RECREATIONAL FISHING AND MARINE FISH POPULATIONS IN CALIFORNIA

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ABSTRACT

We present and review information regarding recreational angling and exploited marine fish populations in California. A comparison of rockfish assemblages among three differently fished areas (one open to all fishing, another open only to recreational fishing, and a de facto marine protected area) revealed large differences in fish density, size structure, and species composition. The area open to all fishing harbored the highest density of rockfishes (7,212 fish/ha), although the size structure and species composition were dominated by small fishes. The area open only to recreational fishing had the lowest rockfish density (423 fish/ha) and a size structure also dominated by small fishes. The de facto protected area possessed high fish density (5,635 fish/ha), but here the size structure and species composition shifted toward larger fishes compared with the two fished areas. Two species federally listed as overfished, cowcod and bocaccio, had 32-fold and 408-fold higher densities, respectively, in the de facto reserve than observed inside the recreational fishing area, and 8-fold and 18-fold higher densities, respectively, than observed in the area open to all fishing. For 17 nearshore fish species, we compared landings by recreational anglers and commercial harvesters and found that, for 16 species, recreational angling was the primary source of fishing mortality. We illustrate the potential damaging effects of mortality associated with catch-and-release programs on long-lived fish populations. Based on this information, we recommend that legislators and natural resource managers reject the assumption that recreational fishing is a low or no impact activity until specific studies can demonstrate otherwise.

INTRODUCTION

The history of fisheries management on the West Coast of the United States records a steady allocation battle between recreational and commercial fishers (e.g., Clark and Croker 1933). This battle recently intensified with the formation of federal and state policies giving marine protected areas (MPAs) a leading role in managing and rebuilding fisheries. Since the extent of protection provided by MPAs varies greatly and often generates semantic confusion, we use the term MPA in this report to mean areas of "no take," that is, where all extraction activities are prohibited. One response to the increasing popularity of federal and state MPA policies is the proposed Freedom to Fish Act. This act would critically modify the Magnuson-Stevens Fishery Conservation and Management Act by allowing areas to be closed to recreational fishing only when there is clear demonstration that recreational anglers contribute to overfishing and all other management options, such as seasonal closures and bag and size limits, have been exhausted. Implicit in this type of legislation are the assumptions that overfishing is caused primarily by commercial harvesting and that recreational fishing does not interfere with other common goals of spatial closures, including (1) creating sustainable fisheries, (2) protecting essential fish habitat, (3) protecting marine ecosystem structure (biodiversity, trophic structure), (4) establishing scientific control areas necessary to distinguish between changes in marine populations caused by anthropogenic or natural sources, (5) creating marine wilderness areas, and (6) enhancing enjoyment of nonconsumptive activities, including educational activities. A null hypothesis of no impact to marine populations and habitats from recreational fishing places a logistical and legal hardship on resource managers and consequently must undergo careful examination before any agency endorsement.

The dynamics of fish populations and fisheries are complex, and predicting the dynamics of complex systems usually contains a measure of scientific uncertainty. Fisheries management decisions must therefore allocate risk, with allocations often reflecting various social values (Ludwig et al. 1993). By seeking to maximize fishery yields, traditional fisheries management places most of this risk burden onto fish populations (Dayton 1998). Such a tendency has been injudicious because (1) fisheries can be overexploited before managers and scientists have sufficient data to indisputably document declining population trends, and (2) overexploited fisheries rarely recover after collapse (Hutchings 2000). In contrast to the history of commercial fisheries, there is little information on the need for management or its effectiveness in recreational fisheries. Thus, it is unclear whether policy regarding recreational fishing and resource protection warrants a precautionary approach.

In this report, we examine data regarding fishing and marine resources in California to assess whether a default policy assumption that recreational anglers have little or no impact is justified. We also illustrate how small increases in mortality associated with catch-and-release programs can affect long-lived fish populations. Such scrutiny is timely given the passage of two acts by the state legislature that reorganize marine resource management in California. The first is the Marine Life Protection Act (MLPA), which requires the California Department of Fish and Game (CDFG) to simplify and expand the current network of marine spatial closures, and the second is the Marine Life Management Act (MLMA), which gives the California Fish and Game Commission new authority and direction to manage certain important fisheries, some of which are exploited by both recreational and commercial fishers.

