Title

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Santa Catalina Island: Reclaiming a National Treasure

A Report to *The Ralph M. Parson's Foundation*

by

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EXECUTIVE SUMMARY

The island of Catalina off southern California has been fished recreationally and commercially for over a century. The marine resources of this popular destination are under increasing pressure as the population of southern California expands rapidly. The effects of this pressure have been dramatic for many marine species off Catalina. Clearly, the marine resources on Catalina are limited while human population growth does not appear to be limited in the near future. Therefore, improved management of the marine resources off Catalina is critical. Improved management consists of adaptively changing traditional management practices such as limiting effort, closing species to fishing, limiting sizes that can be taken, etc. However, a new approach to protecting marine resources and rebuilding fisheries is the use of protected areas where fishing is limited or prohibited. Marine protected areas (MPAs) are an increasingly popular though controversial tool for the management of exploited species and marine ecosystems.

The California Marine Life Protection Act (MLPA) was signed into law in 1999. The MLPA called for the establishment of a network of marine protected areas throughout the state to help rebuild depleted fisheries, enhance recreational activities, protect marine habitats, and conserve biodiversity. The design of marine reserves is complex because many ecological factors must be taken into account to design effective reserve networks. The purpose of this report is to provide information useful for the design of MPAs off Catalina. Here we, (1) review the efficacy and current science of MPAs, (2) present some of the historical changes to marine resources at Catalina, (3) list and discuss current MPAs off Catalina, (4) discuss ecological criteria for the design of a network of MPAs off Catalina, (5) recommend a specific network of MPAs for Catalina, and (6) recommend future research that would aid the design and monitoring of MPAs off Catalina.

There are currently several protected areas off Catalina. The current reserves that limit or exclude fishing, with one exception, are too small to effectively enhance fishery resources, a primary goal of marine protected areas. The goals, governance, and degree of protection vary considerably among these MPAs. Currently, there is no overarching governance or management. Overarching management and governance is needed not only at the scale of Catalina Island but also at the larger scales that are required for MPA networks to achieve the goals of enhancing resources and preserving biodiversity. We recommend such oversight and governance for any network of reserves established at Catalina, recognizing that the MPA network should be considered as a single collective unit for achieving conservation and protection goals. Therefore, we recommend the establishment of an oversight authority in the form of a panel composed of local stakeholders, scientists, and members of state and federal agencies that govern MPAs at larger scales. The panel should be responsible for monitoring the network, gauging its effectiveness, and fine tuning the network as necessary. The panel should also consider the utility of traditional fishery management practices in combination with marine protected areas.

We recommend the following actions for the protection of marine resources at Catalina:

(1) All of the state waters off Catalina should be designated as an Area of Special Biological Significance to protect water quality throughout the Island.

(2) All of the state waters off Catalina should be established as a State Marine Conservation Area. This status permits selected commercial and recreational fishing and establishes the governance to restrict activities that compromise the protection of vulnerable species, communities, habitats or geological features. Nested within this State Conservation Area we recommend the establishment of State Marine Parks and State Marine Reserves to provide higher levels of protection to specific communities and habitats.

(3) The front-side of Catalina from Land's End to Church Rock should be established as a State Marine Park. State Marine Park status protects this area from commercial fishing.

(4) Five State Marine Reserves should be established off Catalina. State Marine Reserve Status prohibits extraction of all plants and animals as well as geological and archeological artifacts. Two of these reserves are expansions of current 'no-take' marine reserves while the rest are new. The State Marine Reserves should extend to either the 100-meter contour or 1.5 nautical miles offshore, whichever is greater.

(5) The current boundaries of the Farnsworth Bank reserve should remain unchanged and the area should be established as a State Marine Park to exclude commercial fishing activities.

(6) The market squid fishery off Catalina should be limited to vessels based solely in California.

(7) The use of all longlines and nets, with the exception of purse seine nets specifically used for squid and baitfish, should be permanently banned in all state waters off Catalina.

(8) Current traditional statewide commercial and recreational fishing regulations (e.g., seasonal, size, bag limits, groundfish closures, closed species) should not be changed for state waters off Catalina.

INTRODUCTION

The status of many coastal ecosystems and marine resources around the world are declining due to increasing human impacts such as overfishing, pollution, and the introduction of invasive species. Improved management and integrated governance of marine ecosystems are clearly needed to address these urgent problems.

Currently, most of the world's fish stocks are heavily exploited. Approximately three-quarters of these stocks are overfished or fully exploited. Coastal ecosystems of southern California are no exception. Many stocks in southern California have been in serious decline since the 1950's. More recently, the rate of decline for many of these stocks has been accelerating. For other stocks, yields have remained somewhat stable despite considerable fishing pressure and there has even been some recovery in a few other stocks. The largest sizes of individuals for depleted stocks and for stable or partially recovered stocks have become significantly smaller due to fishing. The result is that per capita reproductive capacity has decreased and that the ecological roles of many of these species have changed due to fishing. Therefore fishing has fundamentally affected the structure and functioning of marine ecosystems in southern California.

Marine ecosystems are extremely dynamic due to cyclic variations in ocean climate that occur over time scales from a few years, such as the El Nino cycle, to several decades. The result is that the abundances of many exploited species are highly dynamic over these time scales. The rates and extent that species respond to dynamic ocean conditions is quite variable among species depending on life history traits such as reproductive capacity, rates of growth and maturation, dispersal of young, and movement of adults as well as interactions with other species. Ocean variability complicates fishery management practices and is part of the reason they have met with limited success. Overfishing destabilizes the ability of individual species and, by extension, ecosystems to respond naturally to ocean climate dynamics.

The focus of traditional fishery management has been on single species in which fishery yield is thought of as interest in a bank account, with each species having its own 'interest rate' that may be variable in time and space. Individual stocks are fished down to a targeted percentage of their natural unfished stock to maximize reproduction and growth, and therefore the biomass that can be harvested each year. Unfortunately, the dynamic nature of ocean climate and the cascading effects of fishing due to complex interactions with other species greatly complicates this approach. Continual refinement of single species management practices has occurred by including factors such as climate variability. Nevertheless, many stocks around the world, including southern California, are overfished. Because of this, there is an emerging consensus among scientists and managers that the single species approach by itself is inadequate.

Over the last decade, the failure of the single-species approach for many stocks has prompted calls for an ecosystem-based approach to marine resource management. The rationale behind an ecosystem-based approach is the explicit realization that species are integral components of complex ecosystems that respond differently to ocean climate variability within the context of their ecosystems while at the same time affecting one another in complex and profound ways. An important component of ecosystem-based management is marine protected areas (MPAs) in which the harvest of some or all marine resources is prohibited. The use of MPAs to enhance marine resources is a conservationist application that began at least centuries ago in Oceania. More recently, in the decades since WWII, MPAs have been mostly established to protect important habitats and primarily began with wetlands. This approach is protectionist because the primary goal of MPA establishment is the protection of a habitat or species within an area and not the enhancement of marine resources outside of the MPA. Most recently, within the last decade, MPAs and networks of MPAs have been established explicitly to enhance marine resources. Therefore, we have returned to the historic Polynesian model of using MPAs for conservation.

The most common criticism of marine protected areas is the lack of scientific knowledge necessary to design or even predict the conservation benefits to be gained by a network of MPAs. Another criticism is the lack of information on the location, quality, and importance of habitats for species targeted for conservation by MPAs. From a conservation standpoint, these concerns are well justified. However, the protective value of many MPAs has been well documented, even for some that are relatively small, where species have been found to be significantly more abundant and typically larger inside MPAs than in similar unprotected habitat nearby. Further, it has also been shown that protected ecological communities are more resistant to large shifts in structure and when disturbed are more resilient than unprotected communities due to the cascading effects of protection. The capacity of MPAs for resource enhancement, however, is not well known and has only been observed for a handful of MPAs because of the difficulty in gauging enhancement and because most reserves are presently too small to be enhancive.

MPAs enhance fishery stocks through a combination of adult spillover and larval supply. Adult spillover is the migration of adults from protected areas to unprotected areas as resources inside the protected area becoming limiting as species abundances increase inside a protected area. Larval supply is the provision of larvae from stocks protected within an MPA to fished areas. Most species of invertebrates and fish have a planktonic larval stage that is subject to dispersal by ocean circulation. The period that larvae are planktonic varies considerably among species from a few hours to several months.

Modeling studies have been used to determine the effects of MPAs on resource enhancement due to the paucity of empirical studies. These studies have shown that the effects of MPAs are similar to the traditional management strategies of increasing age at first capture and reduced effort. These studies have also shown that MPAs are more enhancive for species with intermediate levels of adult movement and that for reserves to be self sustaining they must be large enough to retain at least some larvae for species with longer planktonic periods.

Marine Life Protection Act

The state legislature of California passed the Marine Life Protection Act (a.k.a., the Shelley Bill) in 1999 in response to concerns about overfishing in state waters. The MLPA called for the establishment of a network of reserves throughout California to:

> *Protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and help rebuild depleted fisheries...* -Shelley Bill (1999)

The MLPA is intended for both protection and conservation. Passage and implementation of the MLPA has been highly controversial mainly due to concerns about closing highly valued fishing areas and the negative socioeconomic impacts anticipated by recreational and commercial fishing interests and the myriad industries associated with fishing. Further complicating matters, has been the lack of public funding to support implementation. The MLPA originally called for the approval of a network of MPAs throughout California by April 2001. Political lobbying by recreational fishing interests and the lack of public funding stalled implementation of the MLPA. Implementation was suspended by Governor Schwarzenegger soon after he entered office in 2003. Implementation of the MLPA has since recommenced in a process called the Marine Life Protection Act Initiative supported by a public-private partnership under the auspices of the California Department of Fish and Game (CDFG). Establishment of MPAs through the Initiative will occur in phases beginning with central California. Currently, the Initiative calls for the design of a network of MPAs off central California by March 2006 that will be adopted by the CDFG commission in November 2006. The design and adoption of MPAs throughout the rest of California will take place between 2006 and 2011.

