Final Report: Mortality and Population Abundance of Three Species of Paralabrax off San Diego, California, R/OPCCFRW-3
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Executive Summary

Part I

While bass species in the *Paralabrax* genus are vital to California recreational fisheries, evidence for population declines and overfishing has prompted recent management actions aimed at improving the fishery. Both Kelp Bass (*P clathratus*) and Barred Sand Bass (*P. nebulifer*) show long-term impacts from fishing and oceanography, while Spotted Sand Bass (*P. maculatosacfiatus*) are more data limited, yet fundamental population statistics are still not fully understood for all three species. We implemented a collaborative study in partnership with the recreational fishing community in southern California in order to estimate population parameters that are essential for future assessments on these three species. During standardized sampling trips, we achieved high catch rates for both Kelp Bass and Spotted Sand Bass, both during and outside their respective spawning seasons, but low catch rates of Barred Sand Bass due to recent changes in spawning aggregation behavior in their traditional spawning grounds. Catch-per-unit-effort (CPUE) did not differ between sites for any of the three species, likely because of high variability in CPUE between surveys. Kelp Bass showed significantly larger size classes in Imperial Beach, as well as both State Marine Reserves (SMRs) in La Jolla. Spotted Sand Bass showed significantly larger size classes in Mission Bay than San Diego Bay. Increased sizes following the 2013 regulatory increases in minimum size limits were documented in 2014 for both Kelp Bass and Spotted Sand Bass. Kelp Bass exhibited the greatest population response in areas open to fishing than within MPA boundaries. Barred Sand Bass, however, showed decreased sizes between 2013 and 2014, possibly due to recent changes in spawning behaviors. The success of this project was largely due to the extensive collaborative relationships we developed between the fishing, scientific, and fisheries management communities, and we encourage this approach for future studies.

Part II

The effectiveness of fisheries management is largely dependent upon fish behavior. Spatial management approaches are common, but require an understanding of species movement patterns, and harvest control rules can ultimately prove ineffective if these regulations are implemented without the knowledge of spatially mediated life history characteristics (e.g., spawning sites). The state of California recently implemented an extensive network of coastal marine protected areas (MPAs).The degree to which species (and ultimately fisheries) benefit from these closures depends largely on their behavior. Understanding the movements and behaviors of fishes relative to reserve boundaries affords the opportunity to quantify the extent of fishing protections (or conversely, spill-over) associated with an MPA or a network of MPAs. This can inform both the design and assessment of MPAs. We conducted a fishing community-based tagging study, and integrated both tag-recapture and acoustic telemetry methods to measure movement patterns of three species of *Paralabrax* on multiple spatial scales. We

externally tagged a total of 12,581 Kelp Bass (*P. clathratus*), 1079 Barred Sand Bass (*P. nebulifer*), and 2353 Spotted Sand Bass (*P. maculatofasciatus*), with recapture rates of 10.8% (1362), 4.5% (49), and 3.8% (90), respectively. Floy tag retention was approximately 81% after 1 year, and 50% after 1.75 years for Kelp Bass. Times at liberty ranged from ~1 min - 733 days, and linear distances travelled ranged from 0m - 95km. Most (77%) recaptures were within 0.5 km of the initial tagging site. We also tagged 41 Kelp Bass and 25 Barred Sand Bass with Vemco coded acoustic transmitters to measure more detailed behavioral patterns. An array of 43 acoustic receivers was used to measure the movements of these individuals throughout the La Jolla kelp bed. Both species showed clear vertical migrations and elevated activity levels during the summer spawning season, and Barred Sand Bass showed seasonal migration to and from a newly documented aggregation site off south La Jolla. Only 12% of acoustically tagged Kelp Bass were regularly detected across multiple La Jolla sites, while the remaining 88% were primarily detected at a single site. However, 48% of Barred Sand Bass were regularly detected at two or all three La Jolla sites, and the apparent spawning site for this species spans the southern boundary of the South La Jolla State Marine Reserve.

Collaboration and Outreach

The cooperative and transparent design of our research program was the single most important contributing factor to its overall success. We achieved broad support from the recreational fishing community via numerous avenues of outreach. The most important avenue was direct participation in the project via field sampling aboard fishing vessel charters. We conducted 52 charters in two years, which created opportunities for over one thousand anglers to get hands-on experience with field research, and to communicate with project researchers. We also gave several presentations to local fishing and dive clubs, published numerous articles in newspapers and fishing magazines, conducted multiple radio show interviews, produced two television show episodes, set up booths at multiple fishing trade shows, and created a smartphone "app" for anglers to report recaptured fish. This diverse array of outreach methods was essential for anglers to learn about the project, and to ultimately show their support. The collaborative relationships that we developed with numerous organizations, such as the California Department of Fish and Wildlife (CDFW), San Diego Oceans Foundation (SDOF), and the Sportfishing Association of California (SAC), were also essential to the success of the project. The CDFW helped to maximize the usefulness of the data for management of the *Paralabrax* fisheries, and SDOF employed their extensive experience communicating to broader audiences about the program, and organizing vessel charters. The SAC filled an essential role communicating our project updates to the recreational fishing industry, and participating in field sampling. This project would not have been possible on this scale without the cooperation and participation of all of these individuals and organizations.

