of near immobility (based upon video seen of the capture). The proposed study expects to capture sharks that are likely twice the mass of Dr. Bonfil's shark. Sharks of this size hooked in the past by Dr. Domeier's team have also bent and broken the first large prototype hooks, as shown in Figure 4. Furthermore, there are no commercially available circle hooks between the small hook (center image, Fig. 4) and the hook that was designed by Dr. Domeier (left-hand image, Fig. 4). In general, smaller hooks will require much longer fight times and therefore additional physiological stress to ensure the hook is not bent. Figure 6 shows a shark one year after it was hooked captured with Dr. Domeier's large hook and the hook was left in the corner of the mouth; the hook is gone and there is no scar to indicate where it had been hooked.

Rod and Reel Gear (Option 3: method considered)

Conventional rod-and-reel gear would not be strong enough to safely capture a fish of this size. Even the largest commercially available reels do not provide enough drag, or have the proper line capacity, to capture such a large fish fast enough to safeguard against lethal physiological stress.

Floats to Provide Drag (Option 4: proposed method)

The shark needs to be tired so that it does not thrash about once lifted from the water because such movement could cause serious injury to both the shark and to the researchers. Fourteen-inch diameter commercial long-line floats, attached to the nylon rope/mainline, would be used to provide sufficient drag to tire the shark quickly and keep it near the surface. When the hooked shark is sufficiently tired, it is brought to the surface by shortening the distance between the floats and the shark (Fig 7). The plastic floats may come into contact with the shark if it rolls at the very end of the fight process and when it is lifted from the water. Lengthening the distance between the hook and the floats would prevent the shark from coming into contact with the floats, but this would allow the shark to duck beneath the platform where the shark could be injured or the line could break. It is possible the floats could be covered with some material to protect the shark from coming into contact with the hard plastic but this could introduce unforeseen complications such as the shark snagging the material in its teeth or the cover coming partially off due to extreme drag and pressure, allowing the shark to grab it or perhaps causing excess drag to be exerted on the hook. There is also the potential for the shark to take the buoy in its mouth, as has happened once before, which could take additional time on deck to remove. The buoys will be sized large enough to prevent this from happening.

Fig. 7. The use of line and buoys to control and tire an adult white shark from a capture boat.

2.1.5 Lifting From the Water

Lift Platform (Option 1: proposed method)

Once the shark is at the surface, the small boat would guide the shark onto a large submerged platform that has been specifically designed to hydraulically lift adult white sharks that can weigh several thousand pounds from the water. Once the shark is stabilized, tagging, measurement, sexing, blood draw and DNA sampling can safely commence (described below). After tagging is complete the lift lowers the shark back into the water so the shark can swim free.

In Water Tagging (Option 2: method considered)

Although tiger sharks (*Galeocerdo cuvier*) have been captured and tagged while restrained in the water (Holland *et al*., 2001), tiger sharks are much smaller (maximum size 18 feet and 3,000 pounds) than white sharks (maximum size 20 feet and 7,500 pounds). There would be several serious problems with attempting to tag an adult white shark while it is still in the water:

- The shark must be upside down to be put in a trance-like state called, “tonic immobility” (see Section 4), which would not allow the attachment of the SPOT tag to the dorsal fin.
- It would be impossible to remove the hook without the researcher incurring serious risk of injury or even loss of life.
- Attempting to tag a shark while it is upright and partially submerged could be very risky to the researchers.

- Accurate measurements or blood sampling could be difficult, if not impossible, to conduct with the shark in the water.
- In water tagging of sharks often involves a researcher getting into the water to assist the handling of the shark; doing so would carry the risk of the researcher getting attacked by other nearby white sharks.

Custom Slings (Option 3: method considered)

Initially a custom rubber sling was designed and put into use to lift the white sharks from the water (Fig. 8). It was thought that this would more evenly distribute the weight of the shark and more firmly restrain the position of the shark. Early trials found that it was so difficult to place the shark in the small sling that the shark had to be tired to the point of complete exhaustion. It was decided that it is likely safer for the shark to tire it less and use a larger platform for the study. The larger surface area allowed much greater degree of flexibility in guiding the shark onto the platform. One very important benefit is that there is no risk of pectoral fin damage with the large platform, whereas with the sling, there was concern that the rigid pectoral fins could be damaged.

Fig. 8. Dr. Domeier's failed rubber-contoured shark cradle.

Quick-Tagging Device (Option 4: method considered)

Dr. John Stevens, a shark expert who works for the Australian government, was consulted by Dr. Domeier about a device Dr. Stevens had designed that was meant to quickly rivet a tag onto a free swimming shark. Considerable funds and time were spent on developing this concept but it did not work.

Dr. Domeier also investigated and constructed a device for a spring-loaded tag attachment method that could be conducted on free-swimming sharks (Fig. 9) but this concept also failed.

Fig. 9. Dr. Domeier's failed spring-loaded SPOT attachment device.

The combined failures by Dr. Stevens and Dr. Domeier caused these concepts to be abandoned in favor of bolting the tag to the dorsal fin, as described in Section 2.1.6.

2.1.6 Examination and Tagging

Once the shark is landed and lifted onto the platform, an irrigation hose would be placed in the mouth of the shark to flush seawater over the gills (Fig. 10). This would provide a steady flow of oxygen. A wet towel would also be placed over the eyes to protect the eyes and to calm the animal. Salt water would be periodically poured over the animal to keep its skin wet.

There are no data to empirically address how long a white shark can stay out of the water. Before Dr. Domeier's SPOT tagging, prior research demonstrated that white sharks had been out of the water at least 20 minutes without incurring mortality (R. Bonfil, pers. comm.). This is an arbitrary threshold and no study has been conducted to determine the length of time that sharks can remain out of the water without risk of mortality. Twenty minutes is a guideline proposed by Dr. Domeier for maximum time-out-of-water based upon the experience of Dr. Bonfil.

Fig. 10. Irrigation hose immediately placed in mouth to begin flow of seawater over the gills. Note water mixed with small amount of blood from the hook wound.

There is evidence that sharks can survive a long time under low oxygen conditions, as demonstrated by their very long dives to low oxygenated waters in the central Pacific Ocean (Nasby-Lucas *et al.*, 2009) but this does not help to determine the maximum time this species can be kept out of the water. Whale sharks have also been captured, taken out of the water, supplied with oxygenated water over its gills and transported in coffin-like boxes via long flights and trucks to aquarium destinations for display (B. Carlson [Georgia Aquarium], pers. comm.).

Based on prior SPOT tagging experience, the study team has become more proficient, with sharks tagged and sampled in less than 10 minutes. This has been accomplished by conducting many of the tasks listed below at the same time while the shark is out of the water. The tasks that take the longest are the tagging and the hook removal (each can take five to ten minutes). Taking the tissue sample, drawing blood, measuring the length and girth, and examining for the presence of claspers can each be accomplished in two minutes or less.

There are no studies that have been able to determine the potential for sub-lethal effects of gravity or artificial irrigation on this species. What is known is that the sharks that have been subjected to these procedures have survived and continued expected migrations. White sharks have also been documented to recover from horrific injuries incurred in the field (Domeier and Nasby-Lucas, 2008; see also http://wn.com/Great_White_Shark_Wound_Healing); although this project does not propose to use methods that would incur such injuries, these examples are some of the only data in existence that provide an indication as to the ability of this species to recover from stress and injury.

Tissue Collection (Option 1a: proposed method)

Small pieces of tissue would be clipped from the dorsal fin and preserved for DNA analysis. These samples would be given to Dr. Barbara Block at Stanford University in order to contribute to an ongoing study of the relationship between Guadalupe Island white sharks and central California white sharks. This is a broadly used, accepted method for tissue collection.

Blood Collection (Option 1b: proposed method)

A hypodermic needle would be used to take a blood sample from the caudal vein. Twenty milliliters (0.68 ounces) of uncontaminated blood is needed and this can only be obtained directly from a vein. The methodology has been refined and the caudal puncture would take less than a minute. The blood samples would be analyzed for reproductive hormone levels by Dr. James Sulikowski at the University of New England. This is a broadly used, accepted method for tissue collection.