Motivation and Purpose of Report

Santa Catalina Island historically has been one of the most popular recreational fishing areas in southern California and remains a popular fishing destination for the burgeoning suburban and metropolitan populations of Los Angeles, Ventura, and Orange Counties (see Fig. 1). Catalina is also fished commercially for market squid, spiny lobsters, live fish for restaurants and several other species of groundfish and baitfish. Thus far, there has been limited comprehensive planning for the design and establishment of MPAs off Catalina for the implementation of the MLPA. The goal of this report is to (1) provide information on the habitats and species that would benefit from protection in MPAs off Catalina, (2) provide an overview of current MPAs off Catalina, (3) present and apply ecological criteria for designing MPAs off Catalina, and (4) introduce and discuss the types of information that are presently not available but would aid in the design of MPAs off Catalina. The focus of our report is the set of ecological factors that should be considered for the design of MPAs off Catalina.

Santa Catalina Island

Brief fishing history

Catalina Island was a popular recreational fishing destination and the site of several commercial fisheries as early as the late 19th century. In a report solicited by the CDFG Commission in 1913, Charles F. Holder, a prominent natural historian, conservationist and sportsman, concluded that fishing activities around the island over the previous 30 years had decreased stocks to the extent that "...the supply has dropped off to a menacing extent, due to lack of laws, lack of protection and over-fishing...". He went on to report that "The angling here [Catalina] in 1886 to 1900 was the most remarkable in the world but with the coming of power boats, the seines, trawls and other nets, the fisheries began to decrease until it was evident that something must be done. The most menacing danger was the alien who attached a gill net to the kelp and ran it out into the sea. Fifty such nets have been counted in a mile and a half." Because of these and similar observations such as "During my recent visit to Santa Catalina Island, I was deeply impressed with the threatened danger to the commercial and valued sport-giving fisheries at the island..." and "... this island for three or four miles off-shore is the spawning ground of the valuable food fishes of southern California, and particularly of Los Angeles, and that this region should be protected absolutely from all kinds of nets or lines handled for commercial or market purposes" by George Kunz in 1912, a reserve was established in the waters around Catalina out to three nautical miles within which all nets were prohibited. Fish could only be taken using hook and line. However, the reserve lasted for less than a year as requests for an annulment of the reserve by the commercial fishermen of Avalon and fish canning interests were granted by the state legislature. While George Kunz and others of his time focused on commercial fishing, no one predicted the increased levels of recreational fishing at Catalina due to rapid human population growth throughout southern California.

Recreational and commercial fishing continued unabated in the waters off Catalina and throughout southern California through the rest of the first half of the 20th century – a period that has been called the 'golden years' of California ocean fishing. There are many well-known photographs that serve as testaments to the epic fishing off Catalina for yellowtail, albacore and yellowfin tuna, striped marlin, giant seabass and white seabass that occurred during this period. Catalina Island was so well known for its abundance of large white seabass that this large croaker was referred to as 'Catalina salmon'. The giant seabass, also known as the 'ocean hippo' in those days, was a very popular sportfish off Catalina. This all began to change after the early 1950's when the commercial catches of many of these and several other species began to decline. This decline coincides with both the post WWII population boom in southern California and a change in ocean climate that we now attribute to the Pacific Decadal Oscillation (PDO). The decline in many of these species prompted Connie Limbaugh, a pioneer diving fish biologist at the Scripps Institution of Oceanography to note in 1955, "… the apparent decline of sport fish was causing sport fishermen great concern". Since then, many of these species are still fished off Catalina but the catch is presently much lower than historical catches. In the meantime, commercial fisheries have developed for several species of invertebrates including rock crabs, lobsters, abalone, red sea urchins, and market squid. The live trap fishery, a fishery in which live fish are taken directly to market, developed in the 1990's and has been a serious problem for many species of fish, especially the California sheephead.

The first marine reserves in southern California, where the harvest of at least some species was prohibited, were established beginning in the 1970's. These first reserves were very small and included 'Lover's Cove Reserve' on Catalina. Since that time larger reserves have been established around the northern Channel Islands and in four areas on the mainland. The latter reserves were established in 1994 as part of the California gill net ban, and some were poorly sited with regard to habitat quality. Presently, there is a confusing myriad of designations, rules, and authorities with regard to MPAs in California. Catalina is no exception with various MPAs designed to protect habitats, water quality, groundfish, and some invertebrates. A major objective of the MLPA is to streamline the governance of MPAs throughout California.

Current Marine Protected Areas off Santa Catalina Island

There are currently several marine protected areas off Santa Catalina Island (see Table 1, Fig. 2). The extent of protection and the resources that are protected by these MPAs vary. The types of protection within MPAs near Santa Catalina Island include (1) no take of any species, (2) no take of select invertebrates, (3) no-take of groundfish, and (4) protection of water quality. There is overlap in both the spatial extent and the jurisdictional authority for many of these MPAs.

The largest MPA off Santa Catalina is the groundfish closure area in state waters (within 3 nautical miles of Santa Catalina) in waters deeper than 360'. The size of the groundfish closure area is enlarged to include waters deeper than 120' in years when either specific quotas are reached or the status of species of concern is changed by the Pacific Fishery Management Council (a federal management council) or the California Department of Fish and Game. In addition, the Pacific Fishery Management Council (PFMC) is currently amending its Groundfish Fishery Management Plan (Amendment 19). As currently drafted, the amendment would ban all bottom trawling in an area of ~459 square miles off Santa Catalina Island and designates all of Catalina as essential fish habitat in so-called Habitats of Particular Concern (HAPC's). Off Catalina these include all areas with giant kelp canopy and rocky reefs. The HAPC designation is the first phase of a groundfish management plan to implement the Sustainable Fisheries Act (an amendment to the Magnuson-Stevens Act) "to minimize to the extent practicable the adverse effects of fishing".

Four MPAs off Catalina are designated by the state of California as Areas of Special Biological Significance (ASBS). These areas were established in 1974 as part of large statewide network in which water quality is protected. Discharges into ASBS's are prohibited unless special exceptions are granted. There are no restrictions regarding the removal of living resources within an ASBS unless the area is protected as part of a different MPA within which extraction is limited or prohibited. The four Areas of Special Biological Significance (see Fig. 2) off Santa Catalina Island are Subarea 1 ASBS (Isthmus Cove to Catalina Head ASBS), Subarea 2 ASBS (N. End of Little Harbor to Ben Weston Pt.), Subarea 3 ASBS (Farnsworth Bank), and Subarea 4 ASBS (Binnacle Rock to Jewfish Pt.).

There are also state-designated marine conservation areas that include (1) Farnsworth Bank to protect the purple coral, *Sylaster californicus*, (2) the Catalina Island Invertebrate Area, (3) Lovers Cove Reserve, and (4) the Catalina Marine Science Center Refuge.

Table 1. Current Marine Protected Areas off Santa Catalina Island in order of establishment. SWQPA=State Water Quality Protection Area, SMR=State Marine Reserve, SMCA=State Marine Conservation Area,

Name	Year Established	Type	Spatial Extent	Regulations
Farnsworth Bank Ecological Reserve	1972	SMR	over waters ~50-250' deep, irregular area 575 yds. x 200 yds.	All take of the purple coral, *Stylaster californicus,* geological specimens, and recreational take of marine plants prohibited
Catalina Island Subarea 1	1974	SWQPA	~11,650 acres along 17 miles of coastline, offshore boundary 300' isobath or 1 nautical mile (whichever greater)	Water quality only, fishing/harvesting not restricted
Catalina Island Subarea 2	1974	SWQPA	3.3 miles of coastline, offshore boundary 300' isobath or 1 nautical mile (whichever greater)	Water quality only, fishing/harvesting not restricted
Catalina Island Subarea 3 (Farnsworth Bank)	1974	SWQPA	same as Farnsworth Bank Ecological Reserve	Water quality only, fishing/harvesting not restricted, but see Farnsworth

				Bank Ecological Reserve
Catalina Island Subarea 4	1974	SWQPA	2.7 miles of coastline, offshore boundary 300' isobath or 1 nautical mile (whichever greater)	Water quality only, fishing/harvesting not restricted
Lover's Cove State Marine Reserve	1974	SMR	~0.3 miles of coastline, offshore boundary (recreational=300' offshore, commercial=1000' offshore)	All recreational take prohibited, commercial take of finfish, lobster, abalone, and crabs permitted
Catalina Island Invertebrate Area	1980	Special Closure	~4.14 km of coastline, Lion Head to Arrow Pt., shoreline to 1000' offshore	take of all invertebrates prohibited
			Arrow Pt. to West End	commercial take of invertebrates prohibited
Wrigley Institute of Environmental Studies State Marine Reserve	1988	SMR	~1 mile of coastline, offshore boundary 300' or 1 nautical mile (whichever greater)	anchoring restrictions, no take
California Groundfish Closure Area	1994	SMCA	periodic closures in waters >360' or >120'	All take of most state groundfish prohibited

Inspection of Table 1 shows that there are already a number of MPAs in waters off Catalina Island. Each MPA, or set of MPAs, were established for different reasons and their governance ranges from county to federal. Presently, there is little coordination among the agencies responsible for oversight of these MPAs to determine their cumulative benefit to the resources and water quality of Catalina Island. There is also little effort to monitor many of these MPAs to determine if they are meeting the objectives set forth in their establishment. For these reasons, this 'network' of MPAs off Catalina is likely suboptimal and in need of revision as well as improved and coordinated governance.

Physiography

Catalina Island is located in the coastal borderlands of the Southern California Bight (SCB). The borderlands of southern California is the wide continental shelf that exists off southern California and is characterized by ridges (the channel islands are ridges that extend above sea level) and basins. The SCB is a marine province stretching from Pt. Conception in central California to the area between Punta Colnett and Punta Eugenia in Baja California. Both Pt. Conception and Punta Eugenia are zonal range boundaries for a large number of species and are referred to as biogeographic boundaries. The SCB therefore supports a characteristic and unique assemblage of marine plants and animals that is fundamentally different than the marine provinces to the north and south.

