CA-SMWP station	Station #	Sample Date	Mussel Type	Exceedance Criteria EDL85[a]	EDL95[b]
Santa Catalina Island/Ribbon Rock	682	12/1980	resident	------	------
		9/1990	resident	Zn	Zn
		2/1993	resident	Pb, Cr	Cr
Santa Catalina Island/Ben Weston	683	12/1980	resident	Cr	Cr
Santa Catalina Island/Silver Canyon	684	12/1980	resident	Cr	------
Santa Catalina Island/Church Rock	685	12/1980	resident	------	------

[a]EDL85: 85th percentile for statewide CA-SMWP samples from 1977-1997.

[b]EDL95: 95th percentile for statewide CA-SMWP samples from 1977-1997.

Summary of sentinel mussel results for the Channel Islands

Trace elements. *Based on California distributions*, mussels in and near the Park have contained elevated levels of several metals in recent years (most frequently, Cd, Pb, Ag, and Cr). In addition, *compared to national distributions*, arsenic (As) has consistently been above the national median, and also "high", in mussels in or near the Park. High concentrations of some trace elements may represent entirely natural conditions (O'Connor 2002). When *groups* of sites in particular regions, rather than individual sites, show high concentrations of particular trace elements, a natural source is more likely. Some natural sources for Cd, Pb, Ag, and Cr have been identified in U.S. surveys. For example, the high As concentrations in southeast U.S. molluscs are probably due to phosphate deposits in that region (Vallette-Silver et al. 1999). The serpentine rocks of the Northwest are a source of both the Cr and Ni that are found at high levels in molluscs along that coast, and serpentine outcrops may be the source for the high Ni in oysters in the Mid-Atlantic (O'Connor 2002). Goldberg et al. (1983) and Farrington et al. (1983) suggested that the high Cd concentrations in mussels of Northern California may reflect the fact that the coastal water in that region upwells from the deep Pacific and that deep ocean waters are naturally enriched in Cd relative to surface waters. Whether or not the high levels of Cd, Pb, Ag and Cr in Park mussels are explained by upwelling, minerals in exposed bedrock, or some form of anthropogenic contamination, has not been investigated. Trace element concentrations evaluated by Lauenstein and Daskalakis (1998) indicated that between 1965 and 1993, more sites on the west coast of the U.S. experienced declines than increases in Ag, Cd and Pb in sentinel mussels. However, from 1986-2002, Ag, Cd and Pb in sentinel mussels at Santa Cruz have not shown decreasing trends (Table 17). In fact, the maximum levels of Cd and Pb measured by the NOAA-MWP in Santa Cruz mussels were obtained in 2001 and 2002, respectively. Interestingly, nationwide, high concentrations of As, Ni, Se and Cd in sentinel bivalves are inversely correlated with human population (O'Connor 2002), suggesting that hot spots for these trace elements are less likely being caused by anthropogenic pollution than are hot spots for other trace elements, such as Pb and Ag. This phenomenon suggests that natural explanations for high levels of As and Cd in Park mussels may be appropriate.

Organic contaminants. Among the islands, the highest DDT levels in the available record were found at San Miguel in 1977-78 - more recent data for the island are unavailable to indicate whether or not San Miguel remains a DDT hot spot. The above was true despite the fact that, among all the islands, San Miguel is the furthest from the most significant source of DDT contamination in the region: sediments near the White's Point outfall on the Palos Verde Shelf.

In 1977, the most contaminated mussels sampled by the CA-SMWP at San Miguel (65.8 ppb DDT based on wet wgt) contained 39% as much total DDT as was contained in mussels at White's Point in 1982 (170.8 ppb DDT based on wet wgt). Although lower than at San Miguel, DDT was also "high" in mussels from Santa Cruz and Catalina as recently as 1996 and 1990, respectively, at the national level. Nationwide, and along the west coast, total DDT, dieldrin and total PCBs are declining in sentinel bivalves (Lauenstein and Daskalakis 1998). Compared to the national distribution, PCB levels have not been notably high in mussels at the islands. However, at the state level, PCB contamination was notable (>EDL85) in mussels from San Miguel in the late 1970s. Consistent with regional trends, the NOAA-MWP time series for Santa Cruz and Catalina suggest that PCBs have declined in mussels at these two islands (Figure 52). MTRLs for PCBs were exceeded in almost every mussel sample taken from every island, indicating that PCB levels in water and mussels around the islands may still be a concern from a human health perspective, and presumably from the perspective of marine mammal health.

Interestingly, total PAH was highly elevated in NOAA samples at both Santa Cruz and Catalina in 1986, but not at any other time sampled. PAHs were analyzed by NOAA at San Miguel in 1988, but were not high at that time. Given that PAH residue in bottom fish taken from the Park (Pacific sanddabs) has a petrogenic, rather than a pyrogenic, signature (Brown and Steinert 2003), it may be appropriate to assume that PAHs in sentinel mussels at the Park also have a petrogenic origin. It would be interesting to know whether events related to the extraction of oil led to transient high levels of PAHs in mussels at these two sites - although the distance between Catalina and Santa Cruz makes a single event a less likely explanation. Given that Hostetler et al. (2004) identified natural seeps near the Park, and one seep in particular off of Fraser Point on Santa Cruz, as the source of the majority of tar that washes up on the beaches in the Park, it seems logical to assume that some fraction of the PAH in Park mussels has a local origin.

III. OTHER CONCERNS

A. EXOTIC SPECIES THAT DIRECTLY AFFECT AQUATIC RESOURCES

A.1. Non-native plants in riparian zones and wetlands

Eucalyptus was brought to the islands during the ranching era, and stands of *Eucalyptus* occur in several locations in the Park, especially in valleys and at harbors on Santa Cruz where ranchers resided. *Eucalyptus* is colonizing the riparian terraces of a number of streams on Santa Cruz (Noon 2003). There have been reports from Australia of decreases in water yield from catchments where *Eucalyptus* plantations have been established (Whitehead & Beadle 2004, Ruprecht & Stoneman 1993), or where *Eucalyptus* forest has replaced native vegetation of shorter stature in South Africa (Dye 1996) and in southern India (Calder 1986). It is tempting to speculate that *Eucalyptus* may have altered the water economy in portions of some drainages in the Park, perhaps reducing water levels in streams or coastal wetlands at some sites. Non-native plants that are displacing native wetland vegetation at some sites include Kikuyu grass (*Pennisetum clandestinum*), smilo grass (*Piptatherum miliaceum*), black mustard (*Brassica nigra*), fennel (*Foeniculatum vulgare*) and milk thistle (*Silybum marinum*) (Noon 2003).

A.2. Feral Pigs

Domestic pigs were introduced to Santa Cruz in 1852 during the occupation of the island by European sheep and cattle ranchers (Schuyler 1988). By 1857, pigs had escaped and become feral on Santa Cruz. Recent annual estimates of the island's pig population have ranged from 1,500 to over 4,000 (CINP 2002a). The environmental consequences of the feral pig population on Santa Cruz has been well described elsewhere (Coonan et al. 2005, Roemer & Wayne 2003, Roemer et al. 2002, CINP 2002a). Feral pigs were implicated in the colonization of Santa Cruz by non-native golden eagles (and the consequent near-eradication of the endemic Channel Island fox), and in the spread of invasive weeds (notably fennel). In addition, feral pigs feed directly on intertidal animals. It is a common contention that the rooting activities of feral pigs has increased erosion and sediment delivery to streams on Santa Cruz. Because feral pigs occur throughout Santa Cruz, the observed differences in the frequency of slope failures (Pinter & Vestal 2005) and nearshore sediment plumes (Otero & Siegel 2004) between the TNC- and NPS-owned portions of the island are probably related to the different lengths of time that sheep have been absent from the two parts of the island. At any rate, a lack of stream studies on Santa Cruz, and the presence of feral pigs throughout the island, makes it difficult to ascertain whether feral pigs actually increase turbidity or sediment transport in island streams. A program to eradicate the feral pigs on Santa Cruz began in March, 2005, and was still in progress at the time of this writing. Feral pigs were also present on Santa Rosa, but were eliminated by 1993.

A.3. Elk and Deer

Vail & Vickers Co. continue to operate a commercial hunting operation for trophy elk and mule deer on Santa Rosa (http://mumwildlife.com/index.php?pg=santarosa). Currently, 425 deer and 740 elk are allowed, although as recently as Dec., 2005, the numbers were a little lower than that (Kate Faulkner, Chief of Natural Resources, Channel Islands National Park, pers. comm.). As discussed in Sections I.C.1 and II.C.3, riparian corridors on Santa Rosa have recovered substantially, and stream water quality has improved, following the complete removal of cattle from the island in 1998. However, according to Park staff, preferential browsing of seedlings by elk and deer is one of the major factors preventing the reestablishment of woody riparian species such as arroyo willow and black cottonwood (the other postulated factor being a shortage of seed sources). Barring future legal maneuvering[15], or changes in the agreement between Vail & Vickers and the federal government, negative impacts caused by elk and deer should diminish in the near future as the hunting operation is phased out, and as the animals are destroyed or removed from the island. Annual reductions in herd size are scheduled for every year beginning in 2008, and complete removal of the elk and deer is scheduled for 2011 (Kate Faulkner, Chief of Natural Resources, Channel Islands National Park, pers. comm.).

[15] For example, on May 3, 2006, the House Armed Services Committee passed a measure by committee Chairman Duncan Hunter (R-Alpine) that would void the court-ordered settlement requiring the elk and deer removal by 2011. The measure is designed to preserve the herds with the a goal of making Santa Rosa Island a hunting destination for disabled veterans. The ultimate fate of this legislation was unknown at the time of this writing.

A.4. Arundo donax

One of the greatest threats to the dwindling riparian resources of coastal southern California is the alien grass species known as *Arundo donax* (Arundo). Arundo (referred to as giant reed, bamboo reed, giant reed grass, arundo grass, donax cane, giant cane, river cane, bamboo cane, and canne de Provence) is among the largest of the grasses, growing to a height of 8 m. It is believed to be native to eastern Asia, but has been cultivated throughout Asia, southern Europe, north Africa, and the Middle East for thousands of years and has been planted widely in North and South America and Australasia in the past century. It was intentionally introduced to California from the Mediterranean in the 1820s in Los Angeles area as an erosion control agent in drainage canals, and was also used as thatching for roofs of sheds, barns, and other buildings. Arundo is also grown to make reeds for musical instruments.

Over the last 25 years the riparian corridors of coastal southern California have become infested with Arundo[16]. Arundo is a hydrophyte, growing along lakes, streams, drains and other wet sites. It uses prodigious amounts of water, as much as 2,000 L/m2. Under optimal conditions it can grow more than 5 cm per day. Arundo dramatically alters the ecological and successional processes in riparian systems and ultimately moves most riparian habitats towards pure stands of this alien grass. By current estimates there are tens of thousands of acres of Arundo along the major coastal drainage systems of southern California, including the Santa Ana, Santa Margarita, Ventura, Santa Clara, San Diego, and San Luis Rey rivers. In addition, Arundo has invaded many of the low order streams that enter the Channel. Arundo is classified by the California Invasive Plant Council as among the top 5 invasive species degrading natural ecosystems in the state, and is listed as an 'A-1' invader (Most Invasive & Widespread Wildland Pest Plants). It was recently declared a Noxious Weed by the California Department of Food and Agriculture.

Among the serious environmental and socio-economic impacts of Arundo are:

- displacing native riparian plants and providing poor quality habitat to wildlife, including numerous officially protected species in Southern California
- reducing water availability in dry regions by transpiring large quantities of water (approx. double the loss rates of native woody plants)
- choking watercourses, exacerbating flooding, and promoting channel erosion
- providing fuel for wildfire, especially near urban areas
- contributing massive debris to riverbanks and beach areas
- interfering with recreational use of river corridors by the public

During large winter storms in Southern California, viable Arundo stems are washed into the ocean in prodigious quantities and are later washed up on beaches. Stands of Arundo are commonly viewed above the high tide line at beaches in the area. Vegetative propagation from drift Arundo at stream mouths allows the invasive plant to gain a foothold in previously unaffected drainages. Arundo stems wash up on Park beaches (Richards and Rich 2006), and are

[16] The discussion of Arundo derives in part from from personal communication with T. Dudley, Marine Science Institute, UCSB, who conducts research on biological control of Arundo in southern California.

removed whenever encountered during beach monitoring or other field work. To date, Arundo has not gained a foothold in riparian zones in the Park, but it remains a serious potential threat.

A.5. Invasive seaweed

Undaria pinnatifida is an edible brown kelp ("wakame") cultured off the coasts of Korea, China and Japan. Within the past thirty years, this species has spread from its native range off the coasts of Japan, Korea, and China to locations worldwide, including the coasts of Great Britain, France, Italy, Argentina, New Zealand, and Australia. The invasive kelp was first discovered in California in the Los Angeles/Long Beach Harbor in 2000 where it was probably introduced on the hulls of commercial ships. It is possible that a piece of a macroscopic sporophyte broke loose and started a new population, or that the gametophyte stage was transported in ballast water. It was found in Santa Barbara Harbor in 2001. *Undaria* is primarily found in sheltered areas, including harbors, but can survive on the open coast as well. Populations in California already occur in Monterey Bay, Santa Barbara Harbor, Catalina Island, and at San Pedro (Thornber et al. 2004). Juvenile *Undaria* plants were seen on a boat that traveled to the islands from Santa Barbara Harbor, and Park staff suspect it is only a matter of time before a population becomes established in the Park (Dan Richards, Marine Biologist, Channel Islands National Park, pers. comm.).

Another invasive algae, *Caulocanthus ustulatus*, was tentatively sighted at Anacapa in November, 2005, and Park staff are still waiting for confirmation. *C. ustulatus* is becoming common on the mainland, especially in Orange County. If confirmed, this will be its first sighting at the Northern Channel Islands (Dan Richards, Marine Biologist, Channel Islands National Park, pers. comm.).

B. COMMERCIAL AND RECREATIONAL FISHING

B.1. Marine protected areas at the Park

In 2003, the State designated 12 areas surrounding the Park islands as Marine Protected Areas (MPAs); ten are State Marine Reserves (SMRs) and two are State Marine Conservation Areas (SMCAs) (Figure 54). The SMRs are no fishing zones. The SMCA at Santa Cruz allows limited recreational fishing, and the SMCA at Anacapa allows limited recreational and commercial catch (Table 21). The establishment of the reserves, combined with two decades of data from the Park's intertidal and kelp forest monitoring programs, has created an opportunity to evaluate whether fishing is responsible for some of the recent changes in nearshore communities at the Channel Islands (as opposed to natural phenomena, such as El Niños, La Niñas and longer-scale regime shift). So far, comparison of monitoring data from inside versus outside fishing refugia at the Park provides the following evidence for fishing impacts on Park biota:

(1) owing to the following trophic cascade:

spiny lobster[17] -» urchins -» kelp,

and the presence of larger and more abundant lobsters inside protected areas, rocky reefs inside protected areas are more likely to support kelp forest than rocky reefs in fished areas (Behrens & Lafferty 2004);

(2) harvest of lobsters indirectly increases epidemics in sea urchins (Lafferty 2004); and

(3) harvest is responsible for 33-83% of the decline in warty sea cucumber numbers that occurred within 3 to 6 years of the rapid expansion of the commercial dive fishery at the Channel Islands (Schroeter et al. 2001).[18]

A review of the anticipated ecological consequences of establishing the MPAs is not provided here. Instead, an overview of commercial and recreational fishing in the Park is provided to address three questions concerning Park habitat where fishing still takes place: (1) which Park species are harvested, (2) where, within the Park, is fishing effort concentrated, and (3) which regulations pertain to particular target species? Detailed descriptions of the pertinent fisheries are available outside this report; links to these sources are provided below, and in Appendix C.

[17]And probably other predators that are fished, such as California sheephead.

[18]In this case, reserve data came from a protected area at Anacapa that pre-dated the establishment of the Anacapa SMR and SMCA.

Table 21. Summary of fishing restrictions for the MPAs, and other closures, at Channel Islands National Park.

MPA or other closure	Recreational Fishing	Commercial Fishing
Richardson Rock State Marine Reserve (San Miguel Island)	All species prohibited	All species prohibited
Special Closure: San Miguel Island	Boating prohibited within 300 yards from shore between Castle Rock and Judith Rock except as noted: Boats may approach no nearer than 100 yards from shore during the period(s) from March 15 through April 30, and October 1 through December 15	Boating prohibited within 300 yards from shore between Castle Rock and Judith Rock except as noted: Boats may approach no nearer than 100 yards from shore during the period(s) from March 15 through April 30, and October 1 through December 15. Commercial Sea Urchin Permittees may enter the portion of the closed area between the western boundary of the Judith Rock SMR and Castle Rock for the purpose of taking urchins.
Judith Rock State Marine Reserve (San Miguel Island)	All species prohibited	All species prohibited
Harris Point State Marine Reserve (San Miguel Island)	All species prohibited	All species prohibited
South Point State Marine Reserve (Santa Rosa Island)	All species prohibited	All species prohibited
Carrington Point State Marine Reserve (Santa Rosa Island)	All species prohibited	All species prohibited
Skunk Point State Marine Reserve (Santa Rosa Island)	All species prohibited	All species prohibited
Gull Island State Marine Reserve (Santa Cruz Island)	All species prohibited	All species prohibited
Scorpion State Marine Reserve (Santa Cruz Island)	All species prohibited	All species prohibited
Santa Barbara Island State Marine Reserve	All species prohibited	All species prohibited
Painted Cave State Marine Conservation Area (Santa Cruz Island)	Lobster and Pelagic Finfish[a] allowed. All other invertebrates, other finfish, and all marine aquatic plants prohibited.	All species prohibited
Anacapa State Marine Reserve	All species prohibited	All species prohibited
Anacapa Special Closure	No nets or traps shallower than 20 feet around entire island.	No nets or traps shallower than 20 feet around entire island.
Anacapa State Marine Conservation Area	Lobster and Pelagic Finfish[a] allowed. All other invertebrates, other finfish, and all marine aquatic plants prohibited.	Lobster allowed. All other invertebrates, all finfish, and all marine aquatic plants prohibited.
Anacapa Pelican Fledgling Area (contained within the Anacapa SMCA)	No entry January 1 to October 31	No entry January 1 to October 31.

