Fisheries independent assessment of a returning fishery: Abundance of juvenile white seabass (Atractoscion nobilis) in the shallow nearshore waters of the Southern California Bight, 1995–2005

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Abstract

Nearshore, coastal and embayment areas off southern California were sampled to determine the spatial and temporal patterns abundance and size distributions of young white seabass in the shallow (5–14 m) waters from Santa Barbara south to Imperial Beach off San Diego. A total of 19 stations, 13 in nearshore coastal waters and 6 in embayments, dispersed along the Southern California Bight were surveyed in each sampling month using 45.7 m variable mesh, monofilament gill nets. In the 11-year period of sampling (April 1995–June 2005), a total of 8075 juvenile white seabass was captured in 42 sampling months. The mean catch-per-unit-effort (CPUE: 2.0 fish/net ± 0.2) for juvenile white seabass varied significantly among stations during the 10-year period (1996–2005) of the full station sampling. Stations located near large rocky headlands, such as Palos Verdes, Santa Barbara, Newport, and La Jolla yielded the highest catches. Although CPUE peaked in August 1999 as a result of strong year classes in 1996–1998, overall, catches tripled over the 11-year sampling period at seven coastal sites increasing significantly at a rate equivalent to 0.22 fish/(net year). These relatively high catches of wild, juvenile fish over the last decade, along with significant increases in commercial CPUE and increased recreational catches overall, indicate that the natural population of white seabass is in the process of recovery. Commercial catches are again comparable to levels attained prior to the fishery collapse in the 1970s and 1980s. Therefore, we propose that the white seabass now represents one of the first documented cases of a recovering, demersal species of commercial importance. The ban of nearshore commercial gill net fishing by Proposition 132 probably contributed greatly to the increase in the population size that led to this recovery. In addition, the succession of warm water years that occurred from 1983 to the strong El Niño event of 1997–1998 also played an important role in the successful recruitment of white seabass.

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1. Introduction

Marine fisheries are in stark decline throughout the world. These declines have most often been attributed to overexploitation (Musick et al., 2000; Hutchings and Reynolds, 2004). Marine fisheries of the Pacific coast of the United States are not immune to this phenomenon, suffering similar precipitous declines over the past six decades (Ripley, 1946; Dayton et al., 1998; Levin et al., 2006). Off California, many shark species including soupfin (Galeorhinus galeus), basking shark (Cetorhinus maximus), and spiny dogfish (Squalus acanthias) were severely depleted during the World War II era and have yet to recover significantly (Ripley, 1946; Holts, 1988; Levin et al., 2006). The largest species of nearshore fish in California waters, the giant seabass (Stereolepis gigas) was driven to the brink of extinction in 1982 (Domeier, 2001). Unfortunately the prognosis for these fishes and the ecosystem they support is grim (Dayton et al., 2002).

Collapsed fisheries of small, pelagic species are more likely to recover due to the short life span, fast growth, high fecundity, and early maturity. The best examples of decline and subsequent recovery are found among the herrings and sardines (Clupeidae) and their relatives (Hutchings, 2000; Hutchings and Reynolds,
In California, the collapse and recovery of Pacific sardine \textit{(Sardinops sagax)} \cite{Baumgartner2012, Wolf2012, Wolf2001} and Pacific chub mackerel \textit{(Scomber japonicus)} \cite{MacCall1979, Wolf2001} give us hope. Unfortunately, large predatory fishes such as sharks, groupers, cods, croakers (e.g., totoaba), and flounders, to name a few, are particularly susceptible to overexploitation \cite{Flanagan1976, Barrera-Guevara1990, Cisneros-Mata2000, Baum2003} and the ability of these stocks to rebound has been questioned \cite{Hutchings2000}.