Catalina is located 32 km from the mainland and has ~90 km of coastline. The physiography of the Island is dominated by two peaks separated by a narrow isthmus. The isthmus divides the Island into what are referred to as the 'west' and 'east' ends, the east end being much larger (Fig. 3). The side nearest the mainland is commonly referred to as the 'front-side' and the other side is referred to as the 'backside'. We will use this terminology throughout the report. Catalina is bordered by basins to the northeast and southwest. The San Pedro Basin, with a maximum depth of ~900m, is located between Catalina and the mainland, and the Catalina Basin (~1300m deep) is located to the southwest of Catalina. There is also a submarine canyon bissecting the western shelf near Little Harbor that forms and alluvial plane with the surrounding shelf at a depht of ~100m. The shelf off Catalina is dominated by a sloping sandy plain between 50 and 150 meters deep. This shelf is extremely narrow compared to the mainland and is narrowest on the northeastern side. The shelf on the southwestern and southeastern ends is much wider and is up to 7 km wide in some areas. There is only a narrow strip of hard rocky bottom at depths where giant kelp and other algae can grow due to the steep submerged slope throughout most of Catalina that flattens out into the sloping sandy shelf. This limits the aerial extent of kelp forests as well as intertidal habitat.

Oceanographic Climate

Oceanographic climate is an important factor to consider when evaluating or designing MPAs. Ocean circulation affects the dispersal of planktonic larvae, which in turn determines the capacity of different areas as sources or sinks for larvae, and the strength of interconnections among various habitats (see MPA criteria below). This information is crucial for designing MPA networks. Ocean climate is also important for MPA design because it determines the productive capacity of different areas. Areas that are frequently exposed to cooler nutrient laden upwelled water are more productive than areas typically bathed by warmer waters. Wave climate, another important physical oceanographic factor, can fundamentally structure marine communities. Catalina has a wide range of ocean climates that are important to consider when designing MPAs.

Currents at the regional scale of the SCB include the southward extension of the California Current, which flows southward from Washington along the narrow continental shelf of the western coast of the U.S. The California Current diverges from the mainland near Pt. Conception and flows along the margin of the southern California borderlands. The Southern California Countercurrent (SCC) flows poleward along the inner shelf of the borderlands inshore of the California Current. The general pattern of surface circulation in the SCB is therefore a counterclockwise gyre. The strength and position of the gyre is highly variable among seasons and years. Superimposed on this general pattern of circulation are wind-driven surface currents and seasonal upwelling, as well as tidal currents. While the large-scale pattern of circulation in the SCB consists of a cyclonic gyre, this pattern is dominated by small scale eddies that are frequently observed throughout the SCB including the vicinity of Catalina Island. Eddies near Catalina are thought to be forced by (1) divergences in the wind field due to the effect of the Island on prevailing winds and (2) the interaction of the Island with the surrounding currents thus forming eddy pairs downcurrent of the Island. Eddies are frequently observed between the mainland and Catalina (Fig. 4) as are eddy pairs off the NW and SE ends of the Island. These small scale eddies typically have diameters of 15-50 km. Such eddies are important for the local retention of larvae and for the exchange of larvae with other habitats located on the mainland.

The productivity of algal stands and the persistence of giant kelp, *Macrocystis pyrifera*, are determined by nutrient and wave climates, both of which are highly variable along the coast of Catalina. A network of MPAs should be designed so that some of the most productive and persistent kelp forests are included. Nitrogen is the major limiting nutrient for marine algae including giant kelp. The largest pool of nitrogen that is utilizable by macroalgae is dissolved nitrate. There is a strong correlation between temperature and nitrate concentration in many marine waters including southern California. Nitrate concentrations increase with decreasing temperature and waters above ~15C contain very little nitrate. The waters of southern California are typically vertically stratified during spring, summer, and fall when cool water below is overlain by a layer of warmer nutrient poor water. The strength and depth of this stratification varies greatly and has profound effects on the productivity of giant kelp.

The temperature, and therefore nutrient, climate of Catalina varies strongly over several time scales. The largest temporal scale of variability is due to the El Nino Southern Oscillation (ENSO) cycle. There are two principal modes of this cycle that repeat themselves over periods from three to nine years. The first is known as El Nino, which is characterized by warm water and a deepened thermocline. The local effect of El Nino is that much of the shallow hardbottom off Catalina is exposed to nutrient depleted warm water leading to severe nutrient stress for kelps. The effect of El Nino on giant kelp is exacerbated relative to smaller species of kelps that mostly grow close to the bottom because most of the nutrient absorbing surface area of giant kelp is near the surface where waters are the warmest. The second mode of the ENSO cycle is La Nina, which is characterized by a shallower thermocline and cooler water, conditions that are highly conducive for kelp growth and recruitment. The next longest time scale of nutrient variability is seasonal. Upwelling due to prevailing coastal winds during spring, summer, and part of fall decreases the depth of the thermocline bringing cool nutrient rich waters into the hardbottom areas off Catalina. The shortest time scale of temperature variability is forced by the tides. The temperature differences due to internal waves forced by tidal waves over a period of several hours can be as great as seasonal differences. Internal waves propagate along the thermocline similar to the manner that surface waves propagate along the air-sea interface except the amplitude of internal waves is much greater. Therefore, during spring tides in seasons when the water column is well stratified, kelp forests are alternatively bathed by warm nutrient poor surface and water and cold nutrient rich surface water that can be displaced upward off Catalina by as much as thirty meters. Much of southern California including Catalina is subjected to an energetic internal wave climate. Another important temperature feature occurs in the lee of Catalina Island. Predominant winds are northwesterly to westerly and the eastern side of the Island is therefore shelter from the wind. Solar radiation heats the ocean surface during the daytime and reduced winds in the lee of Catalina effectively reduces mixing of the upper water column. This leads to enhanced stratification and warmer surface temperatures on the lee side of the Island leading to nutrient stress of giant kelp in the lee of Catalina.

The wave climate of Catalina Island is quite variable because of its complex shoreline and the numerous sources of wave energy. There are five principal sources of wave energy impacting the shallow habitats and shoreline of Catalina: (1) winter storms originating in the Gulf of Alaska, swell direction northwesterly to westerly, (2) regional to locally generated seas produced by northerly to westerly prevailing winds, (3) swells from southern hemispheric winter storms originating off New Zealand during the northern hemispheric summer, swell direction southerly to southwesterly, (4) locally generated seas from easterly 'Santa Ana' winds during fall and winter, and (5) southerly hurricane and tropical storm generated waves originating off southern Baja California. The northern, western and southern shorelines of Catalina are the most frequently exposed while the eastern side is only exposed to episodic Santa Ana storm waves. Large north Pacific winter storm systems typically produce the most energetic waves and have been shown to effect the structure of macroalgal communities on the western and northern sides of the Island. The frequency and magnitude of these storms is exacerbated during El Nino periods. Superimposed onto this pattern of exposed southern, western, and northern coastlines and a typically sheltered eastern coastline are local features such as seafloor aspect and shape that refract or diffuse wave energy creating a patchwork of sheltered areas and areas where the incident swell is greatly magnified.

Any system or network of MPAs off Catalina must include a well-distributed mixture of nutrient and wave exposures at both the Island wide and local scales to increase the likelihood of survival for at least some intertidal and subtidal communities given a major disturbance.

GENERAL CRITERIA FOR MARINE PROTECTED AREAS

The science of marine protected areas has progressed considerably over the last decade. As a result, a set of general criteria for the design of MPAs has emerged as well as a general consensus on how MPAs might be applied to conservation and fishery sustainability. The criteria utilized for the design of MPAs depend on the intended goals of each MPA or network. The scientific certainty of various design criteria varies considerably from highly certain factors such as the location of important habitats to uncertain factors such as adult spillover and the connectedness among different habitats with regard to the magnitude of larval exchange. Because of this, the design of sustainable protectionist (c.f., heritage) MPAs can be accomplished with high certainty as long as habitat quality and distribution are known at an adequately fine scale for the species of interest, and that local movement patterns of species are known. On the other hand, a network of MPAs intended for enhancive conservation is more difficult to design given the uncertainties of larval dispersal and spillover and the large scale of planning and governance that is required for MPA networks. Further complicating matters is the likelihood that larval dispersal and spillover are highly variable among species and locations.

Size

One of the most important factors in MPA design, but one that is still poorly defined, is how large MPAs must be to achieve their specific goals. Initially it was thought that MPAs must cover ~30-40% of a particular habitat for effective conservation. These percentages developed directly from basic fishery management precepts to prevent recruitment overfishing. Individual stocks are managed with the intent to maximize yield and prevent overfishing so that the recruitment of young fish occurs at rates that maintain the sustainability of the stock. Maximizing yield is accomplished by fishing a particular stock down to some fraction of its natural unfished population size. This percentage ranges from 30-40% for many stocks (including highly migratory species) thus leading to the assumption that protecting 30-40% of the habitat for a particular species would effectively conserve that stock. More recently, various reserves have been proposed ranging in size from 5 to 50% for a particular habitat. In most cases, these percentages – referred to as conservation goals – are chosen as a rule of thumb and frequently without much scientific basis with regard to a particular ecosystem or the set of species intended for protection.

The number of species effectively protected by an MPA increases with increasing reserve size as species with ever-larger home ranges are afforded protection. (The home range of a species is the area that individuals of a species range over their post-larval lifetimes – i.e., life stages that are vulnerable to fishing). However, conservation reserves cannot be too large or encompass all of a particular habitat otherwise there would not be effective spillover available for fishing in unprotected areas. Reserve size must therefore be chosen to optimize adult spillover, and larval import and export for all of the species intended for protection. This optimization depends on whether an MPA is designed as a single protected area or part of a network and on what species or ecosystem is targeted for protection. For MPA networks, individual MPAs must be sized to allow adequate protection of targeted stocks in protected areas and be spaced close enough to allow adequate exchange of larvae among individual areas to prevent local extinctions or to facilitate recolonization of individual areas after disturbances such as oil spills.

Alan Shanks, based on a recent study of 32 species, proposes that marine reserves within networks should be 4-6 km in size and spaced 10-20 km apart from one another. The proposed sizing is based on facilitating larval retention for species whose larvae disperse over shorter distances, thereby ensuring some degree of local replenishment. The proposed spacing is based on the average distance that longer dispersing species are able to broadcast their larvae among adjacent reserves.

Species and Ecosystems

The species best suited for conservation using MPAs are species with both intermediate larval planktonic periods and intermediate ranges of post-larval movement. Planktonic periods that are too short limit the ability of source stocks to supply larvae to unprotected areas or other protected areas in a network. Long planktonic periods potentially yield large dispersal distances and increase the uncertainty of larval dispersal patterns. Further, recruitment success for species with long-lived larvae is quite variable because larvae are exposed to the variable ocean climate for longer periods of time resulting in the greater potential for loss from the system due to circulation, or mortality due to starvation during periods when food is scarce or developmental conditions are sub-optimal.