[a]Pelagic finfish, for the purpose of MPAs, are defined as: northern anchovy (Engraulis mordax), barracudas (Sphyraena spp.), billfishes* (family Istiophoridae), dolphinfish (Coryphaena hippurus), Pacific herring (Clupea pallasi), jack mackerel (Trachurus symmetricus), Pacific mackerel (Scomber japonicus), salmon (Oncorhynchus spp.), Pacific sardine (Sardinops sagax), blue shark (Prionace glauca), salmon shark (Lamna ditropis), shortfin mako shark (Isurus oxyrinchus), thresher sharks (Alopias spp.), swordfish (Xiphias gladius), tunas (family Scombridae), and yellowtail (Seriola lalandi). *Marlin is not allowed for commercial take.

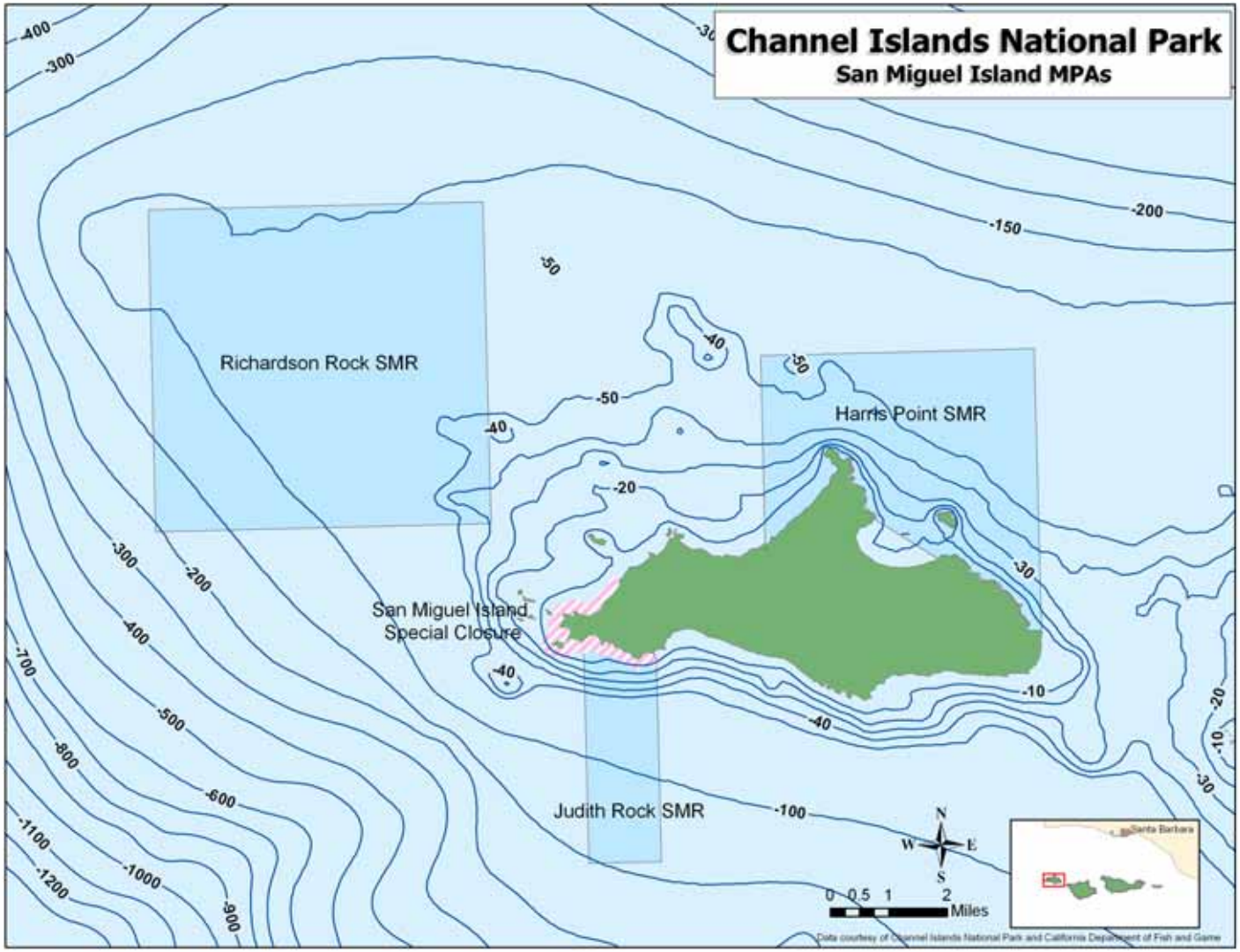

Figure 54. Marine Protected Areas at Channel Islands National Park. Isobaths are in meters. Restrictions and prohibitions are explained in Table 21.

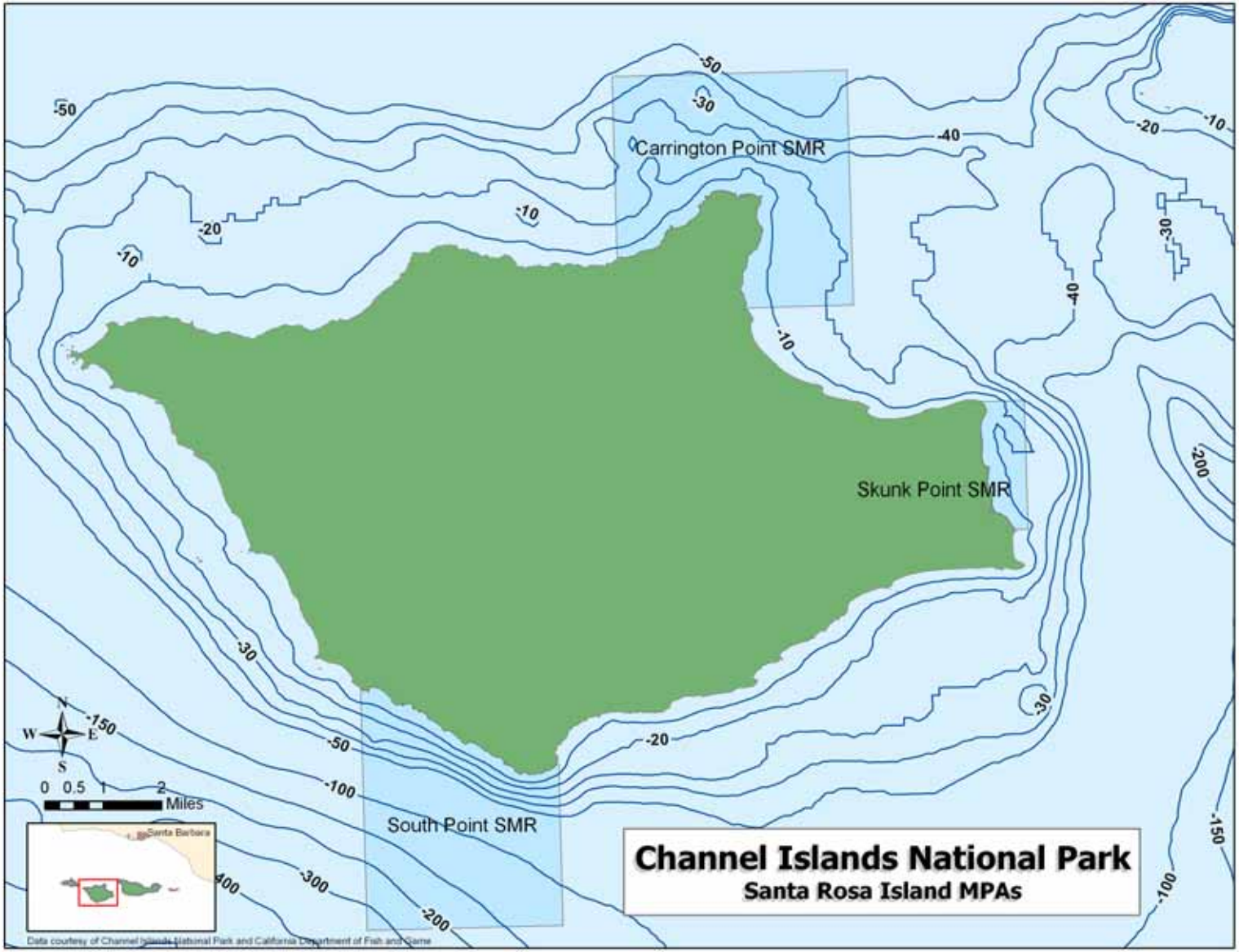

Figure 54. (continued).

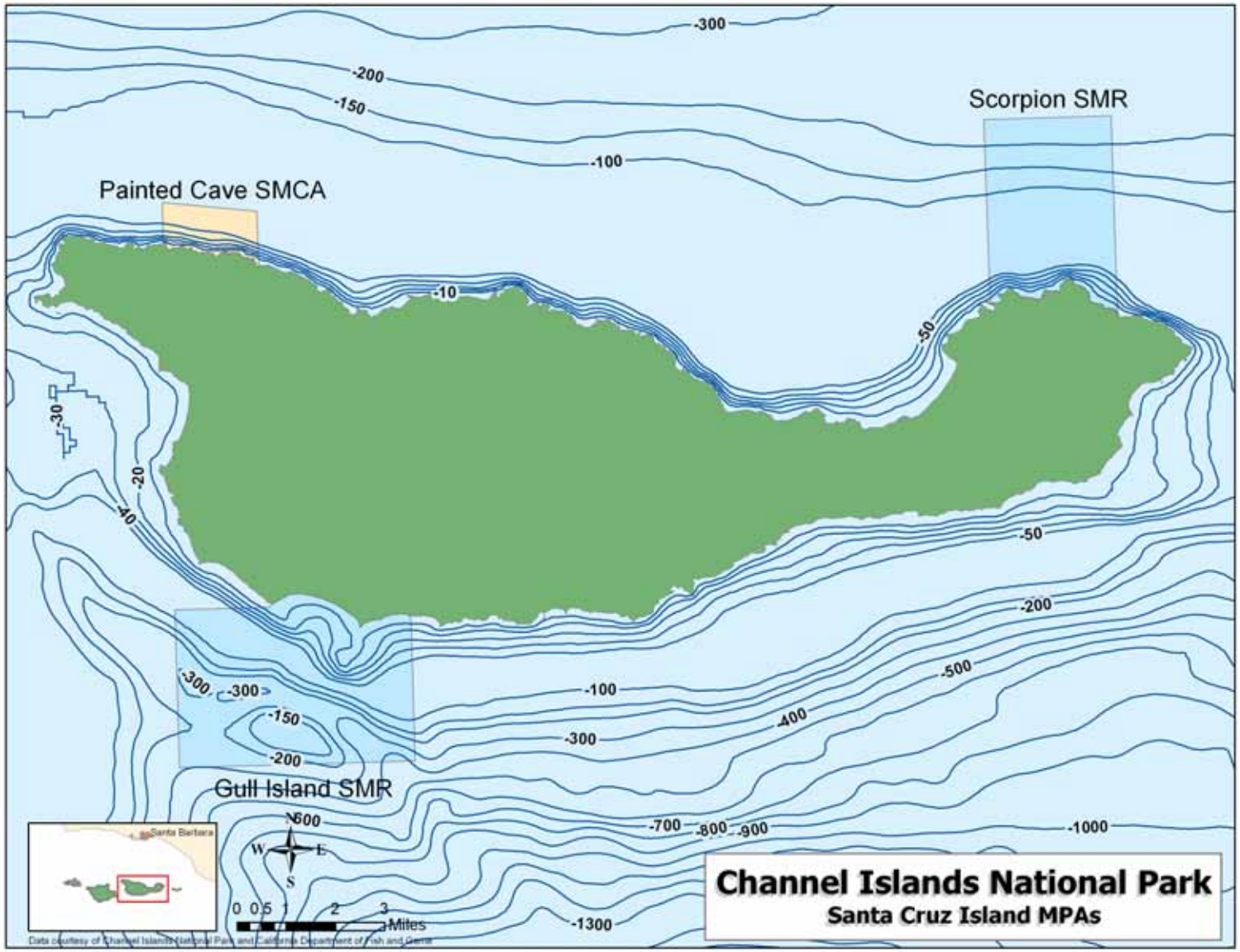

Figure 54. (continued).

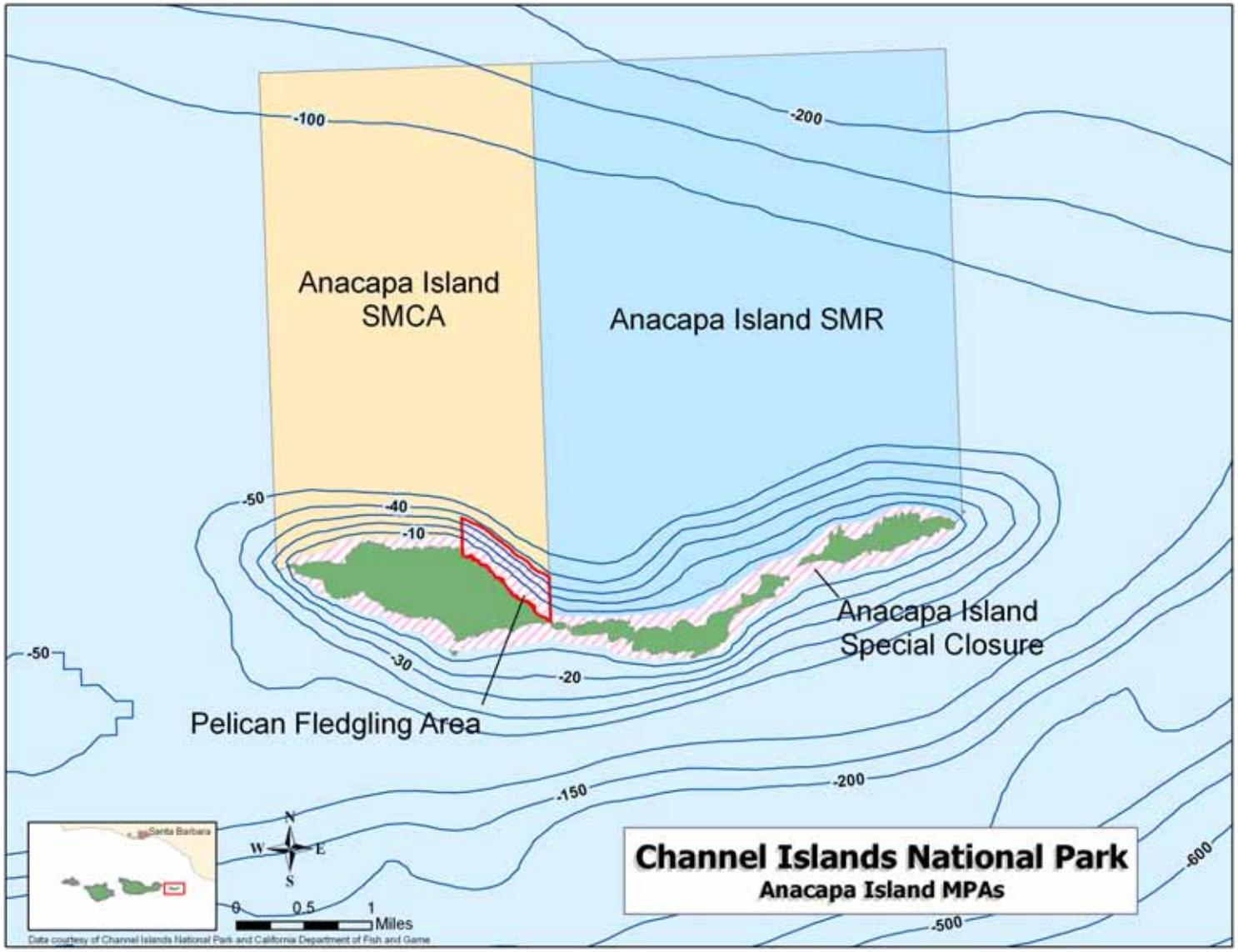

Figure 54. (continued).

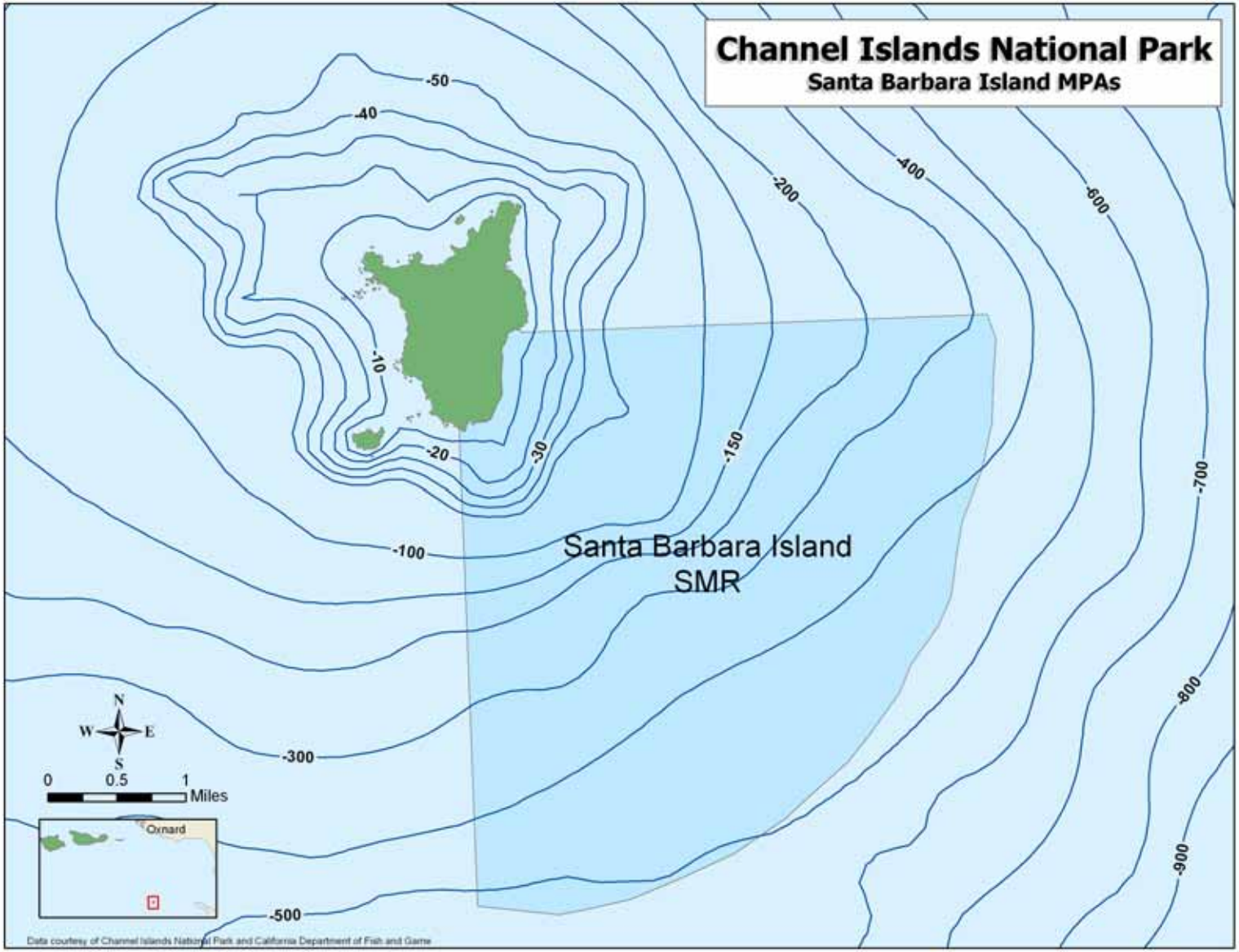

Figure 54. (continued).