THREE CASE STUDIES

Differences in Rockfish Population Structures Among Three Areas: An Area Open to All Fishing, an Area Open Only to Recreational Fishing, and a De Facto Marine Protected Area

Mosqueira et al. (2000) reviewed the effects of MPAs on marine populations and consistently found that mean density and size of exploited fishes within protected areas exceeded that of fished areas. These results manifested under extremely broad conditions and across many biogeographic regions. Therefore, if recreational angling has little impact on marine populations, we would expect an observable "reserve effect" of more and bigger fish in areas that restrict commercial harvest but permit recreational angling when compared to areas that permit all types of fishing. We tested for this reserve effect by comparing fish density, total length size structure, and species composition of rockfishes (*Sebastes* spp.) residing in three differently fished areas (open to all fishing, open only to recreational fishing, and de facto MPA) in the Southern California Bight. We then compared densities of two rockfish species federally listed as overfished, cowcod (*S. levis*) and bocaccio (*S. paucispinis*). Recreational and commercial fishers target many of the 70 species of rockfish that inhabit the northeastern Pacific. Most of these exploited rockfish species are long-lived and residential (Love et al. 2002). Thus, a comparison among differently fished areas provides a good test of recreational angling impacts because species such as rockfishes are sensitive to overfishing (Leaman 1991).

We extracted data from a six-year survey of fishes living on deep natural outcrops and around oil platforms within the Southern California Bight. To quantify fish abundance and associated habitat, we used the *Delta*, a two-person submersible, to perform belt transects of 15-min duration. Each transect was continuously documented with a hi-8 mm video camera and externally mounted lights. From the starboard viewing port, observers verbally annotated each videotape, identifying, counting, and estimating sizes of all fishes within 2 m of the submersible. Two paired lasers were mounted on either side of the external video camera at a fixed distance of 20 cm apart. Lasers projected visible spots onto the seafloor, and these were used to calibrate fish size during the surveys and to calculate transect length in post-dive analyses. Video tapes were used to quantify habitat type in post-dive analyses.

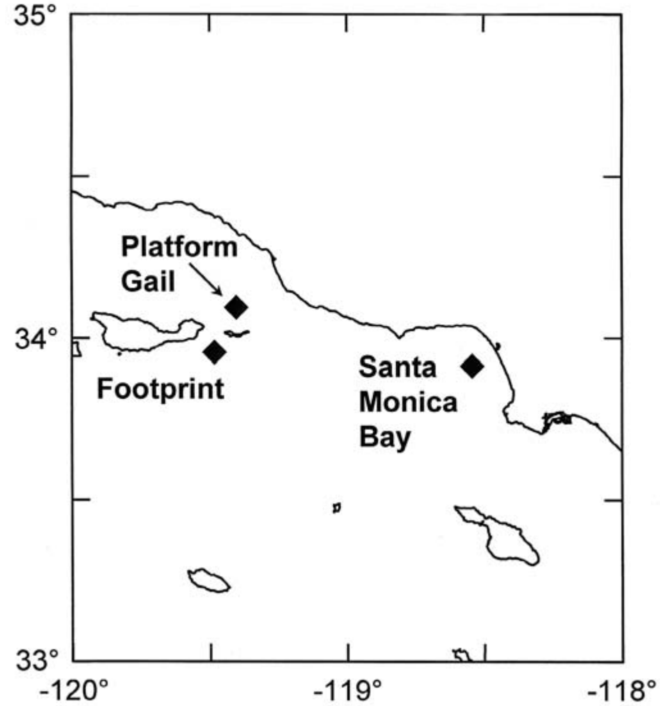

Figure 1. Location of areas where rockfish assemblages were surveyed using the *Delta* submersible. The Footprint is open to all fishing, Santa Monica Bay is open only to recreational fishing, and Platform Gail is a de facto marine protected area.

We compared differently fished areas positioned within similar depths and exposed to similar water masses (fig. 1). The Footprint, an offshore rocky ridge located in the southern Anacapa Passage, is open to all fishing activities and has historically produced large numbers of cowcod and bocaccio to both recreational and commercial fishers. Fish surveys at the Footprint were performed at depths of 100–300 m during 1995, 1998, 1999, and 2000. Since the 1950s, Santa Monica Bay has been closed to commercial fishing activities that use trawls, drag nets, gill nets, and traps, except for a small live-bait fishery that uses lampara nets. Handlines with more than two hooks have also been banned in this region. As our area

TABLE 1
Mean Number of Rockfish per Hectare (+1 SE) at Three Sites in the Southern California Bight

	Commercial and recreational fishing area	Recreational fishing only area	De facto marine protected area
All rockfishes	7,212 (1,300)	423 (69)	5,635 (1,908)
Cowcod	12 (3)	3 (7)	96 (43)
Bocaccio	70 (15)	3 (7)	1,225 (231)