Species that are attached to the bottom or that are highly residential have been observed to greatly benefit from MPAs within many protected areas. However, for these species, the success of an MPA for conservation via spillover is limited due to their limited post-larval movements. At the other extreme are species that are considered highly migratory. The usefulness of MPAs for the protection or conservation of these species is greatly limited except in cases where species have critical habitat needs such as habitat where individuals aggregate to spawn or areas required for recruitment or nurseries. Such areas are also important to protect for many vulnerable non-residential species that are not necessarily highly migratory. Traditional fishery management practices are required for highly migratory species (HMS) possibly in combination with protected areas.

The use of marine protected areas for conservation is the most important component of ecosystem-based management. Of paramount importance for protection and conservation are the ecosystems within which species live. In the past, fishermen and managers have typically focused on individual species. Therefore, traditional fishery management has focused on single species. In the past, this mindset has carried over to marine reserve design to some degree because many reserves were typically designed to protect select species that were depleted, vulnerable, or charismatic - all of which are certainly justifiable reasons. However, the emerging paradigm of ecosystem-based management has led to designing marine reserves to protect interacting ecological communities (e.g., kelp forests, submarine canyons, coral reefs, etc.) that compose entire ecosystems. As such, marine reserves are now being designed to include protection for major representative communities as well as unique or especially vulnerable communities. Therefore any network of protected areas off Catalina must include a subset of these communities spaced to allow at least some degree of larval exchange among them as well as possible exchange with mainland communities.

Socioeconomic Factors

The goal of our report is to list and describe the myriad ecological factors and processes that must be considered for the design of MPAs off Catalina. However, we cannot ignore socioeconomic factors because these factors are the chief motivation for conservation. Socioeconomic factors that are important to consider for a system of MPAs off Catalina include recreational fishing, commercial fishing, and tourism. Recreational fishing and tourism are not mutually exclusive because recreational fishing drives much of Catalina's tourist industry. Recreational fishing and tourism are vital to the local economy of Catalina. Therefore, a network of marine protected areas off Catalina must necessarily exclude a set of habitats that contain high priority target species that are potentially benefited by local protected areas via spillover. These include species having limited home ranges such as lobsters, sheephead, kelp bass and many species of rockfish whose habitats off Catalina include kelp forests, rocky reefs, rock walls, and sand/rock edge habitats. Therefore a representative and adequate set of these habitats must remain open to fishing. On the other hand, many of the most popular species of sportsfish taken off Catalina are migratory. Conservation of these species must be addressed at a larger scale of governance. These species include yellowtail, white sea bass, barracuda, bonito and many species of tuna, billfish, mackerel, and sharks.

Some of the marine related tourism of Catalina does not involve fishing. These tourist activities include diving and snorkeling where an abundance of marine life in healthy 'pristine' communities is highly valued. These areas mostly include hard bottom habitats such as kelp forests, rocky reefs, and the rocky intertidal. An example is the site known as 'Italian Gardens' where black seabass are known to aggregate. A set of representative habitats that are close to ports on Catalina need to be protected for these types of habitats because of their value to the non-consumptive tourist activities off Catalina.

There is also commercial fishing for lobster red sea urchins, and live fish using traps that must also be considered when planning reserves off Catalina. Lobsters are reasonably mobile and some but not all fishermen displaced by reserves could still fish the edges of reserves, but clearly the lobster fishermen would be impacted. Sea urchins, however, are not mobile and those fishermen displaced from reserves would lose their livelihood. It is important that managers be cognizant and transparent about these issues and address them honestly.

Currently, the most important commercial fishery off Catalina as well as throughout California is the market squid fishery, which takes place on Catalina mainly on the backside from Catalina Harbor to Salta Verde Pt. Market squid are migratory. Therefore management of this species must occur at a larger spatial scale than Catalina. Because of the importance of this fishery however, it is reasonable to propose that some of the squid fishing grounds off Catalina be left open to exploitation. Market squid are fished off Catalina close to shore when the squid aggregate in large numbers to spawn during the winter. After spawning, squid lay their eggs on the seafloor, which can be carpeted by squid egg cases after heavy spawns. The squid and their eggs are an important link in the marine food web of southern California. Squid feed mainly on zooplankton and forage over large areas of ocean. Spawning aggregations therefore import large amounts of energy into the nearshore ecosystem of Catalina in the form of spawning adults as well as the eggs they leave behind on the seafloor. The squid and their eggs are then fed on by a host of consumers including commercially important fish, birds, and marine mammals. The importance of these episodic inputs of food into the nearshore ecosystem off Catalina is not well understood, but it could be an important source of reproductive energy for many species.

The effects of closing the squid grounds off Catalina on the population dynamics of *Loligo opalescens*, and therefore its effects on the statewide fishery, are also not clear. There is still not enough information to determine whether the squid population off California is one single population or composed of two or more subpopulations. Therefore, the conservation benefit of a squid closure off Catalina for the population of market squid off California is highly uncertain at this time.

Protection of Biodiversity

Marine reserves should be designed to preserve and foster biodiversity by protecting a diversity of representative, unique, critical, and/or vulnerable habitats. The protection of a diversity of interacting marine communities is also major tool advocated for ecosystem-based management. Catalina has a range of marine habitats all of which should have at least some representative protection. Optimally, these would be located and spaced to optimize the conservation potential of a network of MPAs off Catalina.

Protection of Special Habitats and Species

Special, unique, or especially vulnerable habitats should also be considered for protection. An example off Catalina is Farnsworth Bank where a marine reserve has been established to protect purple coral (*Stylaster californicus*) that is vulnerable to human disturbance because of its fragility, slow growth, and desirability. Another unique habitat is the mudflat in Catalina Harbor that is the sole mudflat community in the Channel Islands.

MARINE RESERVE DESIGN FOR CATALINA

Candidate Habitats off Catalina

There is a high diversity of habitats off Catalina. These include kelp forests, boulder reefs, submarine walls, rocky intertidal, sandy intertidal, seagrass beds, an estuary, sand terraces, pinnacles, and a submarine canyon. The nearshore seafloor topography off Catalina is so steep that kelp forests, the rocky intertidal, seagrass beds, and all other shallow habitats are quite narrow relative to similar habitats on the mainland. These habitats flank Catalina forming a narrow band that in most places is only hundreds of meters wide.

Kelp Forests

Kelp forests provide important habitat and food for many exploited species that are relatively residential, and would therefore benefit from protection. These species include red sea urchins, lobsters, abalone, scallops, wavy turbans, kelp bass, shallow rockfish species, California sheephead, cabezon, sculpin, and lingcod. Kelp forests are typically limited to depths shallower than 35 meters off Catalina. The stability and persistence of kelp forests on the western end of Catalina (‘west end’) has been studied by Bill Bushing. In addition, the California Department of Fish and Game has developed GIS layers of giant kelp cover throughout the entire island from aerial photography. Both of these sources of information are important for determining how giant kelp is distributed in space and time (see Figs. 5-10). Kelp forests that would be the most beneficial to protect are the widest and most persistent. Therefore, an optimal network of MPAs would include at least some of these areas. The largest kelp forests mainly occur on the west end of the Island and the area between Catalina Harbor and Salta Verde Pt. on the backside of the Island. Kelp forests on the front-side of Catalina are mostly very narrow and patchy. The kelp forests on the backside and west end are the most exposed to the prevailing storm wave climate and are therefore the most susceptible to storm disturbances. On the other hand, kelp forests on the southern end and on the front-side of the Island are subject to nutrient and temperature stress.

Shallow Boulder Reefs

Shallow boulder reefs are important habitats for many of the same species that inhabit kelp forests. They also support a high diversity of understory algae and turf algae. Turf algae compose an important nursery habitat for many species of invertebrates. The most conspicuous boulder reef habitats are found at numerous locations on the backside of Catalina as well as at numerous locations on the front-side including areas near Church Rock, Seal Rocks, Pinnacle Rock, Lover’s Cove, Descanso Bay, Toyon Bay to Frog Rock, Hen Rock, Long Pt., Italian Gardens, Twin Rocks, Goat Harbor, Ripper’s Cove, Isthmus Reef, Bird Rock, Ship Rock, Lion Head, Eagle Reef, Indian Rock, Parson’s Landing, and Johnson’s Rocks.

Seagrass Beds

There are two types of seagrass beds off Catalina. The first is composed of shallow stands of the surfgrass, *Phyllospadix spp.*, which grow at depths from the shallow subtidal zone to a few meters. These beds are fairly ubiquitous along exposed rocky coastlines. The second type typically occurs at deeper depths from a few meters to more than twenty meters. These beds are composed of the eelgrass, *Zostera marina*, which typically occurs along relatively sheltered coastlines in sand. Seagrass beds are important ecologically because they provide adult and nursery habitat for several species of fish and invertebrates. Seagrass beds have recently been in decline throughout the world mainly due to human activities.

Other Habitats

Other habitats found off Catalina that should also be considered in marine reserve planning include rhodolith beds, estuaries, sandy shelves, deep reefs, and the submarine canyon located on the backside of Catalina. These habitats support unique assemblages of species in distinct community types and/or they are critical habitats for life stages of exploited species. Rhodoliths are slow-growing calcareous algae that form distinctive aggregations typically at the interface between rocky and soft bottom substrates. Rhodoliths are rare in southern California but Catalina has beds located at Emerald Bay, Cherry Cove, Fourth of July Cove, and Big Fisherman Cove. Estuaries and salt marshes are brackish water soft-bottom habitats that are important nursery grounds for several species of fish and support a distinctive community of animals and plants. These types of habitats are located at Catalina Harbor, Little Harbor, Ben Weston Cove, and Cherry Cove. Sandy shelves are the spatially dominant habitat off Catalina. They support many species of groundfish as well as a diverse assemblage of invertebrates that live on top of or within the sediments. Deep reefs off Catalina support species of invertebrates that only occur on pinnacles and banks in other areas of the southern California borderlands. The most vulnerable of these species are purple hydrocorals and 'black coral' gorgonians. The areas off Catalina having such deep reef communities include Farnsworth Bank, Little Farnsworth, Ship Rock, and the 'High Spot' located just inshore of Ship Rock. The last important habitat type found off Catalina is the Catalina Submarine Canyon. Submarine canyons are important habitat for many species of fish and the upper walls and rims of submarine canyons off southern California provide important nursery habitat for many species of rockfish.