B.2. Which Park species are Harvested?

The Sanctuary and the Park have extremely productive commercial fishing grounds. The majority of fish are caught in nearshore waters that contain kelp beds. Key targeted species include: squid, sea urchin, spiny lobster, sea cucumber, prawn, nearshore finfish (e.g., rockfishes and California sheephead), coastal pelagic species (e.g., anchovy, sardine, and mackerel), flatfishes (e.g., California halibut, starry flounder, and sanddabs), rock crab, tuna, and kelp. Trawling for ridgeback prawn occurs in the Sanctuary outside of state waters. However, trawling for any species (except for California halibut, in the designated trawling grounds) is prohibited in state waters in District 19, consequently, trawling for shrimp or prawn is prohibited within Park boundaries. (Note: *all trawling* for spot prawns in California was halted by CF&G in 2002). Live fish trapping for rockfish, California sheephead, California scorpionfish and other shallow water species occurs primarily near the coastlines of the Channel Islands. This particular fishery has expanded recently owing to demand for live fish in the Asian market. Limited entry Nearshore Fishery Permits, and Deeper Nearshore Species Permits, are now required by the State, and a limited number of live-fish trap endorsements (39 in the South Coast Region) are issued. Without a live-fish trap endorsement, the 19 species regulated as Nearshore Finfish (most are rockfish, see Appendix C) may only be taken by line. It is unlawful to use more than 150 hooks on a vessel, or to use more than 15 hooks per line, to take nearshore fish stocks for commercial purposes in ocean waters within one mile of shore in District 19. Traps are also used to take shrimp and prawns, California spiny lobster, and three types of rock crab (red, brown and yellow). However, south of Pt. Conception, the use of traps to catch shrimp is prohibited in waters <50 fathoms deep (300 ft), which rules out shrimp trapping in the Park, except for a small area of sufficient depth south of Anacapa. The use of gill nets and trammel nets to catch *any* species is prohibited within 1 mile of offshore islands south of Pt. Conception. Consequently, fishing using this gear is prohibited in Park waters. Other fisheries in the Sanctuary include shark and swordfish drift netting, squid seining using purse seines and light boats, urchin diving, and diving or trawling for sea cucumbers (although within 3 miles of shore, sea cucumbers can only be taken by diving). Much of the Sanctuary harvest of market squid, urchins, rockfish, spiny lobster, crab, and sea cucumber takes place close to shore within Park boundaries. The dive fishery for sea cucumber emerged at Park islands in the 1990s. Abalone, once one of the most valuable fisheries in the Sanctuary (over $2.5 million harvested between 1988 and 1997 according to Leeworthy & Wiley 2003), was closed to commercial harvest by the state legislature in 1997. Other Park species for which commercial harvest is closed in California are uncultivated rock scallops, Pismo clams, giant sea bass, California corbina, spotfin croaker, yellowfin croaker, kelp bass, barred sand bass, spotted sand bass, garibaldi, wolf eel, blacktip poacher, pygmy poacher, bluespotted poacher, ocean sunfish, great white shark, basking shark, and striped marlin. There is a small but increasing fishery for turban snails and whelks, which is not currently regulated. The Draft Market Squid Management Plan, submitted to the Commission by CF&G in early 2006, recommends the establishment of area closures (one nautical mile wide areas around the islands) and time closures (1 February through 30 November) prohibiting squid fishing around Anacapa, Santa Barbara and San Miguel Islands. Many of the other commercially important species, such as tuna, flatfish, wetfish (anchovies, mackerel and sardines), shrimp, swordfish, and shark, tend to be caught mostly outside of Park boundaries, in deeper waters than contained within the Park, or using gear that is disallowed by the State within Park waters.

Ranking of Sanctuary fisheries. Twenty-five species, or species groups, that are commercially harvested within the Sanctuary are ranked according to average annual revenue derived from Sanctuary fishing effort in Table 22. Of the Sanctuary's commercially caught species, market squid, sea urchin, spiny lobster, and rockfish are some of the most economically valuable, with urchin and squid exceeding the market value of all other species. Commercial fishermen that use Sanctuary waters also fish outside the Sanctuary. However, high percentages (over 50%) of the revenue obtained by area fishermen from urchin, spiny lobster, sea cucumbers, and market squid result from effort within the Sanctuary (Table 23).

Table 22. Average annual revenue from fish and invertebrates harvested inside Channel Islands National Marine Sanctuary. Data were included from fishing effort within the CF&G 22 Block definition of the Sanctuary (see text). Species/species groups are listed in descending order of importance. Data are from Leeworthy & Wiley (2002).

Species/Species Group	Average 1996-1999 Ex-Vessel Value $
Market squid	13,046,664
Urchins	5,265,233
Spiny Lobster	922,098
Prawn*	703,186
Rockfishes	549,319
Crab	343,664
Tuna	305,665
CA Sheephead	235,928
Anchovy & Sardines	234,367
Flatfish	183,871
Abalone**	178,027
Sea Cucumbers	167,700
Mackerel	67,119
Sculpin & Bass	60,327
Swordfish	39,090
Shark	34,751
Roundfish	33,262
Yellowtail	6,891
Shrimp	5,813
Mussels & Snails	4,694
Salmon	1,411
Rays & Skates	1,164
Surf Perch	695
Grenadiers	211
Octopus	196

* In 2002, the California Fish and Game Commission voted to close the spot prawn trawl fishery.
**The commercial harvest of abalone was prohibited starting in 1997.

Table 23. Proportion of total 1999 revenue for Sanctuary fishermen that resulted from effort inside the Sanctuary, as opposed to outside of it. Data are from Leeworthy & Wiley (2002).

Target Fishery	Percent of 1999 Fishing Revenue that came from the Channel Islands National Sanctuary
Urchin	73.76
Spiny Lobster	58.39
Sea Cucumbers	71.88
Rockfish	20.42
Crab	35.85
Flatfish	10.47
CA Sheephead	49.27
Sculpin and Bass	10.02
Shark	4.72
Squid, using Purse Seine	70.34
Squid, using Light Boats	86.90
Wet Fish by Purse Seine*	22.10

*Wet fish are anchovies, sardines and mackerel. For wetfish, percent is average for 1996-1999.

State and national importance of Sanctuary fisheries.

Although the Sanctuary makes up only about 5% of California's coastal waters, it provides a disproportionate percentage of the total state catch for many species. A large percentage of the Sanctuary catch is landed at ports in the Santa Barbara area (primarily at Santa Barbara, Ventura and Oxnard Harbors, and at Port Hueneme). In Table 24, the 2004 total California landings of commercial species is compared to the combined total 2004 landings of species at four major, plus three minor, Santa Barbara area ports. Among rockfish species, Santa Barbara area landings of bocaccio and Mexican, aurora, copper/whitebelley, copper, grass, rosy, starry, and vermillion rockfishes, make up sizable percentages (~20% or more) of total California landings for those species. With regards to the *more important* state fisheries (>500,000 lbs, based on 2004 landings), Santa Barbara area ports accounted for the following percentages of total state landings:

74 % shrimp

67% of red sea urchin

57% of market squid

51% red rock crab

43% California spiny lobster

20% of California halibut

18% of pacific bonito

16% of spot prawn (after 2002, no longer caught by trawl in state waters)

10% of pacific sardine

Only small percentages (less than 5%) of state landings for other important state fisheries, such as mackerel, sablefish, chinook salmon, sanddab, swordfish, thornyhead spp., tuna, pacific whiting, Dover/English/petrale sole, and dungeness crab, are landed in the Santa Barbara area. Although sea cucumber is not a major California fishery, 95% and 65% of state landings of giant red sea cucumbers and warty sea cucumbers, respectively, are landed in Santa Barbara area ports, and approximately two-thirds of the sea cucumber harvest in California takes place at the five islands of the Park, plus San Nicolas Island, to the south (Schroeter et al. 2001). From the national perspective, Sanctuary harvest of market squid and urchins is significant. Squid and urchins harvested from the Sanctuary constituted 62% and 72% of U.S. landings (lbs) in 1999 (Leeworthy & Wiley 2002).

Stocks of many species found at the Channel Islands have declined regionally (Leet et al. 2001). The PFMC considers several groundfish species that occur in the Park to be overfished including shelf rockfish spp. (canary, yelloweye, and widow rockfishes, cowcod, and bocaccio), lingcod, and Pacific whiting. California populations of lingcod appear to be less than 25% of their pre-1970s levels (Leet et al. 2001). Rockfishes (*Sebastes*) are particularly vulnerable to commercial and recreational fishing because they are long-lived (approximately 13-100 years), grow slowly, mature late (4-12 years), and have unpredictable recruitment. Declines of up to 50% have been observed in recent decades in the length and weight of some rockfish spp. taken in California. Recreational fishing dominates the take of many nearshore species (such as California scorpionfish, kelp greenlings, treefish, and calico, blue, olive, and kelp rockfishes). As far back as the 1970s, recreational angling was suspected to be responsible for the complete lack of mature olive rockfish in heavily fished offshore reefs (Love 1978). Recreational landings of nearshore finfish species declined by at least 65% from the 1980s to the 1990s (Schroeder and Love 2002, Love et al. 1998). Giant seabass have been in decline for several decades, and commercial catch is now prohibited. Catches of pelagic sharks have been in sharp decline since the 1970s (Leet et al. 2001). Fishing has altered the abundance and size structure of California spiny lobster populations at the Channel Islands (Behrens and Lafferty 2004), and populations of warty sea cucumber are also in decline in fished areas (Schroeter et al. 2001).

Table 24. Comparison of 2004 California landings (lbs) with combined landings from Port Hueneme, Ventura Harbor, Santa Barbara Harbor, and Gaviota, Guadalupe and Surf Beaches (the latter three are minor contributors). All species are included for which commercial landings were reported by CF&G for the Santa Barbara area. Landings are from the 2004 Annual Report of Statewide Fish Landings, Department of Fish & Game, Marine Region.

Species	Total State Landings (2004)	Total Landings in Santa Barbara area Ports (2004)	Percent of State Landings from Santa Barbara area Ports
ROCKFISH			
Mexican	156	48	30.8%
Aurora	920	275	29.9%
Bank	199,370	22	0.0%
Black and yellow	23,086	92	0.4%
Black	145,855	870	0.6%
Blackgill	249,678	34,807	13.9%
Blue	20,993	275	1.3%
Bocaccio	19,293	4,253	22.0%

Species	Total State Landings (2004)	Total Landings in Santa Barbara area Ports (2004)	Percent of State Landings from Santa Barbara area Ports
Brown	53,357	933	1.7%
Chillipepper	139,623	162	0.1%
Copper/whitebelley	330	328	99.4%
Copper	10,794	4,167	38.6%
Flag	541	14	2.6%
Gopher	34,766	385	1.1%
Grass	30,090	5,173	17.2%
Greenspotted	641	58	9.0%
group *Bolina*	6,832	29	0.4%
group *Gopher*	3,037	39	1.3%
group *Red*	21,630	4,807	22.2%
group *SHELF*	5,491	173	3.2%
group *SLOPE*	329,627	38	0.0%
Kelp	2,088	110	5.3%
Olive	2,209	66	3.0%
Redbanded	221	2	0.9%
Rosy	419	85	20.3%
Speckled	53	2	3.8%
Splitnose	22,668	3	0.0%
Starry	274	91	33.2%
Treefish	1,536	198	12.9%
Unspecified	6,131	1,677	27.4%
Vermillion	30,704	5,569	18.1%
Widow	19,085	167	0.9%
Yellowtail	20,805	236	1.1%
OTHER FISH			
Northern Anchovy	14,974,777	6,072,683	40.6%
Barracuda, California	57,976	4,128	7.1%
Bass, Giant Sea	8,656	2,594	30.0%
Blacksmith	130	1	0.8%
Bonito, Pacific	780,209	139,095	17.8%
Butterfish	13,136	876	6.7%
Cabezon	108,540	11,663	10.7%
Croaker, unspecified	48,567	58	0.1%
Croaker, white	67,261	5,156	7.7%
Eel, California moray	2,077	1,363	65.6%
Escolar	2,998	54	1.8%
Flounder, unspecified	74,234	55	0.1%
Flyingfish	10	10	100.0%
Greenling, kelp	4,486	1	0.0%
Guitarfish, shovelnose	17,306	9,977	57.7%
Hagfishes	4,466	3,974	89.0%
Halfmoon	145	2	1.4%
Halibut, California	1,000,946	200,168	20.0%

Species	Total State Landings (2004)	Total Landings in Santa Barbara area Ports (2004)	Percent of State Landings from Santa Barbara area Ports
Kelpfishes	4,673	1	0.0%
Lingcod	137,636	4,438	3.2%
Lizardfish, California	86	63	73.3%
Louvar	1,624	445	27.4%
Mackerel, Pacific	7,869,466	154,190	2.0%
Mackerel, Jack	2,264,375	39	0.0%
Opah	41,462	1,375	3.3%
opaleye	18,085	71	0.4%
Pomfret, Pacific	745	12	1.6%
Ray, Pacific electric	1,028	965	93.9%
Ray, Bat	1,688	209	12.4%
Sablefish	3,107,490	47,312	1.5%
Salmon, Chinook	6,186,036	9,440	0.2%
Salmon	3,932	2,997	76.2%
Sanddab, Pacific	3,180	23	0.7%
Sanddab	785,590	5,605	0.7%
Sardine, Pacific	97,649,122	10,436,747	10.7%
Sargo	36	2	5.6%
Scorpionfish, California	11,034	1,646	14.9%
Seabass, white	297,207	173,463	58.4%
Shark, Pacific angel	14,325	13,841	96.6%
Shark, basking	77	77	100.0%
Shark, brown smoothhound	3,129	3,014	96.3%
Shark, leopard	21,864	2,918	13.3%
Shark, shortfin mako	82,385	14,729	17.9%
Shark, soupfin	42,252	9,027	21.4%
Shark, spiny dogfish	58,122	16	0.0%
Shark, swell	159	100	62.9%
Shark, thresher	147,985	54,571	36.9%
shark, unspecified	12,053	100	0.8%
Sheephead, California	87,213	35,695	40.9%
Skate, unspecified	251,845	567	0.2%
Sole, Dover	5,337,785	598	0.0%
Sole, English	677,381	5,498	0.8%
Sole, Petrale	1,080,285	3,202	0.3%
Sole, rex	463,782	42	0.0%
Sole, rock	28,977	6,216	21.5%
Surfperch, barred	27,976	9,359	33.5%
Surfperch, black	54	37	68.5%
Surfperch, rubberlip	326	13	4.0%
Surfperch, unspecified	36,342	1,784	4.9%
Swordfish	1,802,414	24,644	1.4%
Thornyhead, longspine	1,197,918	6,730	0.6%
Thornyhead, shortspine	694,548	29,552	4.3%

Species	Total State Landings (2004)	Total Landings in Santa Barbara area Ports (2004)	Percent of State Landings from Santa Barbara area Ports
Thornyhead	91,313	7,951	8.7%
Tuna, albacore	2,976,800	14,554	0.5%
Tuna, bluefin	20,628	6,884	33.4%
Tuna, skipjack	670,892	117	0.0%
Tuna, yellowfin	1,053,339	139	0.0%
Whitefish, ocean	3,711	1,984	53.5%
Whiting, Pacific	10,454,767	64	0.0%
Wrasse, rock	3	3	100.0%
Yellowtail	47,019	3,213	6.8%
CRUSTACEANS			
crab, dungeness	24,870,614	834	0.0%
crab, box	4,761	1,442	30.3%
crab, claws	3,526	2,235	63.4%
crab, king	343	80	23.3%
crab, red rock	135	69	51.1%
crab, rock, unspecified	808,594	490,752	60.7%
crab, sand	427	341	79.9%
crab, spider	95,251	46,648	49.0%
crab, yellow rock	21	21	100.0%
lobster, California spiny	928,302	396,350	42.7%
prawn, spot	223,628	36,280	16.2%
shrimp, mantis	10,097	571	5.7%
shrimp, unspecified	196	145	74.0%
ECHINODERMS			
Sea cucumber, giant red	288,796	275,101	95.3%
sea cucumber, warty	285,749	174,947	61.2%
sea stars	15,600	5	0.0%
sea urchin, purple	2,839	76	2.7%
sea urchin, red	12,228,501	8,130,828	66.5%
MOLLUSCS			
clam, unspecified	3	3	100.0%
mussel	3,510	109	3.1%
octopus, unspecified	3,602	162	4.5%
sea snail	2,061	1,079	52.4%
snail, top	8,902	150	1.7%
snail, moon	1,091	1,091	100.0%
squid, jumbo	1,528	60	3.9%
squid, market	88,334,632	50,567,042	57.2%
whelk, Kellet's	70,371	24,578	34.9%

During the process leading up to the creation of the State MPAs in 2003, detailed analyses of pertinent fisheries, temporal trends in those fisheries, and spatial analyses of Sanctuary use by commercial and recreational fishermen were conducted by consultants and staff of NOAA's

National Marine Sanctuary Program and the CF&G. Much of this information is contained in the following documents, which are available on-line:

1) Ugoretz J (2002) Final Environmental Document. Marine Protected Areas in the National Oceanic and Atmospheric Administration's Channel Islands National Marine Sanctuary. Volume I.-II. California Department of Fish and Game, Marine Region. State Clearing House Number 2001121116, October 2002. http://www.dfg.ca.gov/mrd/ci_ceqa/index.html#vol2

2) Leeworthy VR & PC Wiley (2002) Socioeconomic Impact Analysis of Marine Reserve Alternatives for the CINMS. U.S. Department of Commerce, National Oceanic and Atmospheric Adminstration, National Ocean Service, Special Projects, Silver Spring, MD, April 29, 2002. http://www.cinms.nos.noaa.gov/marineres/sec4.html

and as revised:

3) Leeworthy VR and PC Wiley (2003) Socioeconomic Impact Analysis of Marine Reserve Alternatives for the Channel Islands National Marine Sanctuary. Silver Spring, MD: NOAA, NOS, Special Projects. 375 pp. http://marineeconomics.noaa.gov/reserves/analysis/analysis.pdf

In 2003, the Sanctuary and CF&G initiated a joint state and federal process to consider enlarging several of the State MPAs into federal waters within the Sanctuary (sometimes referred to as "Phase II" of the Marine Reserves process) (Figure 55). Concise summaries of Sanctuary fisheries (including condition of the stocks, history of the fisheries, gear and methods used, and selected regulatory actions) are contained in the following document:

Staff Preliminary Working Draft Document for Consideration of a Network of Marine Reserves and Marine Conservation Areas within the Channel Islands National Marine Sanctuary: http://www.cinms.nos.noaa.gov/marineres/main.html

Owing to its preliminary nature, material from this document is not presented here, however the reader is encouraged to view the draft document, or subsequent versions that are made public.

