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Effects of fishing and the environment on the long-term sustainability of the recreational saltwater bass fishery in southern California

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Unlike several boom-and-bust fisheries of the last century, the recreational saltwater bass (*Paralabrax* spp.) fishery in southern California has endured oceanographic regime cycles and nearly a century of increasing anthropogenic impacts. We examined regulatory changes and several fishery-dependent and fishery-independent time series to determine historical influences on the fishery and causes of dramatic catch declines in recent years. Our results reveal a complex relationship between bass abundance and harvest rules, fishery recruitment, giant kelp (*Macrocystis pyrifera*), ocean regimes, and fishing. Recent trends in larval abundance and lengths of harvested fish suggest recruitment failure occurred during the last oceanographic regime shift coincident with a peak in exploitation rates. We believe this contributed to poor fishery recruitment, associated declines in catch-per-unit-effort, and a depressed population since the mid-2000s. Although long-standing regulations and periods of optimal environmental conditions appear to have sustained the fishery, we recommend an adaptive management approach to mitigate the effects of fishing pressure during unfavorable ocean conditions.

Key words: barred sand bass, exploitation rate, fishery recruitment, hyperstability, kelp bass, natural mortality, overfishing, *Paralabrax*, population recruitment failure, sustainable fisheries

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The popular southern California recreational fishery for barred sand bass (*Paralabrax nebulifer*), kelp bass (*P. clathratus*), and spotted sand bass (*P. maculatofasciatus*) dates back to 1916. After nearly a century of oceanographic regime cycles and increasing anthropogenic impacts, barred sand bass and kelp bass still consistently rank among the top five species caught in southern California, and popularity of spotted sand bass fishing continues to grow. Nevertheless, saltwater bass catches have decreased for over a decade and increased take restrictions were implemented in 2013 (California Code of Regulations Title 14, Section 28.30). A recent publication concluded that the recreational bass fishery in southern California was collapsed (Erisman 2011). After the Atlantic cod (*Gadus morhua*) tragedy in the early 1990s (Hutchings and Myers 1995), the term "collapse" conjures up depleted fish stocks and fishing moratoriums.

Fisheries that are either undermanaged or lack traditional fishery statistics have been more recently assessed by examining current catches relative to a historic maximum (Worm et al. 2006), whereby those fisheries exhibiting catch declines of 90% or more are classified as collapsed. For fisheries without long-term fishery-independent indices of abundance or other important fishery statistics (e.g., size class distributions, exploitation rates), using this benchmark may be the only tool available for assessing fishery status; however, its use may still be misleading (de Mutsert et al. 2008). The basses have been managed for over 50 years with a minimum size limit (MSL) and bag limit. Although spawning biomass estimates do not exist for the basses, several traditional fishery statistics are available to better assess the health of the bass fishery than the 90% benchmark referenced by Erisman et al. (2011). Given the ecological and economic importance of the saltwater bass resource to the coastal waters of southern California and the long-standing popularity of the fishery, we feel a more thorough investigation of the fishery is warranted.

Examples of fishery collapse over the last century have generally included commercial fisheries characterized by fish populations that form large schools or aggregations (e.g., Radovich 1982, Hutchings and Myers 1995). In these fisheries, hyperstable catches exist due to density-dependent population dynamics, increases in fishing efficiency, and the ability of fishing fleets to target areas of higher fish abundance or density (Hilborn and Walters 1992). Over time, the severity of harvest impacts can reportedly go unnoticed until the fishery is forced to close due to the scarcity of the resource (Sadovy and Domeier 2005, Murphy and Munyandorero 2009). The basses have not been commercially fished since 1953, but they do form spawning aggregations that are targeted to varying degrees (depending on the species) by the Commercial Passenger Fishing Vessel (CPFV) fleet and private boaters (Love et al. 1996a, Allen and Hovey 2001). The nature of a fishery that is primarily dependent on large, seasonal aggregations is expected to exhibit hyperstable catches (Harley et al. 2001, Shelton 2005); thus, evidence of hyperstability alone (Erisman et al. 2011) does not provide the extent to which fishing has affected local bass populations or confirm that the fishery has collapsed.

The lack of management regulations to prevent recruitment overfishing or growth overfishing is often cited as the cause of fishery collapse. Traditional indicators of overfishing include significantly reduced catches of larger, older individuals (recruitment overfishing) and a decrease in the average size of fish caught over time (growth overfishing). The basses were managed under a 30.5-cm MSL from 1959 to 2012. Based on age-at-maturity, this limit afforded the basses one to three spawning seasons before recruiting into the fishery (Allen et al. 1995, Love et al. 1996b) and was intended to provide a maximum yield per recruit. Thus, growth overfishing was not likely to occur. Biological reference points, however, for curbing recruitment overfishing have been less clear for the basses because no estimates of population size or spawning stock biomass have been available. This is of concern, especially for barred sand bass, given that they are targeted by anglers when they aggregate to spawn. Once harvesting has reduced the spawning population below some critical level, recruitment can fail for several years, resulting in a collapsed fishery (Sadovy and Domeier 2005). Well known examples of fishery extirpation of spawning aggregations include the tropical serranids (e.g., Nassau grouper [*Epinephelus striatus*]), of which eight are listed as endangered or critically endangered on the IUCN Red List of Threatened Species in 2012 (IUCN 2012). Fishing pressure on schooling fish or spawning aggregations can also affect the distribution of fish catches over time (Hilborn and Walters 1992). Rose and Kulka (1999) demonstrated a large reduction in the geographic range fished for Atlantic cod over a 12-year period, but this possibility has never been assessed for the basses.

In addition to harvest impacts, changing oceanographic conditions could also influence southern California bass populations by affecting larval survival, habitat-dependent recruitment success (e.g., giant kelp [*Macrocystis pyrifera*]), and spawning behavior cues. Over the last century, the Southern California Bight (SCB) has experienced several ocean regime shifts (e.g., Pacific Decadal Oscillation; PDO) resulting in significant changes in seasonal temperature amplitudes within the upper ocean (Gelpi and Norris 2008). Hsieh et al. (2005) reported long-term positive bass population responses to the warm phases of the PDO, but no study has documented direct relationships between sea surface temperature (SST) and bass fishery recruitment strength. Coastal SSTs from Alaska to southern California vary in phase with the PDO (Mantua et al. 1997), and although the PDO index is primarily a measure of SST anomalies, the PDO also drives atmospheric and oceanographic changes in the Pacific northwest of North America and northeast Pacific Ocean. Regimes typically last 30 years or more; the last extended warm water period occurred in the 1980s and 1990s (NOAA 2012) and cooler conditions since then may have contributed to decreased bass fishery recruitment.

Habitat requirements could introduce complexity in interpretations of oceanographic and fishing effects on bass populations. For example, kelp bass are associated with giant kelp and rocky reef habitat and are generally more abundant when giant kelp is more abundant (Graves et al. 2006). Giant kelp densities can be reduced during warm ocean regimes, especially after El Niño events (Tegner et al. 1997), and this may negatively affect juvenile kelp bass abundance during warm regimes, even though conditions for successful reproduction or larval development, or both, are optimized. Increases in giant kelp generally have a positive effect on kelp bass larval recruitment depending on successful larval transport (White and Caselle 2008).

The objectives of this paper are to provide a historical review of the saltwater bass fishery with emphasis on barred sand bass and kelp bass, and to investigate the factors contributing to their catch declines in recent years. We examined (1) fishery-dependent data (e.g., exploitation rates, catch distribution, size composition); (2) fishery-independent data (e.g., larval and adult abundance); and (3) relationships between bass fishery recruitment strength and larval abundance, giant kelp canopy, and SST. A comprehensive fishery analysis leading up to the saltwater bass regulation changes in 2013 should provide historical perspective and an increased ability to adaptively manage the fishery.

History of the Fishery

The first in-depth fishery analysis for the basses was conducted in the early 1930s by the California Department of Fish and Game (CDFG; now the California Department of Fish and Wildlife [CDFW]) in response to sport fishermen appealing for prohibition of the commercial take of bass. At that time, minor numbers of barred sand bass and kelp bass were caught only incidentally in commercial fishing gear, and so it was recommended that prohibiting commercial harvest would do little to conserve the resource (Clark 1933). It is important to note that prior to recreational catch reporting, the early record distinguished barred sand bass as "rock bass"; however, the rock bass category later came to include all three species of bass on sport fishing logbooks. Although commercial landings were made by many different types of fishing gear, catches were primarily by hand and set line targeting rockfishes (*Sebastes* spp.) and California sheephead (*Semicossyphus pulcher*) during summer months out of the Los Angeles Harbor at San Pedro (Clark 1933, Collyer 1949, Pinkas et al. 1967).

Small-scale recreational charter fishing trips began at the turn of the century after the Tuna Club of Santa Catalina Island was formed in 1898, but the expansion of the "partyboat" (= CPFV) fleet did not occur until after 1929 (Young 1969). During this time, barred sand bass and kelp bass were reportedly numerous in CPFV catches out of Santa Monica Bay, Long Beach, and Newport Beach (Figure 1); spotted sand bass was only a minor component of "rock bass" catches on CPFVs.

Figure 1.—Commercial passenger fishing vessel *Ramona* off Rocky Point, Santa Monica Bay, California on 3 July 1938. Note the fish sacks hanging off the side of the boat. Photo credit: R. S. Croker, California Department of Fish and Game.

Early on, a certain portion of the CPFV catch was sold to the fresh fish markets and comprised about 10% of the commercial landings (Clark 1933). Later, the practice became increasingly popular until it became illegal in 1947 (Collyer 1949). Monthly logbook records became a requirement for all CPFV operators in 1935 (Young 1969), and from 1935 to 1947 (with the exception of 1941–1946 when World War II halted nearly all partyboat activity), recreational rock bass landings were, on average, about three times the commercial landings by weight.

All three basses have been managed together since the early 20th century. In 1939, the state legislature limited take of "kelp bass and rock bass" to a 15-fish aggregate bag limit including several other species (Table 1). After World War II, the CPFV fishery experienced a second expansion and concerns were again raised, this time over declining

Table 1.—Historical record of southern California saltwater bass (*Paralabrax* spp.) minimum size and bag limit regulations.