In the past century, one of the most important commercial and recreational fisheries in California was white seabass \textit{(Sciaenidae: Atractoscion nobilis)}. This species of large, schooling croaker feeds mainly on fish and squid from an early age and attains sizes up to 1.7 m and 38 kg \cite{Vojkovich2001}. The California commercial catch (Fig. 1) fluctuated from 100 to 400 mt throughout the 20th century, but between the years 1980–1981 collapsed to 10% of its historic catch. The commercial fishery for white seabass was based in southern California and historically consisted mainly of landings from the Southern California Bight (SCB) and Mexico \cite{Vojkovich2001}. In 1982, the Mexican government excluded the U.S. fleet concentrating the fishery in California waters and without any further management action, the commercial catch of white seabass remained at a low level (47.8 ± 3.0 mt) through the 1990s. The recreational catch by commercial passenger fishing vessels (CPFVs), which peaked in 1949 at about 64,000 fish, suffered a similar decline. Only 284 fish were recorded in 1978 as angler success dropped from 0.13 fish-per-angler in 1949 to 0.001 fish-per-angler in 1978. The recreational catch from party boats averaged 1400 fish per year from 1980 to 1991, which is only 2% of the 1949 peak in recreational landings \cite{Vojkovich2001}. By 1982 one of the state’s historic and economically successful fisheries was gone.

Over fishing is a simple explanation of this phenomenon, yet the demise of the white seabass fishery was likely also due to the techniques used by California fishers. The commercial fishery for white seabass relied heavily on gill nets usually set in shallow water off rocky headlands. Historically, the greatest catches usually occurred during the months of June, July and August, which is also the main breeding season, and fishers targeted breeding aggregations \cite{Thomas1968}. In 1990, gill nets and trammel nets were banned in state waters (within 3 miles of the mainland and 1 mile of the islands) in the SCB and the ban went into effect in 1994 \cite{CaliforniaStateProposition1994}. This proposition, known as The Marine Resources Protection Act, also implemented fishing depth restrictions off several mainland counties and around the Channel Islands. Because the continental shelf in the SCB is relatively abrupt \cite{Hickey1993}, this ban moved the commercial fishery out of the nearshore ecosystem through most of the region. The nearshore fishery for white seabass subsequently was restricted to a few specific areas along the mainland where set nets could be deployed and an offshore drift net fishery which concentrated efforts on the offshore banks and near the Channel Islands. Neither of these types of fishing methods were able to access the historic spawning aggregations associated with rocky headlands, especially where kelp forests existed, that were traditionally targeted \cite{Thomas1968}.

Offshore commercial catches of adult white seabass in California waters began to increase in 1996 from about 28 mt to a peak over 220 mt in 2002 (Fig. 2). Total catch then decreased to about 138 mt in 2003 and 131 mt in 2004. The commercial fishery is composed of relatively large fish between about 850 and 1350 mm TL and a modal size of about 1100 mm TL from 1999 to 2005. Recreational catches from commercial passenger fishing vessels (CPFVs) have followed a pattern similar to that of commercial catches over the last decade except that total recreational decreased more drastically in 2003 and 2004 after a peak of 360 mt in 2001. In 2002, the commercial fishery landed 219.4 mt, which was within the range of the pre-collapse mean California landings \textit{(231.7 ± 33.0 mt)} \cite{MRFSS, CRFS}. Interestingly, commercial and CPFV catches were estimated to be about equal in 2002 at around 220 mt (Fig. 2). The recreational fishery is composed of smaller adult fish between about 750 and 1150 mm TL in most years from 1999 to 2005.

**Fig. 1.** Commercial catches of white seabass in California waters from 1936 to 2004 (data from: Vojkovich and Crooke, 2001; CDFG, 2006). Arrow denotes the implementation of the nearshore gill net ban by California State Proposition 132.

**Fig. 2.** Comparison of commercial landings and estimated recreational (CPFVs) catch (mt = metric tonnes) of adult white seabass off California from 1995 to 2004.
with modal sizes usually between 750 and 1000 mm TL (CDFG, 2006).