SPECIFIC MPA RECOMMENDATIONS FOR CATALINA

Based on all of the information and considerations discussed thus far, we propose the following set of marine protected areas off Catalina:

(1) Because of the unique nature of the marine communities and their aesthetic importance to a growing population in southern California, we recommend that all of the state waters off Catalina be designated as an Area of Special Biological Significance. The ASBS designation applies to the protection of water quality and prohibits all discharges into the protected area unless a special exception is granted. The small volume of sewage generated on Catalina (<1 million gallons per day) is presently treated to secondary standards, which is then sprayed on land and not discharged into the ocean. The only discharge of any consequence is that from electricity generation and water desalinization plants located near Avalon Harbor. The entire coastlines of the other California Channel Islands are protected as ASBS's. The same protection should be afforded to the state waters off Catalina. This recommendation was originally made in 1981 in reconnaissance survey reports on the ASBS's off Catalina.

(2) All of the state waters off Catalina should be designated as a State Marine Conservation area. Commercial and recreational fishing are allowed in California

state marine conservation areas with some specific controls on activities that might compromise vulnerable species, marine communities, or geological features. This designation would effectively nest areas that we propose for higher levels of protection (see below) within a conservation buffer zone. Such buffers are common in marine reserve design and facilitate timely adaptive management changes based on monitoring and changes in conservation goals.

(3) We propose that a state marine park be established in waters on the front-side of Catalina from Land's End to Church Rock. State marine park status in California extends protection to all living and nonliving resources from commercial exploitation thus effectively closing the area to all commercial fishing. The front-side of Catalina is the most important area to establish protection as part of an MPA network because it has the greatest capacity to exchange larvae with reserves on the mainland due to its proximity with the mainland and the recurrent eddies that are frequently observed between the front-side and the mainland. These eddies can persist over several days and likely entrain larvae from both the mainland and the front-side effectively redistributing fish and invertebrate larvae among these areas. The economic importance of commercial fishing on the front-side is lower than on the backside where most commercial fishing presently occurs. The front-side has been closed to commercial lobster and finfishing for years, except for new fisheries including for urchins, sea cucumbers, and live fish.

(4) We also propose that the commercial fishery for market squid in all state conservation area waters off Catalina be limited to California vessels. The commercial fishery for market squid has grown rapidly within the last decade. The rapidity of this growth and the participation by boats from out of state has drawn analogies to the California gold rush. The sustainability of these practices is highly questionable especially since so little is known about the effects of intensive fishing on this species at so many of its known spawning areas. Specifically for Catalina, this regulation would effectively limit the capacity of the fishery and lessen the impact that the removal of so much biomass has on local marine populations. Limiting the capacity of this fishery is consistent with a precautionary approach. We do not recommend complete closure of the squid fishing grounds off Catalina at this time because of the paucity of information on the importance of the local fishery on the statewide conservation of market squid or on the effects of harvesting so much biomass on the local food web of Catalina and the likely cascading effects on the reproductive capacity of exploited fishes.

(5) We recommend that the use of all longlines and nets be permanently banned from all state waters off Catalina with the exception of purse seine nets for market squid and baitfish. Nets such as drift and gill nets as well as long lines are particularly destructive fishing gear due to their high levels of by catch and their ability to continue killing animals after they are lost. By-catch can account for up to 80% of the biomass taken in some nets, most of which is simply discarded.

(6) We recommend the establishment of five state marine reserves within state waters off Catalina offshore to a distance of 1.5 nautical miles or the 100 meter contour, whichever is furthest from shore, to protect representative kelp forest, boulder reef, cliff face, seagrass, rhodolith, estuarine, and sandy shelf habitats (see Fig. 11). State marine reserve designation in California means that no take is allowed of living or nonliving resources. The state marine reserves should be (a) sized so that species having short larval planktonic periods (less than a few days) are large enough to seed themselves and (b) spaced close enough together so that species with intermediate larval planktonic periods can exchange larvae among the reserves with enough larvae to overcome the large degree of larval mortality associated with the process of larval supply. Empirical information has led to a rule of thumb among many marine ecologists that reserves that are 4-6 kilometers in length scale and spaced 10-20 kilometers apart are most likely to achieve these goals. The reserves should also be placed to take advantage of the circulation patterns that have been observed off Catalina to maximize the ability of Catalina marine populations to broadcast their larvae to remote areas within the Southern California Bight. The most important circulation features are eddies that spin up downcurrent of the island when the incident circulation is aligned with the long axis of the island. These eddies likely entrain larvae of nearshore marine species and retain them as the eddies separate from the island and advect downstream. Such eddies are commonly observed on both ends of Catalina. Therefore, establishing reserves near the both ends of the island that protect important habitat is recommended. The distance that these reserves should extend offshore depends on the slope of the seafloor off Catalina. Most of the nearshore habitat that is important to protect is limited to a narrow band along the shoreline of Catalina because the seafloor is steep relative to that of the mainland. Therefore, it is not necessary to draw the offshore boundaries as far as the limit of state waters (3 nautical miles). The habitats that we have targeted for protection are shallower than ~100m. This isobath corresponds to an average of ~1.5 nautical miles offshore of Catalina. The state marine reserves off Catalina should at least extend to the 100-meter contour. We propose the following state marine reserves:

a. Blue Cavern Pt. to Arrow Pt. (coastal length ~10.5 km) This proposed reserve on the front-side is an expansion of the present Wrigley Institute of Environmental Studies no-take marine reserve. The proposed reserve is close to the western end of the Island, therefore the area is likely to broadcast larvae away from Catalina since cross-shore flows typically dominate such areas. The reserve also encompasses several types of habitats including sandy shelf, marsh, deep reef, persistent kelp forests, boulder reefs, and rhodolith and seagrass beds. Studies conducted on the movements of residential species of fish within this area including California sheephead and kelp bass show that these species are highly likely to remain within this reserve. Moreover, invertebrates are already protected in this area and lobsters have been shown to benefit significantly from this protection. The area is also home to the Wrigley Marine Science Center (University of Southern California) and the proposed reserve would support scientific research and education. Finally, it includes a popular anchorage that would maximize recreational diving.

b. Guano Rock to Little Gibraltar Pt. (coastal length 5.1 km) – This proposed reserve on the front-side encompasses a diverse array of habitats including persistent kelp forest, boulder reefs, submarine walls, seagrass beds and tidepools. It also protects 'Italian Gardens' where black seabass frequently aggregrate. Even though black seabass are a protected species they are still vulnerable to harassment by fishing gear. Closure of this area where black seabass may be spawning would prevent such harassment. This proposed reserve is located at an inflection point along the coastline where cross-shore flows are likely to dominate and export larvae into the eddies that dominate the flow around Catalina effectively exporting larvae to other MPAs as well as fished areas on the mainland.

c. East Avalon Harbor to East End Light (excluding the Mole; coastal length ~6.2 km) – This proposed reserve, which covers the southeast end of the Island, is an expansion of the present Lover's Cove Reserve. The reserve encompasses habitat that is fundamentally different from the other proposed reserves. The area is dominated by soft bottom habitats but boulder reef and kelp forests are also common. The uniqueness of this area of the Island is (a) the occurrence of species that are much less common in other areas off the Island or they are present only in deeper water, and (b) the presence of a stable sandy habitat. The species that are less common to other areas of Catalina include barred sand bass and orangethroat pickleblennies. There are also extensive eel grass beds and a sea lion colony at Seal Rocks. The proximity of this reserve to Avalon would be beneficial for many recreational activities.

d. Salta Verde Pt. to China Pt. (4.8 km) – This area on the backside of Catalina contains relatively large and persistent kelp forests as well as boulder reef habitat. It is also near a major inflection point on the coastline. It is relatively less accessible to recreational use, but it is an important ecosystem.

e. West End to Ribbon Rock (6.5 km) – The proposed reserve on the backside of Catalina at the extreme western end is the most exposed section of coastline on Catalina. Despite this, it has large and persistent kelp forests. There are also boulder reefs and a broad sand habitat and the area has good lobster habitat. Thus it would displace some lobster and urchin fishers as well as recreational fishers at the popular West Cove site.

The proposed network of state marine reserves around Catalina is adequately sized and spaced so they are both self-recruiting for some species and broadcasters for other species among the reserves on Catalina as well as the mainland. They are placed to encompass representative as well as unique or vulnerable habitats along the well-known exposure gradient around Catalina. These reserves also leave open more than 63% of the coastline and more than 80% of state waters off Catalina open to recreational fishing. The MPA network also leaves most of the squid fishing grounds open to commercial and recreational exploitation.

The actual location of the boundaries of these proposed state reserves is certainly flexible. We have used headlands to demarcate boundaries. However, such boundaries typically bisect contiguous hard bottom kelp forest habitats and may therefore not be desirable if entire intact habitats are desired since residential species are likely to cross boundaries drawn at rocky headland habitats. These species are much less apt to migrate among habitats having to cross broad stretches of foreign habitat such as sandy shelves. In this case, it may be better to draw the boundaries to include habitats in their entirety and draw the boundaries accordingly. However, the recreational spillover catch is likely to be greater if the boundaries were drawn in the middle of these hard bottom habitats.

(7) We recommend that the current level of protection for Farnsworth Bank remain the same with the exception that commercial fishing be prohibited. This is consistent with the area being established as a state marine park. The boundaries of the proposed state marine park should stay the same as the boundaries of the current reserve. Recreational surface fishing should still be allowed but the recreational take of all demersal (bottom) species and all invertebrates should be prohibited.

(8) Current statewide recreational fishing regulations should not be changed and therefore kept the same as in other state marine waters. These regulations include seasonal, size, and bag limits, groundfish closures, and closed species.

(9) Our final recommendation is that the governance of all marine protected areas off Catalina be well coordinated among local, regional, state, and federal agencies to (a) ensure that the protected areas at the scale of Catalina Island are optimal within a larger context to help achieve conservation for wider ranging species and fishery management programs, (b) prevent duplication of protected areas that may be conflicting or confusing, and (c) to streamline enforcement and management of the MPAs. Bradley Barr and Stephanie Thornton of NOAA said it best, "...if a box must be drawn, it must be drawn within another larger box, or within an ordered universe where the box is part of a larger management system that recognizes the box and embraces it as part of its governance system. Context is critical, and almost always absent." To address the need for coordinated governance, we recommend the establishment of a volunteer board to ensure that the MPAs off Catalina are well managed, monitored, enforced, and that they mesh with higher levels of governance and larger scales of marine conservation. The board should be composed of representatives from all levels of MPA governance, local stakeholders, and marine scientists.