Year	Saltwater Bass Species Listed	Regulation
1939[a]	kelp bass, rock bass	Bag limit: 15 fish in aggregate
1949[b]	kelp bass, rock bass	Bag limit: 10 fish in aggregate
1951[b]	kelp bass, rock bass	Bag limit: 15 fish in aggregate, with not more than 10 of any one species
1953[c]	kelp bass, rock bass, sand bass, spotted sand bass	Cannot be sold or purchased. Minimum size limit: 26.7 cm (10.5 in) total length
1957[b]	kelp bass, sand bass, and spotted sand bass	Minimum size limit: 27.9 cm (11 in) total length
1958[b]	kelp bass, sand bass, and spotted sand bass	Minimum size limit: 29.2 cm (11.5 in) total length
1959[b]	kelp bass, sand bass, and spotted sand bass	Minimum size limit: 30.5 cm (12 in) total length
1972[b]	kelp bass, sand bass, and spotted sand bass	Bag limit: 20 fish in aggregate, with not more than 10 of any one species
1975[d]	kelp bass, sand bass, and spotted sand bass	Bag limit: 10 fish in aggregate, with not more than 10 of any one species
2013[d]	kelp bass, barred sand bass, and spotted sand bass	Bag limit: 5 fish in aggregate; Minimum size limit: 35.6 cm (14 in) total length

[a]California Fish and Game Code Section 746.
[b]California Code of Regulations Title 14, Section 62
[c]California Fish and Game Code Section 714.7
[d]California Code of Regulations Title 14, Section 28.30

bass catches and the size of kelp bass caught (Young 1963). Following another CDFW fishery analysis, commercial take for all three basses was banned in 1953 and a 26.7-cm (10.5-in) MSL was implemented. The size limit was raised by 1.3-cm (0.5 in) increments in 1957 and 1958, and by 1959 a 30.5-cm (12-in) MSL was implemented. This size limit was based on kelp bass size-at-maturity and size at which to achieve the greatest yield in catch by weight (Young 1963). Contrary to previous reports (Allen and Hovey 2001, Miller and Erisman 2014), the bag limit regulation for the saltwater basses changed several times during the century, ranging among aggregate limits of 10, 15, and 20 fish with no more than 10 per species (Table 1). The most long-standing were the 15- and 10-fish aggregate bag limits during the periods 1951–1971 and 1975–2012, respectively.

During the 1950s and 1960s, kelp bass was referred to as the "mainstay" of the fishery and barred sand bass was considered "scarce". However, barred sand bass became more available in the 1980s and CPFV fishing effort for them increased. According to surveyed CPFV skippers in the late 1980s, the ease of catching legal-sized barred sand bass relative to legal-sized kelp bass was the primary reason for the increase in effort (Ally et al. 1991). By 1985, barred sand bass catches had exceeded kelp bass catches. Two separate fishery analyses conducted in the late 1980s and mid-1990s (CDFG 1991, Love et al. 1996a) concluded that the kelp bass and barred sand bass fisheries were healthy. Love et al. (1996a) cited the transition to warmer ocean conditions in the late 1970s as perhaps contributing to increased recruitment success in the 1980s and 1990s. Nevertheless, catches declined again, and new take restrictions consisting of a 35.6-cm (14-in) MSL and an aggregate bag limit of five fish were implemented for the saltwater basses in 2013 (Table 1, FGC 2012).

Kelp bass are commonly fished along the rocky mainland and island coasts. In contrast, the sand basses have fewer island populations and are much less abundant at these locations. Barred sand bass prefer sand-reef ecotonal habitat (Mason and Lowe 2010, McKinzie et al. 2014) and are fished near structure year-round, except when they form large spawning aggregations over sand flats in water 10–30 m deep (Love et al. 1996a). Spotted sand bass are associated with bays and harbors (Allen and Hovey 2001). Popularity for spotted sand bass fishing quickly rose in the 1980s, becoming primarily a catch-and-release fishery (Hovey and Allen 2000, Sweetnam 2010). Thus, harvested catches have never rivaled the other two basses, and management has considered potential harvest impacts to this species to be minimal.

Temporal Trends in Fishery-dependent Data

Description of catch data sets.—Most of the effort and landings for barred sand bass and kelp bass are from CPFVs and private or rental boats (Table 2). We used CPFV logbook data extracted from the CDFW California Fisheries Information System (CFIS) database (1980–2012) to examine recent CPFV catch trends. Commercial passenger fishing vessel logbook data in the CFIS database are available per vessel-trip since 1980 and include date, number of anglers, number of fish kept, number of fish discarded (since 1995), CDFW fishing block (10-minute latitude by 10-minute longitude), time fished, and other relevant data.

Historical logbook data for species catches prior to 1980 are summarized by month and fishing block and are available from 1935 to 2008 (Hill and Schneider 1999). Reporting requirements for fishing effort changed several times over the century; however, Hill and Schneider (1999) used a conversion factor to standardize effort to angler hours throughout the time series. This historical dataset was also examined for trends in catch and catch-per-

Table 2.—Percent of southern California saltwater bass (*Paralabrax* spp.) catches in the recreational fishery by species and fishing mode from 2004 to 2012.

	Percent of Catch		
Fishing Mode	barred sand bass	kelp bass	spotted sand bass
Party/charter	70.2	59.0	0.4
Private/rental	26.4	35.4	71.0
Man-made	1.5	2.0	19.6
Beach/bank	2.0	3.5	9.0
Total fish (thousands)	2,398.3	1,785.0	154.6

unit-effort (CPUE) from 1947 to 2008. Due to changes in logbook reporting requirements, individual species landings were not consistently reported until 1975; thus, for historical analyses, we queried the catch data for each species and for the aggregate category ("rock bass") and summed the catches by year. Because the historical CPFV data are summarized by month-block, only a single value is provided for the total number of angler hours for a given month-block, regardless of the species queried. Therefore, it was necessary to remove duplicate fishing-effort records when multiple catch records (individual bass species and "rock bass" records) were reported from the same month-block.

We used California Recreational Fisheries Survey (CRFS) data (RecFIN 2013) to capture CPUE trends in the private-rental boat mode from 2004 to 2012. The CRFS began in 2004 and replaced the federal Marine Recreational Fisheries Statistics Survey (MRFSS) conducted by the National Oceanic and Atmospheric Adminstation (NOAA) in California from 1980 to 2003. California Recreational Fisheries Survey landings estimates are not directly comparable to the MRFSS estimates, and the CRFS and MRFSS party or charter estimates are not directly comparable with the CPFV logbook data. Catch data collected by CRFS samplers on a subset of fishing trips are extrapolated to total estimates based on effort (angler days) derived from a phone survey.

Harvested fish (landings and CPUE).—Temporal trends in the historical CPFV logbook data indicate landings and CPUE have fluctuated similarly over the last 60 years. Following the regulation changes of the 1950s, saltwater bass ("rock bass") catches and catch rates increased to an all-time high in the early 1960s (Figure 2a). Both decreased into the 1970s before increasing again in the 1980s and 1990s. The more recent CPFV logbook record, which delineates catches by species, indicated barred sand bass landings and CPUE declined sharply (86% and 70%, respectively) from 2000 to 2012 (Figure 2a). Kelp bass declines were more gradual; from 1982 to 2012, kelp bass landings declined by 72% and CPUE declined by 48% between the peaks in 1992 and 2012 (Figure 2a). Since 1997, the total number of vessel-trips that reported catches of barred sand bass and kelp bass declined by 51% and 40%, respectively.

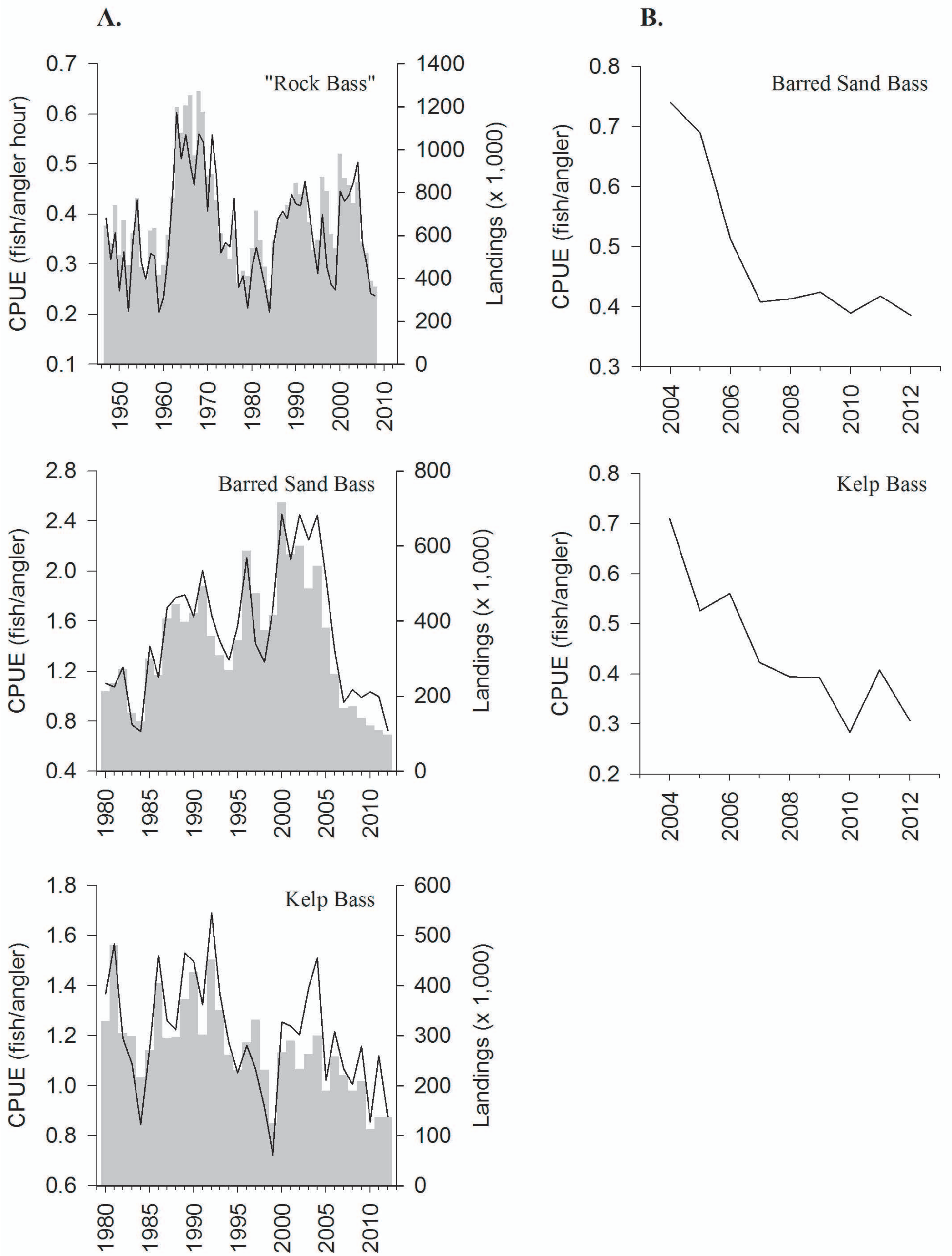

Figure 2.—Temporal trends in landings (grey bars) and catch-per-unit-of-effort (CPUE, line) of harvested saltwater bass (*Paralabrax* spp.) by A) commercial passenger fishing vessel and B) private and rental boat fishing modes in southern California. Data in A) represent California Department of Fish and Wildlife commercial passenger fishing vessel logbook data; data in B) represent California Recreational Fisheries Survey data.