The numbers of commercial vessels contributing to the catches of white seabass over the last decade is well documented by landing receipts and are available from the California Department of Fish and Game (CDFG, 2006). In 1995, 104 relatively small (<30 m) commercial fishing vessels contributed to the catch of adult white seabass. By 2001, effort had grown to 216 vessels, declined steadily to only 80 vessels in 2004, and finally increased again to 97 vessels in 2005. Neither the size of these vessels nor the fishing techniques have changed significantly in the last 11 years. Therefore, it is possible for CPUE to be calculated accurately for 1995–2005 (Fig. 3). Commercial CPUE has increased significantly \( r^2 = 0.83; p < 0.0001 \) over the 11-year period for which data is available increasing from less than 0.5 mt/vessel to over 1.8 mt/vessel in 2005. CPUE does not reflect the decline that overall catch did in from 2003 to 2004, which was 11-year period for which data is available increasing from less than 0.5 mt/vessel to over 1.8 mt/vessel in 2005. CPUE does not reflect the decline that overall catch did in from 2003 to 2004, which was 11-year period for which data is available increasing from less than 0.5 mt/vessel to over 1.8 mt/vessel in 2005. CPUE does not reflect the decline that overall catch did in from 2003 to 2004, which was significantly (\( r^2 = 0.83; p < 0.0001 \)) over the 11-year period for which data is available increasing from less than 0.5 mt/vessel to over 1.8 mt/vessel in 2005. CPUE does not reflect the decline that overall catch did in 2004–2005 fiscal year, (1) one station at Catalina Island (Catalina East) and 1 month of sampling (April) were excluded from the sampling design. Therefore, spatial patterns of abundance were necessarily restricted to the 18 stations that were consistently sampled over the 10-year period of expanded program (August 1996–June 2005). On the other hand, temporal patterns of abundance were best described using catch data from the original seven coastal stations that were established as a baseline and were sampled consistently with equivalent effort (six nets/station) from April 1995 to June 2005.

Variable mesh, scientific gill nets were employed at all stations for sampling Age I, II, III, and IV white seabass. Gill nets were comprised of six, 7.6 m (25 ft) panels with two panels for each of the three square mesh sizes: 25.4, 38.2, and 50.8 mm (1.0, 1.5, and 2.0 in., respectively). A stratified sampling design (Station \( \times \) Time) was used at all sites using six gill nets set proximate to or on reefs that support giant kelp (Macrocystis pyrifera) within a limited depth range. Coastal sites included both sand/rock interface and reef/kelp habitats with one exception. At the Seal Beach site the bottom is sand adjacent to a rock jetty. Nets were set perpendicular to shore or to the kelp forest edge in water depths between 5 and 15 m (MLLW) where prior sampling established that juvenile white seabass were most abundant. In embayments, gill nets were restricted to depths of 3–12 m (MLLW). At all sites, gill nets were deployed in the late afternoon hours and retrieved the following morning. Individual white seabass captured in the nets were measured for standard length (to the nearest mm), weighed (to the nearest g). Surface and bottom temperatures were recorded. We also analyzed temperature data collected from the Newport Pier (http://shorestation.ucsd.edu/).

2. Methods

Nearshore coastal and embayment areas off southern California were sampled to determine the spatial and temporal patterns of distribution and abundance of young white seabass in the shallow (5–14 m) waters from Santa Barbara south to Imperial Beach off San Diego. Fishes were captured in a standardized gill net sampling program that encompassed the 11-year period from April 1995 to June 2005. During the first year of sampling, a baseline was established (April 1995–June 1996) including seven coastal stations (Ventura, Malibu, Palos Verdes, Seal Beach, Newport, Oceanside, and Point Loma) that were occupied every other month of the year. As of August 1996, the program was expanded to 19 stations, but reduced to four times per year in April, June, August, and October (Pondella and Allen, 2000; Fig. 4). Sampling at Marina del Rey began in October 1996. Due to budget constraints, at the beginning of the 2004–2005 fiscal year, (1) one station at Catalina Island (Catalina East) and 1 month of sampling (April) were excluded from the sampling design. Therefore, analysis of spatial patterns of abundance were necessarily restricted to the 18 stations that were consistently sampled over the 10-year period of expanded program (August 1996–June 2005). On the other hand, temporal patterns of abundance were best described using catch data from the original seven coastal stations that were established as a baseline and were sampled consistently with equivalent effort (six nets/station) from April 1995 to June 2005.