RESEARCH PRIORITIES

Gathering more information about the ocean climate, habitats, species and their habits, as well as a better understanding of the local marine food web can only enhance the design of both protectionist and conservationist reserves off Catalina as part of the implementation of the MLPA. Specifically we recommend:

(1) The spatial distribution of habitats and their value to exploited species should be determined at fine spatial scales off Catalina. These studies should utilize both remote sensing methods and visual observational methods. Remote sensing methods are useful to determine the characteristics and depth profiles of the seafloor and can now be done at very fine spatial scales. These studies should be conducted throughout the area that is inshore of the 150m contour. Remote sensing such as LIDAR can also be used to evaluate the algal stands in shallow waters. Direct observation by SCUBA divers including simultaneous habitat quantification and marine life censuses should be conducted over hard bottom habitats. Anyone with some knowledge of marine life knows that every reef and kelp forest is unique in its shape, aspect, exposure, and value or importance to different species. The development of a fine scaled spatial map of habitats using a combination of these methods would facilitate the development of a habitat catalog that would be very useful for both reserve design and spatially explicit fishery studies of fish production.

(2) Movement patterns of lobsters and exploited species of residential fish such as rockfish, other groundfish as well as fish associated with the kelp forests should be studied at a variety of locations throughout Catalina. Some work has already been done on California sheephead and kelp bass but this work has mainly been done at only one location. Movement patterns are likely to vary among different areas because the types and spatial arrangements of the habitats are highly variable. Locale specific knowledge of movement is needed to determine how large reserves should be as well as help design spillover areas for fishermen.

(3) Studies of the circulation climate around Catalina are needed to identify areas that are most likely to retain, receive, or broadcast larvae to other areas. As part of this, circulation models need to be developed and implemented for waters off Catalina to determine the most common patterns of larval advection and diffusion (i.e., an understanding of the larval connectedness among reserves and between reserves and fished areas). The reason for networking MPAs is to ensure that larvae are exchanged adequately among reserves so that they are capable of replenishing one another for as many species as possible in addition to supplying fished areas with larvae. Larval genetic studies or elemental fingerprinting studies might also prove useful for determining patterns of larval dispersal for some species around Catalina and for larval exchange with the mainland.

(4) The effects of the fishery for market squid off Catalina on the local food web of Catalina should be studied. The importance of the food subsidy that is imported to the coastal ecosystem is not known and may be important for the production of residential exploited species.

(5) The effectiveness of any MPAs that are eventually established off Catalina should be determined over time. This means the both reserves and nearby non-reserves must be studied prior to reserve establishment for comparisons after establishment. The most important factors to study are the biomass, age structures, densities, and productive capacity of exploited species. Also important to monitor are changes to community structure since protection can yield dramatic changes to community composition, resilience to disturbance, and persistence through time as the effects of protection cascade throughout the food web.

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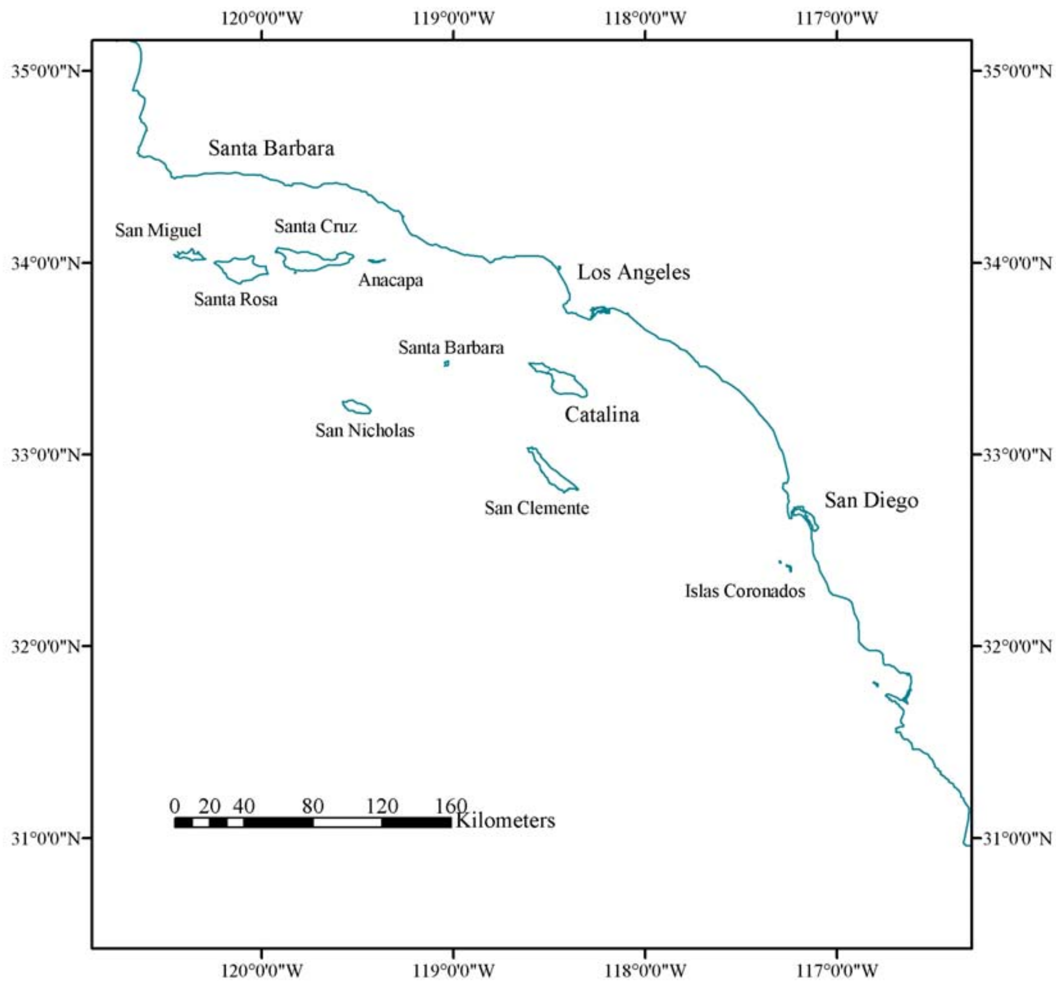

Figure 1. Map of the Southern California Bight including the location of Santa Catalina Island.

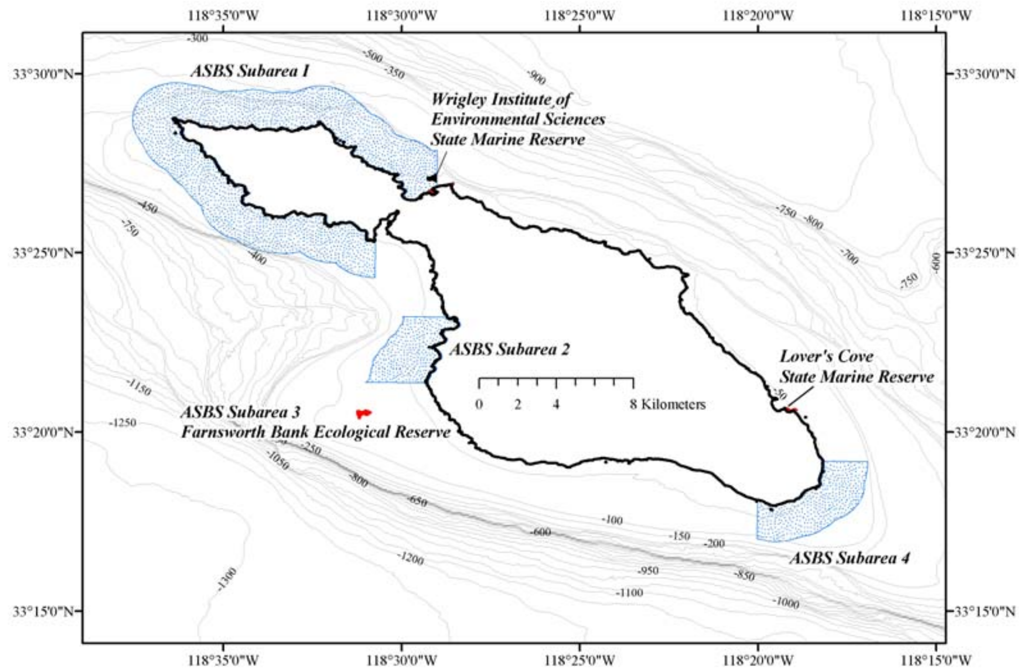

Figure 2. Map of Catalina Island showing locations of existing marine protected areas. See Table 1 for a description of each area. Contour units are meters.

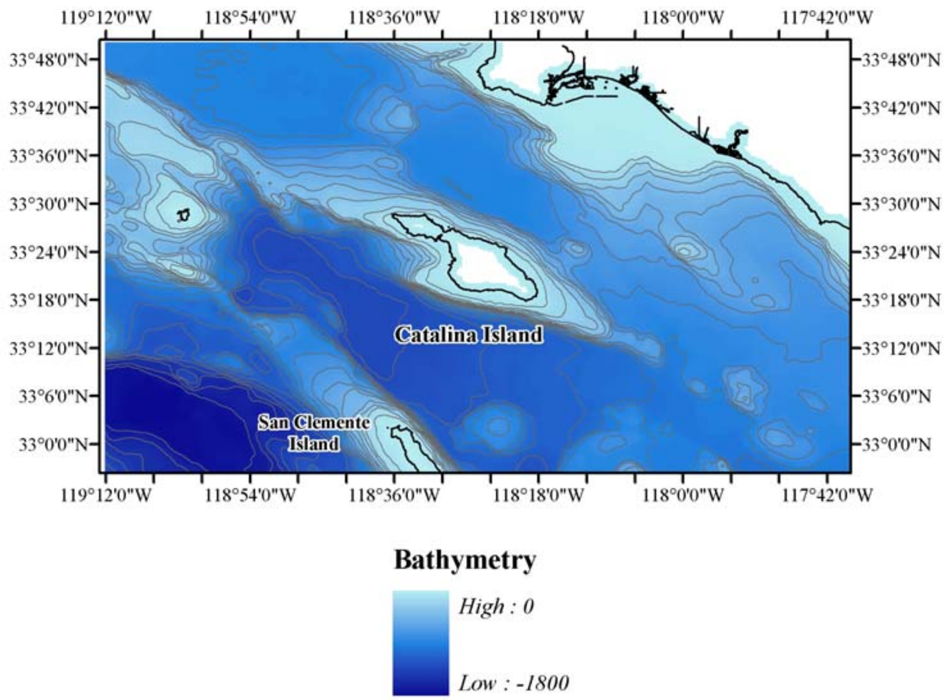

Figure 3. Map of Catalina Island and surrounding bathymetry. Contours are in meters.