Private and rental boat data showed similar declining trends for barred sand bass and kelp bass. Barred sand bass CPUE declined sharply from 2004 to 2007 (62%) and remained at that low level in 2012 (Figure 2b). Kelp bass CPUE steadily declined by 60% from 2004 to 2010 and remained at that level in 2012 (Figure 2b).

Total catch.—Total catch includes number of fish kept and discarded dead, and fish that are released alive. The number of fish released can make up a substantial part of a recreational fishery. Since 2004, the CRFS estimates of fish released from all fishing modes expressed as percentages of the total catch were 54% and 71% for barred sand bass and kelp bass, respectively. Despite recent declines in harvested CPUE, catch ranks using total catch estimates for all fishing modes reported in southern California by decade and sampling survey show that kelp bass and barred sand bass have remained within the top five recreational species caught since the 1980s (Table 3).

Spatial distribution of the catch.—We examined spatial trends in the distribution of southern California barred sand bass and kelp bass catches in the CPFV fleet from 2000 to 2012 by calculating CPFV catch rates by fishing block during peak spawning season (June–August). Fishing blocks that did not contain depth contours from 0-40 m were excluded from the analysis. We first examined temporal trends in the number of fishing blocks reporting bass catches and the percentage of those blocks with high catch rates (>3 fish/angler) from 2000 to 2012. Although the number of blocks with reported bass catches remained stable over the 12-yr period, the percentage of blocks with high catch rates peaked in 2004 at 47% (barred sand bass) and 28% (kelp bass), and then fell to 0% by 2012 (Figure 3).

TABLE 3.—Rank in southern California recreational fishing catch estimates by species, decade, and survey type from 1980 to 2012. Total catch estimates were derived from catch and effort surveys for all fishing modes and include fish kept and discarded. Bold values highlight those species catches within the top 10 ranks.

		MRFSS[a]			CRFS[b]
Common Name	Scientific Name	1980s	1990s	2000–2003	2004–2012
Pacific chub mackerel	*Scomber japonicus*	**1**	**1**	**1**	**1**
white croaker	*Genyonemus lineatus*	**2**	**3**	**10**	15
kelp bass	*Paralabrax clathratus*	**3**	**2**	**3**	**3**
Pacific bonito	*Sarda chiliensis*	**4**	16	32	**8**
barred sand bass	*Paralabrax nebulifer*	**5**	**4**	**2**	**4**
California halibut	*Paralichthys californicus*	**6**	**10**	**7**	14
bocaccio	*Sebastes paucispinis*	**7**	25	45	22
Pacific barracuda	*Sphyraena argentea*	**8**	**5**	**9**	13
blue rockfish	*Sebastes mystinus*	**9**	38	26	42
California lizardfish	*Synodus lucioceps*	**10**	24	23	16

[a]National Oceanic and Atmospheric Administration, Marine Recreational Fisheries Statistics Survey, 1980–2003.
[b]California Recreational Fisheries Survey, 2004–2012.

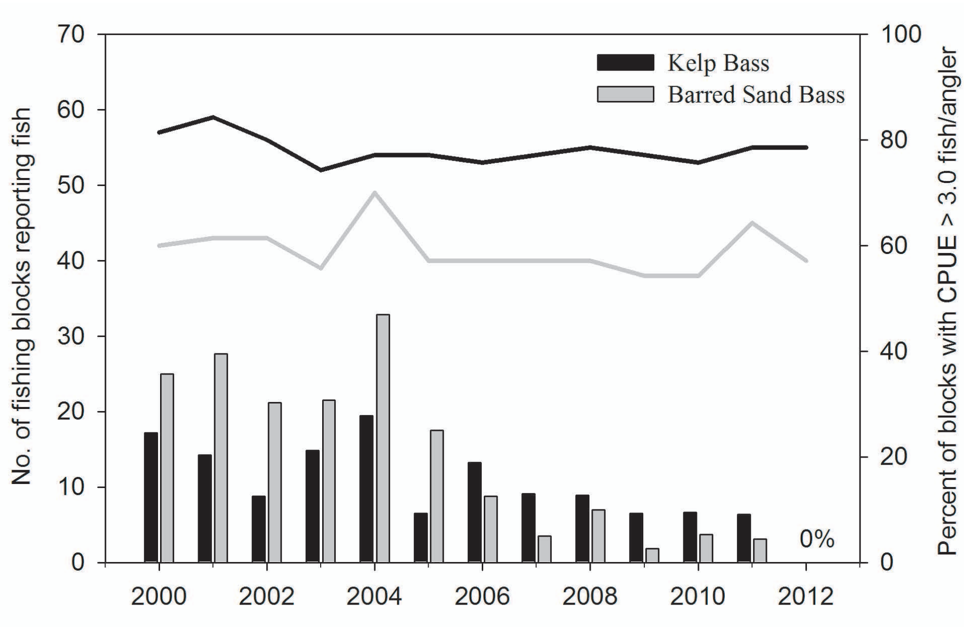

FIGURE 3.—Number of southern California fishing blocks with reported catches of kelp bass and barred sand bass (lines) and percent of fishing blocks with reported catch-per-unit-effort (CPUE) >3 fish/angler (bars) during peak spawning season (June-August) from 2000 to 2012. Data represent California Department of Fish and Wildlife commercial passenger fishing vessel logbook data.

To determine if the declines in CPUE occurred in isolated areas (e.g., hot spots) or throughout the catch range, we plotted the percent change in average CPUE by fishing block between the periods with higher (2000–2004) and lower (2005–2012) catch rates. We used a graduated color scheme to plot the percent change in CPUE using the following categories: declines greater than 50%, 49% to 10%, or 9% to 0%; increases of 1% to 10% or greater than 10%. Localized depletion of stocks between the two catch periods was not evident with barred sand bass or kelp bass. For example, CPUE between the two catch periods declined throughout the catch range, and not only at isolated locations (i.e., fishing hot spots or spawning locations). Known barred sand bass spawning locations off Ventura, Santa Monica, Huntington Beach, San Onofre, and Silver Strand all showed declines similar to declines in other locations throughout the SCB (Figure 4a). Of blocks where barred sand bass was caught, most showed declines in CPUE of greater than 50% (Figure 4a) and occurred throughout southern California (Figure 4a), indicating an overall decrease in barred sand bass availability. Percent increases in barred sand bass CPUE occurred in a few blocks throughout the SCB, including off Silver Strand, San Clemente Island, Santa Cruz Island, and Carpinteria. Most blocks where kelp bass were caught showed declines ranging between 10% and 49% (Figure 4b); these blocks also occurred throughout southern California. Five of eight blocks showing declines greater than 50% occurred in the higher latitude fishing blocks off Ventura and Santa Barbara. Increases in kelp bass CPUE occurred off Encinitas, and San Clemente, Santa Catalina, Santa Rosa, and San Miguel islands.

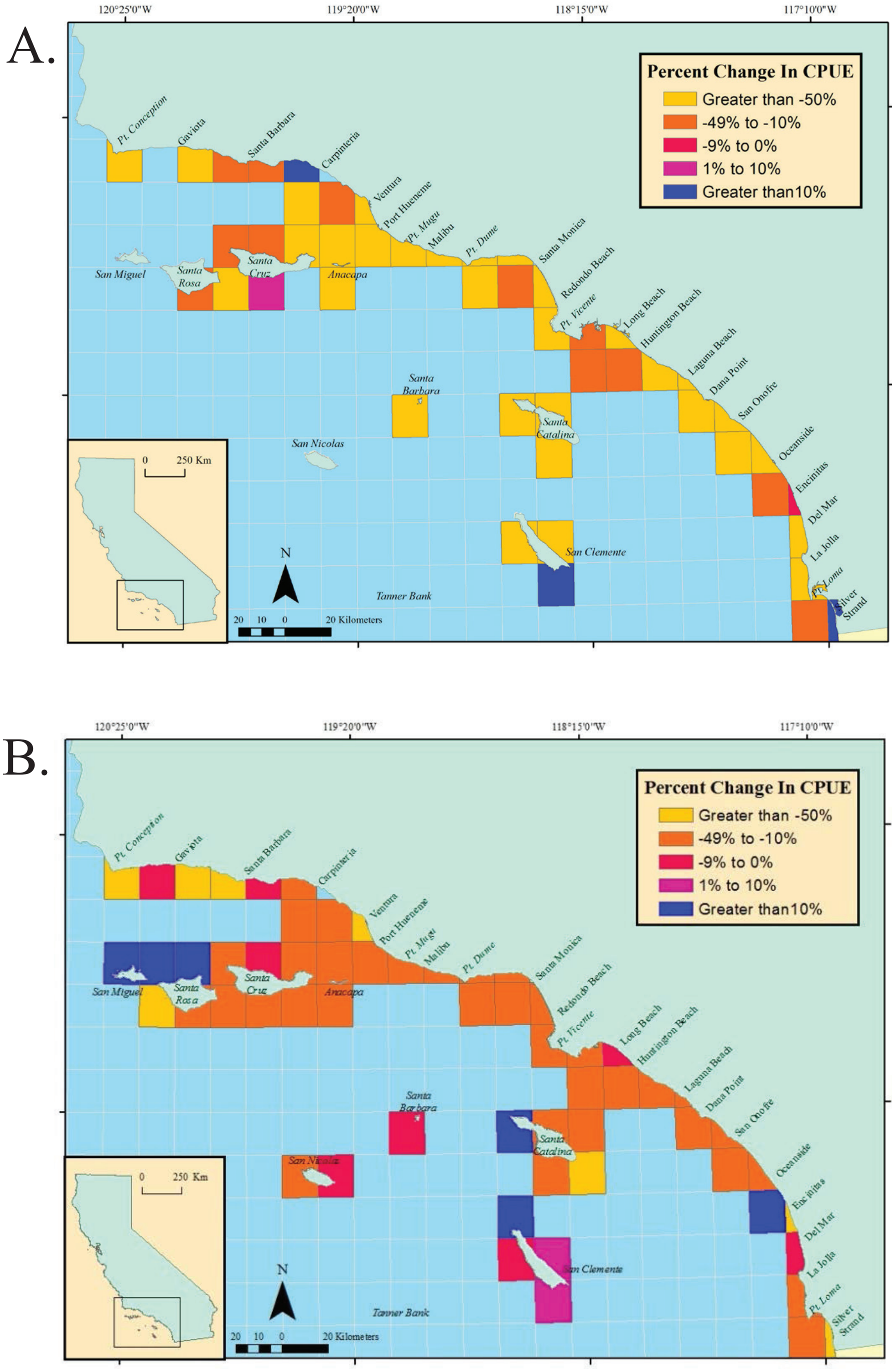

FIGURE 4.—Percent change in catch-per-unit-effort (CPUE) by fishing block during peak spawning season (June-August) for A) barred aand bass and B) kelp bass in southern California between the early (2000–2004) and late (2005–2012) 2000s. Data represent California Department of Fish and Wildlife commercial passenger fishing vessel logbook data.