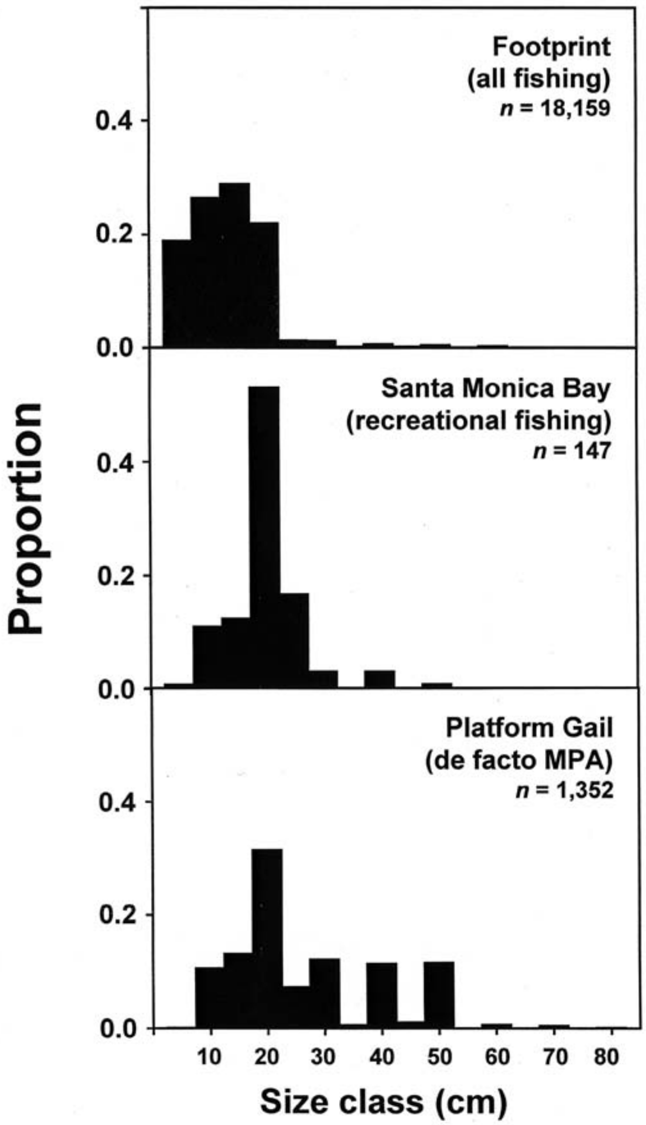

Figure 2. Size structure (total lengths) of all rockfishes observed among three differently fished areas.

open only to recreational fishing, we analyzed transects performed in Santa Monica Bay at depths of 100–300 m from fish surveys conducted in 1997 and 1998. Reef areas surveyed in Santa Monica Bay consisted of high rocky relief and are popular fishing spots with private boat owners and the commercial passenger fishing vessel (CPFV) fleet. At the time of our fish surveys, no deep reef habitat off California had been officially designated as an MPA. However, the offshore oil platforms in the Southern California Bight form de facto reserves. Benthic fishing effort near offshore platforms is very low because platform operators discourage marine vessels from entering a 150 m radius buffer zone around oil platforms. In addition, platform architecture and typically strong offshore currents hamper successful deployment and retrieval of fishing gear to the seafloor adjacent to the structure. As the de facto MPA, we quantified rockfish density only around the base of Platform Gail, which is situated in a depth of 230 m. Other offshore oil platforms in the eastern Santa Barbara Channel are not located at depths suitable for adult cowcod and bocaccio rockfishes. We conducted fish surveys around Platform Gail during 1995, 1996, 1997, 1999, and 2000. Mean rockfish densities from transects surveyed at each area were standardized to number of fish per hectare.

The density of all rockfish species combined was highest at the Footprint, which is open to all types of fishing (tab. 1). Species composition was dominated (67%) by dwarf varieties, such as squarespot (*S. hopkinsi*), swordspine (*S. ensifer*), and pygmy (*S. wilsoni*) rockfishes. The size structure of rockfish total lengths at the Footprint reflects this dominance of small species (fig. 2). In Santa Monica Bay, the density of all rockfish species was an order of magnitude less than rockfish density at the Footprint (tab. 1). Size structure was similar between the two fished areas in that the distribution is sharply truncated at sizes greater than 20 cm (fig. 2). Sixty-three percent of fish observed in Santa Monica Bay belonged to the subgenus *Sebastomus*. At Platform Gail, rockfish densities were also high (tab. 1), but the size structure here was skewed toward a greater proportion of large rockfish (fig. 2). The most commonly observed taxa at Platform Gail were the greenspotted/greenblotched species complex (*S. chlorostictus* and *S. rosenblatti*), which formed 41% of the assemblage.