PART I

Title: Analyses of catch-per-unit-effort (CPUE), length frequency, and post-release mortality of three species of *Paralabrax* relative to coastal marine protected areas (MPAs) off San Diego, California

Introduction

Marine recreational fishing plays a vital role in the ecological, social, and economic constitution of California. In 2006, California recreational anglers generated the highest sales in the nation (by state) at an estimated $3 billion on retail goods and services (Gentner & Steinback 2008). In 2013, California recreational anglers contributed $2.8 billion to the state economy, and spent over 5.3 million angler-days fishing in marine waters (CADFW 2014 Annual Forum Report). Given both the value and impact of recreational fisheries in the state, there is a critical need for detailed and quantitative information specific to fish populations. However, even species with extensive fisheries histories that are relatively well studied have nonetheless exhibited signs of long-term decline, and still lack up-to-date stock status information. One such group of species is in the genus *Paralabrax*, which consists of Kelp Bass (*P.clathratus*), Barred Sand Bass (*P. nebulifer*), and Spotted Sand Bass (*P. maculatofasciatus*). These species have fisheries data that date back to the 1930s, with population analyses dating back several decades (e.g., Clark 1933, Collyer 1949, Collyer and Young 1953, Young 1963), yet signs of population declines have been shown for two of the three species (Sweetnam 2009, Jarvis et al. 2010, Erisman et al. 2011, Jarvis et al. 2014). These two species, Kelp Bass and Barred Sand Bass, consistently rank among the top recreational fisheries by landings. Pooled CPFV logbook data for all targeted fishes in California from 1936-2008 indicate that Kelp Bass ranked 1st in number of fish kept for a single species (excluding "unidentified rockfishes"), with approximately 20.6 million fish landed during the 67-year period. Barred Sand Bass ranked 4th overall (excluding Pacific mackerel and "unidentified rockfishes") with 12.7 million landed. However, both species were often pooled into a "rock bass" category (ranked 5th overall) prior to the mid-1970s, which accounts for an additional 11.9 million fish (Jarvis et al. 2014). Thus, Kelp Bass and Barred Sand Bass likely represent the top two species (excluding Pacific mackerel and "unidentified rockfishes") landed on CPFVs throughout the recorded history of recreational fishing in California. However, signs of their long-term declines have become evident (Erisman et al. 2011), which has been due to a combination of fishing and oceanographic factors (Jarvis et al. 2014).

Susceptibility to overfishing is largely influenced by species behavior and biology. Barred Sand Bass are of particular concern because this species forms large summer spawning aggregations that are highly predictable in time and space (Hovey et al. 2002, Jarvis et al. 2010), and thus easy to target. Erisman & Allen (2006) suggest that Kelp Bass also form spawning aggregations, but they also state that these aggregations are spatially and temporally unpredictable, which implies that the susceptibility of this species to overfishing is lower than that of Barred Sand Bass. Jarvis et al. (2014) recently concluded that a combination of fishing impacts, fisheries regulations, and environmental processes have collectively led to long-term declines in both Kelp Bass and Barred Sand Bass landings. However, current estimates of population statistics for these species are needed, especially given that some data sources are decades old (e.g., Young 1963). Clearly, an intensive study on temporal and spatial dynamics in catch-per-unit-effort (CPUE) and length frequency analyses would not only lend insight into the status of the populations, but would also allow measurements of the effectiveness of recent regulatory changes. These changes include coastal MPAs that were recently implemented, as well as increased minimum size limits and decreased individual bag limits that were adopted in 2013 for all of the bass species. In addition, there has been limited research focusing on the third species of *Paralabrax*, Spotted Sand Bass (*P. maculatofasciatus*) in general. This species inhabits bays and estuaries almost exclusively, and therefore is primarily targeted by private boaters and shore anglers because CPFVs mostly operate along the open coast. Spotted Sand Bass are also targeted primarily for catch-and-release among recreational anglers (Hovey and Allen 2000). This stark difference in recreational use patterns between the bass congeners provides an opportunity to compare differences in the influence of primarily consumptive versus primarily non-consumptive recreational fishing pressure on population dynamics.

Given the popularity of catch-and-release fishing in southern California, especially for the three saltwater basses, there is a need for post-release mortality estimates of each of the three species. Data from the California Recreational Fisheries Survey (CRFS) indicate total catch-and-release rates for Kelp Bass, Barred Sand Bass, and Spotted Sand Bass are 73%, 55%, and 95%, respectively (CalCOFI 2014). Such high catch-and-release rates are likely due to a combination of minimum size limits and the perception among recreational anglers that catch-and-release promotes conservation due to high post-release survival. If post-release survival is much lower than perceived, then these catch-and-release rates would equate to significantly greater overall take from recreational fisheries, which should be factored into population analyses. Lowe et al. 2003, McKinzie et al. 2014, and Freedman et al. 2015 each measured high post release survival of Kelp Bass, Barred Sand Bass, and Spotted Sand Bass, respectively, but generally only fish that appeared healthy were actually tagged in these studies because acoustic transmitters are costly.