Exploitation rates.—Using catch-at-length data, we constructed annual catch curves to investigate temporal trends in the annual rate of exploitation (u). Data from 1980 to 2012 were obtained from the MRFSS and CRFS from all fishing modes. Additional length data (1975–1978) were obtained from fish sampled on CPFV trips by CDFW biologists. Lengths were binned into 2.5 cm increments and the rate of exploitation was obtained from the slope of the regression line through the descending portion of the catch curve (instantaneous mortality rate, Z) and its relationship with the annual expectation of natural death (v), total annual mortality (A), and total annual survival (S) (e.g., $A=u+v$) where $S=e^{-z}$, $A=1–S$, and $v=MA/Z$. The natural mortality coefficient (M) was derived from Pauly's (1980) equation, using age and growth parameters (L_{inf}, K) reported in Love et al (1996b) and a mean annual water temperature of 17.0° C. For barred sand bass, M=0.218 and for kelp bass, M=0.178. The mean annual water temperature was derived from SST data obtained from the Southern California Coastal Ocean Observing System (SCCOOS) website (SCCOOS 2013); the annual mean was calculated from the average annual SST sampled at four stations within the SCB (Santa Barbara, Pt. Dume, Newport Beach, and La Jolla) from 1975 to 2012. Station data for Santa Barbara, Pt. Dume, and Newport Beach in 2011 and 2012 were not available, so these data were substituted with the automated SST data off Stearn's Wharf (Santa Barbara), Santa Monica Pier, and Newport Pier. Although simple regression analysis from catch curves may underestimate total annual mortality (Dunn 2002, Smith 2012), our analysis was focused on the relative change in exploitation rates over time.

The proportion of barred sand bass and kelp bass taken by fishing was lowest in 1976 and 1977 (Figure 5). The barred sand bass exploitation rate then increased to a peak in 1989, decreased in the 1990s, and was above the period mean for most of the 2000s (Figure 5a). Between 1977 and 2012, the exploitation rate of kelp bass increased by 14%

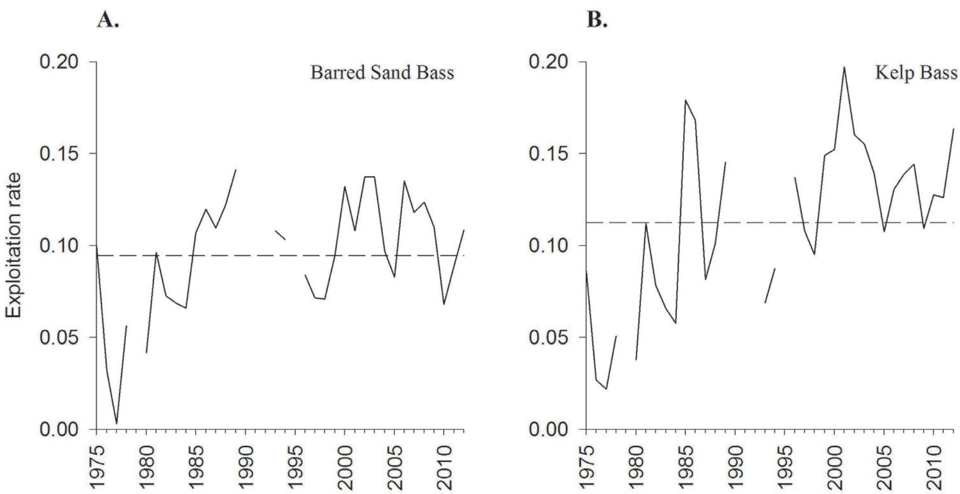

Figure 5.—Annual trends in southern California recreational fishery exploitation rates for A) barred sand bass and B) kelp bass from 1975 to 2012. Dashed lines represent the period means. See text for a detailed description of exploitation rate calculations. Lengths used to derive exploitation rates were obtained from California Department of Fish and Wildlife archives (1975–1978), the National Oceanic and Atmospheric Administration Marine Recreational Fisheries Statistics Survey (1980–2003), and the California Recreational Fisheries Survey (2004–2012).

and, like barred sand bass, was higher than the period mean for most of the 2000s (Figure 5b). Elevated exploitation rates of barred sand bass and kelp bass that occurred between 1999 and 2004 were coincident with increased CPUE observed in both fisheries (Figure 2, Figure 5). The exploitation rate for kelp bass has generally been higher than that of barred sand bass since 1996 (Figure 5).

Size composition of the catch.—To investigate evidence of overfishing, we plotted annual trends in the harvested length data from 1980 to 2012 for (1) percentage of catch that is mature; (2) percentage of catch at optimal length (L_{opt}); and (3) percentage of catch that is mega-spawners (Froese 2004). Ideally, 100% of the harvested catch should be mature and within ± 10% of L_{opt}, the size allowing for the highest yield by weight of the catch. However, because there is no maximum size limit to prevent harvest of larger barred sand bass and kelp bass, the harvested catch represented several size or age classes. In this case, a desirable size structure occurs when approximately 60–80% of the harvested catch is ±10% of L_{opt} and the remaining 20–40% are mega-spawner size (>[L_{opt} ±10%]). If the percentage of mega-spawners declines to below 20%, this may be a sign of prolonged recruitment overfishing and a stock that is less resilient against population recruitment failure (Froese 2004).

Optimal size was estimated from natural mortality (*M*, see *Exploitation rates*, above) and growth parameters using the equation $L_{opt}=L_{inf} \times [3/(3+M/K)]$ (Beverton 1992). Size at first maturity (L_m), maximum length (L_{inf}), and the growth coefficient (*K*) were obtained from Love et al. (1996b). For both species, L_m=27.0 cm TL. For barred sand bass, L_{opt}=34.7 cm TL and for kelp bass, L_{opt}=35.1 cm TL. It is important to note that L_{opt} minus 10% for both species was slightly higher than the 30.5-cm (12-in) MSL during the analysis period; thus, the percentages of optimum size and mega-spawner individuals in the harvested catch did not always sum to 100% (Figure 6).

The percentage of the mature harvested catch was near, or at, 100% during the years examined, showing no signs of growth overfishing (e.g., depletion of mature individuals) of either species (Figure 6a, Figure 6b). The percentages of optimum size and mega-spawner individuals in the barred sand bass catch remained somewhat stable from 1980 to 2002 (Figure 6a). However, after 2002 the percentages of fish harvested at optimum and mega-spawner size decreased and increased, respectively, and became nearly equal at less healthy levels and remained there through 2012. The percentage of barred sand bass mega-spawners harvested exceeded the percentage of optimum size individuals in 2007 and again in 2012 (Figure 6a).

The size distribution of the kelp bass catch remained somewhat stable and within the ranges of a healthy fishery (Figure 6b). Although there were a few years when optimum size was less than 60% and the proportion of mega-spawners dipped below the 20% threshold, these fluctuations were short-term rather than following a long-term trajectory (Figure 6b). Likewise, the declining percentage of mega-spawners in the kelp bass catch since 2005 was most likely driven by a steady increase in fishery recruitment strength rather than long-term recruitment overfishing (see *Fishery recruitment*, below).

Fishery recruitment.—To gauge relative fishery recruitment strength over time, catch-at- length data were binned according to size-at-age (Love et al. 1996b). We calculated the proportion of the catch comprising the fishery recruits (e.g., the first two age classes), and converted the values to Z-scores. The Z-scores provided a relative index of abundance where scores greater than 1 and less than -1 indicated above and below average recruitment strength, respectively. Using a 30.5-cm (12-in) MSL, barred sand bass and kelp bass fishery recruits were approximately 5–7 years old. Fishery recruitment strength for barred sand bass