Measurements and Sexing (Option 1c: proposed method)

Sharks would be measured for both length and girth so that the weight of the animal can be estimated. The shark would also be examined for the presence or absence of claspers to identify the sex of the shark (claspers indicate a male). If the shark is a male, the clasper groove would be examined for the presence of seminal fluid and spermatophores. No sample would be collected.

Tagging (Option 1d: proposed method)

The SPOT would be affixed to the dorsal fin by drilling four small holes through the fin and securing the tag with plastic bolts. The plastic bolts are designed to keep the tag firmly attached. Although the attachment is not designed to release the tag in the future, the plastic will degrade and eventually the bolts may snap and the tag fall free. The primary purpose of the attachment is to keep the tag on the shark for the duration of the tags' battery life (four to six years). At this time there is no means of programming the tag to come off after a set amount of time and, therefore, the tag could remain permanently attached to the shark. This is the same method that has been used by other researchers to secure SPOT tags to sharks.

Anesthesia (Option 2: method considered)

Anesthesia is not used during the attachment of the tag because the effects of such drugs have not been tested in large sharks and their potential to harm the shark is unknown. Sharks lack the neural structures essential for the perception of pain (Snow *et al*., 2003), and direct observations by Dr. Domeier indicate that the sharks do not react when the tags are being attached to their fins. No other large sharks tagged in the wild are anesthetized prior to tagging.

At the end of the examination and tagging procedures, the shark is lowered back into the water and released (Fig. 11).

2.2 No Action (Alternative 2)

The No Action Alternative would entail not permitting this research to continue within the GFNMS. Under this alternative, SPOT tagging of adult white sharks would continue in regions outside of the Sanctuary, such as Guadalupe Island. The existing, permitted white shark research activities would continue to gather adult migration data for periods of less than one year, while the two previously SPOT-tagged adult males would provide multi-year tracking data. No additional white sharks would be attracted in GFNMS and no additional tags would be attached as part of this project. Data collection would be limited to the two sharks previously tagged in 2009.

Fig. 11. Tagged shark being lowered for release. Note size of the fin-mounted tag relative to the dorsal fin. There is a second, acoustic tag attached at the base of the dorsal fin, which is not being proposed.

3. AFFECTED ENVIRONMENT

3.1 Overview

The GFNMS protects one of the most diverse marine ecosystems along the coast of North America, including a myriad of seabirds, marine mammals, and fish. The waters of the GFNMS are nutrient rich after upwelling events, supporting high phytoplankton concentrations. Areas of variable relief and rocky substrate are also often associated with significant ecological richness, spawning and feeding areas, and high species diversity. Together, these form a highly productive ecosystem. The Sanctuary is one of the most important areas along the West Coast for marine commerce including fishing, shipping, whale watching and tourism. It also has one of the world's most significant populations of white sharks and is a destination feeding ground for endangered blue (*Balaenoptera musculus*) and humpback (*Megaptera novaeangliae*) whales (ONMS, 2008).

The Farallon Islands consist of seven islands and large rocks, which lie along the outer edge of the continental shelf, approximately 30 miles due west of San Francisco. The islands are located on part of a larger submarine ridge that extends for approximately 34 miles between the Farallon Islands and Cordell Bank near the shelf break (ONMS, 2008). The Sanctuary seafloor gently slopes offshore along the continental shelf before dropping off abruptly to depths of 6,000 feet west of the islands (ONMS, 2010; Fig. 12).

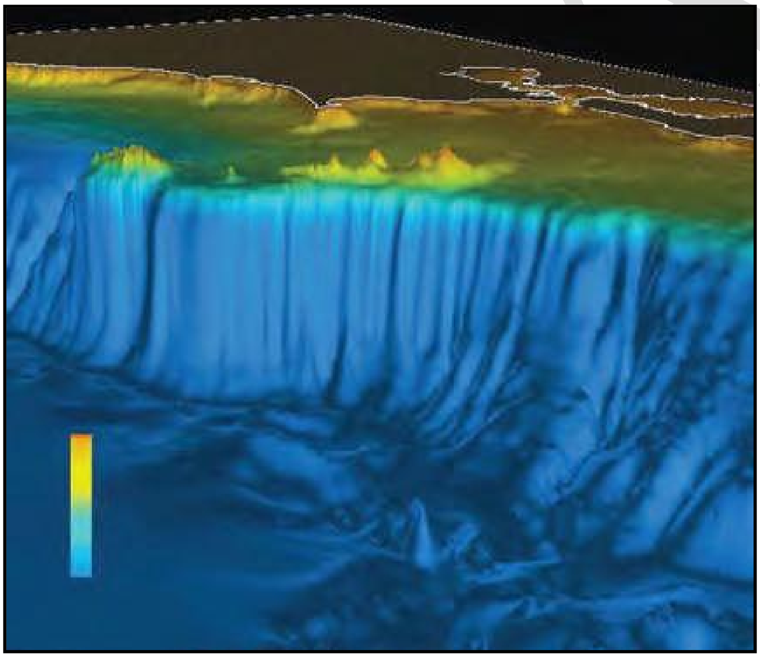

Figure 12. Computer imagery shows the topography of the GFNMS seafloor and the steep drop-off of the continental slope west of the Farallon Islands.

The Farallon Islands, in particular, support the largest seabird nesting habitat, as well as one of the most important seal rookeries, in the lower-48 states. The marine mammals and seabirds that occur on or near the Farallon Islands depend as much on the integrity and productivity of these adjacent ocean and estuarine waters as on the preservation of the shore areas they use for breeding, feeding, and hauling out (ONMS, 2008).

No component of the proposed white shark research involves any terrestrial activities or cultural resources; therefore, the terrestrial environment and cultural resources are not considered further in this EA.

3.2 Physical Environment

3.2.1 Air quality

The climate in the San Francisco Bay area is characterized by moderately wet winters and dry summers. At the Farallon Islands, most of the annual rainfall occurs during winter with a seasonal average of ten inches. There is frequently a dense fog on the islands throughout the summer but this also occurs at other times of the year. Strong northwesterly winds typically occur during the spring and early summer. The temperature remains relatively constant throughout the year, rarely below 45ºF or above 65ºF (USFWS 2009).

The Farallon Islands are not monitored for air pollution by San Francisco County but the air quality directly surrounding the islands is considered good due to marine winds and its relative isolation from the mainland. This area is described as meeting state and federal air quality standards (USFWS, 2009).

Air quality can be affected by emissions from diesel- and gas-powered engines. The calculation of emissions from vessels can be determined by using the emission factors listed in Table 1 for diesel fuel and for gasoline.

Table 1. Emission Factors for Diesel and Gasoline.

Pollutant Type	Amount of emission (in pounds) per 1,000 gallons of fuel
Diesel	
Carbon Monoxide	110
Nitrogen Oxides	270
Sulfur Oxides	27
Gasoline	
Carbon Monoxide	1,822
Nitrogen Oxides	96
Sulfur Oxides	6

From: California Department of Fish and Game 2005.

Pollution emissions that are released when vessels are underway are influenced by a variety of factors including power source, engine size, fuel use, operating speed, and load. The emission factors given in Table 1 only provides a rough approximation of the emission rates (California Department of Fish and Game 2005).

3.2.2 Water Quality

The GFNMS is located in the California Current, one of the world's four major wind-driven upwelling systems. Northerly winds drive a shallow surface layer that moves offshore due to the Coriolis effect. This offshore transport of surface waters results in the upwelling of cold, nutrient-rich waters from depth into sunlit surface waters, which supports a food-rich environment and promotes the growth of organisms at all levels of the marine web. Upwelling may be widespread at times, or localized at upwelling centers (e.g., Point Arena; ONMS 2010).