The goal of our project was to work cooperatively with the recreational fishing community, the California Dept. of Fish and Wildlife, and non-profit organizations to conduct a quantitative analysis of CPUE, length frequency, and post-release mortality for all three bass species in the San Diego county coastal area, both inside and outside local marine protected areas (MPAs). There are primarily two MPA types located in our study area. These include State Marine Reserves (SMRs), which prohibit all extractive activities, and State Marine Conservation Areas (SMCAs), which are primarily no-take, but include some allowances for recreational take only. This information will shed light on functionality of both old and new MPAs, responses of each species to recently increased minimum size limits, and the often overlooked impacts of catch-and-release fishing.

Methods

Study Area

Sampling trips were conducted from Long Beach, California south to the US-Mexico border, although the primary research sites consisted of north San Diego County, La Jolla, Mission Bay, Point Loma, San Diego Bay, and Imperial Beach off the San Diego County coast (Fig. 1). The north San Diego County area was divided into two sites, which consisted of the Swami's State Marine Conservation Area (SMCA) established in 2012, and the adjacent Encinitas area that has always been open to fishing. The La Jolla area was divided into three sites, which consisted of 1) the Matlahuayl State Marine Reserve (SMR), which was expanded and renamed in 2012 from the former La Jolla Ecological Reserve implemented in 1971, 2) La Jolla (has always been open to fishing), and 3) the South La Jolla SMR, which was recently established in 2012. Sites were chosen based on suitable habitat and known popular fishing locations for each of the three species. Adult Kelp Bass generally are targeted along open coast rocky reef and kelp bed habitat, Barred Sand Bass are targeted in bay and coastal sand flats near rocky reefs, and Spotted Sand Bass are fished in primarily soft bottom bay habitats. As such, primary Kelp Bass sites included La Jolla and Point Loma kelp beds, Barred Sand Bass sites included Imperial Beach and north San Diego County, and Spotted Sand Bass sites were located in Mission Bay and San Diego Bay.

Field Methods

Two approaches were used to implement tagging efforts for the three bass species. The first consisted of ¾-day charters aboard Commercial Passenger Fishing Vessels (CPFVs) in collaboration with the San Diego Oceans Foundation, a local 501(c)3 non-profit organization. These CPFV charters focused on sampling coastal sites only (not sites inside bays), and the primary target species for these trips were both Kelp Bass and Barred Sand Bass. The second sampling approach was with private vessels in the two bay sites, Mission Bay and San Diego Bay. These trips focused primarily on tagging the third species of *Paralabrax*, Spotted Sand Bass.

The CPFV tagging charters were separated into sampling periods based on season during the two-year study (Table 1). Seasons consisted of fall 2012 (Sep-Nov), summer 2013 (Jun-Aug), fall 2013 (Sep-Nov), and summer 2014 (Jun-Aug). Each individual charter focused specifically on one site and one target species. This yielded site-specific CPUE for both the target species as well as all bycatch that was associated with each target species. Volunteer recreational anglers were invited aboard each of these charters to assist with the fishing, and SIO researchers were aboard for catch data collection. All fish caught were measured, recorded, and released immediately after capture. The information collected for each individual fish caught consisted of the species, standard length (mm), latitude-longitude, time, depth, and physical condition of the fish.

Catch-and-release mortality was measured using two methods. First, mortality events were observed visually from the boat, yielding an initial mortality estimate. However, initial post-release mortality rates are likely to be underestimates of overall catch-and-release mortality given that they represent only immediate mortality events that were observable from the boat. Thus, the second method consisted of fish being held in moored net pens located in San Diego Bay for a 10-day assessment period, yielding a short-term post-release mortality estimate. Fish from a local annual fishing tournament in both 2013 and 2014 were released into these net pens, and then all fish were released after the temporary holding period. All mortality events during the holding period were recorded.

Data Analysis

Measurements for both CPUE and length frequency were grouped by species and site, while short-term post release mortality was grouped by species and pooled across all sites. Species-specific CPUE estimates were only generated for those trips where the species being estimated was the primary target species (e.g. we only estimated trip-specific Kelp Bass CPUE when Kelp Bass was the primary target species for the trip). Catch per unit effort was used as a measure of relative abundance, and was defined in terms of the number of fish caught per anglerhour. This metric was compared for each species between sites using a one-way ANOVA and *post hoc* Tukey's test for pairwise comparisons. Length-frequency data were compared between sites also using a one-way ANOVA and *post hoc* Tukey's test for pairwise comparisons. Individual growth rates based on tag-recapture data are the subject of a separate study comparing current growth estimates with past studies (Allen et al. 1995, Love et al. 1996). However, in response to signs of long-term population decline among both Kelp Bass and Barred Sand Bass, the California Department of Fish and Wildlife implemented regulatory changes for all three species of *Paralabrax* effective March 1, 2013 (Jarvis et al. 2014). These regulations included an increased minimum size limit from 305 to 356 mm (12 to 14 inches) total length, as well as a decreased individual daily bag limit from 10 to 5 fish. This allowed us to measure potential increases in the size structure of each species following the release of fishing pressure on 12-14-inch fish. We tested for changes in the overall size distribution of each species of *Paralabrax* between the 2012, 2013, and 2014 sampling years at the primary tagging sites with a two-way ANOVA and *post hoc* Tukey's test for pairwise comparisons.