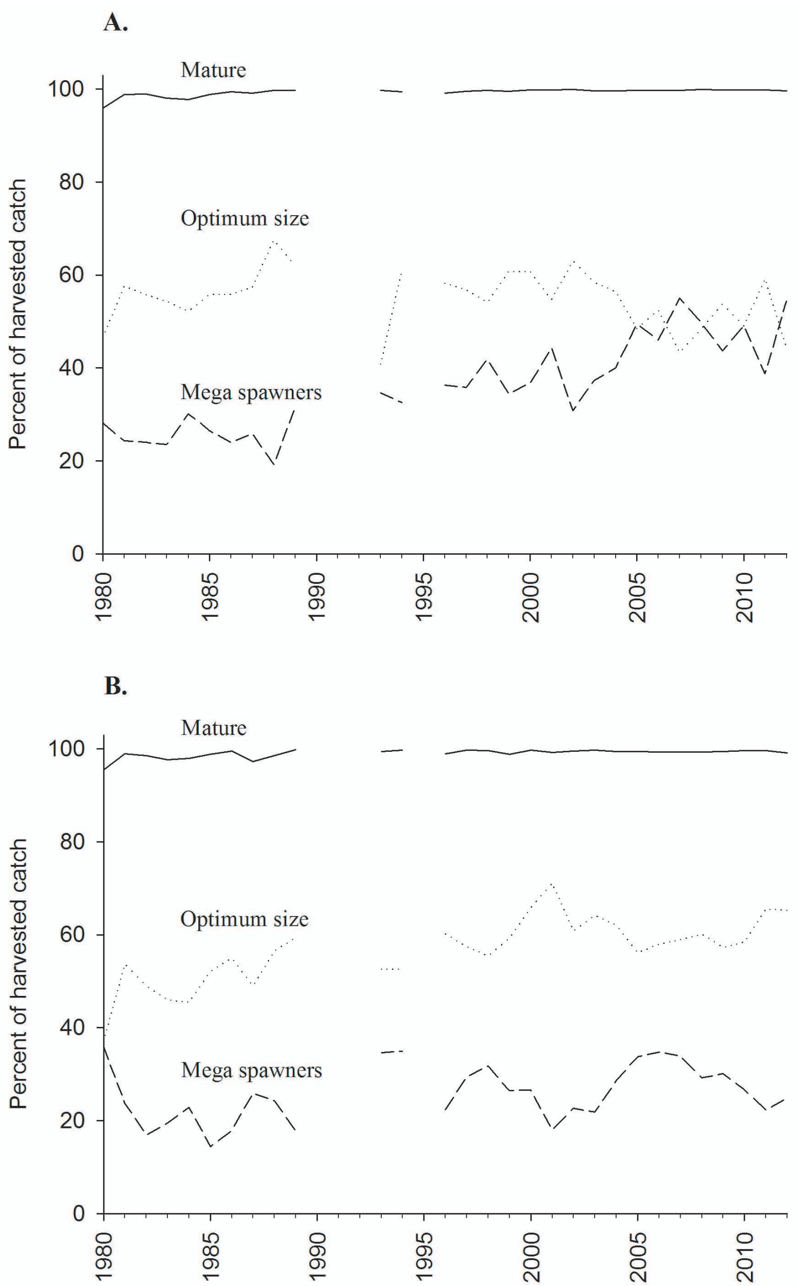

Figure 6.—Percentages of the harvested A) barred sand bass and B) kelp bass recreational catch in southern California comprised of mature, optimum size, and mega-spawner individuals from 1980 to 2012. Sizes (TL) for each category: mature, 270 mm (both species, Love et al. 1996b); optimum size, 312–382 mm for barred sand bass and 316–386 mm for kelp bass; mega-spawners, >382 mm for barred sand bass and >386 mm for kelp bass. See text for a description of optimum and mega-spawner size calculations. Length data were obtained from the National Oceanic and Atmospheric Administration Marine Recreational Fisheries Statistics Survey (1980–2003) and the California Recreational Fishery Survey (2004–2012).

and kelp bass was low in the late 1970s and high in the 1980s; however, fishery recruitment strength returned to below average from 2005 to 2008 (barred sand bass) and from 2005 to 2007 (kelp bass) (Figure 7a). From 2008 to 2011, kelp bass fishery recruitment strength steadily increased and was near average in 2012 (Figure 7a); barred sand bass recruitment dipped below average in 2010 and again in 2012 (Figure 7b).

For both species, the modal length (mm TL) of the catch was determined for each year of length data. During the mid-2000s, the modal length successively increased in the barred sand bass and kelp bass catch (Figure 7b). In effect, the fishery was sustained by a successively older and smaller population of fish for a consecutive 3-4 year period. This

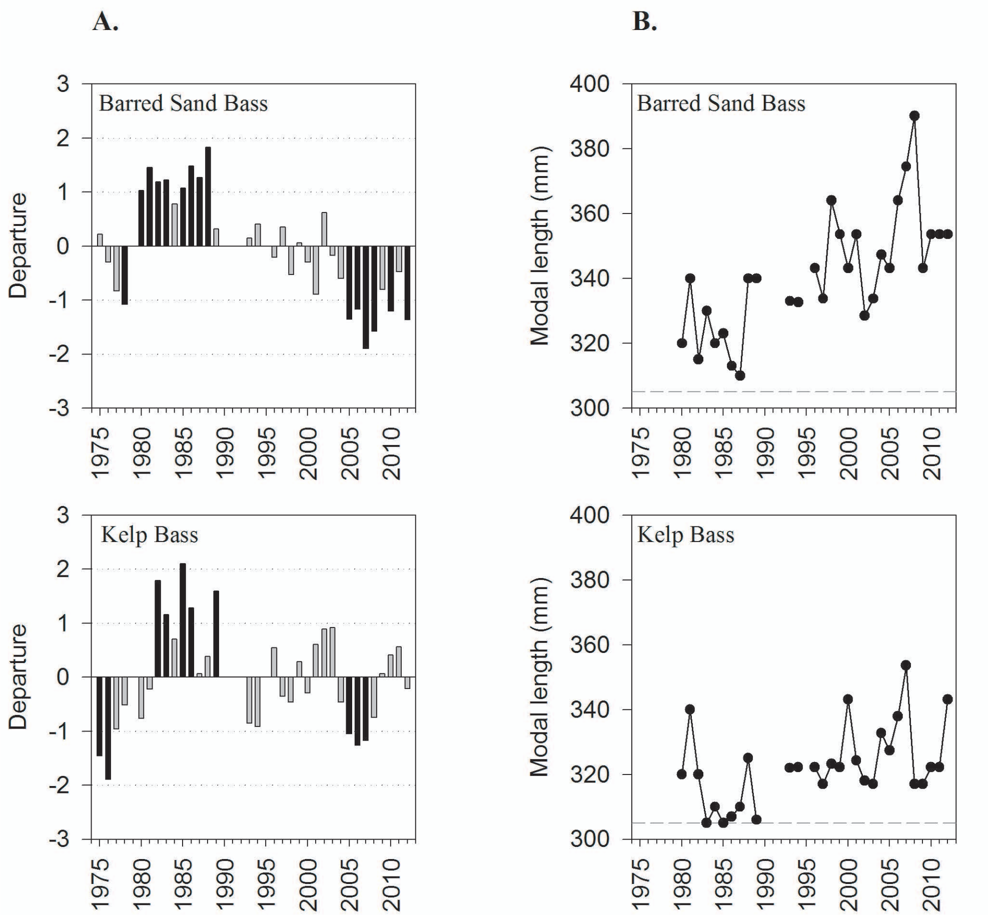

Figure 7.—Temporal trends in A) fishery recruitment and B) modal length of the legal, harvested catch for barred sand bass and kelp bass (1975–2012) in southern California. Fishery recruitment indices greater than 1 or less than -1 represent above and below average recruitment strength, respectively (darker bars). Dashed lines in right panels indicate length at harvestable size (= 305 mm) during the study period. Length data were obtained from California Department of Fish and Wildlife archives (1975–1978), the National Oceanic and Atmospheric Administration Marine Recreational Fisheries Statistics Survey (1980–2003), and the California Recreational Fishery Survey (2004–2012).

result was substantiated by the coincident and dramatic decline in harvested CPUE for both species and the increase in the percentage of mega-spawners in the catch (Figure 2, Figure 6).

We hypothesized that the decrease in barred sand bass and kelp bass fishery recruitment strength in the mid-2000s was due to decreased larval survival or recruitment and (or) decreasing numbers of adult bass. We examined temporal trends in larval abundance in the SCB to gauge relative larval recruitment strength during this period, and adult indices of abundance in scuba surveys to determine whether adult populations had substantially decreased prior to this period.

Temporal Trends in Fishery-independent Data

Larval abundance.—Average annual *Paralabrax* spp. larval abundance taken in the SCB during the California Cooperative Oceanic Fisheries Investigations surveys from 1951 to 2011 was obtained from the NOAA Fisheries Southwest Fisheries Science Center, La Jolla, CA; data from 2012 were not available. *Paralabrax* larvae could not be differentiated into species and include spotted sand bass. Densities were used as a measure of abundance, with numbers of larvae per 10 m^2 summarized by station and month according to their primary distribution during spawning season (Moser et al. 2001) and then averaged for the year. From 1951 to 2011, peaks in larval abundance frequently occurred during the 1980s and 1990s; the periods before and after consisted of sustained below-average abundance (Figure 8). From 1999 to 2003, *Paralabrax* larval abundance was consistently low (Figure 8) suggesting a period of population recruitment failure. This timing coincided with negative SST anomalies (1998–2001; Bjorkstedt et al. 2011) and higher adult exploitation rates (Figure 5).

Diver surveys of adults at the mainland.—Diver surveys of fishes have been

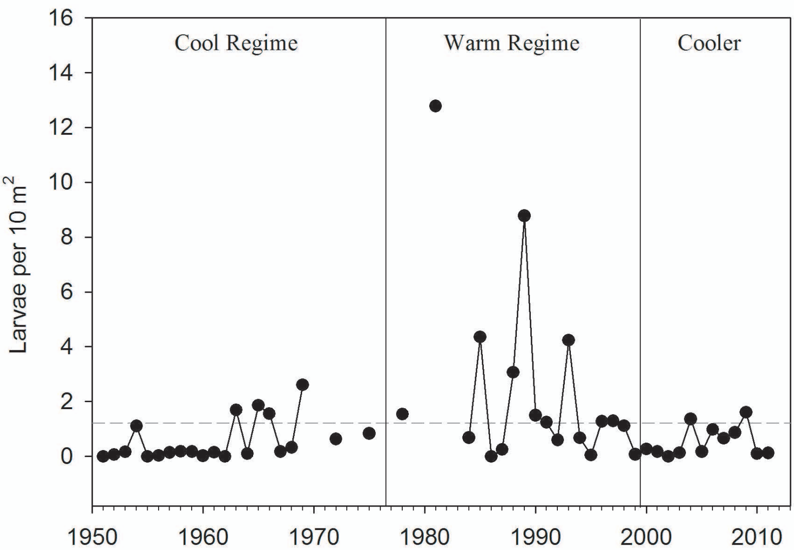

Figure 8.—Temporal trends in southern California *Paralabrax* spp. larval abundance by oceanographic regime from 1951 to 2011. Larvae include kelp bass, barred sand bass, and spotted sand bass. Dashed line represents the period mean. Oceanographic temperature regimes are indicated at the top of the figure and defined in the text. Data source: National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center; 2012 data not available.

conducted from 1974 to the present at King Harbor in Redondo Beach, and off Palos Verdes (Love et al. 1996b). We obtained adult barred sand bass and kelp bass (>25.0 cm TL) densities (fish/transect) at both sites from the Vantuna Research Group at Occidental College, Los Angeles, California. Both survey sites contain biologically relevant habitat for both species, although the giant kelp habitat off PV typically contains more kelp bass than barred sand bass.

Abundances of both species at King Harbor closely followed trends in CPFV CPUE (Figure 2, Figure 9a, Figure 9b). From 2000 to 2004 (the years leading up to the period of below-average fishery recruitment), adult barred sand bass and kelp bass abundance was decreasing at both locations, albeit more so with barred sand bass (Figure 9a, Figure 9b). Barred sand bass abundance peaked twice at King Harbor, once in 1985 and again in 2000.