Striking differences in density were found in cowcod and bocaccio densities among the three areas surveyed. Cowcod densities at Platform Gail, the de facto reserve, were 32 times greater than densities observed at Santa Monica Bay, the area open only to recreational fishing, and nearly 8 times greater than densities at the Footprint, the area open to all fishing (tab. 1). Bocaccio densities observed at Platform Gail were an extraordinary 408-fold greater than Santa Monica Bay estimates, and an 18-fold greater density than Footprint estimates (tab. 1). Composition was also quite different among the three areas: bocaccio constitute 22% of the total number of fish at Platform Gail, compared with 0.7% and 1% at Santa Monica Bay and the Footprint, respectively.

While performing fish surveys at the Footprint, we observed large amounts of gear debris (traps, longlines, trawl nets, and gill nets) from commercial fishing and many dislodged or damaged sponges. Evidence of recreational fishing activity (lead weights, artificial lures, monofilament line, and Budweiser beer cans) was also commonly encountered at the Footprint. In Santa Monica Bay surveys, we observed only recreational fishing debris. Sessile macroinvertebrate populations (sponges, branchiopods, gorgonians, etc.) within Santa Monica Bay appeared abundant and undamaged, perhaps due to the exclusion of trawling gear.

Using the same *Delta* submersible survey methods described earlier, Love (unpub. data) reports that the highest numbers of bocaccio and cowcod occurred on remote sites (near Point Arguello and distant offshore banks) where inclement weather prevents intense fishing effort. Conversely, large tracts of rocky reef in close proximity to harbors and ports contained no or very few large rockfishes. Off central California, Yoklavich et al. (2000) compared deepwater fish assemblages (mainly rockfishes) between a natural refuge and an offshore bank exploited by both recreational and commercial fishers and reported high densities of economically important fish only at the refuge.

Circumstantial evidence cannot demonstrate causation, so we now consider alternative hypotheses to fishing mortality in explaining observed differences in fish populations among surveyed areas. Two alternatives frequently suggested by stakeholders as the primary cause of declining rockfish populations are high pollution levels and changing oceanographic conditions. There is no scientific evidence that pollutants in the Southern California Bight appreciably affect population dynamics of rockfishes. Symptoms that indicate a contaminated environment (fin erosion, ulcers, and tumors) were not observed in any reef fish assemblage (our and others' personal observations). Furthermore, due to increasingly strict discharge regulations, offshore water quality in the Southern California Bight has been steadily improving over the last 20 years at the same time that many fished rockfish populations have been declining. Oceanographic processes that drive fish population dynamics, such as El Niño/Southern Oscillation (ENSO) events or the Pacific Decadal Oscillation, occur over large spatial scales (Cowen 1985; Hollowed et al. 2001). If changing oceanographic conditions were the only cause of observed rockfish decline, we would expect large-scale forcing across all areas and not the pattern where the highest densities and largest fish were found where lowest fishing effort occurs (oil platforms and remote natural reefs).

Could differences in habitat structure among surveyed areas be the primary cause in observed patterns of fish density? Habitat along transects conducted at the Footprint and Santa Monica Bay was characterized by rocky substrate and high density of crevices and shelter holes compared to the somewhat simpler habitat found at the base of Platform Gail. If habitat complexity alone were driving patterns of fish density, we might expect lower fish abundance at Platform Gail rather than the natural reef habitats. Indeed, a comparison of fish assemblages among the shallow portions of nine platforms and nine natural reefs in the Santa Barbara Channel region showed platforms to have on average 42% lower habitat value (as defined by the density, mean size, and persistence of fish species) and 24% lower species diversity than natural reefs (Schroeder et al. 2000).

Although our fish surveys were not originally designed to test for effects of recreational fishing, the existence of a spatial pattern in deepwater rockfish assemblages congruent with a spatial pattern in fishing pressure warrants further experimental investigation into the mechanisms generating such patterns, and this can only be done by establishing MPAs.

Relative Fishing Pressure Between Recreational Anglers and Commercial Harvesters in California's Nearshore Fishery

If recreational angling contributes little to overall fishing mortality, we would expect the relative catch of exploited species by recreational anglers to be much less than that of the commercial sector, especially in instances where stocks may be depleted. To test this hypothesis, we compared landings in California's nearshore fishery from 1980 to 2000 between these two groups using data compiled by CDFG for the Draft Nearshore Fishery Management Plan. The MLMA defines nearshore waters to be from the shoreline out to 20 fathoms (36 m). A suite of 19 species that inhabit these depths for at least part of their life cycle form the nearshore fishery (tab. 2). Due to declining aggregate catches and widespread anecdotal evidence of overexploitation, conflict and allocation battles frequently arise in this fishery among recreational anglers, commercial harvesters, and nonextractive users.