Results

Realized tagging effort

Our tagging efforts consisted of a total of 51 individual ¾-day tagging charters aboard local CPFVs (Table 1), and 151 private vessel trips conducted from Sep 30, 2012 - Sep 17, 2014. Tags were deployed at 11 sites between Long Beach, California and the U.S.-Mexico border, including two State Marine Reserve sites (Matlahuayl SMR and South La Jolla SMR) and one State Marine Conservation Area (Swami's SMCA). A total of 19,327 fish from 71 species were caught-and-released during the trips, although Pacific Jack Mackerel (*Trachurus symmetricus*), Chub Mackerel (*Scomber japonicus*), and Jacksmelt (*Atherinopsis californiensis*) were not recorded due frequently high catches that often interfered with data collection for other species. A total of 12,581 Kelp Bass, 1079 Barred Sand Bass, and 2353 Spotted Sand Bass were caught and released during this period (Table 2). The basses represent 84.2% of the total records in the catch dataset, and the remaining 15.8% bycatch consisted primarily of Pacific Barracuda (2.45%), Brown Rockfish (1.76%), Kelp Rockfish (1.51%), Bonefish (1.36%), Yellowfin Croaker (1.06%), and 60 additional species with less frequent catches (Table 3).

Catch Per Unit Effort Across Species and Sites

Neither Kelp Bass (Fig. 2, $F = 0.93$, $df = 6$, $p = 0.44$) nor Barred Sand Bass (Fig. 3, $F = 0.08$, $df = 1$, $p = 0.78$) showed significant differences in CPUE between survey sites. There were also no significant differences in Spotted Sand Bass CPUE between sites (Fig. 4, $F = 0.069$, $df = 1$, $p = 0.794$). However, there were significant differences between sampling seasons in Kelp Bass CPUE (Fig. 5, $F = 16.14$, $df = 3$, $p = 0.0002$), with the Tukey test showing higher values during the summer seasons ($p < 0.01$), and no differences in the same seasons between years ($p = 0.85$). Barred Sand Bass were primarily only caught during summer months, which precluded seasonal analyses. California Recreational Fisheries Survey (CRFS) estimates of recreational landings from Los Angeles and San Diego CPFVs show very few fish caught at all in 2013, and only slightly more in 2014 (Fig. 6); in nearly all years since 2004, CPUE was highest during the spawning season for this species (summer months). Spotted Sand Bass showed significant differences in CPUE by season (Fig. 7, $F = 6.32$, $df = 3$, $p = 0.001$). The Tukey's post hoc test showed higher CPUE in winter months ($p = 0.01$), and no differences between the other seasons ($p = 0.64$), although only summer and fall had very low sample sizes.

Length frequency Across Species and Sites

All three basses showed significant spatial differences in length-frequency distributions. Kelp Bass showed significant differences between sites (Fig. 8, F = 60.42, $df = 9$, $p < 0.001$), with the post hoc test showing the largest mean bass size in Imperial Beach (283mm SL ± 2mm 95% CI, $p < 0.001$), followed by Matlahuayl SMR (267mm SL ± 2mm, $p < 0.001$), South La Jolla SMR (260mm ± 2mm, $p < 0.001$), La Jolla (254mm ± 1mm, $p < 0.001$), and lastly Point Loma (251mm SL ± 2mm, $p = 0.049$). Kelp Bass did not show significant differences inside and outside of the Swami's SMCA (Fig. 9), but these data were only generated from a single tagging trip at each site inside and outside the SMCA. Barred Sand Bass were larger at Imperial Beach than all other sites (Fig. 10, F = 10.24, $df = 3$, $p < 0.001$), but sampling was limited at sites other than Imperial Beach due to low catch rates. Spotted Sand Bass showed significantly larger sizes in Mission Bay than San Diego Bay (Fig. 11, F = 171.07, $df = 1$, $p < 0.001$). Inside/outside reserve comparisons don't apply to Spotted Sand Bass in this study because they generally only live inside bays and estuaries where there have been no MPAs implemented (there are several de-facto reserves in these areas, such as naval zones, but these sites were not sampled). We also compared the size distributions of the top 5 demersal bycatch species in the La Jolla sites (La Matlahuayl SMR, La Jolla, and South La Jolla SMR; Fig. 12). These consisted of Brown Rockfish (*Sebastes auriculatus*), California Sheephead (*Semicossyphus pulcher*), Kelp Rockfish (*S. atrovirens*), Gopher Rockfish (*S. carnatus*), and Treefish (*S. serriceps*). California Sheephead were the only species that showed significant differences between sites (F = 16.31, df = 2, $p < 0.001$), with the Tukey's post hoc test showing larger sizes inside the two SMRs than in the adjacent outside area of La Jolla ($p < 0.001$), but no differences between the two SMRs ($p = 0.63$).