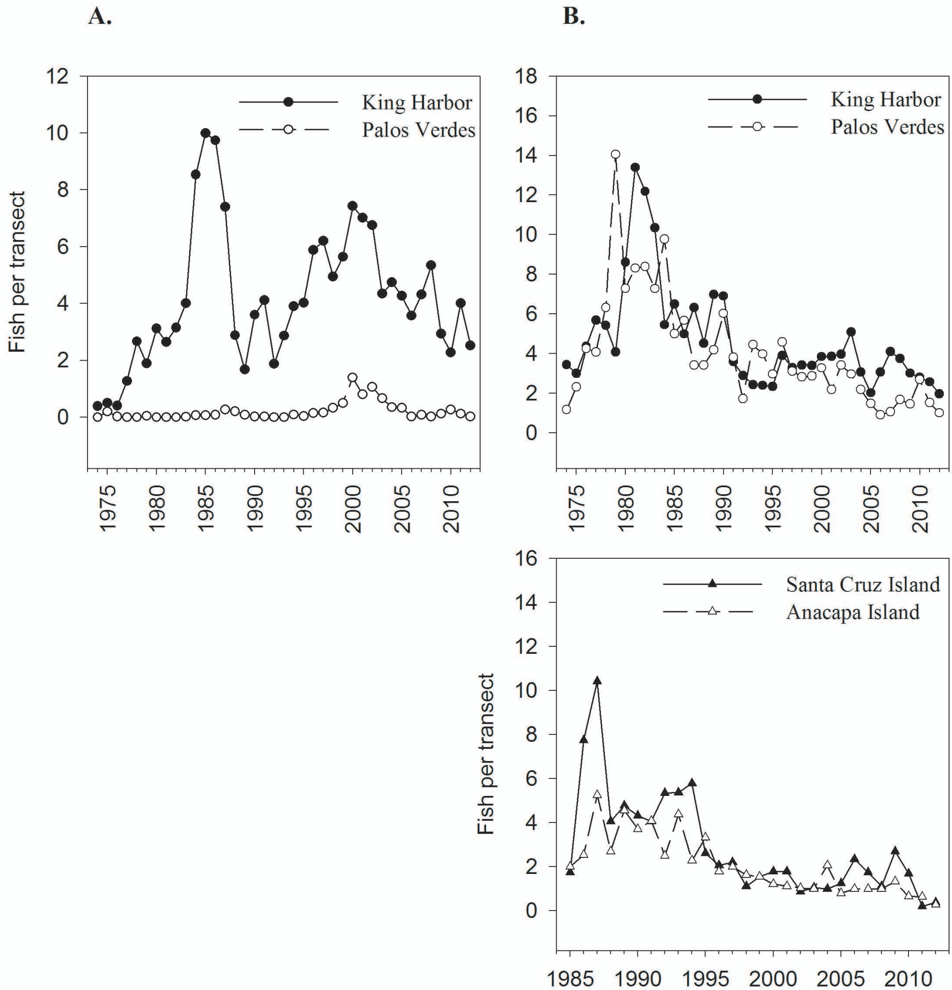

Figure 9.—Temporal trends in scuba transect densities of A) adult barred sand bass at King Harbor and Palos Verdes and B) adult kelp bass at King Harbor and Palos Verdes (top), and Santa Cruz and Anacapa islands, California (bottom). Data source: mainland transects (1972–2012), Vantuna Research Group, Occidental College; island transects (1985–2012), Kelp Forest Monitoring, National Parks Service.

Although barred sand bass abundances at the Palos Verdes site did not compare numerically to the King Harbor site, the Palos Verdes site also showed a peak in 2000 followed by a decrease through 2012 (Figure 9a). Kelp bass abundances at both locations increased into the early 1980s followed by a substantial decline by the early 1990s (Figure 9b). In all data sets, abundances of both species by 2012 were near or at the same lower level in the earliest part of the time series.

Diver surveys of adult kelp bass at the islands.—We also obtained Channel Islands Kelp Forest Monitoring kelp bass data from the National Park Service, Ventura, California for the years 1985–2010. Densities (fish/transect) of adult kelp bass (>25.0 cm TL) at Santa Cruz and Anacapa islands were highest in the 1980s before dropping off to low levels by the mid-1990s (Figure 9c). In contrast to the two mainland sites, adult kelp bass densities were somewhat stable (albeit at low levels) at the islands sites in the years (2000–2004) leading up to below average fishery recruitment.

Environmental relationships.—We conducted a time delay analysis using larval abundance, SST, and giant kelp canopy coverage data to determine whether these variables were a predictor of fishery recruitment strength. Correlation coefficients were calculated between these variables and fishery recruitment strength separately for barred sand bass and kelp bass. Bass fishery recruitment was measured as the annual proportion of the first two age classes in the harvested catch (see *Fishery recruitment*, above). Average annual SST was obtained from the SCCOOS website (SCCOOS 2013). Annual values of Region Nine Kelp Survey Consortium total giant kelp canopy coverage (km^2) were obtained for Orange County and San Diego County and summed (MBC 2012; data from the northern region of the SCB were only available from 2002 and were not included). We used the 17-yr period from 1996 to 2012 because it was a continuous time series spanning above and below average periods of bass fishery recruitment strength and the transition from warmer to cooler SSTs in the SCB. To account for autocorrelation present in the residuals of the kelp bass fishery recruitment data sets (Durbin-Watson test, k=1, α=0.05: $d_{1996\text{-}2011}$=0.76, $d_{1996–2012}$=0.83) and possible autocorrelation in the residuals of one of the barred sand bass fishery recruitment data sets ($d_{1996–2012}$=1.36), we used an adjusted degrees of freedom and critical value for r for testing correlations at zero to seven-year lags (Modified Chelton at N/5 lags; Pyper and Peterman 1998).

Trends in barred sand bass and kelp bass fishery recruitment strength showed significant, positive correlations with trends in *Paralabrax* larval abundance and coastal SSTs (Table 4). Bass fishery recruitment was most positively correlated with *Paralabrax* larval abundance and with coastal SSTs at five-year lags (Table 4). Barred sand bass fishery recruitment was negatively correlated with kelp canopy coverage at a six-year lag, and kelp bass fishery recruitment showed a very strong negative correlation with kelp canopy coverage at a five-year lag (Table 4).

Discussion

This is the first in-depth fishery analysis conducted for the saltwater basses in several decades, documenting both long-term changes in fishery-dependent and fishery-independent indices of abundance, fishery size-at-catch and catch distribution data, exploitation rates, and relationships with environmental variables (SST and kelp canopy). Our analyses indicate the environment and fishing have affected saltwater bass populations in southern California for nearly a century. Episodic successful recruitment and early implementation of catch

Table 4.—Seven-year time-delay correlations between California saltwater bass (*Paralabrax* spp.) fishery recruitment and larval abundance, coastal sea surface temperature, and giant kelp canopy coverage from 1996 to 2012. Bold values indicate significant correlations relative to the $\pm r_{crit}$ significance level at $P<0.05$.

	Correlation Coefficient		
Common Name	Larval Abundance[a]	Temperature[b]	Giant Kelp[c]
Barred sand bass[d]			
0	-0.074	0.158	-0.332
1	-0.198	-0.257	-0.001
2	0.048	0.197	-0.016
3	-0.063	-0.202	-0.058
4	0.215	0.013	-0.146
5	**0.689**	**0.570**	-0.420
6	**0.625**	0.394	**-0.628**
7	**0.616**	0.114	-0.322
Kelp bass[e]			
0	-0.387	-0.359	0.236
1	-0.279	-0.110	0.433
2	-0.069	-0.135	0.325
3	0.124	-0.133	-0.131
4	0.359	0.189	-0.485
5	**0.788**	**0.602**	**-0.803**
6	**0.650**	**0.519**	-0.391
7	0.360	0.009	0.129

[a]California Cooperative Oceanic Fisheries Investigations *Paralabrax* larval abundance data (data include barred sand bass, kelp bass, and spotted sand bass; no 2012 data available).
[b]Mean annual sea surface temperature obtained from Southern California Coastal Ocean Observing System website (www.sccoos.org).
[c]Annual values of Region Nine Kelp Survey Consortium total giant kelp (*Macrocystis pyrifera*) canopy coverage for Orange County and San Diego (MBC 2012).
[d]r_{crit} values: larval abundance, 0.497; temperature, 0.524; giant kelp, 0.613.
[e]r_{crit} values: larval abundance, 0.556; temperature, 0.512; giant kelp, 0.701.

regulations managed to sustain the fishery for several decades. However, dramatic catch declines in recent years were attributed to a very critical period during the early 2000s when relatively high exploitation rates, combined with cooler-than-average SSTs, resulted in an overall decrease in bass availability and ultimately, recruitment overfishing. Overall CPUE and population declines began earlier with kelp bass (in the mid-1980s) than with barred sand bass (in the early 2000s). Our results suggest this earlier decline resulted from increased exploitation rates of kelp bass into the 1980s, combined with declines in giant kelp during the same period.

Interestingly, barred sand bass and kelp bass catches continued to rank among the top five species caught in southern California in recent years despite decreases in bass availability and fishing effort. This suggests an overall decline in the availability of nearshore sport fishes in the region. In fact, the total estimated southern California recreational catch declined by 44% between 2004 and 2012 (RecFIN 2013). Coastal power plant entrapment data also indicated region-wide declines in southern California's nearshore fishes, including non-game fishes, since the 1970s (Miller and McGowen 2013). The relative degree of anthropogenic and oceanographic influence on this trend for exploited fishes likely depends on the fishery. However, our findings on the saltwater basses do not substantiate the claim of bass fishery collapse due to overfishing (Erisman et al. 2011). Although there is little doubt that exploitation partly contributed to decreases in saltwater bass availability, we found no evidence of growth overfishing and no evidence of serial depletion (e.g., localized depletion due to fishing), the common trademarks of under-regulated hyperstable fisheries. Temporal trends in the catch distribution of barred sand bass and kelp bass indicated availability decreased over the entire catch range, rather than in isolated fishing areas.

Overall, the catch distribution for both species in southern California has remained relatively unchanged since the mid-1980s, as reported by Love et al. (1996a). In addition, nearly four decades of size composition data indicated a somewhat stable size or age distribution leading up to the recent catch declines. We believe the long-term sustainability (>90 years) of the saltwater bass fishery is largely due to the implementation of the size and bag limits in the 1950s, the subsequent reduction in the bag limit in 1975, and the return to warmer oceanographic conditions in the 1980s and 1990s.