Recreational landing summaries in the nearshore fishery were based on data from the Recreational Fisheries Information Network (RecFIN), maintained by the Pacific States Fishery Management Council as part of the federal Marine Recreational Fisheries Statistics Program. The RecFIN database provides estimates by area and user group (CPFV, private/rental boat, beach, and man-made structures) of total effort (angler-days and angler-hours) and the total number of fish taken. These estimates are calculated using field and telephone interview surveys. Numbers of fish are converted into weights by multiplying catch by average weight. Commercial landing summaries in the nearshore finfish fishery were

TABLE 2
Fish Species in California's Nearshore Fishery

Common name	Scientific name
Monkeyface prickleback	*Cebidichthys violaceus*
Kelp greenling	*Hexagrammos decagrammus*
Rock greenling	*Hexagrammos lagocephalus*
California scorpionfish	*Scorpaena guttata*
Cabezon	*Scorpaenichthys marmoratus*
Kelp rockfish	*Sebastes atrovirens*
Brown rockfish	*Sebastes auriculatus*
Gopher rockfish	*Sebastes carnatus*
Copper rockfish	*Sebastes caurinus*
Black-and-yellow rockfish	*Sebastes chrysomelas*
Calico rockfish	*Sebastes dallii*
Quillback rockfish	*Sebastes maliger*
Black rockfish	*Sebastes melanops*
Blue rockfish	*Sebastes mystinus*
China rockfish	*Sebastes nebulosus*
Grass rockfish	*Sebastes rastrelliger*
Olive rockfish	*Sebastes serranoides*
Treefish	*Sebastes serriceps*
California sheephead	*Semicossyphus pulcher*

based on the Pacific Fisheries Information Network (PacFIN) database, also maintained by the Pacific States Fishery Management Council. This database collates information on commercial landing receipts, vessel registration, and permit information, and is supplemented by data sources that supply species composition and catch-by-area proportions developed from port sampling and trawl logbook data systems.

Suspension of the Marine Recreational Fisheries Statistics Program occurred during 1990 to 1992. This three-year data gap coincides with the development of the commercial live/premium finfish market, which began conspicuous participation in the nearshore fishery in the early 1990s. We summarize data within two time periods 1980–89 (hereafter "the 1980s"), and 1993 to 2000 (hereafter "the 1990s"), to reflect this development.

Total landings of 17 nearshore species decreased considerably over the time frame examined. Mean total landings during the 1990s were 42% less than mean total landings during the 1980s. The decline observed in the 1980s, before the establishment of a large live/premium finfish market, was much steeper than the decline observed in the 1990s (fig. 3a), although the 1990s decline may have been somewhat stemmed by stricter total-allowable-catch regulations in 1999. A change in the relative catch between recreational anglers and commercial harvesters occurred with the advent of the live/premium finfish market. During the 1980s, recreational anglers caught about 87% of the total landings, but this decreased to 60% of total landings in the 1990s. However, recreational catch still exceeded commercial catch in all years (fig. 3b).

Greater variability in patterns of exploitation among user groups emerged when species were examined separately. The 1990s recorded an increase in relative commercial landings in all species, with the largest shifts occurring in seven species: California sheephead, cabezon, and grass, quillback, black and yellow, china, and copper rockfishes (fig. 4). At the other end of the spectrum, recreational anglers landed 75% or more of the total catch in seven species: California scorpionfish, kelp greenling, treefish, and calico, blue, olive, and kelp rockfishes (fig. 4).