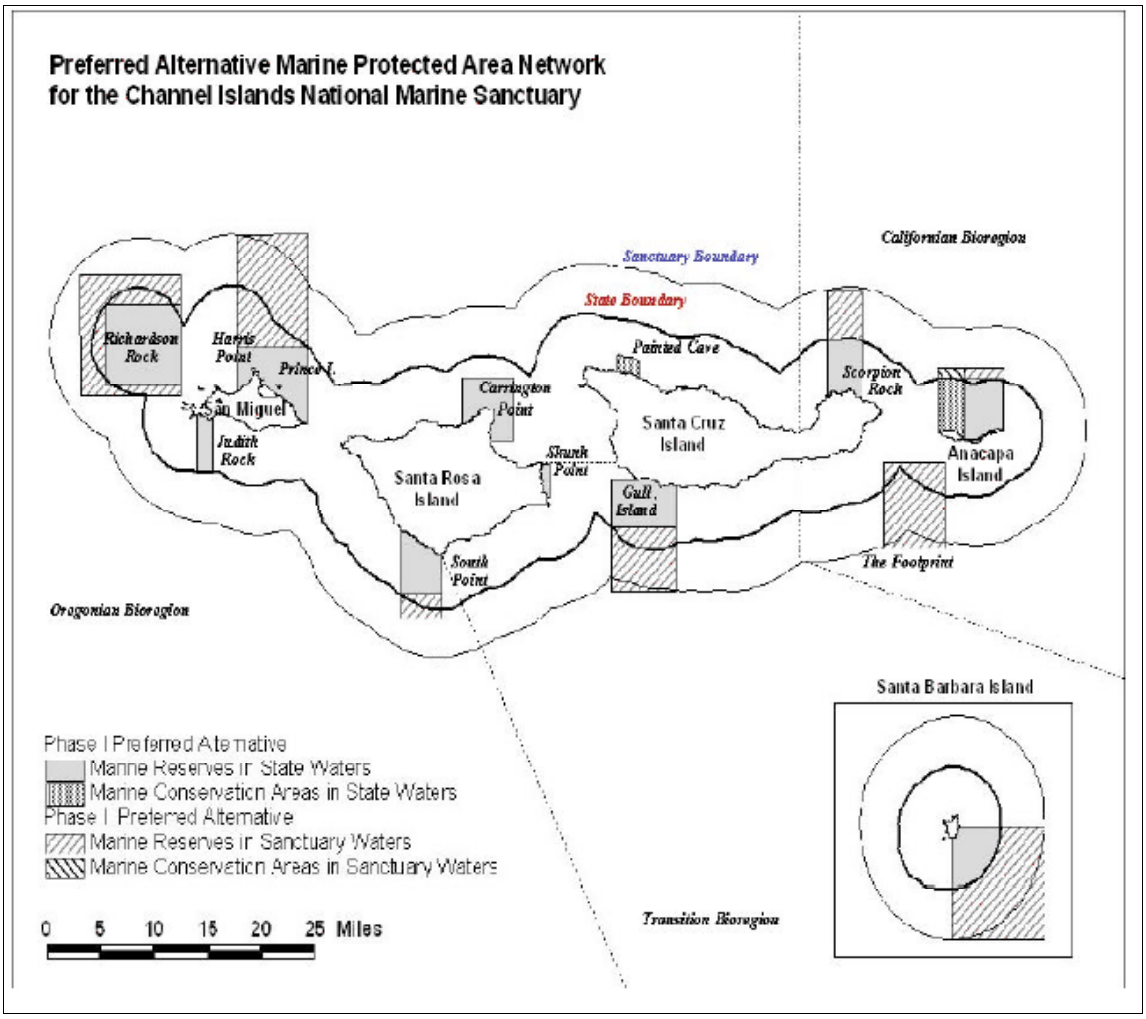

Figure 55. One version of the areas under consideration for the extension of no-fishing zones into federal waters contained within the Sanctuary (downloaded from website of CF&G).

B.3. Where in the Park is Fishing Effort Concentrated?

As part of NOAA's socioeconomic analysis of marine reserves in the Sanctuary (Leeworthy & Wiley 2002, 2003), maps were created showing (1) the spatial distribution (1x1 km grid) of fishing revenue from the Sanctuary (ex vessel values) for kelp, squid, tuna and wetfish, and (2) maps showing the areas most valued by Sanctuary fishermen (termed "exclusion zones" in the reports, because in surveys the fishermen identified sites in the Sanctuary which they wished excluded from the reserves). Although these maps were created using data from 1996-1999, they reveal spatial patterns of use that should still be valid for locations outside of the MPAs that were created in 2003, subsequent to the surveys. Based on visual inpection, the establishment of the MPAs interfered with preferred locations for commercial fishing in the Park in the following ways:

market squid: In general, the siting of the MPAs did not coincide with the most desirable locations for squid fishing, with the exception of the Anacapa SMR and SMCA (compare Figures 54 and 56).

urchin: The SMRs off San Miguel and Santa Rosa, and the Gull Island Reserve off Santa Cruz, eliminated sites well-used by urchin fishermen (compare Figures 54 and 57). Holders of commercial sea urchin permits are exempt from restrictions in part of the Special Closure Area at San Miguel that lies outside the Judith Rock SMR (Table 21).

spiny lobster: Large percentages of preferred lobster trapping grounds at the islands remain outside of the reserves. Some preferred lobster trapping areas were impacted by the SMR at Anacapa, the Gull Island Reserve at Santa Cruz, and the Carrington Point Reserve on Santa Rosa (compare Figures 54 and 58). Both commercial and recreational lobster fishing is allowed in the Anacapa SMCA.

rockfish: All of the reserves except for two (Scorpion Reserve at Santa Cruz, and Harris Point Reserve at San Miguel) impacted stretches of island coastline preferred for rockfish trapping and fishing (compare Figures 54 and 59).

crab: The preferred crabbing areas south of Santa Cruz, at Skunk Point and in Becher's Bay at Santa Rosa, and along the north shore of San Miguel were impacted by reserves. Much of the crabbing area between Santa Cruz and Santa Rosa, and to the south of both Santa Rosa and San Miguel, remains open (compare Figures 54 and 60).

sea cucumber: Almost all of the preferred sea cucumber grounds in the Park were eliminated by the reserves except for the stretches of coastline between Potato Harbor and Painted Cave and from Kinton Point to Morse Point on Santa Cruz, at Crook Point on San Miguel, and at the west end of Santa Rosa (compare Figures 54 and 61).

prawn and tuna: For the most part tuna and prawn are harvested outside of Park boundaries (Figures 62 and 63).

wetfish: anchovies, sardines, and (to a lesser extent in the Sanctuary) mackerel: Most of the commercial effort for wetfish occurs just outside of Park boundaries, although some activity occurs close to the Park south of Santa Cruz and Anacapa (Figure 64). Recreational fishing for these taxa is allowed in the Anacapa and Painted Cave SMCAs (Table 21).

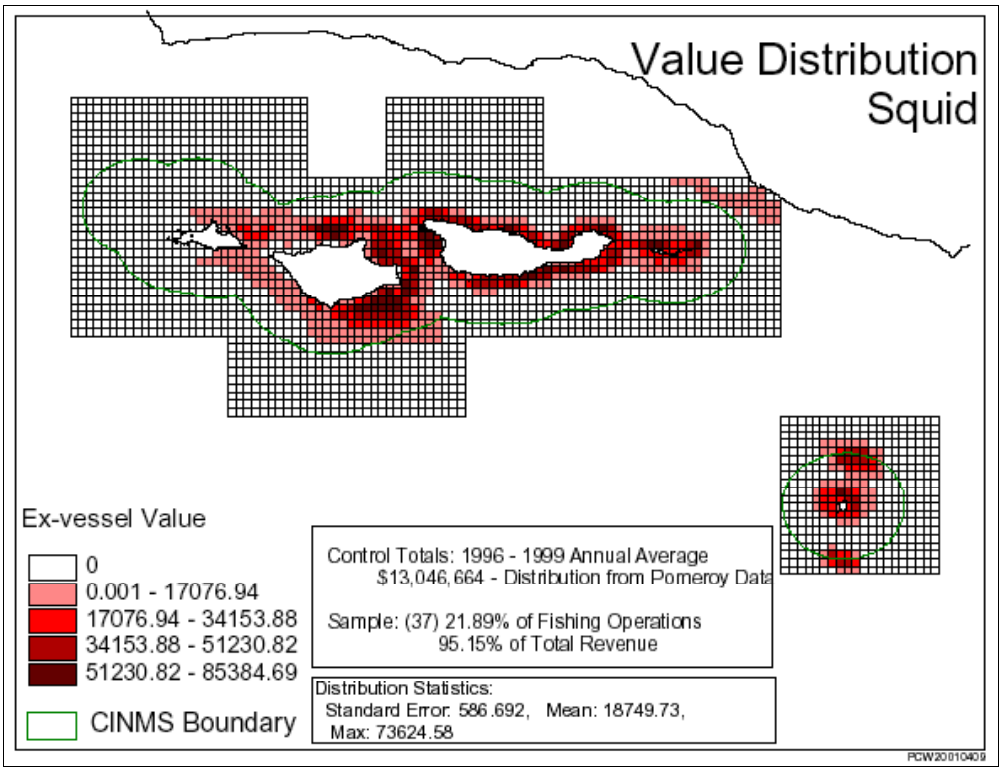

Figure 56. Average annual ex-vessel values for market squid (Leeworthy & Wiley 2002).

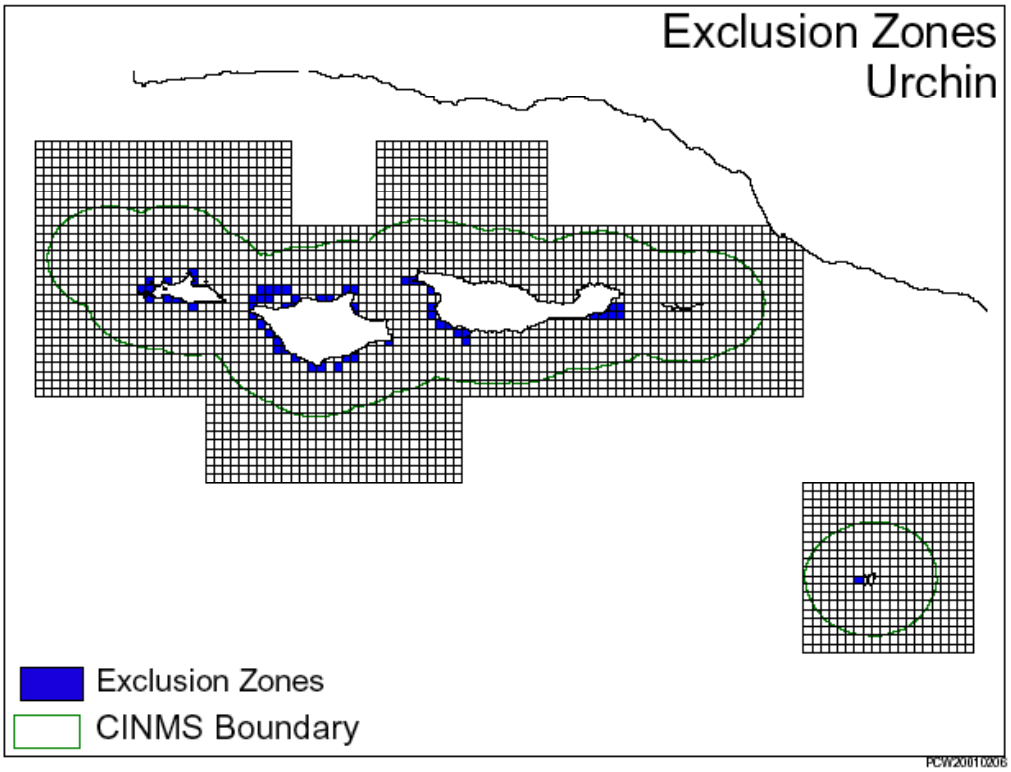

Figure 57. Areas in the Sanctuary preferred by urchin fishermen (Leeworthy & Wiley 2002).

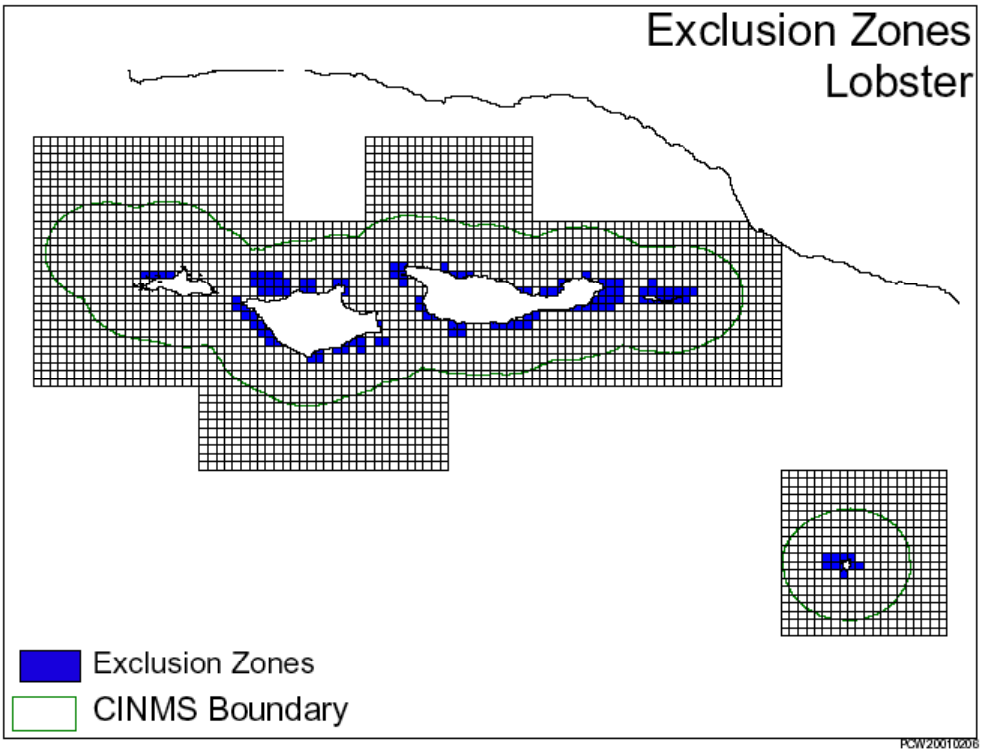

Figure 58. Areas in the Sanctuary preferred by lobster fishermen (Leeworthy & Wiley 2002).

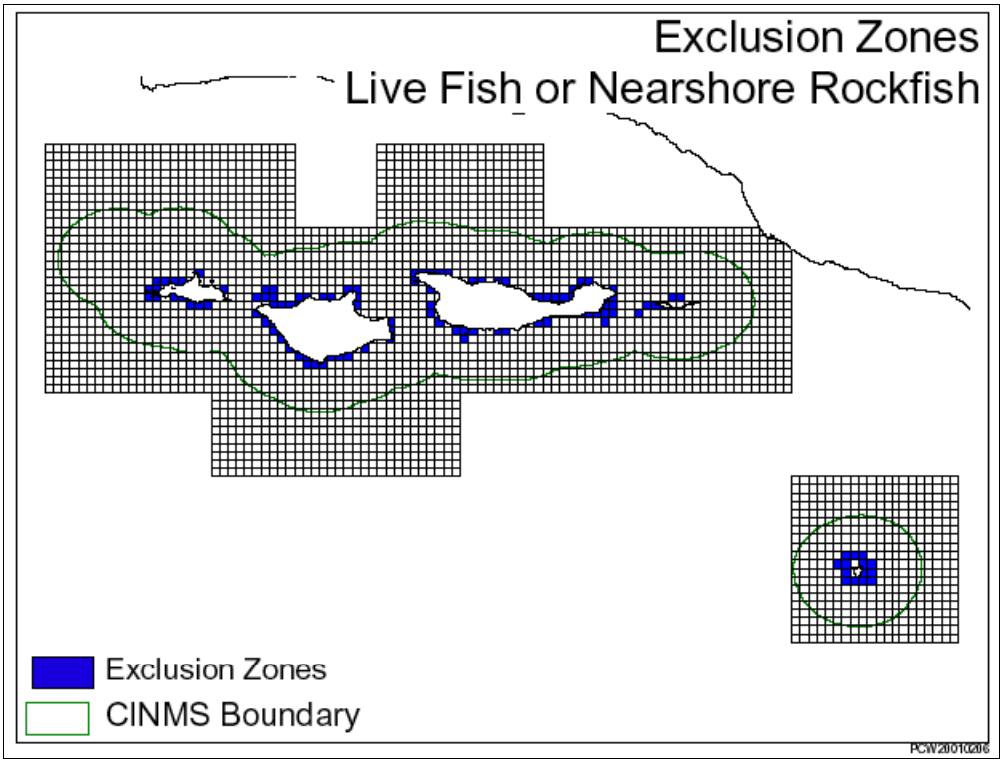

Figure 59. Areas in the Sanctuary preferred in the live fish and nearshore rockfish fishery (Leeworthy & Wiley 2002).