The 1959 implementation of the MSL to correspond with size-at-maturity was a biologically relevant management tool that showed almost immediate and measurable effects in subsequent years. Although CPUE dramatically decreased again during the cool regime of the 1960s and 1970s, CPUE during the warm regime of the 1980s and 1990s increased, but never reached the historic maximum. This occurred despite major advances in fish-finding technology and navigational systems that should have otherwise yielded higher catch rates had the bass populations been as historically abundant. Thus, the exploitation rate just prior to the 1980s and 1990s was probably high. Indeed, during that earlier time the bag limit was higher and the overall bass population was probably smaller (Love et al. 1996a, Jarvis et al. 2010); the aggregate bag limit remained at 15 fish for 22 years (1951–1972), and then increased to 20 fish for an additional three years. The rapid decline in the exploitation rate between 1975 and 1978 probably reflects the bag limit reduction from 20 to 10 fish in 1975. Even though exploitation rates increased again in the 1980s and 1990s, this bag limit reduction, along with successful episodic recruitment, is likely responsible for sustaining the fishery into the next cool oceanographic regime.

The increase in exploitation rate from 1999 to 2002 may be explained by fishing effort shifts. During this period, CPUE for the saltwater basses was increasing and fishery recruitment levels remained stable during those years. Just prior, during the 1997–1998 El Niño, saltwater bass catches had dropped as larger, more desirable migrant fishes (e.g., yellowtail jack [*Seriola lalandi*]) became more available (Dotson and Charter 2001). After the El Niño, saltwater bass catches increased again as CPFVs shifted their effort back to the basses during the summer months. Winter saltwater bass fishing also increased, probably in response to the January–February moratorium on southern California nearshore and shelf rockfishes that began in 2000.

Although there is no fishery-independent index of adult saltwater bass abundance prior to the early 1970s, long-term fluctuations in CPUE and larval abundance indicate that saltwater bass populations fluctuated over time in response to changing oceanographic conditions, being relatively more abundant during warmer ocean conditions (Moser et al. 2001, Hsieh et al. 2005, this study). More recent declines appeared to have been influenced by increases in exploitation rates and coincident low larval abundances (population recruitment failure) during the ocean regime shift to cooler temperatures between 1999 and 2003. Kelp bass larval recruitment data collected via Standard Monitoring Units for the Recruitment of Fishes (SMURFs) at the northern Channel Islands from 1999 to 2003 also indicated a sustained period of kelp bass population recruitment failure (White and Casselle 2008), and Miller and Erisman (2014) reported especially low values of their southern California power plant entrapment young-of-the-year (YOY) index for kelp bass from 1998 to 2003 and for barred sand bass from 2000 to 2004. The subsequent fishery recruitment failure we identified in this study ultimately resulted in recruitment overfishing that occurred from 2005 to 2008, when CPUE dramatically declined and the modal length of the catch successively increased for 3–4 consecutive years. Consequently, the percentage of mega-spawners in the barred sand bass catch twice exceeded the percentage of optimum size individuals in recent years. Given that barred sand bass are targeted during peak spawning season and that fishery recruitment remains below average, this is especially a cause for concern.

The timing between the apparent barred sand bass and kelp bass population recruitment failure (1999–2003) and subsequent fishery recruitment failure (2005–2008) corresponds well with the significant time delay correlations we identified between bass fishery recruitment strength and larval abundance (5–7 year lag), and between fishery recruitment strength and SST (5–6 year lag). Moreover, our results are biologically meaningful since barred sand bass and kelp bass fishery recruits during the era of the 30.5-cm MSL ranged from five to seven years of age (Love et al. 1996b).

The positive correlations we reported between SST and fishery recruitment for both species corroborate previously published reports that cooler SSTs have negatively influenced *Paralabrax* larval abundance in southern California (Moser et al. 2001, Hsieh et al. 2005) and that warmer temperatures are more conducive to successful larval survival for barred sand bass (Gadomski and Caddell 1996). Miller and Erisman (2014) identified a positive correlation between SST and their southern California power plant entrapment YOY index for barred sand bass at a lag of 7 years, but no SST correlation was found for kelp bass. Although we reported strong positive correlations between SST and fishery recruitment of both species, barred sand bass may be especially sensitive to cooler oceanographic conditions than kelp bass; barred sand bass range from central California to southern Baja California, whereas kelp bass range farther north to Washington (Miller and Lea 1972). Likewise, although fishery recruitment for both species was negatively correlated with kelp canopy, kelp bass populations could be especially sensitive to changes in kelp habitat.

From 1950 to 1960, the giant kelp beds in southern California seriously declined (Quast 1968) and again after the oceanographic regime shift to warm water conditions in the late 1970s (Parnell et al. 2010). Holbrook et al. (1990) suggested that a prolonged period of regional giant kelp declines could result in a "recruitment bottleneck" that would eventually lead to a reduction in adult kelp bass density. Thus, despite more favorable oceanographic conditions for bass larval survival during the warm regime of the 1980s and 1990s, regional declines in giant kelp habitat most likely decreased larval settlement rates, which would have contributed to the observed declines in adult kelp bass catches a few years later. The declines we observed in fishery-independent indices of adult kelp bass abundance showed similar timing. As to direct impacts to adult kelp bass, we found that kelp bass fishery recruitment strength was negatively correlated with giant kelp canopy coverage at a five-year lag. This result is likely an artifact of temperature effects on larval survival, whereby favorable conditions (cooler years) for giant kelp are suboptimal for kelp bass larval survival. Nevertheless, our results also support previous studies. Holbrook et al. (1990) reported that densities of adult kelp bass were not strongly related to the density of giant kelp among reefs and that older kelp bass, unlike YOY, were common on reefs without giant kelp. And, White and Casselle (2008) showed a negative relationship between older kelp bass (age 1–2 yr+) and giant kelp densities, with larval supply being the only significant predictor of older kelp bass densities.

The increased kelp bass exploitation rate spanning 1993–2003 appeared to primarily affect mainland kelp bass populations as abundances of adult kelp bass at Anacapa and Santa Cruz islands remained somewhat stable while mainland abundances decreased again after 2003. We were not able to distinguish between exploitation rates at the islands when compared to the mainland, but recreational fishing pressure at the islands tends to be lower due to their greater distances from harbors. The only island to show a prominent decline in kelp bass CPUE after 2004 was Santa Catalina Island, and this was primarily in fishing blocks closest to the mainland.

Management changes implemented in 2013 could help offset recent saltwater bass catch declines by decreasing exploitation rates; however, it might take several years before regulation effectiveness can be addressed. The L_{opt}±10% size range we reported for barred sand bass (31.2–38.2 cm TL) and kelp bass (31.6–38.6 cm TL) is inclusive of the 35.6-cm (14-in) MSL implemented in 2013, but the fishery could also benefit from several years of strong larval or fishery recruitment, or both. Unfortunately, recent oceanographic data collected from the SCB indicate mixed-layer temperature anomalies remain below-average (Wells et al. 2013). Thus, continued active monitoring of fishery discard lengths, fishery recruitment indices, and the proportion of optimum and mega-spawner size individuals in the harvested catch will be important for determining whether further management action is necessary, especially for barred sand bass. In addition, continuing to obtain more robust reproductive (Jarvis et al. 2014) and age and growth estimates for the basses should enhance our ability to monitor stock resilience and sustainability of this historic, long-standing fishery in southern California.

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Literature Cited

Allen, L. G., and T. E. Hovey. 2001. Barred sand bass. Pages 224-225 *in* W. S. Leet, C. M. Dewees, R. Klingbeil, and E. J. Larson, editors. California's living marine resources: a status report. California Department of Fish and Game, Sacramento, USA.

Allen, L. G., T. E. Hovey, M. S. Love, and J. T. W. Smith. 1995. The life history of the spotted sand bass (*Paralabrax maculatofasciatus*) within the Southern California Bight. California Cooperative Oceanic Fisheries Investigation Reports 36:193-203.

Ally, J. R. R., D. S. Ono, R. B. Read, and M. Wallace. 1991. Status of major southern California marine sport fish species with management recommendations, based on analyses of catch and size composition data collected on board commercial passenger fishing vessels from 1985 through 1987. California Department of Fish and Game Marine Resources Division Administrative Report No. 90-2. Available from: http://aquaticcommons.org/id/eprint/113

Beverton, R. J. H. 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. Journal of Fish Biology 41:137-160.

Bjorkstedt, E. P., R. Goericke, S. McClatchie, E. Weber, W. Watson, N. Lo, B. Peterson, B. Emmett, R. Brodeur, J. D. Peterson, M. Litz, J. Gomez-Valdez, G. Gaxiola-Castro, B. Lavaniegos, F. Chavez, C. A. Collins, J. Field, K. Sakuma, S. J. Bograd, F. B. Schwing, P. Warzybok, R. Bradley, J. Jahncke, G. S. Campbell, J. A. Hildebrand, W. J. Sydeman, S. A. Thompson, J. L. Largier, C. Halle, S. Y. Kim, and J. Abell. 2011. State of the California Current 2010–2011: regionally variable responses to a strong (but fleeting?) La Niña. California Cooperative Oceanic Fisheries Investigation Reports 52:39-69.

CDFG (California Department of Fish and Game). 1991. Final supplemental environmental document, ocean sport fishing regulations (sections 27.00–30.10, Title 14, California Code of Regulations): kelp/sand bass. California Department of Fish and Game, Sacramento, USA.

CDFG. 2010. Review of selected California fisheries for 2009: coastal pelagic finfish, market squid, red abalone, Dungeness crab, pacific herring, groundfish/nearshore live-fish, highly migratory species, kelp, California halibut, and sandbasses. California Cooperative Oceanic Fisheries Investigation Reports 51:14-38.

Clark, F. N. 1933. Rock bass (*Paralabrax*) in the California commercial fishery. California Fish and Game 19:25-35.

Collyer, R. D. 1949. Rockbass. Fish Bulletin 74:113-115.

de Mutsert, K., J. H. Cowan, T. E. Essington, and R. Hilborn. 2008. Reanalyses of Gulf of Mexico fisheries data: landings can be misleading in assessments of fisheries and fisheries ecosystems. Proceedings of the National Academy of Sciences of the United States of America 105:2740-2744.

Dotson, R. C., and R. L. Charter. 2003. Trends in the southern California sport fishery. California Cooperative Oceanic Fisheries Investigation Reports 44:94-106.