Kelp Bass showed significant effects of both site (F = 74.21, $df = 4$, $p < 0.001$) and year (F = 12.36, df = 2, $p < 0.001$) on mean size. Significant increases in size were found from 2013 to 2014 ($p < 0.001$), with the greatest increases occurring in La Jolla and Point Loma, the two areas open to fishing. No significant changes in size were measured from 2012 to 2013 ($p = 0.022$). Barred Sand Bass showed a significant decline in size from 2013 to 2014 (F = 10.47, $df = 1$, $p = 0.001$), but this is largely driven by fish from Imperial Beach. Barred Sand Bass from Imperial Beach were significantly larger sized than in San Diego Bay (F = 61.21, df = 1, $p < 0.001$). Spotted Sand Bass showed significant effects of both site (F = 188.68, df = 1, $p < 0.001$) and year (F = 11.79, df = 2, $p < 0.001$), with increases in size from 2012-2014 in both San Diego Bay and Mission Bay. Individual growth rates are the focus of a separate ongoing study that compares historical analyses to current estimates of *Paralabrax* demographics.

Post-release mortality

Initial post-release mortality for all species combined was 1.84%, sources of which primarily included fishing-related trauma (64.8%), predation from California sea lions (25.4%), predation from seabirds (7.8%), predation from harbor seals (2.0%), and predation from other fish (0.6%). California sea lions consumed most of the common species caught, but showed clear preferential behavior towards Pacific barracuda, Pacific bonito, chub mackerel, and white seabass. Initial post-release mortality for the basses alone were 1.87%, 0.92%, and 0.63% for Kelp Bass, Barred Sand Bass, and Spotted Sand Bass, respectively (Table 4). Fish held in net pens over a ten day period exhibited a 3.1% mortality rate during this trial period prior to release. Note however, that these fish were Floy tagged prior to placement inside the holding pens for a separate mark-recapture study. Thus, this mortality rate likely represents an over-estimate of the extended-term post release mortality.

Discussion

Population declines of Kelp Bass and Barred Sand Bass were documented in the 1940s due to commercial overfishing, which ultimately led to a ban on commercial fishing for these species in 1953 (Young 1963). While recreational fishing is considered to have lesser impacts than fishing on commercial scales, the popularity of these bass species among the recreational fleets has resulted in over 45 million bass landed aboard CPFVs alone in California waters since 1936 (CDFW logbook data). Overfishing is thus a concern for these species, not only because of the sheer numbers landed, but also due to the social and economic importance of the species. In addition, the regulatory history for these species has been dynamic throughout the history of the fishery (Jarvis et al. 2014), and the California Department of Fish and Wildlife recently implemented new individual bag limits and size limits for the basses, as well as new MPAs for all species. An understanding of the response of the bass fisheries to these harvest control rules and spatial regulations can help to establish management actions that ultimately facilitate a productive and sustainable fishery.

As expected, Kelp Bass CPUE was highest during the summer spawning months (Jun-Aug), although even the relatively lower catch rates incurred during the fall sampling season (Sep-Nov) translated to several hundred fish caught per trip in many cases. However, there were no site-specific differences in Kelp Bass CPUE, which was largely driven by a few days of exceptionally high catch rates outside MPA boundaries in La Jolla. In general, CPUE is impacted by numerous factors that can result in high variability in estimates. In our case, catch rates were potentially influenced by angler skill level, bait availability (e.g., anchovy, sardine, squid), and physical conditions, all of which translated into more variable CPUE. Catch-per-unit-effort may not be a particularly sensitive metric for the assessment of abundance differences among sites (Beverton and Holt 1957, Hilborn & Walters 1992), and as such may not be sufficient to detect modest differences in abundance. We also measured no significant spatial differences in CPUE for the basses relative to MPA boundaries. The South La Jolla SMR is likely still too young to show a significant MPA effect; however, the Matlahuayl SMR has been protected for over four decades, yet no MPA effect was detected relative to CPUE. Parnell et al. 2005 found limited signs of an effect within this same MPA, and highlighted the limited value of small MPAs. Hastings et al. 2014 also found similar fish communities inside and outside this MPA. The extent of the Matlahuayl SMR was expanded in 2012, and this increase in size may yield increased fish abundance in the future.

Catch rates for Barred Sand Bass were far lower than expected, despite focusing our sampling efforts at known spawning locations during spawning season (Jun-Aug). Based on both landings records and personal communication with CPFV captains, Barred Sand Bass spawning aggregations did not form as expected at their traditional southern California sites, which normally include Imperial Beach, San Onofre, Huntington Beach flats, and Ventura flats. Such broad-scale alteration of traditional spawning behavior had never been documented since the aggregations were first discovered decades earlier. In the San Diego area, the 2013 and 2014 spawning seasons consisted of much smaller isolated groups of spawning Barred Sand Bass that were found on isolated rocky reefs off Imperial Beach, and in the Point Loma kelp forest, and these smaller "satellite" aggregations were targeted heavily by local CPFVs. Barred Sand Bass landings do tend to be lower during warmer years, and 2014 was characterized by anomalously warm sea surface temperatures (Bond et al. *in press*, Kintisch 2015), with an annual mean value that was surpassed only once in 1997 by temperatures resulting from El Niño (Scripps Institution of Oceanography Pier water temperature data). The warm waters in 2014 brought offshore species within range of ½-day CPFVs, so most of these vessels were targeting these offshore species when they would normally target Barred Sand Bass. However, 2013 was much closer to average temperatures extending back to the late 1970s, yet Barred Sand Bass spawning aggregations were virtually absent during both 2013 and 2014, and at all other traditional southern California aggregation sites during both years. Thus, it is likely that factors in addition to warm temperatures have impacted the species.