In addition to this upwelling, San Francisco Bay may be an important source of nutrients and organic matter in the Gulf of the Farallones. The result is that high concentrations of phytoplankton are observed in the Gulf of the Farallones near the water surface, making them available to zooplankton and higher trophic prey species such as krill, whales, fish and birds. In addition to upwelling-driven productivity in bays, estuaries and other nearshore environments during spring and summer, seasonal blooms may occur in response to rainfall and runoff at other times of the year (ONMS, 2010). The average sea surface temperature surrounding the Farallon Islands is approximately 53.5º F (USFWS, 2009).

In contrast to the especially rich, near shore waters, the open ocean is much less fertile, gradually becoming less productive farther from shore. At depths of about 60 feet, the lack of adequate light penetration limits kelp growth. Many organisms that live on the continental slope and in the deep sea depend on primary production occurring in surface waters and produce their own light through bioluminescence, which is used to find or attract food or mates (ONMS 2010).

Water quality within the Sanctuary is generally considered to be good due to the rural character of the coastline (i.e., there are no major industrial discharges) and exposure of the coastline to the strong currents of the open ocean. Nevertheless, there are several potential threats to water quality including the discharge of the San Francisco Bay Estuary, agricultural waste products from the Central Valley, and residual sediments and metals from the California gold rush era. These discharges may periodically have an impact on Sanctuary waters depending on coastal currents. Other potential threats to water quality include floating debris (e.g., plastics), accidental spills, and residual materials from historical ocean dumping (GFNMS, 2008).

The waters surrounding the Farallon Islands were designated by the State Water Resources Control Board (State Water Board) in 1974 as an Area of Special Biological Significance. In 2003, the state reclassified these areas as State Water Quality Protection Areas (SWQPAs). California's Ocean Plan prohibits waste discharges into SWQPAs unless authorized by an exemption (USFWS, 2009). The offshore region near the Farallon Islands is at a slight risk from non-point source pollution but the threat is generally considered to be less due to the distance from the sources of pollutants and the continuous circulation of the offshore waters. The primary concerns to water quality are from large or continuous discharges from the mainland, spills by vessels, and illegal dumping activities or residual contaminants from past dumping activities (GFNMS, no date). In addition to current threats, persistent organic pollutants such as DDT and PCBs were widely used nationwide before the mid-1970s and residuals of these chemicals still remain in sediments and organisms within the Sanctuary. Elevated levels of pollutants have been reported for fish, seabirds and marine mammals, and are suspected to have caused and sustained in part the decline of pupping rates in Steller sea lions (ONMS, 2010).

3.2.3 Noise

SEFI is an important seabird and pinniped breeding habitat; as such, there is a relatively high level of ambient noise created by these animals. Restrictions on human activity are in place to curtail anthropogenic sources of noise. For example, boaters must abide by the five miles per hour speed limit within 1,000 feet of the shoreline of all the islands. Between March 15 and August 15, vessel traffic is also prohibited within 300 feet of the shoreline at specified portions of SEFI and North Farallon Island. This includes no boats passing between Saddle Rock and SEFI (Section 630(b)(71), Title 14, California Code of Regulations).

3.3 Biological Environment

The GFNMS contains a complete spectrum of marine habitats, ranging from unique inland estuarine and intertidal areas to pelagic and deep-oceanic environments. The high marine productivity near the Farallon Islands, in particular, attracts a diverse assemblage of fish, seabirds and marine mammals, which are described below.

3.3.1 White Sharks

White sharks occur seasonally in the Gulf of the Farallones region, arriving during the summer months to the near shore areas in the vicinity of large pinniped haul-out and breeding colonies between Año Nuevo, the Farallon islands, Tomales Point at the north end of the Point Reyes peninsula and Bodega Headlands in Marin and Sonoma Counties (ONMS, 2010). White sharks are known to feed in the vicinity of the Farallon Islands from August through November (Klimley *et al*., 1996; Pyle *et al*., 2002; Weng *et al*., 2007). It is thought that this apex predator aggregates within the GFNMS, particularly offshore SEFI, to exploit the seasonal presence of pinnipeds (Long and Jones, 1996).

The total number of white sharks that visit the Farallon Islands is not known but modeling efforts are under investigation and one estimate suggests there are around 219 adults and sub-adults (T. Chapple, pers. comm.). The sharks leave the Sanctuary every winter and migrate to Hawaii and the central Pacific in an area located halfway between the coast of North America and Hawaii (Jorgensen *et al*., 2010). This same offshore region is visited by adult white sharks from Guadalupe Island. White sharks remain offshore for up to six months before returning to adult aggregation sites along the Pacific coast. Domeier and Nasby-Lucas (2007) found that the overall sex ratio for white sharks at Guadalupe Island was 1.2:1 (males to females). However, females do not return to the islands each year so it is expected the ratio is even more biased toward males. It is likely, but not known, if similar ratios are found with the Farallones white shark population but this population also appears to be male biased.

Tagging and tracking studies and DNA analyses have confirmed that white sharks undertake long distance trans-oceanic movements, for example between South Africa and Australasia[1] (Pardini *et al*., 2001; Bonfil *et al*., 2005) and California and the Hawaiian Islands (Boustany *et al*., 2002). Despite these trans-oceanic movements, the northeastern Pacific white shark population is genetically distinct from white shark populations in South Africa and Australia/New Zealand (Jorgensen *et al*., 2010).

Photo-identification records of individual shark visitation patterns to both Guadalupe Island and the Farallon Islands have revealed that males return to these aggregation sites every year but adult females may disappear for one to two years (Anderson and Pyle, 2003; Domeier and Nasby-Lucas, 2007). Individual adult white sharks have been found to demonstrate seasonal site fidelity to the Farallon Islands as well as Guadalupe Island, being sighted year after year (Anderson and Pyle, 2003; Domeier and Nasby-Lucas, 2007).

[1] Australasia is a region consisting of Australia, New Zealand, the island of New Guinea, and neighboring islands in the Pacific Ocean.

The huge size of white sharks prohibits researchers from routinely measuring their length and girth. Based on a limited number of measurements from SPOT tagging, the Guadalupe Island sharks range from 10.33-17.75 feet in length (average of 14.67 feet; n=18) and Farallon Island sharks range from 14.0-14.8 feet (14.44 feet average; n=2; Domeier, unpubl. data). These sample sizes are very small but anecdotal observations suggest that the sharks at Guadalupe Island and the Farallon Islands have a similar size distribution. Weng *et al*. (2007) visually estimated the length of 20 white sharks at the Farallon Islands, resulting in an average size of 13.45 feet.

Male white sharks become sexually mature at around nine to ten years of age. Females become mature around 14 to 16 years of age and can have between two and 14 pups per litter (Wilson and Patyten, 2008). The gestation period for female white sharks is believed to be in excess of one year, with available data suggesting a 14 to 18 month gestation period (Mollet *et al*., 2000), which means that female white sharks may breed only once every two years. Incidental gillnet bycatch of young-of-the-year white sharks indicates that female white sharks give birth between April and August, prior to their arrival at adult aggregation sites such as Guadalupe Island and the Farallon Islands (Domeier, unpubl.). Unpublished reproductive hormone data from sharks studied indicate that females at the Farallon and Guadalupe adult aggregation sites are not pregnant. Currently, it is not known where female white sharks from the Farallones give birth.

Off the west coast of the U.S. and Mexico (the region south of Point Conception, California, along the coast of the Baja Peninsula, Mexico), is a suggested nursery ground. Juvenile sharks tend to remain near shore over the continental shelf. Despite their small size they are capable of large-scale migrations and movements into the Sea of Cortez, Mexico. While not targeted, juvenile sharks are taken incidentally in a range of fishing gear.

White shark life history parameters such as late maturity, low fecundity, low natural mortality, and longevity (Table 2) mean that this species has a particularly low intrinsic rate of population increase. This, combined with the vulnerability of the species due to other factors, makes it particularly prone to depletion (Wildlife Conservation Society, 2004). (There is relatively little information on white sharks worldwide and the data presented in Table 2 are only used to show the range of parameters at the time and may not reflect conditions found in the northeastern Pacific white shark population.)