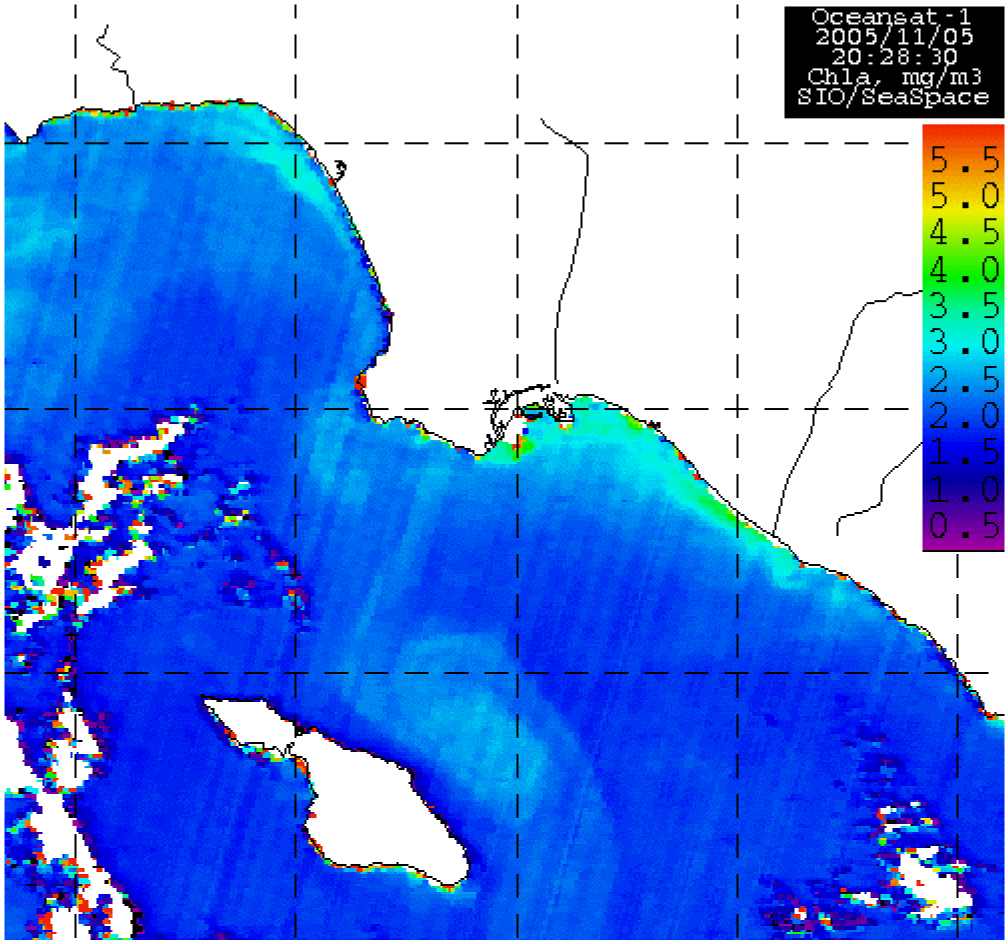

Figure 4. Satellite image of *Chl a* concentrations. Note the eddy located between the mainland and Catalina Island.

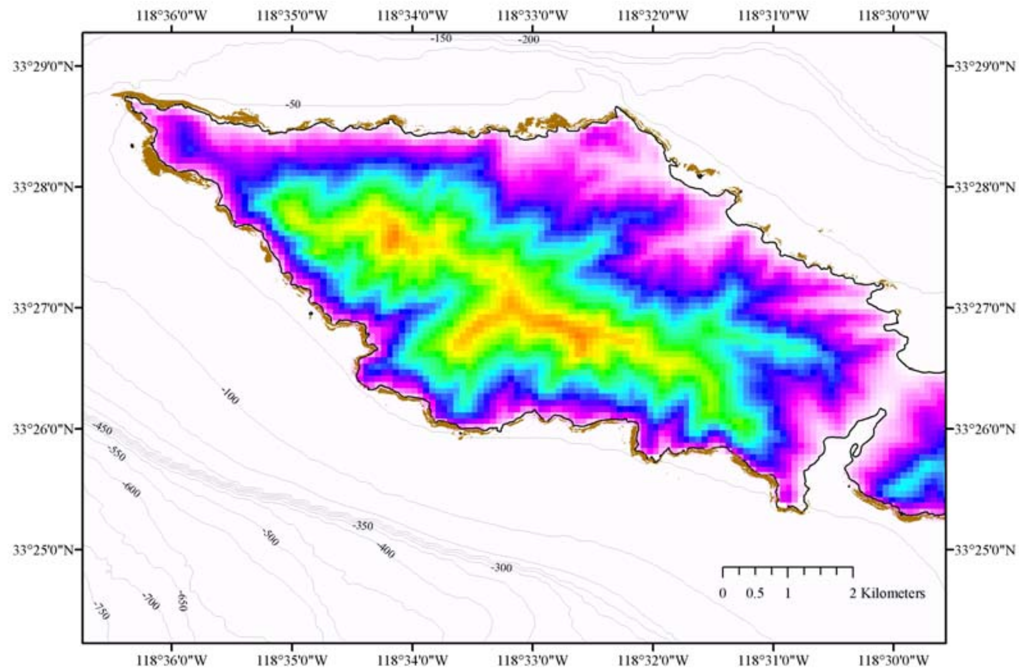

Figure 5. Distribution of giant kelp along the West End shoreline. Kelp is shown as golden brown in figure. Contours are in 50 meter intervals.

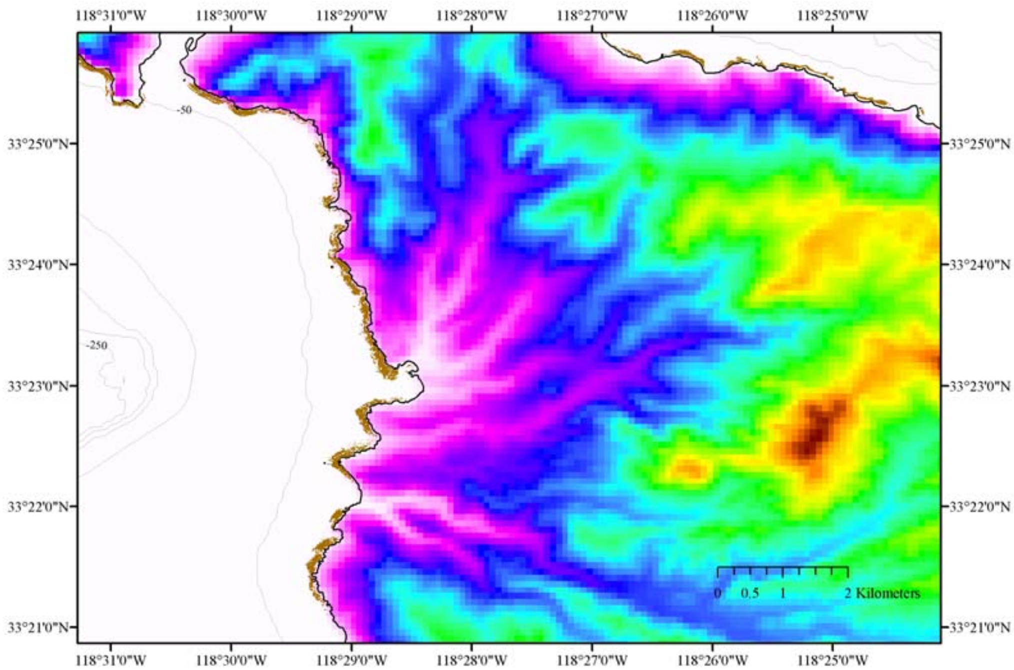

Figure 6. Distribution of giant kelp along the backside of Catalina Island. Kelp is shown as golden brown in figure. Contours are in 50 meter intervals.

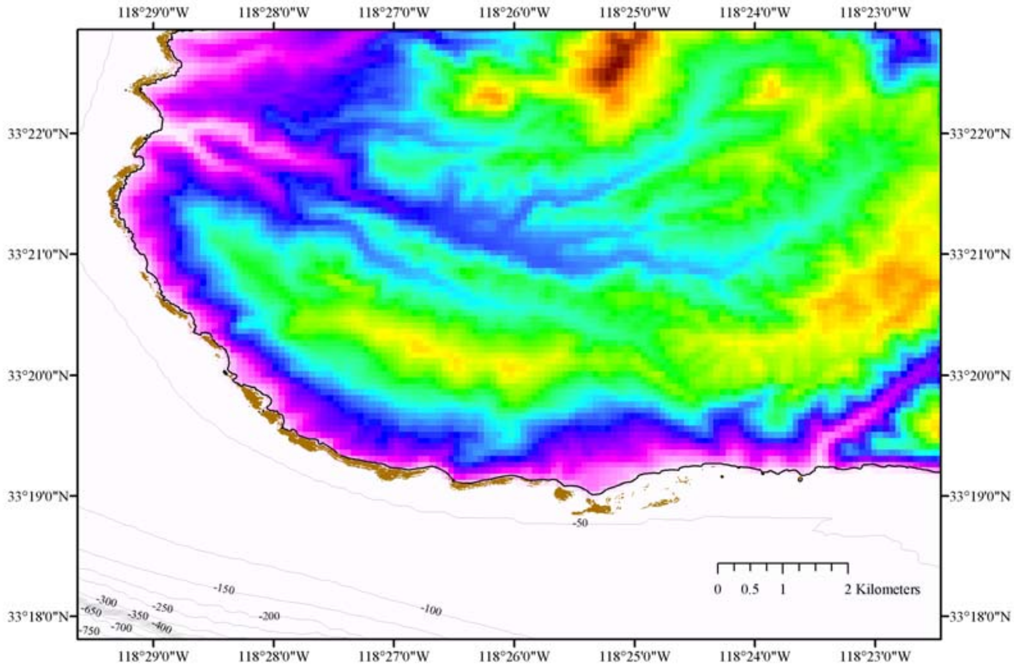

Figure 7. Distribution of giant kelp along the southwestern end of Catalina Island. Kelp is shown as golden brown in figure. Contours are in 50 meter intervals.