Differences in the mean size of fishes inside and outside La Jolla reserve sites indicate that reserves are affording some degree of protection for larger fish. A comparison of mean Kelp Bass size between the La Jolla sites indicated that fish were significantly larger inside both reserves, with the largest fish inside the oldest reserve. California sheephead also showed significantly larger sizes inside the Matlahuayl SMR. This species has been heavily targeted for decades by both recreational and commercial fishers (Hamilton et al. 2007); whereas most other fishes in the kelp forests are targeted only by recreational anglers. This higher fishing pressure on California Sheephead outside the MPA may reflect the differences in size between the areas inside and outside of the MPA boundaries. Interestingly, across all sites studied, Kelp Bass were largest in Imperial Beach, which has always been open to fishing. We believe this finding reflects the relatively limited fishing pressure this site faces relative to Point Loma and La Jolla, combined with the fact that fish densities in the La Jolla reserve sites are at least partially mediated by fishing pressure due to spill-over (the movement of legal fish from inside reserves to open areas). Barred Sand Bass were also relatively large off Imperial Beach, but this is likely because this site is a historical spawning ground for this species. While spawning aggregations were not found, the small numbers of fish we did find were generally larger, and mature individuals often exhibit fidelity to their spawning grounds (Jarvis et al. 2010).

Spotted Sand Bass showed a greater abundance of smaller size classes in San Diego Bay relative to Mission Bay. Most of the smaller individuals from San Diego Bay were caught in the southern half of the bay, which contains a very expansive, shallow eelgrass (*Zostera marina*) flat where the species generally recruits (Allen 1985, Allen et al. 1995). Mission Bay also has extensive eelgrass habitat, but virtually all of the shallow flats were completely re-shaped by massive dredging and filling operations in the late 1940s. If shallower eelgrass flats are the preferred recruitment habitat for this species, then this could potentially translate to differences in smaller size classes between the two bays.

In addition to spatial differences in size classes, differences in mean size were found between the three sampling years. The sites that have historically been open to fishing, northwest La Jolla and Point Loma, both showed the greatest increases in Kelp Bass size structure from 2013 to 2014. Point Loma showed the greatest increase in sizes between the two sites, possibly due to its closer proximity to San Diego's primary fishing port, San Diego Bay, and thus historically higher levels of fishing effort in the area. Such higher levels of fishing effort would imply a greater release from fishing pressure for smaller size classes following more conservative regulations, and ultimately an increase in the number of fish at previously legal sizes. Spotted Sand Bass also showed significant increases in size in both Mission Bay and San

Diego Bay following increases in size limits, with a more consistent pattern apparent in San Diego Bay. Taken together, these findings suggest that anglers are adhering to the new regulations and that these fisheries have responded rapidly to the increased minimum size limits.

Understanding the mortality rates associated with catch-and-release angling is a necessary part of any effort to assess cumulative fisheries impacts. All three of the basses are targeted by a significant portion of the recreational fishing community for catch-and-release purposes only. California Recreational Fisheries Survey data from 2004-2013 indicate that 73% of all Kelp Bass, 55% of all Barred Sand Bass, and 95% of all Spotted Sand Bass are released by recreational anglers (CalCOFI report 2014). We found that both initial and short term mortalities associated with catch and release are surprisingly low at 1.84% and 3.1%, respectively. The CDFW currently assumes a 10% mortality rate associated with catch-and-release. While this may be high relative to the measurements in this study, it also represents a conservative approach for long-term management of the stocks. Our estimates of mortality may under-estimate the total long-term mortality associated with catch-and-release. However, given that catch-and-release mortality usually occurs within just a few days following catch-and-release (Aalbers et al. 2004, Lowe et al. 2009), it seems unlikely that extending the duration of our holding study would influence our findings. Additionally, the stress of catching and holding the fish in the net pen after an all-day fishing tournament likely imposes additional stress to the fish, with a concurrent increase in the risk of mortality. As such, we believe our estimates provide an accurate estimate of initial and short-term catch-and-release mortality.