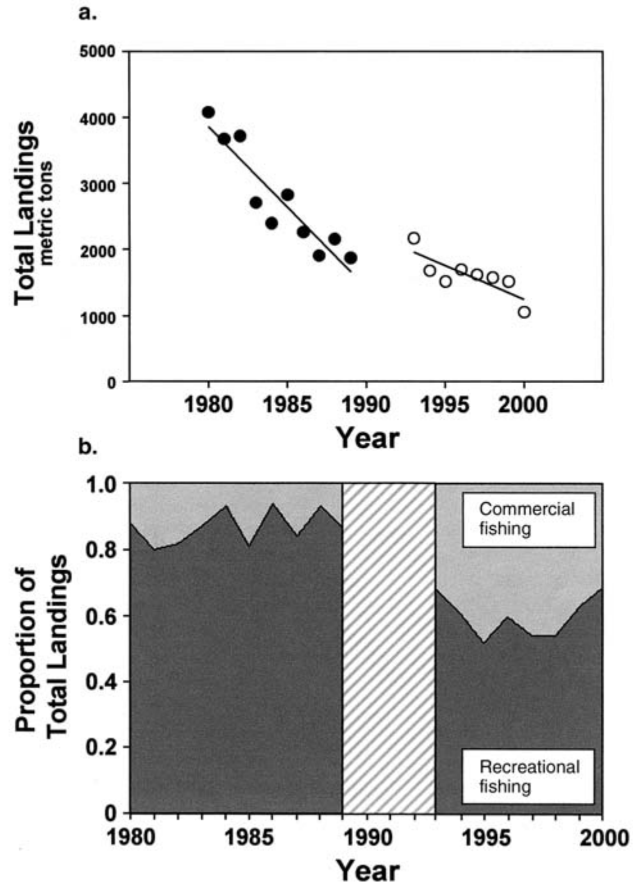

Figure 3. Annual landings in the nearshore fishery off California. No recreational data were collected in 1990–92. (*a*) Total landings, summing both recreational and commercial catches. Straight lines for each data set were calculated using the least squares method. (*b*) Proportion of total landings caught in each year by recreational or commercial fishers.

In light of these data trends, one can easily understand the alarm of recreational anglers about the nearshore environment. A steep decline in landings combined with an increasing proportion of the catch going toward commercial harvesters is such that in the 1990s, the average recreational angler in California caught 65% less in the nearshore than what he or she might have caught in the 1980s. Nevertheless, it remains clear that in the aggregate, recreational fishers impacted nearshore populations more than commercial harvesters.

Recreational anglers dominate other fisheries that show signs of depletion. Karpov et al. (1995) report that

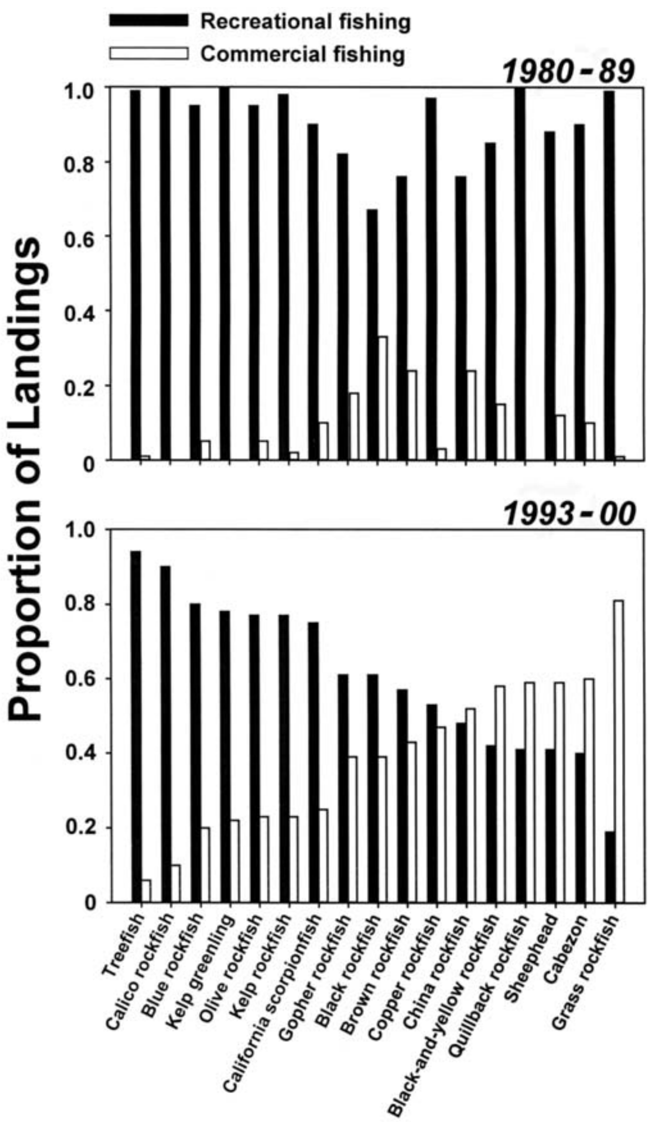

Figure 4. Proportion of fish landings for 17 nearshore species by either recreational or commercial fishers from landings summed during the time periods 1980–89 and 1993–2000. No data were available for monkeyface prickleback or rock greenling.

total surfperch landings from northern and central California during the period 1981–86 were 240 metric tons for recreational fishing and 56 metric tons for commercial harvesters.