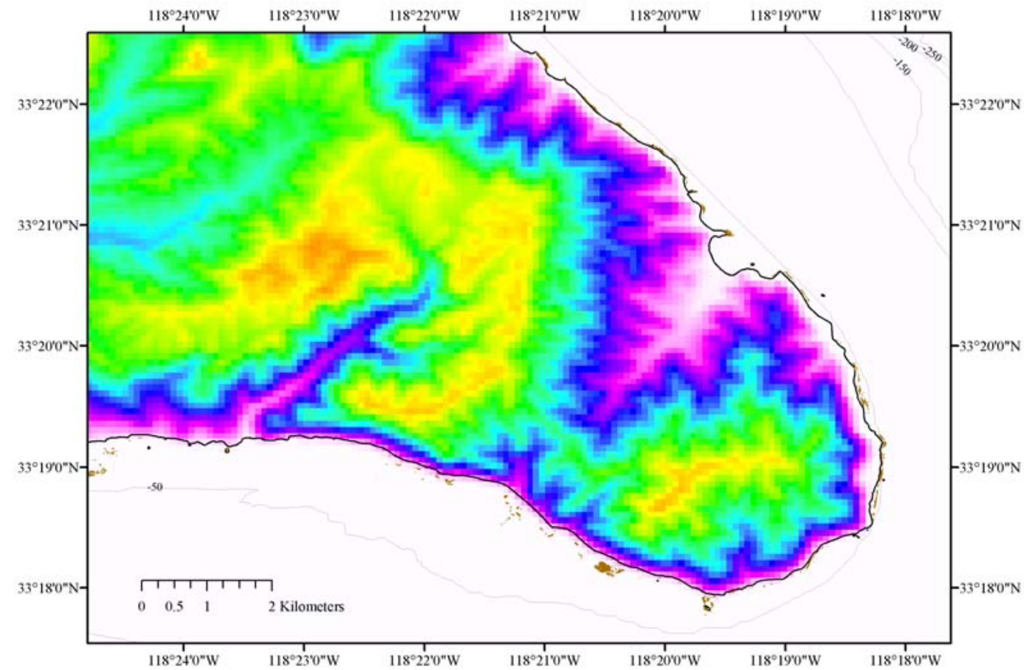

Figure 8. Distribution of giant kelp along the southeastern end of Catalina Island. Kelp is shown as golden brown in figure. Contours are in 50 meter intervals.

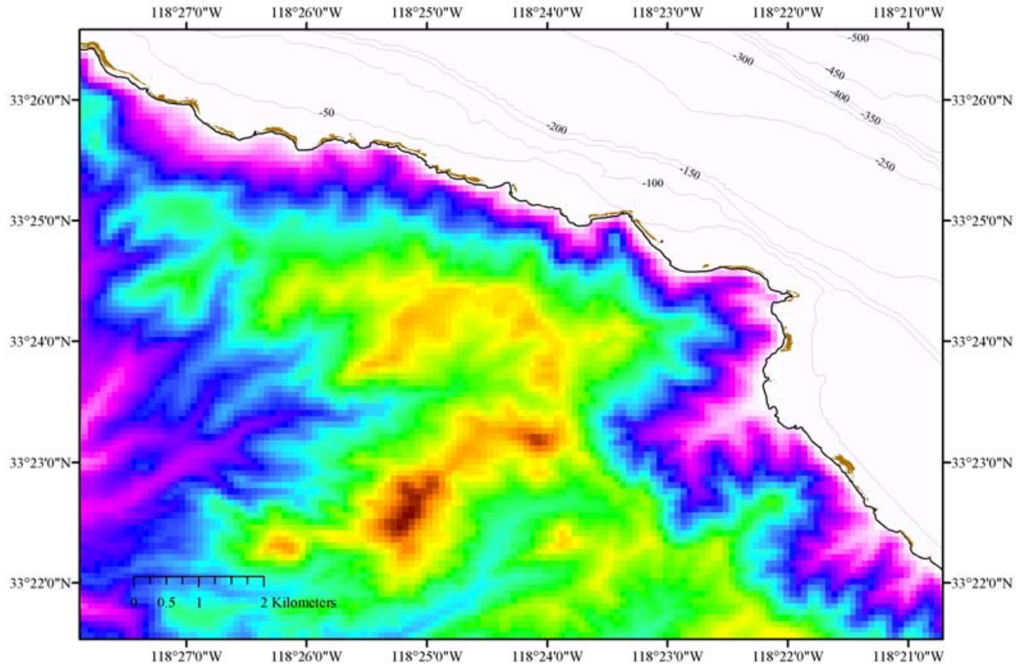

Figure 9. Distribution of giant kelp along the front-side of Catalina Island. Kelp is shown as golden brown in figure. Contours are in 50 meter intervals.

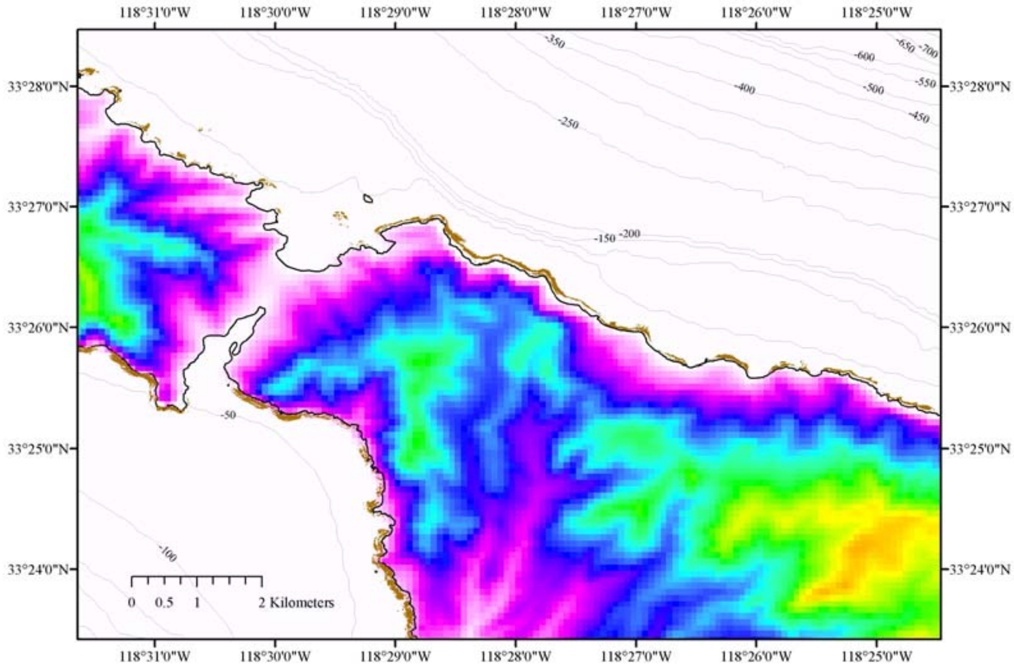

Figure 10. Distribution of giant kelp along in the vicinity of the Isthmus. Kelp is shown as golden brown in figure. Contours are in 50 meter intervals.

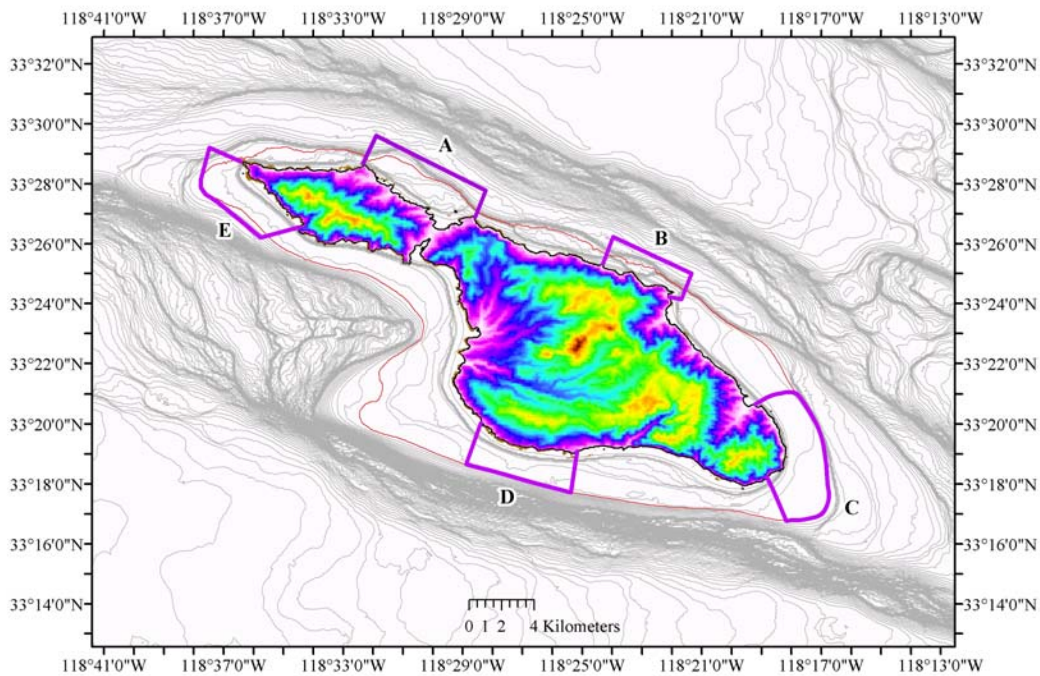

Figure 11. Map of Catalina Island showing the proposed State Marine Reserves. A) Blue Cavern Pt. to Arrow Pt., B) Guano Rock to Little Gibralter Pt., C) East Avalon Harbor to East End Light, D) Salta Verde Pt. to China Pt, and E) West End to Ribbon Rock. Contour intervals are 10 meters and red contour is 100 meters.