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Data summarization and graphics were accomplished using Microsoft Excel and STATISTICA 6.0 (Statsoft, Inc.). Data analyses including length frequency analysis, one-way ANOVAs, Kolmogorov–Smirnov test for normality, t-test assuming unequal variance, and correlation/regression were carried out using STATISTICA. Catch-per-unit-effort (CPUE) data was log-transformed ($\log_{10}(x+1)$) in order to satisfy the assumptions of parametric analysis. Log-transformation yielded homoscedastic CPUEs in all cases. The assumption of normality was met for log-CPUE over sampling months combined for stations ($K$–$S$, $d = 0.2$; $p > 0.2$), however, log-CPUE by station over months was non-normal due to zero catches ($K$–$S$, $d = 0.11$; $p < 0.01$). We proceeded with parametric analysis because Underwood (1997) established a strong case for analysis of variance being robust and therefore relatively insensitive to violations of the assumption of normality.

3. Results

3.1. Distribution and abundance

In the 11-year period of sampling from April 1995 to June 2005, we captured 8075 juvenile white seabass in 4214 net sets (Table 1). Of these fish, 6575 (81%) were taken in the 13 coastal stations, while 1500 (19%) were collected in six embayment sites. Among coastal sites, Palos Verdes yielded the most juvenile seabass between August 1996 and June 2005 (1110), followed by Santa Barbara (922), Newport (806), La Jolla (538), and Malibu (514) (Table 1). The two coastal sites at Santa Catalina Island yielded 203 white seabass over the same sampling period. Most of the white seabass caught in embayments were taken in Newport Bay (429), Marina del Rey (406), Mission Bay (292), and Agua Hedionda (240). The August 1999 sampling effort yielded the highest catches at the coastal stations (520) over the 11 years, followed by the samples of June 1999 (425), April 2000 (313), and June 200 (308).

Patterns in the abundance of juvenile white seabass varied greatly over space and time within the SCB from 1996 to 2005 (Fig. 5). Although catches varied among stations over time, the coastal stations of the northern portion of the sampling area yielded the highest individual catches during the 1999 sampling year. These spatial and temporal patterns will be examined further in the following sections.


The mean CPUE (2.0 fish/net ± 0.2) for juvenile white seabass over the 10-year period of bight-wide coverage (August 1996–June 2005) was significantly different across stations (one-way ANOVA; $F_{[17,612]} = 9.22$; $p \ll 0.001$) (Fig. 6). Based on post hoc testing (Tukey HSD), the high mean CPUE rates recorded at Palos Verdes (5.3 ± 2.0), Santa Barbara (4.4 ± 1.4), and Newport (3.8 ± 1.1) were indistinguishable statistically, but were, as a group, significantly higher than those at all other sites. In addition, catches were significantly lower in San Diego Bay and all sites off Santa Catalina Island when compared to mainland sites (Fig. 6).


Catches at the seven coastal stations that have been consistently sampled since 1995 provided the valid and consistent data set for the unbiased examination of trends over time. Mean CPUE of wild, juvenile white seabass at these seven coastal stations began low and fluctuated around 1 fish/net over the baseline sampling in the first year of our investigation (Fig. 7).
Table 1

Numbers and CPUE (#fish/net) of wild white seabass captured during the 11-year period of OREHP juvenile White Seabass Gillnet Survey, April 1995 to June 2005 (N = number of net sets)

<table>
<thead>
<tr>
<th>Month</th>
<th>Coastal sites</th>
<th>Embayment sites</th>
<th>Total</th>
<th>CPUE (#fish/net)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Santa Barbara</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>April 1995</td>
<td>1</td>
<td></td>
<td>1</td>
<td>42</td>
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<tr>
<td>June 1995</td>
<td>0</td>
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<td>0</td>
<td>43</td>
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<tr>
<td>August 1995</td>
<td>7</td>
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<td>11</td>
<td>42</td>
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<td>October 1995</td>
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<td>December 1995</td>
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Total: 922 CPUE: 4.4
Fig. 5. Catch-per-unit-effort (CPUE; #fish/net) of wild juvenile white seabass captured at coastal and embayment stations both at mainland and island sites over the 10-year period, August 1996–June 2005.