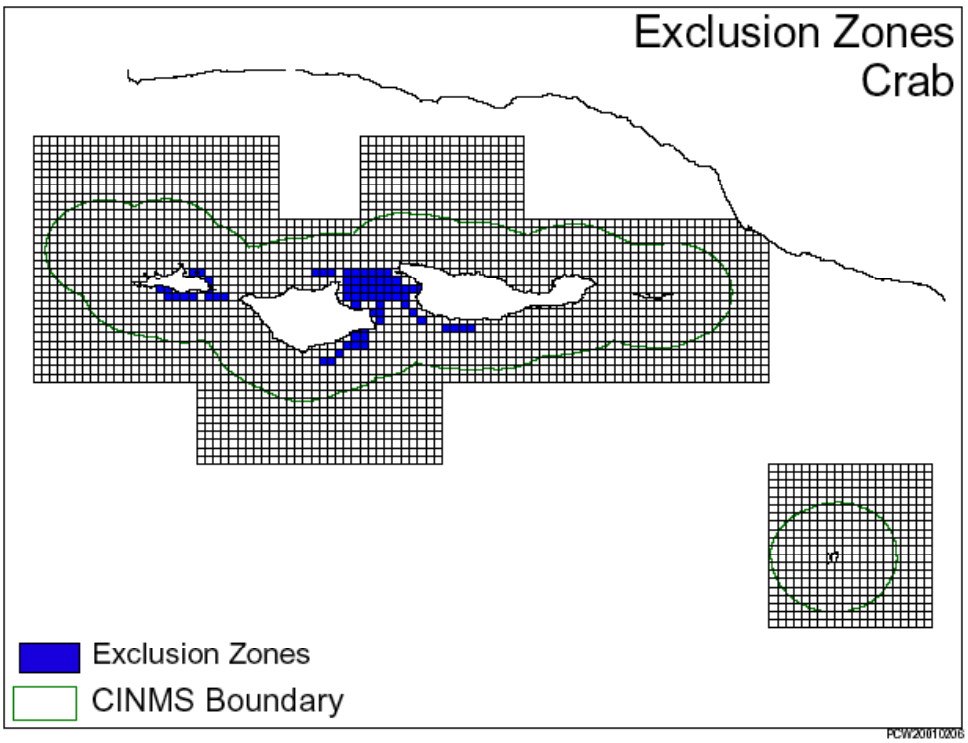

Figure 60. Areas in the Sanctuary preferred by crab fishermen (Leeworthy & Wiley 2002).

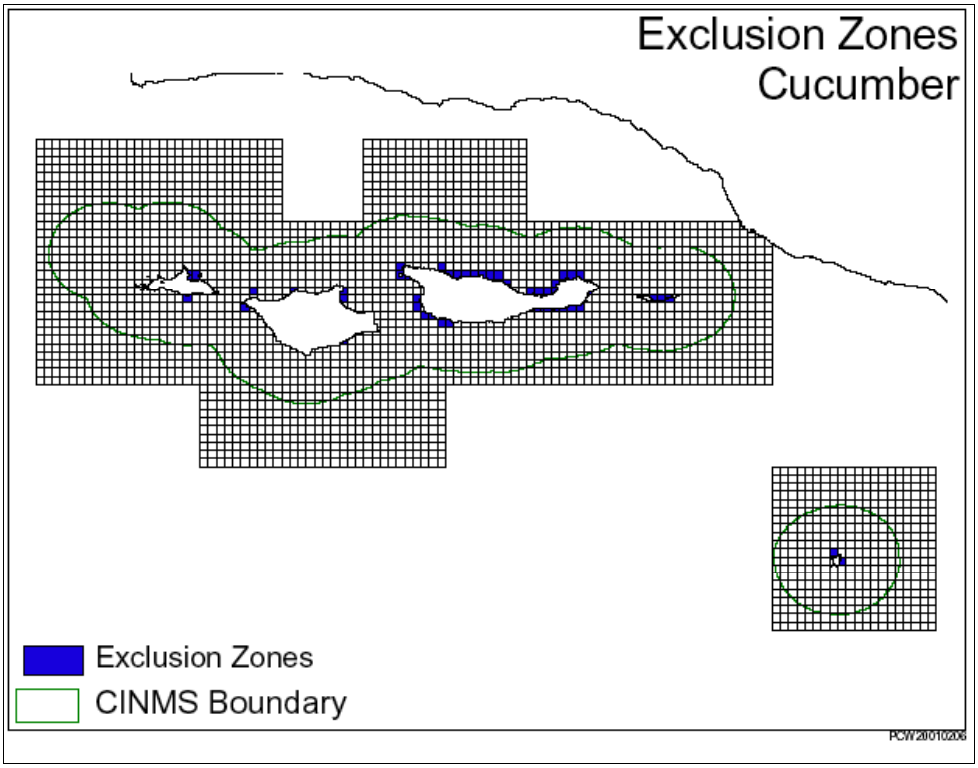

Figure 61. Areas in the Sanctuary preferred by cucumber fishermen (Leeworthy & Wiley 2002).

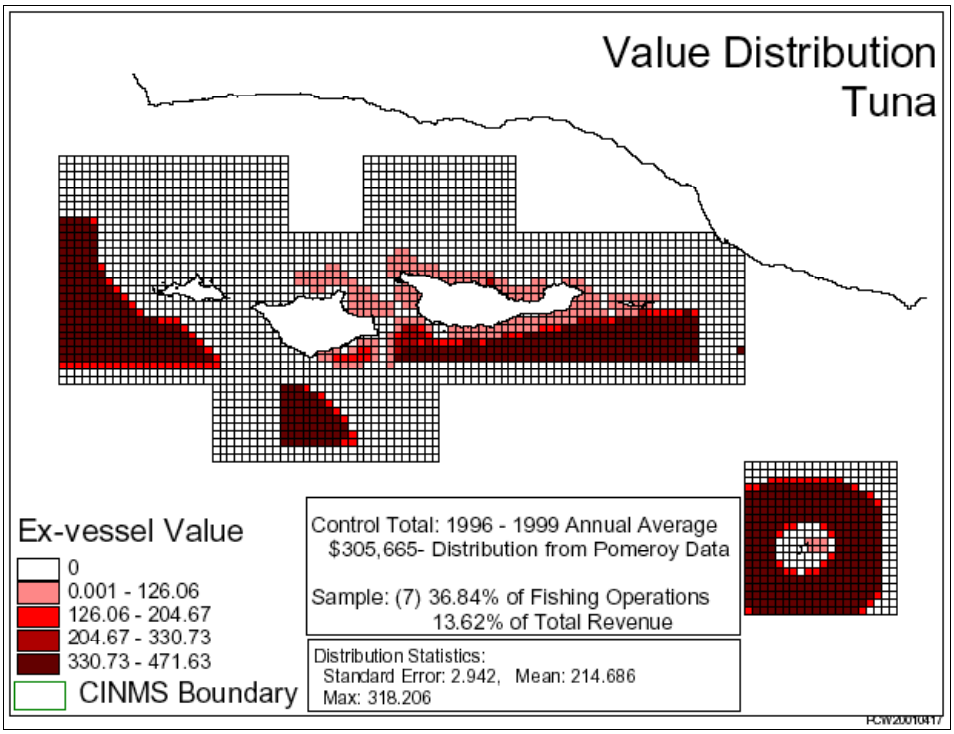

Figure 62. Average annual ex-vessel values for tuna (Leeworthy & Wiley 2002).

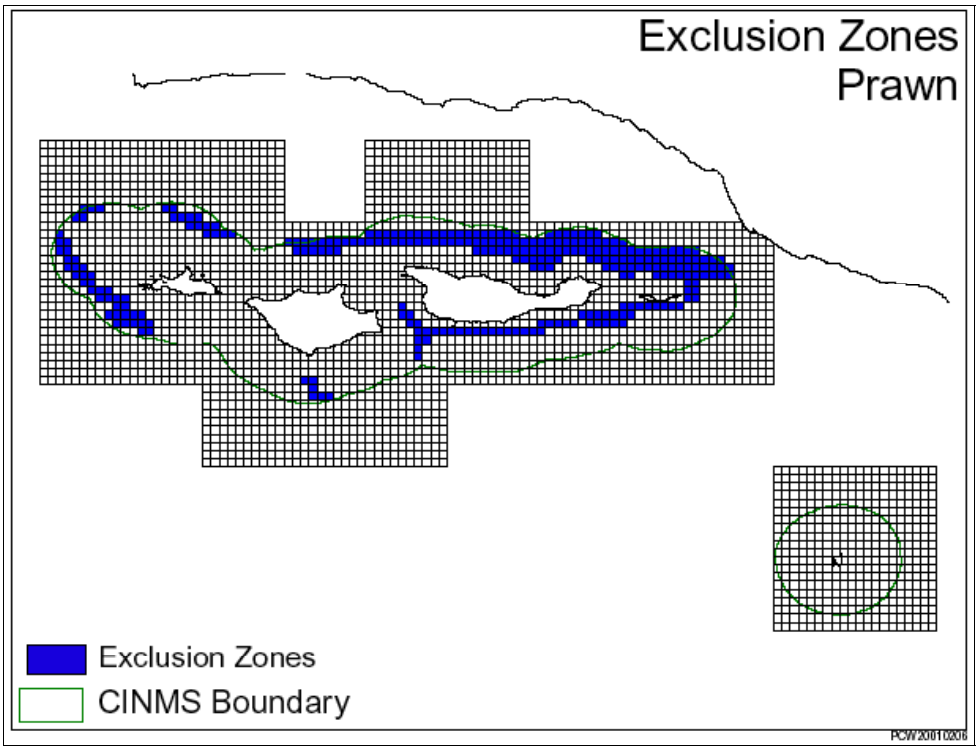

Figure 63. Areas in the Sanctuary preferred by prawn fishermen (Leeworthy & Wiley 2002).

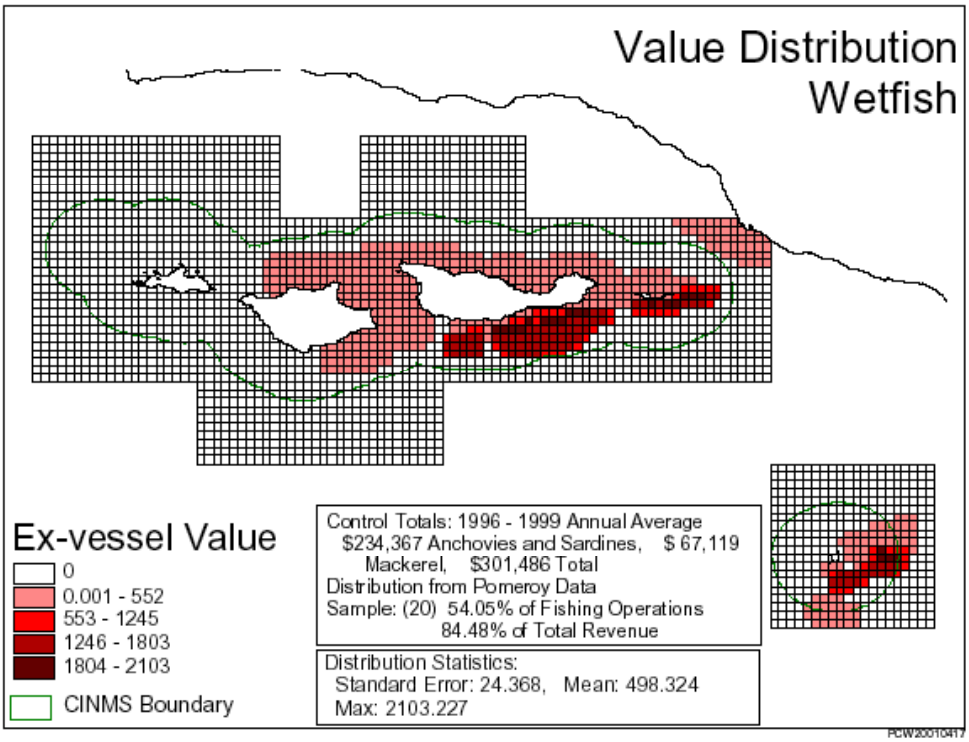

Figure 64. Average annual ex-vessel values for wetfish (Leeworthy & Wiley 2002).

Sport Fishing

Sport fishing and consumptive diving occurs from commercial passenger fishing vessels (CPFVs), charter boats (party boats), and private boats. Table 25 ranks the top 16 species/species groups according to the 2004 CPFV landings at the four Santa Barbara area ports combined (Point Hueneme, Oxnard, Ventura and Santa Barbara). As a group, rockfishes are taken in the largest numbers by the recreational fleet, followed distantly by barred sand bass, calico kelp bass, and ocean whitefish.

In the recent past, charter boat fishing and consumptive diving were especially concentrated around Anacapa and the Park-owned east end of Santa Cruz. The creation of the MPAs, and in particular the reserves at Anacapa and the Scorpion Reserve at Santa Cruz, excluded sport fishermen and consumptive divers from some of the areas most highly valued by them in recent years. Patterns of Park use by private fishing boats is distinct from that of the charter boats. The waters off San Miguel and Santa Rosa are more frequently visited by private fishing boats than by CPFVs.

Table 25. 2004 landings by CPFVs at Port Hueneme, Oxnard, Ventura, and Santa Barbara Harbors. Data are from the Annual Report of Statewide Fish Landings, Department of Fish & Game, Marine Region.

Species	Landings (numbers)
Rockfishes, unspecified	176,839
Rockfish, blue	21,446
Rockfish, copper	15,016
Rockfish, gopher	1,611
Rockfish, yelloweye	481
Rockfish, canary	194
Barred sand bass	51,327
Calico kelp bass	23,855
Ocean whitefish	23,195
California barracuda	6,352
Sanddab	3,239
Pacific bonito	3,132
Pacific mackerel	2,890
California sheephead	2,434
White sea bass	2,049
Yellowtail	390

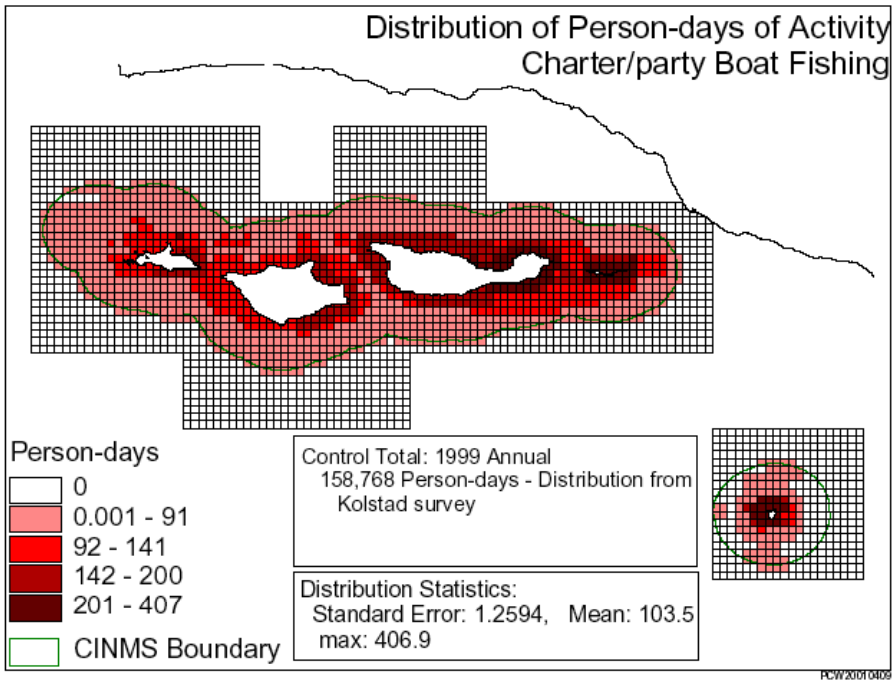

Figure 65. Spatial distribution of person-days of charter/party boat fishing in 1999 (Leeworthy & Wiley 2002).

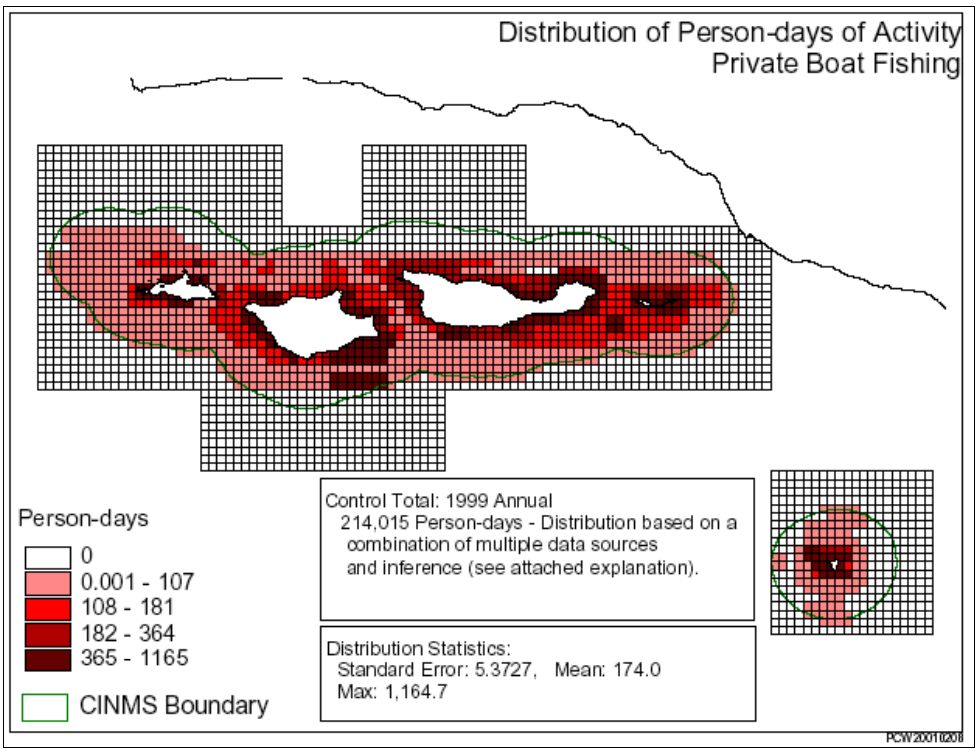

Figure 66 Spatial distribution of person-days of private boat fishing in 1999 (Leeworthy & Wiley 2002).