Dunn, A., R. I. C. C. Francis, and I. J. Doonan. 2002. Comparison of the Chapman-Robson and regression estimators of Z from catch-curve data when non-sampling stochastic error is present. Fisheries Research 59:149-159.

Erisman, B. E., L. G. Allen, J. T. Claisse, D. J. Pondella, II, E. F. Miller, and J. H. Murray. 2011. The illusion of plenty: hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. Canadian Journal of Fisheries and Aquatic Sciences 68:1705-1716.

FGC (Fish and Game Commission). 2012. Initial statement of reasons for regulatory action [Internet]. Amend Sections 27.65 and 28.30 Title 14, California Code of Regulations Re: Basses. Available from: http://www.fgc.ca.gov/ regulations/2012/27_65isor.pdf

Froese, R. 2004. Keep it simple: three indicators to deal with overfishing. Fish and Fisheries 5(1):86-91.

Gadomski, D. M., and S. M. Caddell. 1996. Effects of temperature on the development and survival of eggs of four coastal California fishes. Fishery Bulletin 94:41-48.

Gelpi, C. G., and K. E. Norris. 2008. Seasonal temperature dynamics of the upper ocean in the Southern California Bight. Journal of Geophysical Research—Oceans 113(C4):1-18.

Graves, M. R., R. J. Larson, and W. S. Alevizon. 2006. Temporal variation in fish communities off Santa Cruz Island, California. Research Final Report, California Sea Grant College Program. University of California, San Diego, USA.

Harely, S. J., R. A. Myers, and A. Dunn. 2001. Is catch-per-unit-effort proportional to abundance? Canadian Journal of Fisheries and Aquatic Sciences 58:1760-1772.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York, USA.

Hill, K. T., and N. Schneider. 1999. Historical logbook databases from California's commercial passenger fishing vessel (partyboat) fishery, 1936–1997. Scripps Institution of Oceanography Reference Series 99-19.

Holbrook, S. J., M. H. Carr, R. J. Schmitt, and J. A. Coyer. 1990. Effect of giant kelp on local abundance of reef fishes: the importance of ontogenetic resource requirements. Bulletin of Marine Science 47:104-114.

Hovey, T. E., and L. G. Allen. 2000. Reproductive strategies of six populations of the spotted sand bass, *Paralabrax maculatofasciatus*, from southern and Baja California. Copeia 2000:459-468.

Hsieh, C. H., C. Reiss, W. Watson, M. J. Allen, J. R. Hunter, R. N. Lea, R. H. Rosenblatt, P. E. Smith, and G. Sugihara. 2005. A comparison of long-term trends and variability in populations of larvae of exploited and unexploited fishes in the southern California region: a community approach. Progress in Oceanography 67:160-185.

Hutchings, J. A., and R. A. Myers. 1995. The biological collapse of Atlantic cod off Newfoundland and Labrador: an exploration of historical changes in exploitation, harvesting technology, and management. Pages 37-93 *in* R. Arnason and L. Felt, editors. The North Atlantic fisheries: successes, failures, and challenges. Island Studies Press, Charlottetown, Prince Edward Island, Canada.

IUCN (International Union Conservation of Nature). 2012. IUCN red list of threatened species [Internet]. Version 2012.1 [cited 2012 Feb]. Available from: http://www.iucnredlist.org

Jarvis, E. T., C. Linardich, and C. F. Valle. 2010. Spawning-related movements of barred sand bass, *Paralabrax nebulifer*, in southern California: interpretations from two decades of historical tag and recapture data. Bulletin of the Southern California Academy of Sciences 109:123-143.

Jarvis, E. T., K. A. Loke, K. Evans, R. E. Kloppe, K. A.Young, and C. F. Valle. 2014. Reproductive potential and spawning periodicity in barred sand bass (*Paralabrax nebulifer*) from the San Pedro Shelf, southern California. California Fish and Game 100: 289-309.

Love, M. S., A. Brooks, and J. R. R. Ally. 1996a. An analysis of commercial passenger fishing vessel fisheries for kelp bass and barred sand bass in the Southern California Bight. California Fish and Game 82:105-121.

Love, M. S., A. Brooks, D. Busatto, J. Stephens, and P. A. Gregory. 1996b. Aspects of the life histories of the kelp bass, *Paralabrax clathratus*, and barred sand bass, *P. nebulifer*, from the Southern California Bight. Fishery Bulletin 94:472-481.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78:1069-1079.

Mason, T. J., and C. G. Lowe. 2010. Home range, habitat use, and site fidelity of barred sand bass within a southern California marine protected area. Fisheries Research 106:93-101.

MBC (MBC Applied Environmental Sciences). 2012. Status of the Kelp Beds 2011. San Diego and Orange Counties. Region Nine Kelp Survey Consortium June 2012. Available from: http://kelp.sccwrp.org/reports.html

McKinzie, M. K., E. T. Jarvis, and C. G. Lowe. 2014. Fine-scale horizontal and vertical movement of barred sand bass, *Paralabrax nebulifer*, during spawning and non-spawning seasons. Fisheries Research 150:66-75.

Miller, D. J., and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Fish Bulletin 157:249.

Miller, E. F., and B. E. Erisman. 2014. Long-term trends of southern California's kelp and barred sand bass populations: a fishery-independent assessment. California Cooperative Oceanic Fisheries Investigation Reports 55:1-9.

Miller, E. F., and J. A. McGowan. 2013. Faunal shift in southern California's coastal fishes: a new assemblage and trophic structure takes hold. Estuarine, Coastal and Shelf Science 127:29-36.

Moser, H. G., R. L. Charter, P. E. Smith, D. A. Ambrose, W. Watson, S. R. Charter, and E. M. Sandknop. 2001. Distribution atlas of fish larvae and eggs in the Southern California Bight region 1951–1998. California Cooperative Oceanic Fisheries Investigation Atlas 34.

Murphy, M. D., and J. Munyandorero. 2009. An assessment of the status of red drum in Florida waters through 2007. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute. Available from: http://research.myfwc.com/images/ articles/32280/red_drum.pdf

NOAA (National Oceanic and Atmospheric Administration). 2012. Pacific decadal oscillation (PDO). [Accessed June 2012]. Available from http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ca-pdo.cfm

Parnell, P. E., E. F. Miller, C. E. Lennert-Cody, P. K. Dayton, M. L. Carter, and T. D. Stebbins. 2010. The response of giant kelp (*Macrocystis pyrifera*) in southern California to low-frequency climate forcing. Limnology and Oceanography 55:2686-2702.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES Journal of Marine Science 39:175-192.

Pinkas, L., J. C. Thomas, and J. A. Hanson. 1967. Marine sportfishing survey of southern California piers and jetties, 1963. California Fish and Game 53:88-104.

Pyper, B. J., and R. M. Peterman. 1998. Comparison of methods to account for autocorrelation in correlation analyses of fish data. Canadian Journal of Fisheries and Aquatic Sciences 55:2127-2140.

Quast, J. C. 1968. Observations on the food and biology of the kelp bass, *Paralabrax clathratus*, with notes on its sport fishery at San Diego, California. Fish Bulletin 139:81-108.

Radovich, J. 1982. The collapse of the California sardine fishery: what have we learned? California Cooperative Oceanic Fisheries Investigation Reports 23:56-78.

RecFIN (Recreational Fisheries Information Network). 2013. Estimated total catch with releases (a+b1+b2) in thousands of fish caught by marine recreational anglers fishing for all possible species by year and state for all modes of fishing in all marine areas in southern California from January-December in 2004-2012. [Accessed September 2013]. Available from: http://www.recfin.org/

Rose, G. A., and D. W. Kulka. 1999. Hyperaggregation of fish and fisheries: how catch-per-unit-effort increased as the northern cod (*Gadus morhua*) declined. Canadian Journal of Fisheries and Aquatic Sciences 56(suppl. 1):118-127.

Sadovy, Y., and M. Domeier. 2005. Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. Coral Reefs 24:254-262.

SCCOOS (Southern California Coastal Ocean Observing System). 2013. Sea surface temperatures within the Southern California Bight. Available from: http://www.sccoos.org/

Shelton, P. A. 2005. Did over-reliance on commercial catch rate data precipitate the collapse of northern cod? ICES Journal of Marine Science 62:1139-1149.

Smith, M. W., A. Y. Then, C. Wor, G. Ralph, K. H. Pollock, and J. M. Hoenig. 2012. Recommendations for catch-curve analysis. North American Journal of Fisheries Management 32:956-967.

Tegner, M. J., P. K. Dayton, P. B. Edwards, and K. L. Riser. 1997. Large-scale, low-frequency oceanographic effects on kelp forest succession: a tale of two cohorts. Marine Ecology Progress Series 146:117-134.

Wells, B., I. D. Schroeder, J. A. Santora, E. L. Hazen, S. J. Bograd, E. Bjorkstedt, V. J. Loeb, S. McClatchie, E. D. Weber, W. Watson, A. R. Thompson, W. Peterson, R. D. Brodeur, J. Harding, J. Field, K. Sakuma, S. Hayes, N. Mantua, W. J. Sydeman, M. Losekoot, S. A. Thompson, J. Largier, S. Y. Kim, F. P. Chavez, C. Barcelo, P. Warzybok, R. Bradley, J. Jahncke, R. Goericke, G. S. Campbell, J. A. Hildebrand, S. R. Melin, R. L. DeLong, J. Gomez-Valdes, B. Lavaniegos, G. Gaxiola-Castro, R. T. Golightly, S. R. Schneider, N. Lo, R. M. Suryan, A. J. Gladics, C. A. Horton, J. Fisher, C. Morgan, J. Peterson, E. A. Daly, T. D. Auth, and J. Abell. 2013. State of the California Current 2012–2013: no such thing as an "average" year. California Cooperative Oceanic Fisheries Investigation Reports 54:37-71.

White, J. W., and J. E. Caselle. 2008. Scale-dependent changes in the importance of larval supply and habitat to abundance of a reef fish. Ecology 89:1323-1333.

Worm, B., E. B. Barbier, N. Beaumont, J. E. Duffy, C. Folke, B. S. Halpern, J. B. C. Jackson, H. K. Lotze, F. Micheli, S. R. Palumbi, E. Sala, K. A. Selkoe, J. J. Stachowicz, and R. Watson. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314:787-790.

Young, P. H. 1963. The kelp bass (*Paralabrax clathratus*) and its fishery, 1947–1958. Fish Bulletin 122:67.

Young, P. H. 1969. The California partyboat fishery 1947–1967. Fish Bulletin 145:91.

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