Table 2. Estimated life history parameters of white sharks

Age at maturity (years)	female: 12-14, male: 9-10
Size at maturity (feet)	female: 14.76-16.40, male: 11.48-13.45
Longevity (years)	≥23-36
Maximum size (feet)	≥21
Size at birth (feet)	3.58-5.41
Average reproductive age (years)	>20?
Gestation time (months)	>12?
Reproductive periodicity	2 or 3 years?
Litter size	Approximately 5 pups (2-10 pups/litter)
Intrinsic annual rate of population increase	0.04-0.056
Natural mortality	0.125

From: Wildlife Conservation Society, 2004

3.3.2 Other Fish

Fish are an abundant resource in the Sanctuary and the continental shelf and slope, in particular, are highly productive areas for commercial fisheries. The comparatively wide continental shelf and configuration of the coastline is vital to the health and existence of Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, northern anchovy (*Engraulis mordax),* rockfish (*Sebastes* sp.) and flatfish populations. The extension of Point Reyes and the resulting current patterns tend to retain larval and juvenile forms of these and other species within the Sanctuary, thereby easing recruitment pressures and helping to ensure continuing populations. Sanctuary waters surrounding the Farallon Islands serve as an offshore location for shallow and intertidal fishes that further enhance finfish populations (ONMS, 2010).

The Farallon Islands fish community is dominated by an assemblage of rockfish with more than 48 species inhabiting the Sanctuary's rocky banks in water depths greater than 180 feet. Shortbelly rockfish (*Sebastes jordani*) are found in greatest abundance near the Farallon Islands, particularly in waters deeper than 400 to 700 feet. At the mid-depth or meso-pelagic range over sand and mud bottoms, chilipepper rockfish (*S. goodie*), widow rockfish (*S. entomelas*) and Pacific hake (*Merluccius productus*) are common. Large predatory finfish such as sharks, tunas and mackerel are found in near shore pelagic areas. Concentrations of sardines, northern anchovies and Pacific herring (*Clupea pallasi*) are a critical food source for birds and marine mammals (ONMS, 2010).

The composition of fish species in the pelagic zone varies throughout the year with migration and spawning, and from year to year due to environmental fluctuations. A small number of migratory pelagic species dominate the fisheries of central and northern California, including northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), Pacific hake (*Merluccius productus*), and jack mackerel (*Trachurus symmetricus*). These pelagic species spawn in the Southern California Bight and migrate into waters off central and northern California but the composition of larval fish species varies with oceanographic conditions (ONMS, 2008).

3.3.3 Other Wildlife

Seabirds

The Farallon Islands is the most important area for nesting seabirds and home to the largest concentration of breeding seabirds within the contiguous United States (ONMS, 2010). More than 300,000 adult birds nest on the islands alone from May through July during the height of the breeding season. These and other birds are highly dependent on the Sanctuary's productive waters. Eleven of the 16 species of seabird known to breed along the U.S. Pacific coast have breeding colonies on the Farallon Islands and feed in the Sanctuary. These include Ashy and Leach's storm-petrels (*Oceanodroma homochroa, O. leucorhoa*); Brandt's, pelagic and double-crested cormorants (*Phalacrocorax penicillatus, P. kenyoni, P. auritus*); western gulls (*Larus occidentalis*); common murres (*Uria aalge*); pigeon guillemots (*Cepphus columba*); Cassin's auklets (*Ptychoramphus aleuticus*); tufted puffins (*Fratercula cirrhata*); and rhinoceros auklets (*Cerorhinca monocerata*; ONMS, 2010). These birds are present on the islands in response to upwelling that occurs in the late winter and early spring, which brings nutrients to the surface, creating a plankton bloom that supports the fish and krill that allow the seabirds to successfully raise their young.

General human-caused threats to bird populations include competition for food with commercial and recreational fisheries; entanglement in fishing gear; ingestion of marine debris; disturbance of roosting and breeding birds by watercraft, aircraft and human visitors; and oil spills. In addition to human impacts, changes in climate and oceanographic conditions also affect bird populations. The prevalence of marine birds using Sanctuary waters changes from year to year due to fluctuations in marine conditions, including El Niño, Pacific decadal oscillations, and changes in intensity and timing of upwelling conditions in the spring/summer (GFNMS, no date).

Changes in fish and krill abundance can also have cascading trophic effects on other species, including seabirds. For example, within the Gulf of the Farallones, common murres used to feed their chicks mostly juvenile shortbelly rockfish but turned to anchovies and sardines after rockfish became scarce. As another example, local Cassin's auklets did not breed in 2006 and had very poor breeding success in 2005 due to low productivity and severely reduced biomass of krill within the Gulf of the Farallones region (ONMS, 2010).

Marine Mammals

Thirty-six marine mammal species have been observed in the GFNMS: six species of pinniped (seals and sea lions), 28 species of cetaceans (whales, dolphins and porpoises) and two species of otter.

The Farallon Islands provide habitat for breeding populations of five species of pinnipeds, including the once-extirpated populations of northern fur seals and northern elephant seals. For more than 170 years prior to 1996, northern fur seals had not been known to breed on the Farallon Islands but recently a small colony of about 90 seals resumed breeding on the South Farallon Islands during the summer. From November through June, thousands of female and immature fur seals migrate through the western edge of the Sanctuary along the continental shelf. The Sanctuary also serves as a breeding ground for 20 percent of California's harbor seals (estimated at 32,000 in 2005). It also contains one of the last populations in California of the threatened Steller sea lion, which appear year-round throughout the Sanctuary. This threatened population has decreased dramatically in the southern part of its range, which includes the Farallon Islands. The population in the Gulf of the Farallones region has declined by 80 percent compared to population numbers from 50 years ago (ONMS, 2010).

The California sea lion is the most conspicuous and widely distributed pinniped in the Sanctuary. It is found year-round in the Gulf of the Farallones, with the population increasing at about eight to 12 percent each year. The northern elephant seal is the largest pinniped species in the Sanctuary, with a total breeding population of about 13,000. They are primarily found at Point Reyes, the South Farallon Islands, Point Año Nuevo and Año Nuevo Island. Immature (one and two-year old) northern elephant seals arrive at the Farallon Islands beginning in September and continuing through November. The small pocket beaches and surge channels around the islands offer undisturbed haul out sites and resting areas. The arrival period of the white shark coincides to the seal's arrival (Anderson, 2001). Northern elephant seals are known to be a critical food source to white sharks, and shark predation rates at the Farallon Islands have been found to increase or decrease depending upon current seal populations (Brown *et al*., 2010).

Significant changes in abundance and distribution of sea otters, Steller sea lions and northern fur seals can be attributed to human activities including hunting that drove these populations in California to near extinction. All three taxa are carnivores that can have considerable influence on lower levels of the food chain, and their removal can greatly affect community structure. Pupping rates and general population health of Steller sea lions in California have decreased since the 1950s. The breeding population at the Farallon Islands has stabilized in recent years, but remains depressed (ONMS, 2010).

Twelve cetacean species are seen regularly in the Sanctuary, and of these, the minke whale (*Balaenoptera acutorostrata*), harbor porpoise (*Phocoena phocoena*), Dall's porpoise (*Phocoenoides dalli*) and Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) are considered year-round residents. The harbor porpoise is the most abundant small cetacean in the Gulf of the Farallones, with 16,000 residing throughout Northern and Central California. The Sanctuary serves as a nursery for harbor porpoises and Pacific white-sided dolphins.

The Sanctuary is also a destination feeding ground for endangered blue and humpback whales, and is a major migration route for gray whales (*Eschrichtius robustus*), which migrate from Alaska southward through the Sanctuary from December through February. Their northward migration through the Sanctuary begins at the end of February and peaks in March but a few gray whales remain in the Sanctuary year round. The gray whale population has recovered to the point that it was recently removed from the Endangered Species List. Other large baleen and toothed whales migrate to the GFNMS to feed in its nutrient-rich waters during the summer and fall months.