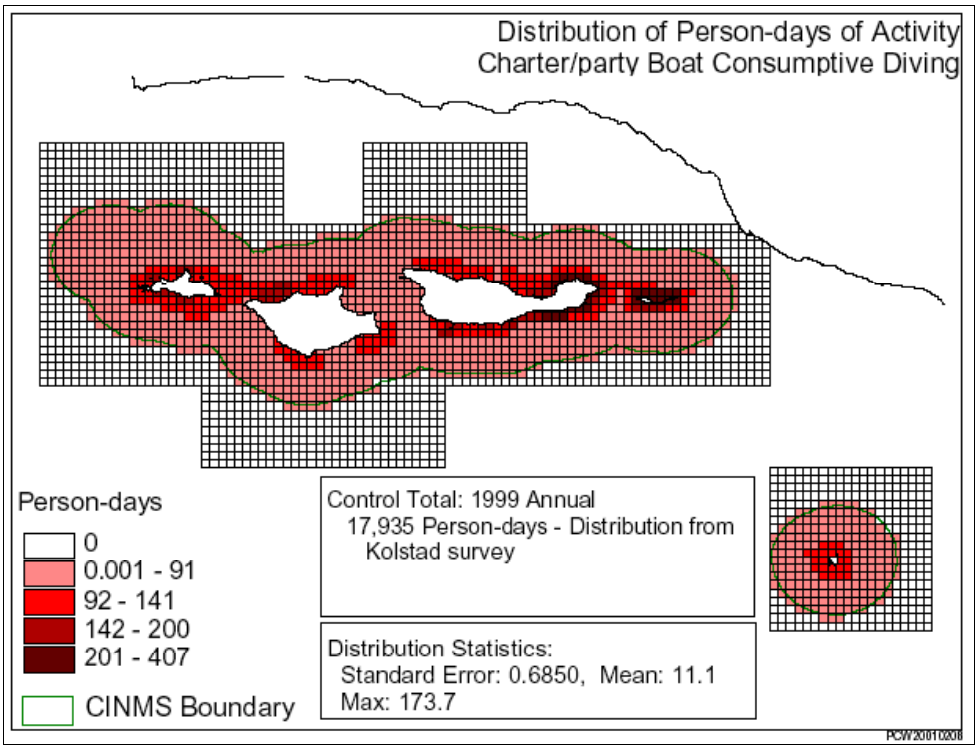

Figure 67. Spatial distribution of person-days of activity by charter/party boat consumptive diving (Leeworthy & Wiley 2002).

B.4. Harvesting of Plants

According to state law (CCR Title 14/Ch.4/Sect.30.10), no surfgrass or eelgrass may be cut or disturbed in California. There are 74 designated kelp beds in California which may be leased. Beds open to harvest by permitted companies exist around the entire perimeter of San Miguel, Santa Rosa and Anacapa, and about 75% of the coastline of Santa Cruz. Beds available for 20-year leases occur along ~25% the southwestern coast of Santa Cruz and entirely around Santa Barbara. In recent years ISP Alginates was the only company harvesting giant kelp in the Park, but their activity now (2005) is restricted to the San Diego area and they will soon be moving operations to Scotland (Dan Richards, Marine Biologist, Channel Islands National Park, pers. comm.). Figure 68 shows the spatial distribution of average annual revenue from kelp harvest in Park waters from 1996-1999. At least during these years, kelp harvest was concentrated around San Miguel and Santa Rosa (Figure 68).

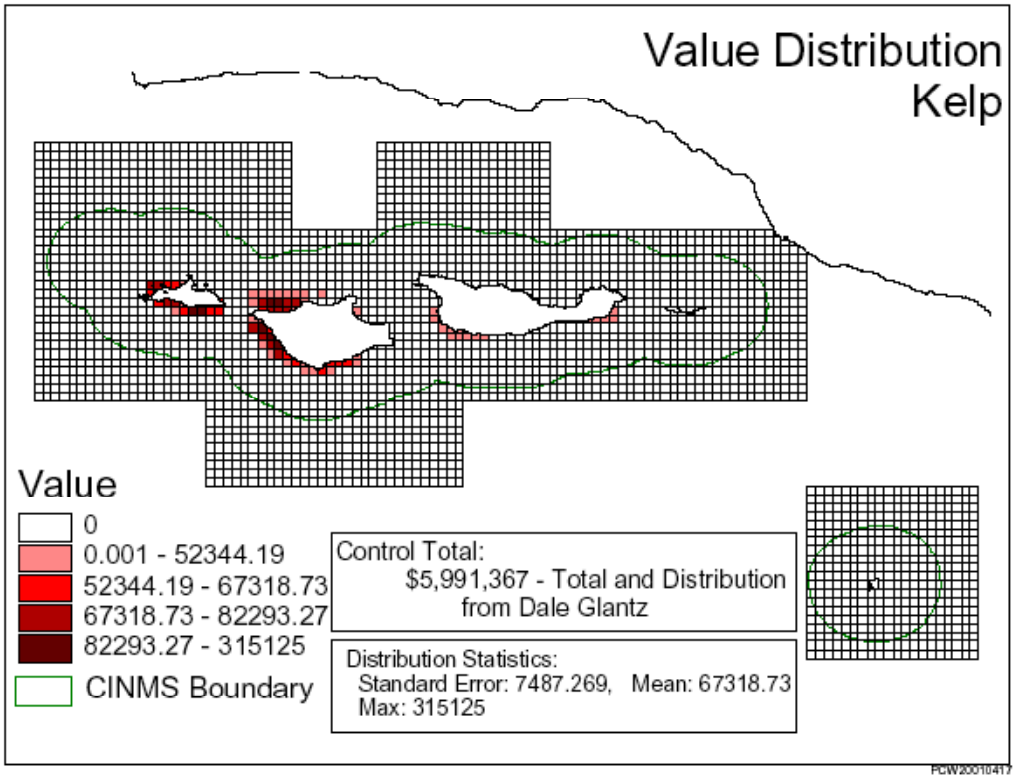

Figure 68. Spatial distribution of the average annual value of kelp harvested from Park waters (Leeworthy & Wiley 2002).

B.5. Pertinent Fishing Regulations

Sanctuary and Park waters belong to California's Commercial Fishing District #19 and the Southern Federal Groundfish Management Area. Many of the Park's nearshore fish are subject to management through the U.S. Pacific Coast Groundfish Fishery Management Plan (which pertains to all rockfish species and many sharks, skates, roundfish, and flatfish), and/or the California Nearshore Finfish Management Plan (which pertains to 19 species that frequent kelp beds and reefs in <120 ft of water, and includes 13 rockfish species). Although the Sanctuary and the Park are within state waters, California law concerning federally managed groundfish, coastal pelagic species, salmon, and highly migratory pelagic species must conform to the federal management plans for them.

A detailed explanation of fishing regulations for all species harvested within the Park is not provided here. Instead a tabular tool was created for this report (Appendix C) for all of the fish species reported from Park waters that are targets of commercial or sport fishing. In the table, fish are grouped according to (1) habitat (e.g., *Nearshore, Shelf, Pelagic*) and (2) taxonomic categories (e.g., *rockfish, groundfish, surfperch, flatfish*). References to on-line sources of information about species are provided, along with codes indicating which principal federal or state regulatory actions pertain to them. Finally, many details about fishing regulations (prohibitions, seasons, limits, gear restrictions, etc.) are provided in the table for each species/species group. Similarly, details about fishing regulations for commercially harvested invertebrates are included in the species table for Park invertebrates (Appendix B).

C. Nonconsumptive Use of Aquatic Resources

Nonconsumptive uses of aquatic resources in the Park include kayaking, whale watching, sailing, surfing, beach camping, and diving. Kayaking and private sightseeing by boat (e.g., sailboats) takes place mostly along the northern coast of Santa Cruz; off Santa Rosa in Becher's Bay, between Ford and South Pts., and between Carrington and Brockway Pts.; and off San Miguel from Cuyler Harbor to Cardwell Pt. (Figure 69). Whale watching is concentrated around Anacapa and from Carrington Point, on Santa Rosa, to Painted Cave on Santa Cruz (Figure 70).

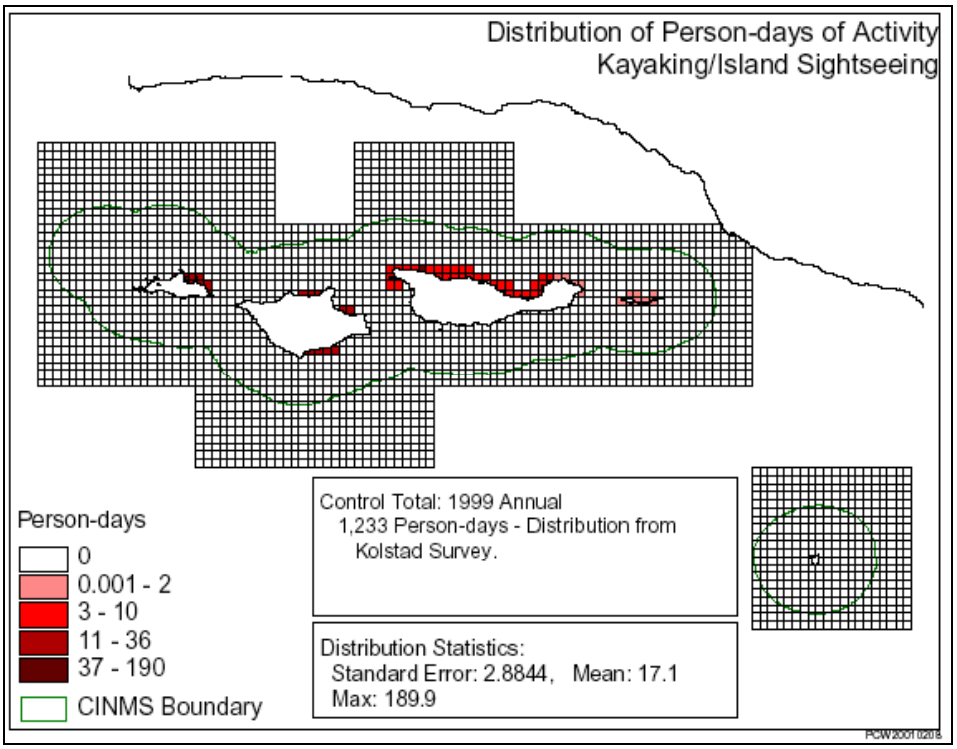

Figure 69. Spatial distribution of person-days of kayaking and island sightseeing in 1999 (Leeworthy & Wiley 2002).

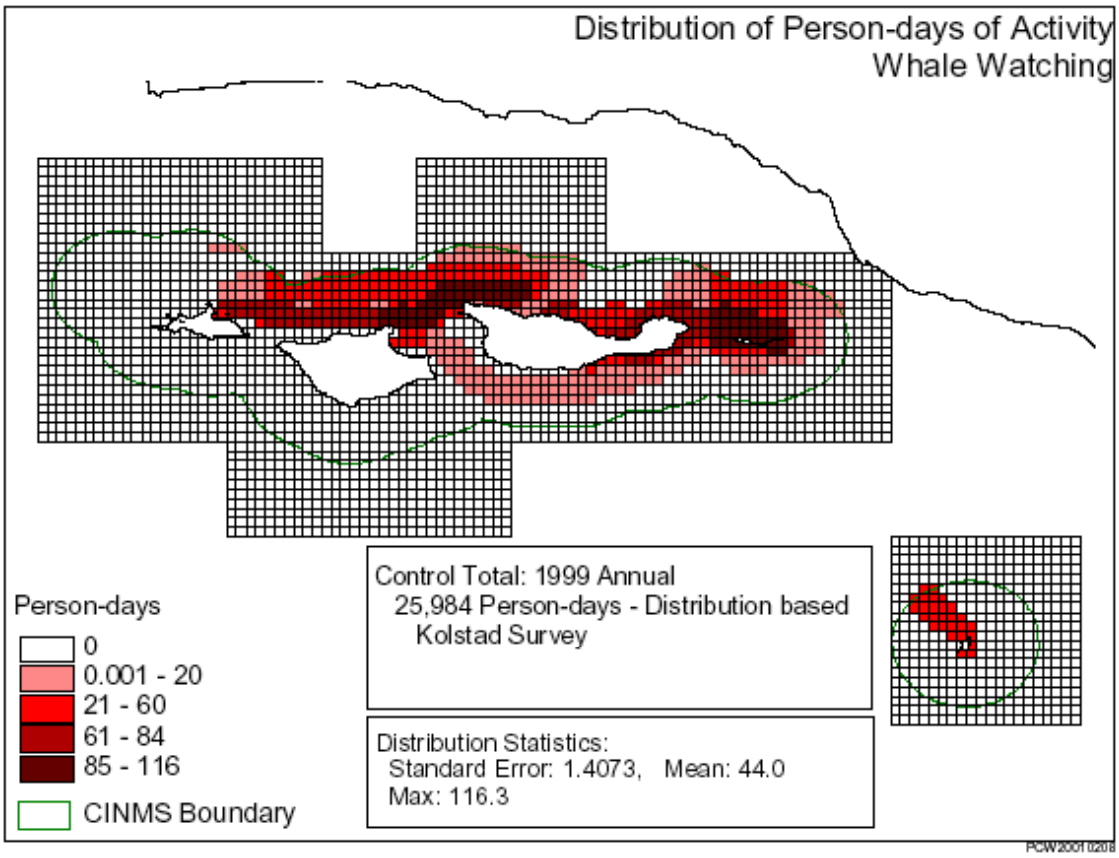

Figure 70. Spatial distribution of person-days of whale watching in 1999 (Leeworthy & Wiley 2002).

The Park protects important seabird and pinniped habitat through permanent and seasonal closures of certain trails, beaches, sea caves and sea cliffs. In addition, all access to offshore rocks and pinnacles is prohibited. For the most part, kayakers, hikers and campers comport themselves in a manner which does not threaten aquatic resources (Dan Richards, Marine Biologist, Channel Islands National Park, pers. comm.). During busy holiday weekends, illegal releases of sewage from private boats may be leading to short-term decreases in water quality in Park anchorages; high bacteria levels were measured on the Fourth of July weekend, 2005, in water at two anchorages at Santa Cruz (total coliform only-see Section II.C.7), and were presumably related to high numbers of private boats anchored there during the holiday weekend.

Examples of Park closures designed to protect aquatic life are listed below (obtained from the Park website).

Santa Barbara. Because the shoreline of Santa Barbara serves as a rookery and haulout for seals and sea lions, the shoreline, cliffs and beaches of Santa Barbara Island are closed to landing and public access except at the landing cove below the ranger station. Sections of trail may be temporarily closed on a seasonal basis to protect nesting California Brown Pelicans.

Anacapa. To protect nesting and roosting seabirds, several closures exist:

- On east Anacapa Island, the area east of a north/south line drawn 100 ft. west of the lighthouse is closed. The trail to the lighthouse is closed except with ranger escort.
- Middle Anacapa Island is closed, except for beaches.
- West Anacapa Island is closed except that boats may land at the beach at Frenchy's Cove.

Santa Cruz. Bat Cave is a dry sea cave where visitors would land on a beach and then walk into the cave. The cave is a nesting area for the endangered Xantus's murrelet in the spring. Beginning in July and August, the floor of the cave hosts the nests of storm petrels. There are more storm petrel nesting in this cave than in any other one place in world. For these reasons, Bat Cave and the Cavern Point Cave Complex are closed to entry.

Santa Rosa. The Sandy Point area is a substantial harbor seal and elephant seal refuge, consequently, it is closed to the public. This includes all beaches and land areas 300 ft. inland from 0.75 miles north from the Sandy Point benchmark to 0.85 miles south from the Sandy Point benchmark. In order to protect breeding and nesting snowy plovers, Skunk Point area of Santa Rosa Island, from March 1 to September 15, is accessible only by permit, from Sandy Point Ridge to the East Point Lagoon and 300 feet inland from the beach/grassland interface.

San Miguel. In order to protect the seal and sea lion rookery at Pt. Bennett, all areas west of the research station or west of a line drawn from Anubis Point to Ferrelo Point are closed to the public. San Miguel shoreline, cliffs and beaches are closed to landing except for the beach at Cuyler Harbor. The areas open to the public are the beach at Cuyler Harbor, Nidever Canyon trail, the Cabrillo Monument, campground, and the Lester Ranch site. A ranger escort is required outside these areas.

Sea Caves, generally. Because the ledges and cobble beaches inside dry sea caves are nesting habitat for seabirds. Visitors exploring sea caves by boat (including kayak or skiff) may not set foot ashore inside those caves.

D. PHYSICAL IMPACTS

Owing to its location within the Sanctuary, no alterations of the sea bed are allowed within the Park or within 6 nautical miles of island shores. At the time of this writing, the only planned changes to Park infrastructure that involve water bodies are:

1. Rebuilding the pier at Santa Rosa in Becher's Bay, near the mouth of Windmill Canyon.
2. Building new bridges at road crossings of Windmill and Cherry Creeks, near the ranger station at Becher's Bay.

Roads were built on Santa Cruz, Santa Rosa and San Miguel during the ranching era, and many either cross streams or are adjacent to them. These roads are unpaved, and many road sections are now entrenched, leading to gullying and sediment transport into some creeks (CINP 2002b). In response to the 1995 Clean-up or Abatement Order from the State (see Section II.C.3), restoration of abandoned sections of one of the main roads on Santa Rosa (the Smith "highway") was started in 2000; the reader is directed to CINP (2002b) for more detail. In July, 2002, an inventory of 46 road crossings of creek beds on Santa Rosa was undertaken. None of the crossings that still contained water at that time (8) had functional culverts, and most had tire ruts,

some of which were severe and impeded stream flow. Road cut erosion was widespread, and at many crossings new channels were forming. The problems noted during this survey may be indicative of processes occurring on Santa Cruz, although no information was reviewed for this report about the condition of roads on Santa Cruz.