Spatial and temporal analyses of CPUE and length frequency, as well as estimates of initial and short term post-release mortality will ultimately help to inform future stock assessments of the three bass species. This will be especially true when combined with individual growth and movement data, as well as population abundance and mortality estimates that are the subject of a separate study using the same dataset. The extensive stakeholder collaborations we developed as part of this study were vital to our research success. The scientific community, southern California fishing community, the San Diego Oceans Foundation, and California Department of Fish and Wildlife biologists all combined their knowledge, expertise, and labor to address specific needs for local fisheries management. Hanan and Curry (2012) had similar success with the recreational fleet in Southern California, and tagged 32,366 rockfish during a 4-year period in southern California. Additionally, the success of the California Reef Check Program demonstrates that recreational enthusiasts can serve as citizen-scientists that provide useful data for subtidal MPA monitoring (e.g., Hodgson 2000). The recreational fishing community is a valuable source of information fisheries studies, and future research efforts would significantly benefit from such collaborative partnerships not only with respect to data collection, but by also gaining increased research validation through stakeholder participation.

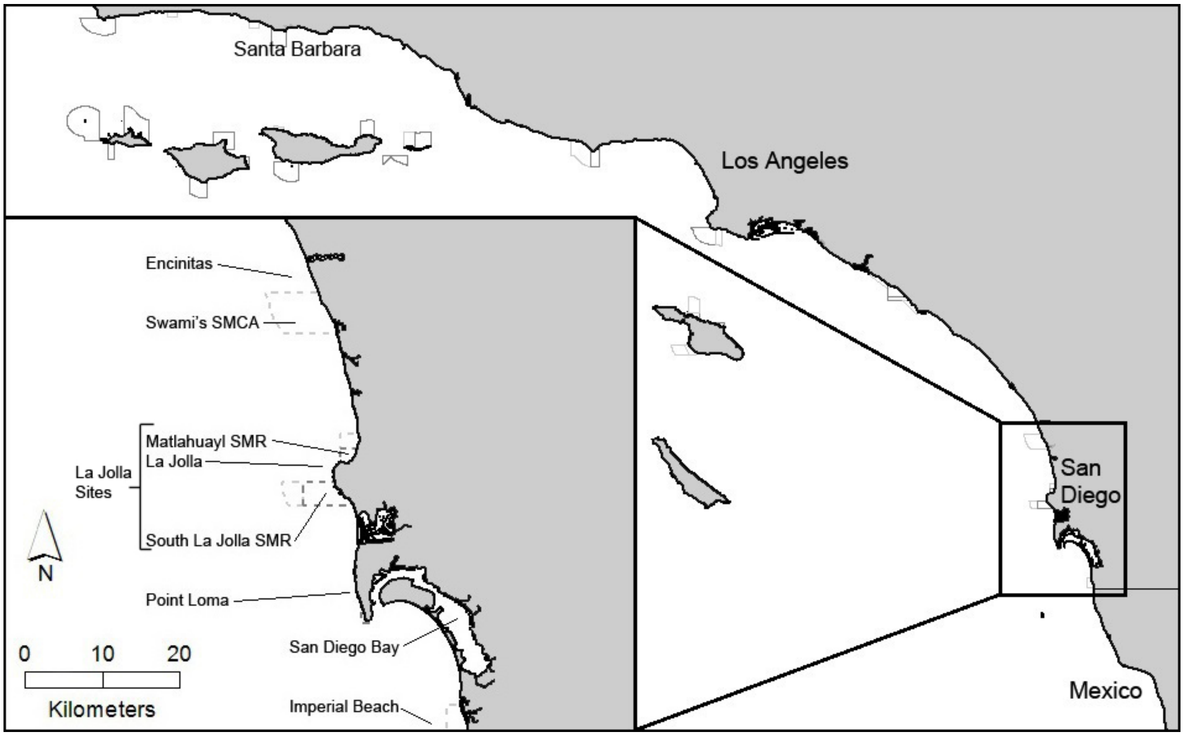

Figure 1. Map of sampling sites off San Diego, California, including MPA boundaries. Dark gray dashed lines represent State Marine Reserve (SMR) boundaries, and light gray dashed lines represent State Marine Conservation Area (SMCA) boundaries.

Sites	Inside / Outside	Fall 2012	Summer 2013	Fall 2013	Summer 2014
Matlahuayl SMR	inside	3	2	3	3
La Jolla	outside	3	2	3	2
South La Jolla SMR	inside	3	2	3	2
Point Loma	outside	3	2	3	2
Imperial Beach	outside		3		3
Long Beach	outside		1		
Mission Beach	outside				1
Encinitas	outside		1		
Swami's SMCA	inside		1		

Table 1. Number of CPFV sampling charters by site and sampling season. Sites are separated by location inside or outside of MPAs, which include Matlahuayl SMR (La Jolla Cove), South La Jolla SMR, and Swami's SMCA (Encinitas).

Site	Kelp Bass	Barred Sand Bass	Spotted Sand Bass	Total
La Jolla	3523	13		3536
Matlahuayl SMR	2766	25		2791
South La Jolla SMR	2670	35		2705
San Diego Bay	71	577	1968	2616
Point Loma	2300	40		2340
Imperial Beach	528	266		794
Encinitas (in/out)	452	70		522
Mission Bay	4	1	363	368
Mission Beach	185	15		200
Long Beach	82	37		119
Newport Bay			22	22

Table 2. Total number of fish caught-and-released for each of the three bass species at each site, excluding initial mortalities.