Humpback and blue whales (estimated at 1,400 and 1,700 individuals, respectively, for California, Oregon and Washington waters) feed in the Sanctuary between April and November and represent one of the largest concentrations of these whales in the Northern Hemisphere. They also represent two of the few recovering populations of baleen whales found throughout the world (ONMS, 2010). Within the national marine sanctuaries of the Pacific coast, humpback whales were the most common whale species and Pacific white-sided dolphins were the most common delphinid (Forney, 2007).

3.4 Socioeconomic Environment

3.4.1 Tourism, Outreach and Conservation

White sharks have often been portrayed in popular media as blood-thirsty killers that hunt humans as prey. In fact, white shark attacks offshore California on humans are very rare (only 11 fatal cases since 1950; Wilson and Patyten, 2008). These encounters are hypothesized to be examples of humans being mistaken for their preferred pinniped prey.

White sharks are of economic value for ecotourism, such as viewing from a boat or cage diving, which is a relatively recent but rapidly expanding industry. Commercial passenger fishing vessels (party boats) have responded to increased interest in ecotourism by directing more effort toward whale watching, seabird and shark ecotourism trips (ONMS, 2010).

Two companies are currently permitted to operate ecotourism boats in the vicinity of the Farallones. These cage diving operations, which are specifically intended to view white sharks, are known as “adventure tourism.” Naturalists are on board these vessels and have been trained by the Sanctuary to present a scientifically accurate portrayal of white sharks to the public as well as communicate the following messages:

1. GFNMS protects the wildlife and habitats of one of the most diverse and bountiful marine environments in the world.
2. White sharks depend on the rich Sanctuary ecosystem and as apex predators, play a key role in maintaining a balanced ecosystem.
3. White sharks are considered internationally threatened and thus it is important to identify vulnerable life history stages so protection can be implemented.
4. Common myths have vilified white sharks. Debunk the myth— we are more of a threat to them then they are to us.
5. You can help conserve sharks—the information you share plays a critical role in the protection of the species.

A vessel monitoring study, lead by GFNMS in collaboration with PRBO Conservation Science Shark Watch and the U.S. Fish and Wildlife Service, is being conducted to assess whether vessel operators are complying with Sanctuary regulations and to provide baseline information of vessel traffic near SEFI. The vessel monitoring study is part of a larger survey effort that has been occurring for the past 22 years by biologists positioned at the SEFI lighthouse. The vessel monitoring study is conducted in conjunction with observations of white shark predation events, which are recorded between September 1 and November 30, during daylight hours. The total number of survey hours per day depends on the number of biologists on the island and the surveys are cancelled and resumed at a later time, if weather limits the visibility of the observer to less than one kilometer of water around the island.

As many as 12 vessels have been seen in the vicinity of SEFI at one time (which occurred on October 11, 2009) but for more than half the time of the observations, no vessels were in the area. The two most frequently seen vessels at SEFI include recreational fishing vessels and commercial vessels (refer to Sections 3.4.2 and 3.4.3). Recreational vessels seen in the vicinity are generally 18 to 35 feet in length. Commercial vessels include eco-tourism vessels, whale watchers and bird watchers that frequently pass through and visit near the island. These types of vessels can range from about 54 to 65 feet and generally they are not fishing. As many as four recreational sailboats have also been observed at SEFI at one time (S. Tezak [GFNMS], pers. comm.).

3.4.2 Sport and Commercial Fishing

A small number of migratory pelagic species dominate the fisheries of central and northern California, including northern anchovy, Pacific sardine (*Sardinops sagax*), Pacific hake and jack mackerel (*Trachurus symmetricus*). These pelagic species spawn in the Southern California Bight and migrate into waters off central and northern California; however, the composition of larval fish species off central and northern California varies with oceanographic conditions (ONMS, 2010).

Productive commercial fisheries for deep-sea fish occur on the continental slope. The species targeted include deep-sea rockfishes such as blackgill rockfish (*Sebastes melanostomus*), thornyheads (*Sebastolobus* sp.), sablefish (*Anoplopoma fimbria*) and Dover sole (*Microstomus pacificus*). Many of these species occupy similar habitats and generally are caught together (ONMS, 2010). Trawling activity levels have been reduced by recent area closures that are intended to allow for the recovery of many of the offshore impacted habitats. A recent study by de Marignac *et al*. (2009) suggests that trawling continues to impact Sanctuary resources but that recovery is happening in areas where trawling has been curtailed (ONMS, 2010). Overharvest of some rockfish populations (i.e. yelloweye, canary and cowcod), combined with poor recruitment, has severely impacted their populations along the West Coast and has resulted in the closure of some groundfish fisheries in an attempt to rebuild depleted populations (ONMS, 2010).

Recreational or sport fishing primarily targets rockfish species, lingcod (*Ophiodon elongates*), California halibut, striped bass (*Morone saxatilis*), salmon species, albacore (*Thunnus alalunga*), surfperch species and Dungeness crab. A recreational fishery for Humboldt squid (*Dosidicus gigas*) has begun, but the levels of take and impacts from the recreational catch of squid have not yet been assessed (ONMS, 2010).

The California Recreational Fisheries Survey provides the best estimates available on recreational catch of finfish by geographical area. Overall, recreational fishing effort appears to have stabilized for at least two reasons: fishing regulations have become more restrictive by depth and season, and some bag limits have been reduced in the past decade (ONMS, 2010). Fishing generally occurs north and south of SEFI but the fishing boats may come near the island for shark predation events and just to see the island (S. Tezak [GFNMS], pers. comm.).

On May 1, 2010, the North-Central Coast Marine Protected Areas went into effect under the California Marine Life Protection Act. This included 22 marine protected areas, three State Marine Recreational Management Areas, and six Special Closure Areas that cover approximately 153 square miles (20.1 percent) of state waters within this north central coast area. The protected areas near the proposed project are the: North Farallon Islands and SEFI State Marine Reserves, North Farallon Islands and SEFI Special Closures, and SEFI State Marine Conservation Area (http://www.dfg.ca.gov/mlpa/pdfs/nccmpas/nccmpas_guide.pdf). The Special Closure at SEFI is year-round, extending 300 feet offshore except at Fisherman's Bay and East Landing, which has a seasonal closure from December 1 to September 14. At North Farallon Islands, there is a year-round, 1,000-foot closure including a 300-foot closure around the Isle of St. James.

3.4.3 Recreational and Commercial Vessel Traffic

For recreational boaters, the Gulf of the Farallones can provide a magnificent cruise to the vicinity of the islands during mild weather but often this passage is turbulent and landings on the islands are not allowed. For any recreational boater in distress, the islands would not be able to provide a safe port of refuge (California Dept. of Boating and Waterways, no date). The Farallon Lighthouse is located on SEFI and there is anchorage in about 50 feet of water just north of the lighthouse but it is considered a "fair weather berth" (Fagan, 2002).

The GFNMS contains some of the West Coast's busiest shipping lanes with the fifth largest port in the nation located in San Francisco Bay (California Dept. of Boating and Waterways, no date). Three major shipping lanes converge in the Sanctuary just west of the Golden Gate Bridge at the entrance to San Francisco Bay. The volume of large vessel traffic in and out of San Francisco Bay totaled more than 6,000 inbound and outbound transits in 2004 (GFNMS, no date).

Shipping traffic can be hazardous to marine life via direct collisions (particularly cetaceans) and via toxins disbursed into the air and the sea. Vessel traffic has also been increasing, which results in increased impacts from noise, dredging of shipping lanes, discharges of ballast and wastewater from cargo vessels and cruise ships, and increased potential for large oil spills. However, there has also been an increase in management and enforcement activities to help reduce the amount of chronic oil pollution from sunken vessels and illegal discharges of oily bilge water (ONMS, 2010).

Fig. 13. Vessel Traffic Scheme for Gulf of the Farallones (NOAA Nautical Chart #18465).