IV. CONCLUSIONS AND RECOMMENDATIONS

Below are brief summaries of (1) information gaps concerning water resources at the Park, (2) principal threats to freshwater and marine resources at the Park, and (3) recommendations for solving high priority information gaps. Table 26 categorizes the documented, and suspected, problems in the Park's aquatic systems.

A. WATER BODIES WITH UNDOCUMENTED STATUS

Streams. Numerous streams, temporary and permanent, occur on Santa Rosa, Santa Cruz, and to a lesser extent, on San Miguel. Aside from the monitoring of three streams on Santa Rosa for basic water quality parameters since 1993 (in Lobo, Quemada, and Old Ranch House Canyons), and one sampling of a stream on Santa Cruz in 1993, water quality in streams in the Park is virtually unstudied. Within-stream fauna and microflora are unstudied thoughout the Park.

Vernal pools. Vernal pools occur on Santa Cruz, Santa Rosa and San Miguel. Almost all of them are unmapped and poorly studied. Vernal pool invertebrates and water quality were last surveyed in twelve ponds on Santa Rosa in 1995, three years before cattle were removed from the island.

Coastal wetlands and lagoons. Small coastal wetlands occur at the mouths of numerous canyons on Santa Cruz and Santa Rosa, and in at least one canyon (Nidever Canyon) on San Miguel. Small wetland areas occur at the mouths of numerous streams on Santa Cruz and Santa Rosa Islands. The status of these sites can alternate from freshwater seeps; to impounded winter runoff with palustrine vegetation; to small, brackish or saline lagoons produced by wave overwash. Although emergent vegetation has been described for at least two of the palustrine wetlands on Santa Cruz (at Prisoner's Harbor and Scorpion Bay), aquatic fauna, microflora, water quality, and hydrology are undescribed at all of the coastal wetlands at Santa Cruz. Small, but persistent lagoons (produced by wave overwash) occur at at the mouths of Willows and Laguna Canyons, and at Christy Beach on Santa Cruz, and at six sites on Santa Rosa (at the mouths of Old Ranch, Old Ranch House, Water, La Jolla Vieja, and Arlington Canyons and Canada Tecelote). Two of the lagoons on Santa Rosa (Old Ranch, and Old Ranch House Lagoons), and one brackish wetland (Oat Point Wetland) have been monitored (water quality, invertebrate fauna, avifuana) on an annual basis since 1994. Other lagoons are unstudied.

Groundwater. Aside from bacterial counts from five wells at the Park (and presumably some water table information from a network of shallow wells installed at Prisoner's wetland in 2005), the condition of groundwater is unknown in the Park. Sources of groundwater contamination are lacking in the Park. The dramatic alteration of vegetation that occurred during the grazing era on the islands probably altered water yield in Park drainages, and possibly patterns of groundwater supply to springs and streams.

Seawater. Standard oceanographic parameters (salinity, transmissivity, nutrients, temperature) are routinely measured, and current speed and direction are continuously measured, at several sites around the islands. Concentrations of anthropogenic pollutants (organo-pesticides, PCBs,

PAHs, trace metals, etc.) have not been measured in Park waters[19], although indirect evidence for their presence in the marine water column is provided by sentinel mussel data (see more below in recommendations). Bacterial counts have only been conducted in seawater a few times, in several anchorages at Anacapa and Santa Cruz.

B. Summary of Known or Potential Degradations of Freshwater Resources

Cattle, sheep, pigs, elk and deer

From water quality data and surveys of riparian vegetation and stream bed geomorphology, it is apparent that since the final removal of livestock from the island (cattle, in 1998), streams on Santa Rosa are recovering from past decades of use by sheep and cattle. However, a postulated lack of seed sources in many areas, and browsing of seedlings by the remaining elk and deer, are impeding the reestablishment of native woody riparian species (cottonwood and willow) on Santa Rosa. Although stream condition has not been formally studied on Santa Cruz, riparian vegetation and stream function were certainly altered there by decades of cattle and sheep grazing. Based on experience at Santa Rosa, a recovery process should be already be underway in streams on Santa Cruz. The ten years that transpired between the removal of cattle and sheep from the TNC-owned part of Santa Cruz (completed in 1988) and the final removal of feral sheep from the NPS-owned portion of Santa Cruz (completed in 1999) was enough time to produce a substantial difference in the rates of erosion and slope failures on the two parts of the island during torrential rains of the 1997/1998 El Niño. The removal of feral sheep from Santa Cruz has reportedly resulted in longer flows and deeper water in small estuaries on the southern side of the island. Because feral pigs have been present throughout Santa Cruz, and are just now being exterminated, it is not easy to distinguish their effects on stream habitat from the lingering effects of feral sheep. Consequently, it is not known how much stream habitat will benefit from the removal of feral pigs.

Owing to the facts that (1) cattle and feral sheep are now gone from all of the islands, (2) feral pigs are being eradicated now on Santa Cruz, (3) elk and deer are slated to be removed completely from Santa Rosa by 2011, and (4) even in the continuing presence of elk and deer, the streams on Santa Rosa have recovered substantially during the seven years without cattle, it is reasonable to expect that damaged streams on Park islands will continue to recover in several ways from the effects of introduced livestock without much human intervention. Basic water quality monitoring (temperature, DO, nutrients, etc.) of undocumented streams does not seem warranted. Transplantation of cottonwood and willow seedlings to stream reaches lacking mature specimens may be warranted on Santa Rosa, but seems impractical until the remaining elk and deer are removed. A survey of stream reaches may be warranted on Santa Cruz and Santa Rosa to identify reaches that would benefit from seedling transplantation.

Roads

From the available evidence from Santa Rosa, functioning culverts are lacking at many creek crossings in the Park, leading to deep tire ruts in stream beds, channel diversions, erosion, and stream flow interruption. A comprehensive survey of road crossings in the Park is not available.

[19] Note: PISCO may have some measurements of trace metals in seawater at the islands from deployments of DGTs.

Currently, vehicles drive off-road across the floodplain at Scorpion Bay on Santa Cruz, and they may do so at other areas in the Park.

Physical alterations of watercourses

The lower stream courses and coastal wetlands at Prisoner's Harbor and Scorpion Bay on Santa Cruz were both substantially altered in the past by dredging, fill, and channelization. The Park is already considering the restoration of pre-settlement wetland geomorphology at Prisoner's wetland. In light of this potential undertaking, it seems prudent to gather baseline information about water flow, water quality, and aquatic biota in the existing remnant wetland at Prisoner's Harbor.

Non-native vegetation

Non-native tree species (*Eucalyptus* and olive) are colonizing riparian terraces in many stream reaches on Santa Cruz. It is unknown whether these trees have altered the water budget of affected streams. Invasive weeds (such as fennel) are widespread in canyon bottoms on Santa Cruz and Santa Rosa, as well as on hillsides. Many non-native plants have colonized the coastal wetlands at Scorpion Bay and Prisoners Harbor on Santa Cruz. A review of terrestrial vegetation was not conducted for this report, thus it is not known whether the other small coastal wetlands on Santa Cruz and Santa Rosa are similarly affected, or have even been surveyed. Introduced grasses were reported to surround many vernal pools on Santa Rosa in 1995.

C. Summary of Known or Potential Degradations of Marine Resources

Notable trends for marine taxa at the Park, and presumed causes (in parentheses), include:

- collapse of black abalone (overfishing and disease)
- same, for white abalone - a federally endangered species (overfishing)
- near disappearance of ochre sea stars, and declines in other sea stars, during recent El-Niños (bacteria-caused disease)
- elimination of eelgrass beds at Anacapa Island (feeding fronts of white urchins)
- declines in numbers of warty sea cucumbers (mostly commercial harvest)
- declines in harvestable sizes of red urchins (commercial harvest)
- purple urchin population explosions, creating urchin barrens (trophic cascade related to lobster fishing [more recently], and disappearance of sea otters [historically])
- appearance of a wasting disease affecting purple sea urchins (unnaturally high urchin densities)
- El-Niño related declines in extent of giant kelp (wave damage, higher temperatures, and lower nutrients)
- increasing numbers of typically more southern fish species (regime shift, beginning in 1977)
- decreases in primary productivity and zooplankton abundance (regime shift)
- declines in pelagic sea birds (regime shift)

- declines in commercial and recreational landings, and shifts in size structure, for many nearshore and shelf fish species (fishing pressure and regime shift)
- occasional sightings of previously locally extinct sea otters (numbers expected to increase since California Fish & Game Department ceased to relocate Park otters in 2001).
- ongoing recovery of breeding populations of California brown pelicans, peregrine falcons and bald eagles (reductions of DDT in the marine food chain)

Storm plumes from the mainland

Storm plumes resulting from winter rains potentially introduce a suite of contaminants, including bacteria, pesticides and herbicides, trace metals, DDTs, PCBs, and PAHs, into the coastal ocean near the Park. At least once a year, turbidity plumes covering about 20% of the surface of the Santa Barbara channel are produced by outflow from the Santa Clara River near Ventura and other smaller coastal drainages. Rain events with 2-year return intervals can produce jets of freshened surface water extending ~10 km from the mainland shore. Less frequent, larger storms (~10-year events) can produce turbidity plumes extending ~30 km into the Channel. However, analysis of several years of salinity data from stations spanning the Santa Barbara Channel, and from several locations near the Park islands, reveals that only during extraordinary rains (≥ 25-year events), such as occurred during the 2004/2005 winter, does mainland runoff dilute the surface ocean all the way across the Channel to Anacapa, Santa Cruz or Santa Rosa Islands. Long time series of satellite data from the vicinity of Los Angeles indicate that storm plumes entering Santa Monica Bay or the San Pedro Shelf are very unlikely to ever reach Park waters surrounding Santa Barbara Island. Acute toxicity in storm plumes in Santa Monica Bay appears to be restricted to portions of plumes containing at least 10% terrestrial runoff, a value which confines toxicity to within a few km of the mainland coast during runoff events in most circumstances. Whether the eventual advection of some fraction of fine particulates from mainland runoff to the Park, and subsequent settling there, contributes to background levels of contaminants in Park sediments is unknown. Based on available evidence, this route of contamination is probably very minor. In the Bight, sediments directly offshore from stormwater discharge sites along the mainland coast contain more cadmium, chromium, copper, lead and zinc than sediments further away, however only copper is *significantly* higher in sediments near these discharge points than away from them. Settling of particulates at stormwater discharge points is not currently producing DDT or PCB hotspots in sediments along the mainland coast.

Contaminated sediments

Sediments at most sites within the Santa Barbara Channel, contain concentrations of trace metals and organic contaminants that, in most cases, are below background levels for the Bight as a whole. Silver, nickel, zinc, lead, copper and chromium are considered anthropogenically enriched at a only few sites in the Channel which lay shoreward of the northern 200 m isobath in the Channel (thus close to the mainland coast). Interestingly, cadmium, nickel, and DDTs have been found in sediments at Channel Islands sites at concentrations that exceed the NOAA's ERLs for those constituents. However, of 25 sites sampled near Park islands, sediment was found to be moderately toxic to amphipods at only 1 site, near the 200 m isobath north of Santa Rosa (outside of Park boundaries). However, sediments near the mainland, especially off the Palos Verdes Peninsula (a notorious site of DDT and PCB contamination), Los Angeles Harbor, and Santa Monica Bay, are enriched with heavy metals, PAHs, DDTs, PCBs, and other synthetic organics. In addition, between 1947-1961, DDT-laced sludge was deposited in barrels onto the

sea floor near Catalina Island (albeit in very deep water). Active dredge disposal sites in the Los Angeles/Long Beach are accumulating heavy metals, PCBs and PAHs. Chemical munitions, low-level radioactive waste, and explosives are among the materials that may also have been dumped in the ocean in past decades in the region. For many decades, DDT from sources outside the Park has entered the Park food web, and accumulated in avifauna and pinnipeds that use Park habitat. DDT-related damage to Park avifauna is diminishing over time, and breeding populations of California brown pelicans, bald eagles, and peregrine falcons are recovering at the Park. However, sport fish in the Los Angeles area (including rockfish, and other species that are prey for Park piscivores) remain sufficiently contaminated with DDTs and PCBs that limited consumption, or no consumption, by humans is advised by the State for many species. As recently as 2002, p,p'-DDE body burdens in female sea lions breeding at San Miguel were high enough to indicate that they obtain fish from the Palos Verdes shelf and Santa Monica Bay. The indirect transfer of harmful substances to the Park through seabirds and pinnipeds that consume contaminated fish at other sites continues to link the Park with contaminated sediments in the region.

Offshore oil industry

Of the 19 active oil platforms in the Santa Barabara Channel, Platforms Gail and Gina are the closest to the Park. Each is located approximately one nautical mile outside the boundary of the Sanctuary to the north of Anacapa. This locates them at least 6 nautical miles away from the marine boundary of the Park surrounding Anacapa. Produced water from oil platforms introduces heavy metals, PAHs, cyanides and organosulfur compounds (but not PCBs or DDTs) into the local environment. Based on dilution rates, and other evidence to date, produced water released at oil platforms results in sublethal harmful effects for a variety of invertebrates (larvae of bryozoans, ascidians and sea stars; sea urchins; mussels) up to 1 km from discharge points. The oil platforms are far enough away from the Park to ensure that produced water is not a direct threat to biota contained within Park boundaries.

Serving as artificial reefs and de-facto fishing reserves, oil platforms are often sites of extremely high densities of epibiota and fish (especially rockfish). Foraging at platforms by Park seabirds or pinnipeds may be a route by which metals and other contaminants from oil operations are transferred to Park habitat. The only report of body burdens found in this study for platform biota in the Channel was from the 1970s, which showed that concentrations of hexane-extractable materials, volatile solids, cadmium, chromium, copper, lead, molybdenum, nickel, silver, vanadium, and zinc, were not anomalously high (compared to control sites) in rockfish, crabs and mussels at two of the Channel platforms (Hilda and Hazel), with the exception of higher, but non-toxic, levels of vanadium in rockfishes. Hydrocarbons were not detected in mussels or crabs.

New measurements of trace metal body burdens in rockfish from area oil platforms should be available from researchers at UCSB sometime in 2006. These results should be evaluated to see whether the potential consumption of fish at oil platforms by Park piscivores should be of concern to Park managers. In addition, arrangements should be sought through the MMS, or NOAA, to survey epibiota (i.e., mussels) growing on oil platforms for a suite of trace elements and organic compounds. Unfortunately, commercial harvesters of mussels at area platforms are not required to analyze mussel tissue for any contaminants other than bacteria and paralytic shell-fish toxin.

Drilling muds and cuttings are not produced during the extraction of oil and gas, but there is evidence that drilling solids can disperse almost 7 km away from the debris mounds created at the platforms during drilling operations. This implies that some of the heavy metals and hydrocarbons in drilling wastes deposited at the platforms closest to the Park (Gail, Gina, Gilda and Grace) could have been advected to the benthic habitat surrounding Anacapa Island.

Intertidal habitat, sea birds and pinnipeds at Anacapa and Santa Cruz were directly impacted by the 80,000-barrel Santa Barbara Oil Spill of 1969, although birds were the only vertebrates killed by the oil slicks. Since 1969, there have been 843 small oil spills off southern California. Only one spill resulted in documented seabird mortality: the 163-barrel Platform Irene pipeline spill off Point Arguello in 1997, which resulted in the loss of more than 700 birds. Although the another large oil spill could happen again in the Santa Barbara Channel, it is worth observing that the largest natural oil seep in the area (Coal Oil Point seep field) naturally releases more than 100 barrels of oil per day into the coastal ocean near Santa Barbara, with no apparent ill effects to sea birds or marine mammals that use the affected area. Apparently, birds and mammals are able to avoid the natural slicks, which can extend up to 15 km in the crossshore direction and up to 50 km in the alongshore direction.

Marine Vessels

The only marine vessel traffic that *directly* impacts Park waters are privately-owned recreational fishing boats, charter boats (CPFVs), commercial fishing vessels, sailboats, whale watching and other sight-seeing boats, NPS and other agency boats, research vessels, and boats transporting visitors and staff to Park islands. These smaller vessels potentially release bilge water, fishing debris, untreated sewage, spilled fuel, and trash into Park waters. Ballast water, black and gray water, and other hazardous wastes are potentially discharged from container and other cargo ships, and cruise ships (the latter are infrequent) that use the international shipping lane that runs through the Channel, although now most of these discharges would be illegal if they occurred in state water. Dryfall of particulates from diesel exhaust may introduce metals and PAHs into the water column of the Park. The molecular signature of PAHs might reveal whether combustion byproducts (such as from diesel exhaust) are contributing to PAH levels in Park water, sediment or biota. For example, the relative importance of petrogenic PAHs versus pyrogenic PAHs could be compared in substrates (i.e., mussels, water, or sediments) at sites in the Park closest to the shipping lane (or in the prevailing lee of ship exhaust plumes) versus near natural oil seeps at the islands (e.g., Fraser Point) or other potential localized chronic sources of PAHs, such as creosote impregnated pilings at the pier at Anacapa (a petrogenic source)[20], or consistently crowded anchorages where small craft may be releasing fuel or oil.

Pinnipeds and sea birds as conduits for anthropogenic pollution

Although other avenues of entry are not ruled out by the information in this report, it seems highly likely that the pinnipeds and piscivorous seabirds that feed on contaminated fish outside the Park (and the Sanctuary), and then return to roost, haul-out, or breed, on Park islands are

[20]Leaching of creosote from submerged pilings results in PAHs with petrogenic signatures. There are only a few locations in the Park where creosote-impregnated pilings occur: (1) at the Santa Barbara pier (affected pilings are 20 years old and out of the water, (2) at Anacapa pier (affected pilings are over 20 years old, and are both in and out of the water, (3) at Santa Rosa pier (creosote is out of the water). Park staff are not sure whether any creosote pilings remain at Santa Cruz; an old pier at Prisoner's Harbor did have them, but was replaced a few years ago (Kate Faulkner, Chief of Natural Resources, Channel Islands National Park, pers. comm.).

contaminating other marine ecosystem compartments at the Channel Islands. The wide array of organo-pesticides, other synthetic organics, PAHs, and trace elements that are detected in Park mussels (many at high levels from the state and national perspective) bears evidence that pollutants without sources near the Park (and in some cases, without sources in most of the Channel) are entering the water column of the Park. Indeed, transfer of DDTs and PCBs to the Park via pinnipeds and piscivorous sea birds foraging elsewhere is one of the *only* routes by which these particular organic compounds can enter the the Park itself. DDT has accumulated in Park sediment sufficiently to exceed NOAA's ERL threshold in 34% of sites sampled at the Channel Islands by SCCWRP during Bight '03 (2003). In a 25-year old evaluation of sentinel mussel data, marine bird and pinniped colonies (including at Point Bennett on San Miguel) were invoked as the cause of mercury hot-spots that were remote from other sources of pollution on the Pacific coast (Flegal et al. 1981). Except for this study and a few measurements of DDE or PCBs in milk and blubber of sea lions at the Park, this avenue for water pollution at the Park appears to be unstudied.