Catches then began a modest climb to about 2 fish/net in October 1997 followed by a decrease to less than one-half of a fish/net in April 1998. Catch then increased precipitously to a peak of almost 8 fish/net in August 1999 followed by a general decrease until April 2001. Catch then varied between about 2 and 4 fish/net through to the end of sampling. Mean CPUE over time was neither correlated with mean station temperature ($r^2 = 0.022$; d.f. = 42; $p = 0.34$) nor standardized mean temper-

Fig. 6. Mean catch-per-unit-effort (CPUE ± 2 S.E.; #fish/net) of wild juvenile white seabass captured at coastal and embayment stations both at mainland and island sites over the 10-year period, August 1996–June 2005.

Fig. 7. Time-series of catch-per-unit-effort (CPUE; #fish/net) for juvenile white seabass captured at the original seven coastal stations over the 11-year period from April 1995 to June 2005.
Fig. 8. Log10-transformed catch-per-unit-effort (CPUE; #fish/net) for juvenile white seabass captured at the original seven coastal stations from April 1995 to June 2005. Trend line depicts significant increase over time.

ature data recorded at the Newport Pier ($r^2 = 0.006$; d.f. = 42; $p = 0.56$).

Overall, log-CPUE of juvenile white seabass increased significantly over time from April 1995 to June 2005 ($r^2 = 0.28$; d.f. = 42; $p < 0.001$) at a rate equivalent to 0.22 fish/(net year) (Fig. 8). Overall, this represents between a doubling and tripling of CPUE at the seven coastal stations (Ventura, Malibu, Palos Verdes, Seal Beach, Newport, Carlsbad, and Point Loma) over the course of the entire study. Again, the presence of three strong year classes from 1996 to 1998 that appeared in the catches during the fourth, fifth, and sixth year of the study (see following section) resulted in catches up to as high as eight times those at the beginning in 1995.

3.4. Length frequency

Most of the juvenile white seabass captured were between 200 and 600 mm SL (Fig. 9). Ageing of a sub-sample of 800 specimens captured from 1996 through 2004 revealed that at least eight size/age classes (Age Classes 0–VII) were represented in the catch (Williams et al., 2007). The mean length (mm SL ± 1 STD) of these age classes were: Age 0 = 222 ± 22; Age I = 279 ± 38; Age II = 360 ± 42; Age III = 435 ± 34; Age IV = 513 ± 35; Age V = 580 ± 24; Age VI = 660 ± 33; and Age VII = 713 ± 69. Based on this sub-sample, about 43% of the white seabass caught in our gill nets were Age II fish (mean = 360 mm SL; Fig. 9). Age I and III fish accounted for about 23% of the fish each. Therefore, Age I, II, and III constituted about 88% of all fish caught. The size ranges and size class proportions were not significantly different in the coastal and embayment sites (chi-square = 0.217, d.f. = 39, $p > 0.05$), with the smallest size class present in both types of habitat.

Length frequency analysis over time revealed an expected orderly progression of early year classes through successive sampling periods (Fig. 10). The smallest fish (Age O and I) fish typically entered the catch in either August or October of each year. Early in the study (June 1995–June 1996) size classes were generally ill-defined and scattered reflecting the generally low abundance of fish during that time period. Beginning in August 1996 stronger, well-defined size structure appeared in the catches and persisted more-or-less to the end of the study.
By October 1998 signs of a series of strong year classes (1996, 1997, and 1998) became evident and persisted in the catches through 2001 (Fig. 10).