To minimize the risk of collisions and groundings of large, ocean-going vessels, the U.S. Coast Guard's Vessel Traffic Service was established in 1972. The system designates separated traffic lanes, a precautionary area and seven regulated Navigation Areas, to coordinate the flow of deep-draft traffic into, out of and within the central portion of the bay (California Department of Boating and Waterways, no date). The established traffic lanes are shown in Figure 13, which are northeast and southeast of the Farallon Islands.

4. ENVIRONMENTAL CONSEQUENCES

4.1 Alternative 1: Proposed Action

The following is the effects analysis regarding the impacts of the proposed action on the environmental conditions that were discussed in Section 3.

4.2 Physical Environment

4.2.1 Air quality

The project's primary research vessel would remain on-site for five days at a time for possibly 30 days total during the proposed four-year project duration but this would be highly dependent on weather and capture/tagging success. The main engine is a Mitsubishi S12 R-MPTA (four/cycle, direct-injected, twin turbocharged and after-cooled V 12 cylinder) that burns 35 gallons of diesel per hour. This would be shut down while on-site but a generator would run around the clock for auxiliary power. The generator is a John Deere 4045T FM75 (turbocharged, inline four cylinder diesel engine) that burns 3.5 gallons per hour. When the boat is on auxiliary power, it would burn 84 gallons of diesel in a 24-hour period. The ship's primary engine would burn approximately 140 gallons of diesel per round trip to the site (approximately six trips total). The estimated fuel used for the length of the project would be 3,360 gallons of diesel.

The small boat (type unknown but likely this would be 20 to 25 feet in length with dual outboards) would only run during the portion of time the shark is hooked and in the water; generally the boat would remain in idle. This vessel would average about 0.5 gallons of gasoline/day or 15 gallons for the length of the project.

Table 3 provides a comparison of the expected emissions of the project over four years compared to mobile emissions in San Francisco County from vessels on the Outer Continental Shelf and out to 100 miles offshore. Half of the estimated diesel emissions from the proposed project would occur during the transit to the project site.

Table 3. Emission Estimates for the Proposed Project.

Pollutant	Emissions from the proposed project over four years	2008 offshore marine emissions for San Francisco County
	Diesel	
Carbon Monoxide	370 pounds	4,100 pounds
Nitrogen Oxides	907 pounds	27,320 pounds
Sulfur Oxides	91 pounds	11,540 pounds
	Gasoline	
Carbon Monoxide	27 pounds	N/A
Nitrogen Oxides	1 pound	N/A
Sulfur Oxides	0.1 pound	N/A

The overall exhaust from the project vessels is expected to have a minor impact on air quality near the Farallon Islands, similar to other vessels that enter the Sanctuary, but this impact is likely to be short-term as the typical prevailing winds would rapidly disperse these pollutants.

4.2.2 Water Quality

The tagging process would involve placing a hook baited with salvaged marine mammal flesh and blubber into the water. The bait would slowly leak marine mammal lipid (i.e., fatty substance) into the water, causing a temporary slick that is expected to dissipate within hours of the baits' removal from the water, as the current carries it away from the source. This slick would not be expected to have any lasting impact on water quality. Such slicks are also naturally created each time a white shark kills a seal within the GFNMS.

Vessel operations have the potential to affect water quality from accidental releases or unlawful discharges of petroleum products or wastes from sewage. The vessels that would be used for the proposed research would be in compliance with applicable U.S. Coast Guard and State of California boating laws to ensure that unlawful discharges are prevented and to reduce the potential for accidental releases.

4.2.3 Noise

The sound of the engines and generator would be heard by people or animals that may approach or be in the vicinity of the vessel. This slight increase in ambient sound would not likely affect the environment in any lasting or meaningful way; it would be the same as other activities that utilize boats near the Farallon Islands. The majority of the vessel time is also not expected to occur between March 15 and August 15 when vessel traffic is prohibited within 300 feet of the shoreline in certain areas of Southeast and North Farallon Islands. The research vessel would also abide by the five mile per hour speed limit and noise restrictions within 1,000 feet of all islands resulting in minimal impact to wildlife on or near the Farallon Islands. There are no other sensitive resources near the proposed study site that could be affected by noise from the project's research vessels.

4.3 Biological Environment

4.3.1 White Sharks

Population

The proposed project would involve a sample size of 11 individuals (13 cumulatively), which may represent up to five percent of the population of adults and sub-adults offshore central California (Chapple, pers. comm.) but the total population size has not been established. As proposed, the overall number could be larger than 11 if more males are caught before the desired eight females are tagged. Seventeen white sharks have already been SPOT-tagged using these methods at Guadalupe Island, along with four in southern California and two at the Farallones, and all have been re-sighted or their tags have transmitted to satellites (the tags will only transmit if the shark is at the surface). This indicates no mortality associated with tagging efforts to date and white sharks are not anticipated to be killed from the proposed tagging project.

If a female with a late-term pregnancy were captured there could be a risk of causing the fetal sharks to be aborted due to the pressure of the shark's own weight out of water, but pupping is documented to occur in early summer (Klimley, 1985). Unpublished reproductive hormone data indicate that the females tested at the Guadalupe Island adult aggregation sites are not pregnant. It is unlikely but not conclusive that females would be pregnant during the season of capture and tagging. It is also unlikely that female white sharks at the Farallon Islands are carrying late-term embryos given that they do not arrive until after the expected time of pupping. Hormonal analysis from blood samples taken from the sharks during the study would be useful information to confirm the females' pregnancy status.

Behavior

All the sharks currently being tracked via the SPOT tags are exhibiting known, normal migration patterns as determined by previous PSAT tagging (Boustany *et al*., 2002; Weng *et al*., 2007; Domeier and Nasby-Lucas, 2008; Jorgensen *et al*., 2010). Although sufficient numbers of SPOT-tagged individuals are not available to conduct a statistically meaningful analysis, all of the SPOT-tagged males resumed their normal seasonal migratory patterns (Domeier, unpubl. data).

Data from prior PSAT tagging studies indicate that the timing of departure of individual sharks is not synchronous; instead it is highly variable. More insights can be gained by comparing PSAT and SPOT tagged animals from Guadalupe Island where the sample size is larger. The males appear to resume their typical migratory cycles, generally moving offshore to the SOFA/Café and then returning to the island. Most of the SPOT-tagged sharks at Guadalupe remained in the vicinity of tagging after release but on two occasions a released shark migrated 100 to 200 miles offshore before immediately returning to the island. These sharks routinely cover great distances and it is not known if this behavior was caused by the tagging; SPOT tagged sharks have been observed to make such movements a year or two after tagging, which indicates that this behavior is not only associated with the stress of capture (Domeier, unpubl.). SPOT tagged sharks from both the Farallones and Guadalupe Island migrated offshore and returned, as one would predict from previous data collected with PSAT tags. SPOT tagging does not appear to affect seasonal migration.

Table 4 depicts the departure dates of the two sharks tagged in 2009. Shark #1 is the individual that had part of the hook left in its esophagus.

Table 4. Tagging, Departure and Return Dates of Farallon Sharks

	Tagging date	Departure date	Return date	Expected Departure Range
Shark #1	October 29, 2009	~ December 13, 2009	~ July 26, 2010	Mid-November through March
Shark #2	November 2, 2009	~ November 8, 2009	~ August 4, 2010	

Both sharks left the GFNMS earlier than average based on previous observation by Jorgensen *et al*. (2010) and Weng *et al*. (2007), although departure times appear to be quite variable. In the Jorgensen study, most tagged shark departures began after December 1, with the majority of departures occurring in January through mid February. In the Weng study, departures occurred between November 19 and March 24 with an average departure date of January 2. However, in 1997 and 2009 orcas (*Orcinus orca*) were present near the Farallon Islands and white sharks tagged with PSAT tags have been found to depart the Farallones for their offshore habitat shortly after an observed orca predation event. For example, on October 4, 1997, an orca was observed preying on a white shark (Pyle *et al*., 1999). Following this, two more white shark sightings were observed but only 12 white shark observations in total in 1997, while there were 48 sightings on average per month from 1987 through 2009 (Tiez, 2009). Orcas were also present in 2009 at the approximate time of the SPOT tagging. After the orcas were seen in 2009, the sighting rates of white sharks dropped with a total of 15 observed predation events for the year (Tietz, 2009). The orcas were first sighted in the GFNMS on November 2 and the available sightings data for the area indicate no records of sharks in the area past November 8, 2009. While the departure dates of the two tagged Farallon sharks – especially the one on November 8 – may be earlier than most based on the other tagging studies, it is not possible to assign a cause to these departures. Whether or not the departure of the tagged sharks was directly or indirectly caused by the orcas cannot be proven or disproved but it remains a possibility. As was shown in Figure 5, both tagged sharks are exhibiting what are considered normal migration patterns.