Natural shifts in oceanic conditions

Although they are natural events, short-term shifts (El Niños, 1-2 years) and longer term shifts (multiple decades) in oceanic conditions strongly influence marine biota at the Channel Islands. El Niño conditions lead to significant losses of giant kelp for two main reasons: (1) higher temperatures and lower nutrient concentrations produced by intrusions of water masses from the South cause a deterioration in kelp growth rates, and (2) swell during powerful winter storms physically detaches and tears kelp plants. Increased frequency of El Niño events appears nested inside a recent longer-term shift in oceanographic conditions in the Bight, referred to as a *regime shift*. The current regime shift, which is believed to have begun in 1977, has produced warmer than average ocean temperatures (about 1°C) in the Bight. The regime shift is correlated with several key community changes documented at the Channel Islands during the 1980s and 1990s, including increased numbers of southern species at Santa Rosa and San Miguel, advection of typically tropical species into the Channel (such as albacore, barracuda, dorado, yellowfin tuna, marlin and triggerfish), decreases in primary productivity and macro- and micro-zooplankton abundance, decreases in nearshore fishes and invertebrates, declines in commercial fish landings, declines in pelagic sea bird numbers, invertebrate "disease" epidemics, and sea urchin overgrazing phenomena. For example, as recently as 1999, 11 of the Park's 16 kelp monitoring sites were dominated by sea urchins, or were urchin barrens.

Fishing

Recreational and commercial fishing is allowed by the State in Park waters, except in the areas included in the SMRs. The nearshore waters surrounding the islands, and especially the nearshore kelp beds, are especially well-exploited for market squid (by purse seine and lampara boats), sea urchins (by divers), sea cucumber (in the Park, by divers), spiny lobster (by traps), red rock crab (by traps), and nearshore finfish, especially rockfish spp. (*Sebastes*), and California sheephead (by hook and line, and live traps). Coastal pelagic species (such as anchovy, sardine, mackerel, and tuna), flatfish, and prawn are commercially important in the Sanctuary, but account for a smaller proportion of commercial harvest within Park waters. Several kinds of commercial fishing gear are prohibited within 1 nautical mile, or 3 nautical miles, of Park islands, such as trawls, and set- or drift-gill nets. Additionally, the numbers of hooks allowed per vessel is restricted in the nearshore finfish fishery, and a limited number of live-fish trap permits are issued in the nearshore fishery. Recreational fishing in Park waters (via hook and line, and

diving) primarily targets rockfish, barred sand bass, calico kelp bass, ocean whitefish, lobster, and scallops.

Fishing is implicated in the regional declines, in many cases starting in the 1970s, in the stocks of many fish and invertebrates that are harvested within Park waters. Commercial stocks that have declined include several rockfish species (especially shelf rockfish spp.), lingcod, Pacific whiting, giant sea bass, pelagic sharks, spiny lobster, spot prawn, abalone, warty cucumber, red sea urchin. Commercial harvest of several Park species is closed in California, including uncultivated rock scallops, Pismo clams, all abalone, giant sea bass, California corbina, spotfin croaker, yellowfin croaker, kelp bass, barred sand bass, spotted sand bass, garibaldi, wolf eel, blacktip poacher, pygmy poacher, bluespotted poacher, ocean sunfish, great white shark, basking shark, and striped marlin. Recreational fishing dominates the take of many nearshore species (such as California scorpionfish, kelp greenlings, treefish, and calico, blue, olive, and kelp rockfishes); recreational landings of nearshore species declined by at least 65% between the 1980s and the 1990s.

The establishment, in 2003, of twelve no-fishing (and limited fishing) reserves that contain Park waters creates a new opportunity to differentiate between fishing pressure and natural stressors (such as regime shift, El Niños, and disease) as the causes of recent declines of many fish and invertebrates that occupy Park habitat. In addition, the reserves provide an avenue for investigating indirect impacts of fishing on community structure (such as through trophic cascades). The long record of data from the Park intertidal and kelp forest monitoring programs provides a good basis for such "before and after" studies. The Park has added 16 sites to its kelp forest monitoring program to better compare biological trends inside versus outside the SMRs. So far, comparison of monitoring data from inside versus outside protected areas at the Park has revealed that (1) spiny lobsters, as natural predators of sea urchins, reduce the incidence of urchin barrens at rocky reefs inside fishing refugia; (2) harvest of lobsters indirectly increases epidemics in sea urchins; and (3) the commercial dive fishery is responsible for 33-83% of the populations decline in sea cucumbers at the Park in recent years.

Exotic species

To the knowledge of the NPS, marine habitat at the Park has not been colonized by invasive seaweeds or other problematic exotic marine species. Because the invasive kelp *Undaria pinnatifida* has been found at Santa Barbara Harbor and Catalina Island, and has been seen on a boat that visited Park waters, this species poses a risk to the Park. Drift Arundo occasionally washes up and spouts on Park beaches (but is removed when discovered); vigilance is required to prevent Arundo from colonizing Park drainages and wetlands.

Disease

Several Park invertebrate species are experiencing regional declines, in some cases severe, from diseases. Withering syndrome has reulted in nearly complete disappearance of black abalone since the mid-1980s along mainland shores south of Point Conception and at many of the Channel Islands. A number of sea star species, including *Pisaster ochraceus* (ochre sea stars), *P. giganteus*, and *Asterina miniata*, have been struck by wasting diseases in the Park, usually associated with strong El Niños, such as in 1997. A warm-water bacterium in the genus *Vibrio* is blamed for the ochre sea star disease. An urchin-specific bacterial disease entered the Channel Islands region after 1992 and has acted since then as a density-dependent mortality source. Regime shift, and trophic cascades caused by fishing pressure on predators (leading to extremely

dense urchin populations), are among the hypothesized causes of disease emergence in the region.

Absence of a keystone mammalian predator

Once common at the Channel Islands, the federally endangered southern sea otter (*Enhydra lutris nereis*) was hunted to local extinction by the end of the 1800's. As predators of sea urchins, their absence is hypothesized as one of the factors allowing for localized population explosions of sea urchins, and consequently the formation of urchin barrens in habitat that normally supports kelp forest. Now, a few sea otters are spotted in the Park. From 1987-2001, USFWS caught and relocated all sea otters that appeared south of a line drawn from Pt. Conception to San Miguel Island. Relocation areas were near the city of Santa Cruz and Moss Landing to the north, and San Nicolas Island to the south. This activity was part of a political compromise designed to placate commercial fishermen of crab, urchins and lobsters in the Santa Barbara area, who were competing with the otters for crab, urchins and lobsters. On October 5, 2005, the USFWS announced its intent to end the relocation program and to allow sea otters to recolonize the Southern California coast at a natural rate. As a result, although sea otters have been essentially absent from the Park for almost a century, it is reasonable to expect that they will begin to recolonize the Channel Islands at some point in the future.

Non-consumptive use of aquatic resources

Nonconsumptive use of aquatic resources in the Park include kayaking, whale watching, sailing, surfing, beach camping, and diving. Kayaking and private sightseeing by boat takes place mostly along the northern coast of Santa Cruz; off Santa Rosa in Becher's Bay, between Ford and South Pts., and between Carrington and Brockway Pts.; and off San Miguel from Cuyler Harbor to Cardwell Pt.. Whale watching is concentrated around Anacapa and from Carrington Point, on Santa Rosa, to Painted Cave on Santa Cruz. The Park protects important seabird and pinniped habitat through permanent and seasonal closures of certain trails, beaches, sea caves and sea cliffs. In addition, all access to offshore rocks and pinnacles is prohibited. Limited opportunities for primitive camping and hiking occur on all five Park islands. According to Park staff, kayakers, hikers and campers generally comport themselves in a manner which does not impair aquatic resources. During busy holiday weekends, illegal releases of sewage from private boats may be leading to short-term decreases in water quality in Park anchorages; high bacteria levels were measured on the Fourth of July weekend, 2005, in water at two anchorages at Santa Cruz, and were presumably related to high numbers of private boats anchored there during the holiday weekend.

Table 26. Existing and hypothesized degradations of aquatic resources at Channel Islands National Park. Codes are as follows: EP - existing problem based on direct evidence; PP - potential and likely problem; OK - not currently, or expected to be, a problem; Shaded - evidence is lacking, limited, or indirect; ? - not enough information available to categorize threat level; blank - not applicable

	Streams/Riparian Habitat			**Vernal Pools**			**Coastal wetlands**		**Lagoons**		**Ground-water**	**Rocky inter-tidal**	**Subtidal, Reefs, & Kelp**	**Seabirds, Pinnipeds**
Stressor	S.Mig.	S.Rosa	S.Cruz	S.Mig.	S.Rosa	S.Cruz	S.Rosa	S.Cruz	S.Rosa	S.Cruz				
Water Quality														
high N & P	OK	OK	PP	?	?	?	OK	?	OK	OK	?			
Low DO	OK	OK	OK	OK	OK	OK	?	?	OK	OK				
Turbidity	?	EP	PP	PP	PP	PP	?	?	OK	OK				
Water Quantity														
Altered depth/duration of flow	PP	PP	PP	?	?	?	PP	PP	OK	OK	?			
Pollutants														
Fecal bacteria	OK	OK	PP	OK	OK	PP	OK	PP	OK	PP	OK	OK	EP[1]	
Heavy metals/trace elements	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	EP	PP	PP
Pesticides & other organics	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	EP	PP	EP
Physical Disturbance														
Feral pigs (rooting)			EP			PP		PP		PP				
Lingering effects of past cattle & sheep	PP	EP	EP	PP	EP	PP	PP	EP	PP	PP				
Dredging/fill			EP					EP						
Road crossings	OK	EP	EP				EP	EP						
Watershed erosion	PP	EP	EP				EP	EP	EP					
Other														
Non-native flora or algae	PP	EP	EP	PP	EP	PP	PP	EP	PP	PP		PP	OK	
Elk & deer browsing		EP			PP		PP		PP					
Fishing - Direct												PP	EP	
Fishing - Indirect												PP	EP	EP[3]
El Niños	PP[2]	PP[2]	EP[2]				PP[2]	PP[2]				PP	EP	EP
Regime Shift												PP	EP	EP
Absence of sea otters													EP	
Disease												EP	EP	OK

[1]Refers to bacterial contamination at anchorages

[2]Refers to El Niño related floods, erosion, and landslides

[3]Refers to disruption of nocturnal seabird activity from squid boats (although ingestion of hooks and entanglement with gear is applicable, but not addressed in this report)

D. RECOMMENDATIONS FOR ADDRESSING INFORMATION GAPS

Below, steps are suggested to address many of the information gaps identified in this study. Priority is given to investigation of known or hypothesized anthropogenic influences; studies are not described for all of the undocumented features of the Park's water bodies listed at the beginning of this section. Omitted are studies about the consequences of natural phenomena (such as regime shift and El Niño) on aquatic resources at the Park, which are not mitigable. Recommendations are assigned the letters H, M, or L to indicate high, medium, or low priority, respectively.

1. Continuation of all aspects of the Park's existing monitoring programs is highly recommended (H).

2. Digitally map the coastal wetlands and lagoons in the Park (L). With the exception of the lagoons that are monitored on Santa Rosa, the locations of the Park's coastal wetlands and lagoons are not in the Park's GIS. The areal extent of wetlands and lagoons is unmapped.

3. Rigorously monitor beaches, coastal wetlands and stream mouths for recruitment of highly invasive exotic plant species that directly affect aquatic habitat, such as Arundo (H).

4. Discover the post-grazing status of vernal pools on Santa Rosa (L). Resurvey the twelve vernal pools visited by L. Furlong on Santa Rosa in 1995. In addition, it seems prudent to map the locations of all vernal pools on Santa Cruz, Santa Rosa and San Miguel for inclusion in the Park GIS. Vernal pools on Santa Cruz may have been impacted by feral pigs, and should be compared to those on Santa Rosa.

5. Evaluate stream function and riparian zone condition on Santa Cruz (H). Feral sheep have been absent from the TNC-owned portion of Santa Cruz for about 10 years longer than on the NPS-owned portion of the island. A study of riparian zone condition and stream function (such as was conducted on Santa Rosa in 1995 and 2002) in strategically selected watersheds on the island may clarify expectations for future changes in Park streams as watersheds and riparian zones (presumably) continue to recover from the effects of sheep grazing. In light of planned restoration work at Prisoner's wetland, inclusion of the stream in Cañada del Puerto in such a study is a priority. In addition, the study would provide baseline information for detecting changes that may result from the removal of feral pigs, which have been present throughout the island, and which are being eliminated as of this writing.

6. Prepare a strategy for enhancing recovery of native woody riparian vegetation on Santa Rosa and Santa Cruz (the latter, if warranted by the results of #5 above) (M). The feasibility of transplanting willow and cottonwood seedlings to stream reaches that no longer host mature specimens should be evaluated. A first step would be to map remaining stands of mature trees on both islands for inclusion in the Park GIS.

7. Expand baseline data in anticipation of restoration work at Prisoner's wetland and in its watershed, Cañada del Puerto (M). Some features of the altered wetland at Prisoner's Harbor were recently described (soil profiles, vegetation, shallow wells installed). To this information should be added baseline data about the volume of flow in the stream that enters the wetland, and water quality and aquatic fauna in the currently existing wetland. A hydrologic study utilizing shallow groundwater wells above and below selected stream reaches containing *Eucalyptus*

stands in Cañada del Puerto would contribute to understanding the ecological impact of these non-native trees on water flow in streams and coastal wetlands in the Park.

8. Conduct a thorough survey of road crossings of water courses (H). Armed with a GPS and a digital camera, road crossings of streams and wetlands on Santa Rosa and Santa Cruz could be surveyed and entered into the Park GIS. Locations for culvert construction, or other mitigation steps, could be prioritized. It may be possible to compare the current and past status of some road crossings using archived photos in the possession of the Park.

9. Better exploit sentinel mussels to map spatial variation and temporal changes in seawater contamination in the Park (H). The last time sentinel mussels were sampled at each of the Park islands is as follows:

San Miguel: west island 1978, Tyler Bight, 1988
Santa Rosa: never
Santa Cruz: Fraser Point, 2002
Anacapa: 1980
Santa Barbara: 1978

Both of the times that mussels from San Miguel were analyzed, levels of total DDT and two or more trace elements exceeded the national 85th percentiles for those constituents. The single time mussels from Santa Barbara were analyzed, four trace metals that can be toxic to marine biota (cadmium, lead, silver, and zinc) were present at levels that exceeded the national 85th percentiles for them.

The only time series of body burdens available for Park mussels is from Fraser Point, on Santa Cruz, which is not near breeding colonies, or other especially large congregations, of pinnipeds or seabirds (which may be one of the most significant entry points in the Park for mainland-derived contaminants). This time series does not provide clear evidence for a steady decline in total DDT in mussels at Fraser Point since 1977. Total DDT in mussels at Fraser Point was above the national 85th percentile as recently as 1996. NOAA (which surveys mussels every 2 years) should be approached about restarting mussel sampling at San Miguel, Santa Rosa, Anacapa and Santa Barbara Islands.

10. Compare sediment loads of priority contaminants at sites within the Park reflecting different chronic exposure levels to potential sources of pollutants such as ship traffic, mainland runoff, and seabird and pinniped colonies (M for most sites, H for seabird and pinniped colonies). Lobby for inclusion of more nearshore sediment sampling sites at the Channel Islands during Bight '07. SCCRWP has sampled sediment for toxicity and chemistry at numerous locations in the Sanctuary during its Bight surveys, but few sites are located within Park boundaries and previous sites are not well located to investigate spatial trends of contamination that may be associated with some of the sources identified in this report.

11. Measure pollutants in the water column at the Park using moorable, passive in-situ exposure samplers (H). Body burdens in sentinel mussels at the Park prove that within the last decade (and as recently as 2002 in some cases) the following constituents (at a minimum) resided at least part time in the water column at the Park:

Trace elements: Ag, Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Zn
Organics: alphachlordane

transnonachlor
heptachlor, heptachlor-epoxide
DDT, DDD, DDE
PAHs (any of:1,6,7-trimethylnaphthalene, 1-methylnaphthalene, 2,6-dimehtylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(k)fluoranthene, benzanthracene, benzo(g,h,i)perylene, benzo-a-pyrene, benzo-b-pyrene, benzo-e-pyrene, benzo-k-flouranthene, biphenyl, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, perylene, phenanthrene, pyrene)
PCBs
aldrin
dieldrin
organotin
chlorpyrifos
cis-nonachlor
gamma chlordane
chrysene
dibenzothiophene
endosulfan
fluorene
alpha, beta and delta HCH
lindane
hexachlorobenzene
mirex
naphthalene
oxychlordane
pentachloroanisole
tetrachlorobenzene

Concentrations of selected organics and trace elements should be compared in areas at the islands with and without aggregations of seabirds and pinnipeds, and in areas that are differentially exposed to other potential sources such as from the shipping lane, or mainland runoff.

Synoptic studies of water quality using towed or ship-board instruments would be expensive and would require collaborators with research vessels and sophisticated equipment. Filtration methods can require processing as much as 2500 L to achieve detection for organic constituents and trace elements in seawater (e.g., Zeng et al. 2002). Other options for real-time measurements exist. For example, real-time ship-board measurements of trace metals in seawater were achieved by Esser & Volpe (2002) using separation chemistry with inductively coupled plasma mass spectrometry. The U.S. Navy employs a real-time data acquisition system dubbed MESC for synoptic surveys in San Diego Bay. The MESC includes a towed sensor package and on-board equipment that measures dissolved copper (using potentiometric stripping analysis) and PAH (using uv-fluorescence).

The most practical way to directly measure trace metals and organics in seawater at the Park might be to deploy (i.e., moor) passive *in-situ* exposure samplers which integrate background