4. Discussion

Sampling along the mainland open coast and embayments throughout the SCB yielded relatively high catches of juvenile white seabass over the course of this study. Mainland coastal sites adjacent to sizeable rocky headlands (e.g., Palos Verdes, Santa Barbara, Newport, and La Jolla) produced the highest catches. Overall, the catches of wild fish at the mainland coastal sites were greater than those in the mainland embayments and island stations that were sampled. This supports the view that, although they are found in embayments, juvenile white seabass are basically fishes of the open coast from settlement through to maturity (Allen and Franklin, 1988, 1992; Donohoe, 1997). Along the mainland open coast, juvenile white seabass prefer stretches of coast with sandy beaches bordering on kelp forest or reef habitats. Most large croakers such as red drum and spotted weakfish (Cynoscion nebulosus) from the gulf coast and eastern seaboard of the United States are widely acknowledged as being estuarine dependent because their juvenile stages are spent almost entirely within the large estuaries of those coasts (McEachron et al., 1998). Recent evidence based on oxygen isotope ratios in otoliths also indicates that two other croakers from the eastern Pacific in the Gulf of California, the totoaba (Totoaba macdonaldi) and the gulf corvina (Cynoscion othonopterus) spend their first few years of life in the brackish waters of estuaries (Rowell et al., 2005). White seabass do not seem to follow this large croaker pattern. Estuarine (in this case, embayment) independence in California waters bodes well for white seabass populations because embayments are relatively small and rare along the southern coast of California (Allen et al., 2006).

The catches of juvenile white seabass in the gill net survey at the seven, primary coastal sites have increased between two- and threefold since the beginning of sampling in 1995. It is important to note, however, that current catches are about half of those in encountered in 1999 and 2000 when catches peaked at eightfold higher than the 1995 baseline catches. This “peak” in catches is undoubtedly due to the strong 1997 and 1998 year classes of white seabass in the Southern California Bight. These pronounced patterns of temporal abundance were not directly correlated with temperature change. However, it has been determined that temperature significantly impacted growth rates of the 1996–2003 year classes of juvenile white seabass sampled in this study (Williams et al., 2007). The influence of temperature directly on year class strength is currently being investigated. Concomitant with the overall increase in abundance of juvenile white seabass, commercial and recreational catches have returned to levels only observed in California prior to the fisheries collapse. Not only has catch returned to near historic levels, commercial CPUE is continuing to increase significantly. Clearly the increase in recruitment seen in the last 11 years has contributed to the ongoing return of the adult stock. It is true that recreational landings are down in recent years, but it also stands to reason that the recreational fishery is more sensitive to fluctuations in year class strength since that fishery is primarily based on younger adult fish. Most importantly, the overall increase in recruitment of juvenile white seabass is a strong indicator that the growing stock of adults has been reproductively successful thereby accounting, in large part, for the white seabass fisheries’ ongoing recovery and sustainability.

In 1994, when the nearshore gill net ban was first implemented, the white seabass fishery had declined significantly and was on the verge of collapse. The exclusion of gill nets in state waters, while a contentious issue at the time, did not negatively impact the offshore commercial white seabass fishery. In fact, the ban now appears to be largely responsible for the recovery of that fishery. Moving the nets out of state waters effectively removed the commercial fishery from access to the reproductive aggregations they were previously targeting. It is well known that fishery species that aggregate to reproduce and are targeted during these aggregations are known to decline precipitously (Bolden, 2000; Sadovy and Domeier, 2005). Thus, this management action, while fortuitous for this fishery, is likely to be an appropriate model for the recovery of other large marine fishes in coastal waters.

In conclusion, the relatively high catch rates of wild, juvenile white seabass over the last decade, along with significant increases in commercial CPUE and generally increased recreational catches in recent years, indicate that the natural populations of white seabass are now doing quite well. We believe that they are, in fact, in the process of recovery. Commercial catches are again comparable to levels attained prior to the collapse in the 1970s and 1980s. Recreational catches have seemingly returned from virtual oblivion. The ban of nearshore commercial gill net fishing by Proposition 132 probably contributed greatly to the increase in the population size that led to this ongoing recovery. In addition, the succession of warm water years that occurred from 1983 to the strong El Niño event of 1997–1998 may also have played an important role in the successful recruitment of white seabass. Finally, having made this optimistic claim, we would also like to offer a word of caution. Even fish stocks judged to be in recovery need to be managed carefully. In this particular case, the strong year classes of white seabass in 1996–1998 are just now entering the commercial fishery. The sustainability of future catches (both commercial and recreational) of white seabass will only be accomplished if the variability of natural recruitment as demonstrated herein is taken into full account. Hopefully, the White Seabass Fishery Management Plan implemented by the California Department of Fish and Game in cooperation with the recreational, commercial, and scientific communities will provide such wise management.

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