Information presented by the Monterey Bay Aquarium's White Shark Project, which began in 2002, provides some evidence that even long-term, captive sharks will resume normal behavior patterns once released. Monterey Bay Aquarium has caught, or obtained from fishermen, five white sharks from southern California that were kept on exhibit as long as 6.5 months and as little as 11 days. Once released, these sharks resumed patterns that were considered expected for normal behavior (http://www.montereybayaquarium.org/cr/whiteshark.aspx).

It is possible that the stress of capture could disrupt behavior but there is no evidence for this. Based on the available information, there could be minor, short-term impacts on the behavior of up to 11 white sharks as a result of the proposed research.

Hooking and Tagging

Although hook-and-line fishing stresses the captured sharks, this level of stress is necessary for the safe handling of the shark. The sharks must be brought on deck because the tag cannot be safely and securely affixed to the dorsal fin while the shark remains in the water. If sharks were captured without physiological stress, they could inflict serious injury to themselves and to the researchers by expending their energy on deck. It appears that the stress from capture is temporary based on previous tagging results in which the sharks resumed expected seasonal migratory behavior.

One of the greatest potential threats to the sharks in this study is the wound caused by the hook. When hooked in the mouth the shark will receive a superficial wound that, based upon field observations, will rapidly heal (Domeier and Nasby-Lucas, 2007; Fig. 6, this document). New methods were developed as a result of the white shark that was hooked in the throat at the Farallon Islands in 2009. Although the shark in question survived and is providing excellent tracking data (Fig. 5), the causes of the incident were analyzed and improvements to the capture method were implemented for the proposed research.

One new method being proposed is to use a device to prevent the shark from swallowing the hook. One potentially negative effect from the use of this type of device is that it could break during the hooking and capturing of the shark thereby allowing the shark to swallow a piece of the plastic. Although this possibility exists, it is expected that the shark could regurgitate the PVC without any lasting harm to the animal. For example, sharks have been documented to swallow PSAT tags and regurgitate them days to weeks later (Kerstetter *et al*., 2004). Another drawback of using a preventer device is that if it is broken during the operation, there would be discharge to the Sanctuary because the pieces would not likely be retrieved before they sink.

A secondary method being considered to reduce the risk of the hook getting lodged in the stomach, throat or gills involves presenting the baited hook at the surface, so that the shark has to turn away from the line as soon as the hook is taken into the mouth. Pressure would be immediately placed on the line to prevent the shark from swallowing the hook and this would theoretically set the hook either in the mouth or it would be pulled free. This method would also significantly reduce the possibility of the shark swallowing the hook.

A study in South Australia found that 10 to 30 percent of free-swimming sharks that were sighted carried remnants of fishing gear or showed signs of damage from capture (Wildlife Conservation Society, 2004). A white shark that had been struck by a whale watching vessel in 2008 offshore Cape Town, South Africa, was found to have completely healed from a large and deep propeller wound when it was sighted nine months later (Towner, Smale and Jewell, 2010). All of the 23 white sharks previously SPOT-tagged by Dr. Domeier that had been captured by the proposed hook-and-line method have survived.

The long-term impacts of carrying SPOT tags are likely to be minimal. There are no “temporary” multi-year tags available and also no small device that could trigger a release of the tag safely after multiple years but the use of nylon bolts rather than stainless steel increases the chances that the tags will break free after time because the plastic fasteners will degrade. Photos of tagged sharks two years after tagging indicate that biofouling of the tags is very minimal due to the anti-fouling paint used on the surface of the tags, which does not come into contact with the skin. It is likely that tags will become more fouled in the future as the paint wears off and this could have a minor effect due to drag or abrasions on those sharks in which the tags stay attached for more than two or three years.

Although adult white sharks can normally be brought onto the platform right-side-up or on their sides, occasionally an individual could turn upside down when entering or exiting the platform. Some sharks have remained motionless, with the exception of gills pumping, for short periods of time after tagging and this may be a case of tonic immobility. It is not known what causes tonic immobility but many species of sharks have been found to go into tonic immobility when turned upside-down. Many researchers use tonic immobility as a regular part of the tagging and handling methods and there is nothing to suggest that tonic immobility has either short or long-term impacts on the health of sharks. In all cases, the sharks revived and swam away.

In this study as proposed, as soon as the sharks are lifted from the water, they would be immediately irrigated with fresh seawater, which would provide a steady flow of oxygen. It has been found that the short time white sharks would be kept out of the water (20 minutes or less) does not affect their survivorship and does not seem to cause any other lasting effects. This 20-minute guideline is not a “threshold,” *per se*, since white sharks have been kept out of the water for longer periods without incurring mortality. The goal of previous SPOT tagging was to conduct the research activities as quickly as possible and with all due consideration to the duration the shark remains on deck to ensure that they are returned to the water in the least amount of time. The proposed study would ensure that the sharks are back in the water in a timely manner by using this arbitrary guideline of 20 minutes or less even though it is not known how long white sharks can be kept out and not suffer debilitating effects. White sharks are known to exploit very deep ocean depths where oxygen levels are low and this could explain their tolerance to anoxic conditions for short periods of time but it is not directly comparable to tiring a white shark then bringing it on deck. An even larger species of shark, the whale shark, has been lifted from the water, supplied with oxygenated water over its gills and then transported via long flights and trucks to aquarium destinations for display, which further demonstrates the physiological resilience of sharks.

The stresses described above from the hooking and tagging procedures are expected to cause short-term, minor impacts to the animals.

Sub-lethal Effects

There are concerns that the sharks could suffer injury to their internal organs due to the pressure of lying unsupported on the deck. Organ crush has been observed to occur in very large baleen whales but these whales are an order of magnitude larger than white sharks. Furthermore, whales have air space within their bodies (lungs) whereas sharks do not. Air spaces are very compressible but the lack of such a space in sharks makes them relatively incompressible. Organ injury due to the weight of a shark out of water has never been documented. Many of the previous studies that have been conducted with other sharks have been done in the water or in a cradle or sling, and are not directly comparable to lying on a flat deck. Unfortunately, any type of internal injury and its potential impacts are difficult to assess but all 23 SPOT-tagged sharks have resumed normal behaviors and do not appear to have suffered any internal injuries.

Photographic data of SPOT-tagged sharks, taken years after tagging, show there has been very little fouling and no necrosis on the fin. These results do not provide information on the potential for sub-lethal impacts; however, and any type of internal injury or its potential impacts are difficult to assess. One possible indicator of sub-lethal stress is the post tagging behavior of the sharks and the resumption of normal seasonal migrations. Practically nothing is known about their mating behavior and it cannot be determined whether there would be any effect on mating behavior nor are there any means of studying whether such an impact has occurred. The maintenance of normal seasonal migratory patterns in males suggests that sub-lethal effects are not debilitating and have not had any significant impact.