Multiple causal factors may be contributing to landing declines in the nearshore fishery, including adverse oceanographic conditions, deteriorating coastal habitats, sustained high fishing mortality, and changing economic or social factors. Regrettably, there are few fishery-independent data that permit us to directly assess how trends in landings correlate with trends in stock abundance. Love et al. (1998a) reported a steep decline in impingement rates of some species of rockfishes at southern California electrical-generating stations in the 1980s and 1990s. This decline mirrored declines in CPFV landings in southern California (Love et al. 1998b). A few other information sources provide demographic clues to the existence of depleted nearshore stocks and implicate overfishing as contributing to this depleted state. The annual CalCOFI survey of early larval fishes has described a steady decline in abundance of some rockfish taxa over the last few decades, suggesting that spawner abundance has also declined (Moser et al. 2000). Abundance of pelagic juveniles for some nearshore rockfish species has also declined (Ralston and Howard 1995). On localized rocky outcrops, depletion in olive rockfish populations has been described by Love (1978), who found a complete lack of mature individuals in areas heavily fished by recreational anglers; lightly fished areas had many mature fish. Finally, Paddack and Estes (2000) compared fish populations inside and outside central California MPAs and suggested that fishing pressure significantly alters size structure and reproductive output of some nearshore fish stocks (*S. atrovirens* and *S. chrysomelas*).

Although the landing data reviewed above suffers from a number of technical uncertainties, we consider it to possess sufficient strength to persuade marine resource managers to consider the activities of recreational anglers nontrivial sources of fishing mortality.

Potential Impact of Catch-and-Release Programs

Catch-and-release (CR) is a popular management strategy in recreational fisheries. Public comment workshops during the MLPA process revealed a common stakeholder perception that catch-and-release fishing is not harmful to fish populations and should be allowed in MPAs. We address this supposition in this section.

Fish that have been hooked, landed, and released by anglers may still die from tissue trauma, bacterial infection, or increased vulnerability to predation resulting from a CR event (Muoneke and Childress 1994). Factors important in determining post-hooking mortality rate include position of hook location, bait type (natural or artificial), hook type (circle, "j," barbless, or treble), handling time, angler experience, water temperature, depth of capture, salinity, swim bladder deflation, and size, age, and species of fish (Gitchlag and Renaud 1994; Muoneke and Childress 1994; Render and Wilson 1994; Wilson and Burns 1996; Diggles and Ernst 1997). Published CR mortality rates range from zero to 100%, suggesting that managers should conduct a case-by-case evaluation of CR impacts for each fishery. If such a study is not available, managers have used a 20% mortality rate per CR event (e.g., Schirripa and Legault 1999), a factor that seems conservatively reasonable given that many published CR mortality rates in marine fishes are equivalent or greater than this value.

We now consider the effects CR mortality may have on protected fish populations by examining a case study of giant sea bass (*Stereolepis gigas*). An area along the north shore of Anacapa Island has recently been designated as a no-take MPA, in part due to numbers of giant sea bass frequently observed there. These fish attract recreational (nonspearfishing) scuba divers and play an increasingly important role in the education and outreach program at the Channel Islands National Marine Sanctuary (K. deWet-Oleson, pers. comm.). The take of giant sea bass has been prohibited in recreational and commercial fishing since 1981, after the species had already plummeted to catastrophically low levels (Crooke 1992). Giant sea bass live to at least 75 years and probably longer (Love 1996). They are the largest reef fish in California, and adults feed on a variety of fishes, decapod crustaceans, and cephalopods. Numerous videos taken by recreational divers suggest that most giant sea bass observed near Anacapa Island are from one successful year class that recruited during the 1983–84 ENSO event.

The effect of a small increase in mortality rate on population dynamics may be difficult to visualize because such rates are compounded through time, causing populations to decline in an exponential manner rather than in a linear one. This means that very small CR rates may have considerable impact on long-lived fish populations. Ironically, a fishing public that does not differentiate between a 6% and 7% annual mortality rate may immediately recognize the considerable difference between a 6% and a 7% annual interest rate on a 30-year mortgage, even though both examples compound rates through time. We therefore choose to use graphical methods to demonstrate the potential consequences of CR mortality to giant sea bass under five different demographic regimes: natural mortality only, and natural mortality plus one of four CR mortality rates (1%, 5%, 10%, or 20%). There are no estimates of natural mortality in giant sea bass, so we used Hoening's (1983) regression formula, which predicts annual mortality rate, m, on the basis of maximum age, t_{max}, by the formula $ln\ (m) = a + b\ ln\ (t_{max})$, where $a = 1.44$ and $b = -0.982$. A maximum age of 75 years translates into an annual mortality rate of 6%. We also lack information on CR mortality rates of this species, although a scientific tagging study on these fish around Anacapa Island recorded one fatality among six tagged individuals in 2000 (S. Fangman, pers. comm.). Given the low numbers of giant sea bass, their aggressive nature, the close proximity of Anacapa Island to several major harbors, and the large number of fishers present in the northern California Channel Islands, it is reasonable to assume that each giant sea bass at Anacapa Island is hooked once per year. This assumption allows the CR mortality rate and the natural mortality rate to be on the same temporal scale.