The proposed research could have positive implications on the Sanctuary's management decisions related to the conservation and protection of white sharks that would outweigh the short-term negative effects of catching and tagging 11 white sharks resulting in a cumulative total of 13. The life history questions that could be answered by this research could also help foster increased coordination opportunities with other white shark aggregation areas such as Guadalupe Island as well as the protection of the pupping areas. Management decisions made by ONMS would benefit from the following information obtained from the proposed tagging project:

- Identifying regions/seasons that individuals from the Farallon Island white shark population are particularly vulnerable to threats;
- Determining the location of mature females during the years they are absent from the adult aggregation;
- Tracking mature females during the known pupping season to identify the connectivity between the pupping and nursery areas to the Farallones;

- Determining the degree and locations of mixing with the Guadalupe Island, Mexico, population of white sharks; and
- Determining the mating season and location for the Farallon Islands white shark population.

The research is proposed to occur within the GFNMS because of the separate population structure in the Gulf of the Farallones, and South East Farallon Island provides predictable access to adult white sharks as well as some protection from the wind and seas, which allows for safe research operations

4.3.2 Other Fish

The salvaged marine mammal flesh and blubber used to bait the hooks may temporarily increase the density of marine fish in the vicinity through the process of attraction. Although some fish species may pick at the bait, most of the life attracted to the bait would not benefit nor be harmed by its presence. If small pieces of bait are shed from the hook, some individual fish could benefit from this natural food source. No overall effect on fish habitat or fish populations would be expected since the project is not extracting or adding any resources to the GFNMS.

4.3.3 Other Wildlife

Seabirds

The seabird nesting season would be finished at the time of the proposed white shark research, so there would be no impact on the vast majority of species as they will have already departed. Some local species of gulls, however, may remain in the vicinity year round (GFNMS, no date), and could be attracted to the bait used to attract white sharks. This could provide a positive effect on the gulls, which may benefit from shreds of bait (pinniped or cetacean blubber) that fall from the hook. This could then result in an indirect negative effect to other birds on the island if the gull population increases but given the short time period of the research (estimated to be about 30 days total over four years), the total amount of bait available to the gulls would likely be negligible in comparison to the rich food supply generally available in the surrounding waters.

Marine Mammals

There are a number of cetaceans, delphinids and pinnipeds that may be present during the white shark research activities but there are no foreseen interactions between the research and these species. The most likely species to be in close proximity to the white shark research are elephant seals and California sea lions but they do not feed on pinniped or whale blubber and will not show any interest in the bait. The use of this bait has been authorized by NOAA National Marine Fisheries Service (refer to Appendix B) and the bait would be obtained from the Southwest Fisheries Science Center. No disease transmission or other effects to the cetacean, delphinid and pinniped populations in the area are anticipated from the use of this bait.

4.4 Socioeconomic Environment

4.4.1. Tourism, Outreach and Communication

White shark research can lead to a better understanding of white shark life history, which can be put into a realistic context for educating the public on the true role of this species in the marine ecosystem. White sharks are a charismatic species and therefore the public is interested in learning more about these relatively little-known animals. It is important to impart the message that humans are in fact a much larger threat to the survival of white sharks than vice versa.

The implementation of GFNMS shark attraction and approach regulations in March 2009 was intended to reduce user conflicts between shark researchers and adventure tourism, and prevent interference with the seasonal feeding behavior of white sharks. The presence of this research activity could enhance the possibility that passengers on shark viewing vessels would see white sharks near the Farallon Islands, providing a positive effect on these tourism vessels and their passengers.

4.4.2 Sport and Commercial Fishing

It is not likely there would be any effects to sport or commercial fishing activities as a result of the proposed project because the fisher men and women tend to focus their efforts in areas north and south of the study site.

4.4.3 Recreational and Commercial Vessel Traffic

No effects to commercial traffic would occur as a result of the proposed project because the routes taken by commercial vessels that are entering or exiting the San Francisco Bay area are sufficiently far enough away such that no potential for conflict exists.

The presence of the proposed research activity could enhance the possibility that people on recreational vessels in the vicinity of the islands would see white sharks, likely providing a positive effect if they are aware of the purpose of the research. Otherwise, seeing the attraction of white sharks without knowledge of the conditions of the permitted activity could result in a misunderstanding of Sanctuary prohibitions related to feeding or attracting white sharks. Outreach efforts to boaters about the research efforts could minimize the potential for this effect.

4.5 No Action Alternative

Taking no action would alleviate any stress related to the capture of the proposed SPOT-tagged individuals. Any negative or positive public perceptions that might be generated about the study in the Sanctuary would be eliminated.

Not having long-term monitoring data on GFNMS white shark populations, particularly the females, could inhibit the identification of vulnerable life history stages. The lack of data could also hinder the implementation of domestic and international management efforts that could lead to better conservation and protection practices for this species.

Existing permitted white shark research activities are not capable of determining the location of females in the years they are absent from the GFNMS. Without a complete understanding of GFNMS white shark life history, the extent to which these sharks are vulnerable when they are not within the refuge of the Sanctuary will remain unknown, impeding efforts to fully protect this population in the future.

5. LIST OF PREPARERS

The following were involved with the development of this EA.

Name	Title	Education
Irina Kogan	NOAA, Resource Protection Specialist	B.S. Tufts University; M.S. University of North Carolina at Chapel Hill
Carliane D. Johnson	NOAA Consultant, Resource Protection Specialist	B.S. Florida State University
Michael L. Domeier	President, Marine Conservation Science Institute	B.S. Florida Institute of Technology; Ph.D. Univ. of Miami

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Appendix A: Chronological List of Dr. Domeier's Scientific Publications

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Appendix B: Letter of Authorization to Possess Blubber from Pinnipeds or Small Cetaceans

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

151408SWR2009PR00006:JGC

AUG 20 2009

Michael L. Domeier, Ph.D.
President
Marine Conservation Science Institute
2809 South Mission Road, Suite G
Fallbrook, California 92028

Dear Dr. Domeier:

Thank you for your letter requesting authorization to possess pinniped and small cetacean carcasses for use in the Institute's white shark life history study. The specimens will be obtained from our Southwest Fisheries Science Center. The specimens will be used to lure white sharks close enough to the research vessel so that they may be captured and tagged externally with Smart Position or Temperature Transmitting (SPOT) tags.

This letter authorizes the Marine Conservation Science Institute to possess the aforementioned specimens for scientific purposes, provided that the specimens are used in the white shark life history study only. The specimens may be used in areas both inside and outside any national marine sanctuary in California, provided that you possess the appropriate Sanctuary permits. You must also adhere to any special conditions included in any Sanctuary permit that differ from this authorization. This authorization is valid for five years.

You should provide us with an annual report of all specimens received. The report should include the specimen type (carcass), the species, the field identification number of the animal, the animal's original stranding date, the date you received the specimen, the final disposition of the specimen (destroyed, discarded, or ingested by shark), and the date of the final disposition. The report should be received in our office no later than February 1 of each year. We would also appreciate receiving a copy of your findings at the conclusion of your research.

If you have any questions, please contact Joseph Cordaro, Coordinator of the California Marine Mammal Stranding Network, at (562) 980-4017.

Sincerely,

Russell Strach
Acting Assistant Regional Administrator
for Protected Resources

Appendix C: Glossary of Terms

^{0}F	degree Fahrenheit
EA	Environmental Assessment
CFR	Code of Federal Regulations
CITES	Convention on International Trade of Endangered Species
DDT	dichloro-diphenyl-trichloroethane
DNA	deoxyribonucleic acid
FONSI	Finding of No Significant Impact
GFNMS	Gulf of the Farallones National Marine Sanctuary
MCSI	Marine Conservation Science Institute
NOAA	National Oceanic and Atmospheric Administration
ONMS	Office of National Marine Sanctuaries
PCBs	polychlorinated biphenyls
PRBO	PRBO Conservation Science
PSAT	Pop-up Satellite Archival Tag
PVC	poly-vinyl chloride
SAC	Sanctuary Advisory Council
SEFI	Southeast Farallon Island
SIMoN	Sanctuary Integrated Monitoring Network
SOFA	Shared Offshore Foraging Area
SPOT	Smart Position or Temperature Transmitting Tag
SWQPAs	State Water Quality Protection Areas
USFWS	United States Fish and Wildlife Service