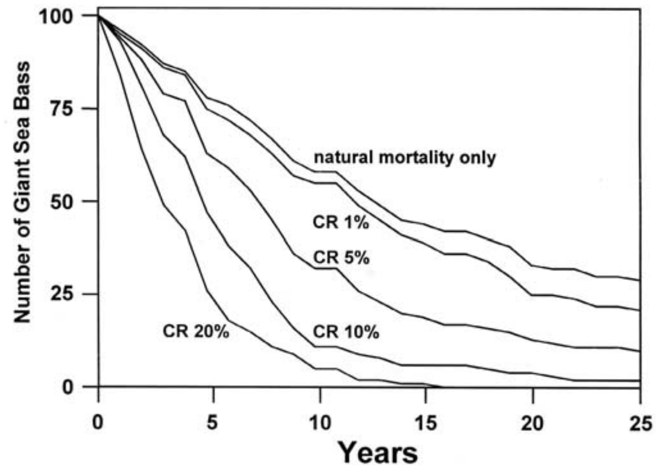

Figure 5. Population trajectories of giant sea bass (*Stereolepis gigas*) under five different mortality regimes: natural mortality only, and natural mortality plus one of four catch-and-release (CR) mortality rates.

We projected population abundance through time by exposing each giant sea bass in the model population to independent mortality risks at each yearly time step. The population projection lasted 25 years, during which time we assume no immigration of individuals (juvenile or adult) from other areas. The baseline population began with 100 fish that endured only the estimated natural mortality rate; that is, at each time step, each fish had a 6% chance of dying from natural causes. The baseline population trajectory was then exposed to varying rates of additional mortality (1–20%) to delineate changes in population dynamics that may be associated with a catch-and-release program for this species.

After 25 years, 29 giant sea bass remained alive in the baseline population; the addition of any CR mortality changes this number considerably (fig. 5). A 20% CR mortality rate causes extinction of the giant sea bass population after 16 years. A 10% CR mortality rate leaves two fish remaining at the end of the time period considered, and a 5% CR mortality rate leaves 10 fish. A CR rate of only 1% reduces the baseline population by 28%, down to 21 fish (fig. 5). It may be that in southern California, juvenile recruitment of giant sea bass is only significant during strong ENSO events. Consequently, without steady juvenile recruitment events, a small amount of CR mortality added to giant sea bass population dynamics may perilously delay population recovery or even cause local extinction.

The sea bass example presented here is one possible scenario; other fish species may tolerate a CR program quite successfully. Important variables likely to affect tolerance to a CR program include mean fish life span, degree of density dependence in demographic rates, and the rate at which individuals within a population experience a CR event.

CONCLUSION

In California waters, the view that recreational angling has no or little impact on marine populations is not supported by the best scientific information available. Our results agree with other reports that find recreational anglers capable of measurably impacting marine resources (Buxton and Clarke 1991; Bennett 1993; Sluka and Sullivan 1998; Young et al. 1999; Jouvenel and Pollard 2001). California has the third largest number of recreational anglers in the United States, with approximately 1.7 million anglers making nearly 6 million fishing trips during 2000 (MFRSS database). With such large numbers of fishers pursuing limited numbers of fish, the results we present here are not unexpected.

Our findings also suggest that recreational angling may be incompatible with some common goals of spatial closures, such as protecting marine ecosystem structure, and establishing scientific control and marine wilderness areas. Large predators may disappear when a reef is fished even lightly, and this in turn may alter ecosystem structure through top-down, trophic cascades (Dayton et al. 1995; Boehlert 1996; Pinnegar et al. 2000). Local depletion of California sheephead and subsequent changes in sea urchin and giant kelp dynamics may be an example of this phenomenon (Pinnegar et al. 2000). Places that permit substantial recreational angling cannot be considered marine wilderness areas, nor would these places provide suitable scientific controls to separate anthropogenic impacts from the natural variability of marine systems.

Many of California's exploited marine species possess life history traits (e.g., long life or irregular juvenile recruitment) that may inhibit timely population recovery once overfishing occurs. We thus conclude this report by strongly advising legislators and natural resource managers to adopt a precautionary approach in managing California's fisheries, where any source of fishing mortality, recreational or commercial, is assumed to be significant until specific studies demonstrate otherwise.

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