Species	N	Scientific Name	Mean SL (mm)	SD (mm)
Pacific Barracuda	474	*Sphyraena argentea*	442	75
brown rockfish	341	*Sebastes auriculatus*	217	34
kelp rockfish	293	*Sebastes atrovirens*	232	20
bonefish	264	*Albula vulpes*	310	
yellowfin croaker	206	*Umbrina roncador*	275	25
CA sheephead	177	*Semicossyphus pulcher*	301	62
gopher rockfish	134	*Sebastes carnatus*	199	23
olive rockfish	110	*Sebastes serranoides*	241	28
white seabass	104	*Atractoscion nobilis*	440	80
CA halibut	81	*Paralichthys californicus*	396	164
treefish	68	*Sebastes serriceps*	225	34
smoothhound	62	*Mustelus californicus*	*514	
CA scorpionfish	61	*Scorpaena guttata*	220	26
cabezon	54	*Scorpaenichthys marmoratus*	273	45
CA lizardfish	49	*Anisotremus davidsonii*	241	41
sargo	49	*Synodus lucioceps*	261	21
bat ray	43	*Myliobatis californica*	***586	25
vermilion rockfish	39	*Sebastes miniatus*	249	42
lingcod	38	*Ophiodon elongatus*	544	80
round stingray	36	*Urobatis halleri*		
black surfperch	35	*Embiotoca jacksoni*	209	26
shovelnose guitarfish	29	*Rhinobatos productus*	*1219	
calico rockfish	27	*Sebastes dalli*	139	29
copper rockfish	25	*Sebastes caurinus*	213	35
giant kelpfish	21	*Heterostichus rostratus*	317	45
Pacific bonito	21	*Sarda chiliensis lineolata*	**338	24
white croaker	16	*Genyonemus lineatus*	208	25
black croaker	13	*Cheilotrema saturnum*		
shortfin corvina	11	*Cynoscion parvipinnis*	290	101
butterfly ray	9	*Gymnura marmorata*		
sharpnose seaperch	8	*Hypsopsetta guttulata*	206	14
diamond turbot	8	*Phanerodon atripes*		
grass rockfish	8	*Sebastes rastrelliger*	213	38
blacksmith	7	*Caulolatilus princeps*	161	12
ocean whitefish	7	*Chromis punctipinnis*	360	38
opaleye	7	*Girella nigricans*	293	18
blue rockfish	7	*Sebastes mystinus*	202	35
senorita	6	*Oxyjulis californica*	159	17
leopard shark	5	*Triakis semifasciata*	*1270	

CA moray	5	*Gymnothorax mordax*	794	156
horn shark	5	*Heterodontus francisci*	*726	47
black and yellow rockfish	5	*Sebastes chrysomelas*	203	9
white surfperch	3	*Phanerodon furcatus*	220	14
rubberlip surfperch	3	*Rhacochilus toxotes*	297	19
honeycomb rockfish	3	*Sebastes umbrosus*	160	16
halfmoon	3	*Medialuna californiensis*	271	7
bocaccio	3	*Sebastes paucispinis*	177	
starry rockfish	2	*Sebastes constellatus*	223	18
queenfish	2	*Seriphus politus*		
fantail sole	2	*Xystreurys liolepis*	304	55
rainbow surfperch	2	*Hypsurus caryi*	188	
spiny dogfish	2	*Squalus acanthias*		
squarespot rockfish	2	*Sebastes hopkinsi*	166	62
common thresher	1	*Alopias vulpinus*		
CA yellowtail	1	*Seriola landali*	**480	
painted greenling	1	*Oxylebius pictus*	143	
longfin sanddab	1	*Citharichthys xanthostigma*	219	
garibaldi	1	*Hypsypops rubicundus*	188	
pacific sanddab	1	*Citharichthys sordidus*	207	
needlefish	1	*Strongylura exilis*		
spotfin croaker	1	*Roncador stearnsii*		
banded guitarfish	1	*Zapteryx exasperata*		
plainfin midshipman	1	*Porichthys notatus*		
released before ID	44			
Total	3049			

Table 3. Total number of records (N), mean standard length (SL mm), and standard length standard deviation (SD mm) of bycatch species. Sizes are shown in standard length (mm), but a * denotes total length (mm) , ** denotes fork length (mm), and *** denotes disc width (mm). Species with only a single size value did not have a standard deviation. and some fishes were not measured at all when tagging was too busy. The last row shows 44 individual fish that were not identified because anglers accidentally released them before they were seen by the project scientist. Anglers could usually identify them to rockfishes, croakers, and surfperches, but complete species identification was not possible.

Species	Caught	Initial mortalities	Initial mortality (%)
Kelp Bass	12821	240	1.87
Barred Sand Bass	1089	10	0.92
Spotted Sand Bass	2368	15	0.63
Bycatch (other spp)	3049	91	2.98
Total	19327	356	1.84

Table 4. Initial post-release mortality rates for each of the three bass species as well as a combined estimate both for all other bycatch species and for all species. The total tagged-and-released represents the number of initial mortalities subtracted from the number caught.

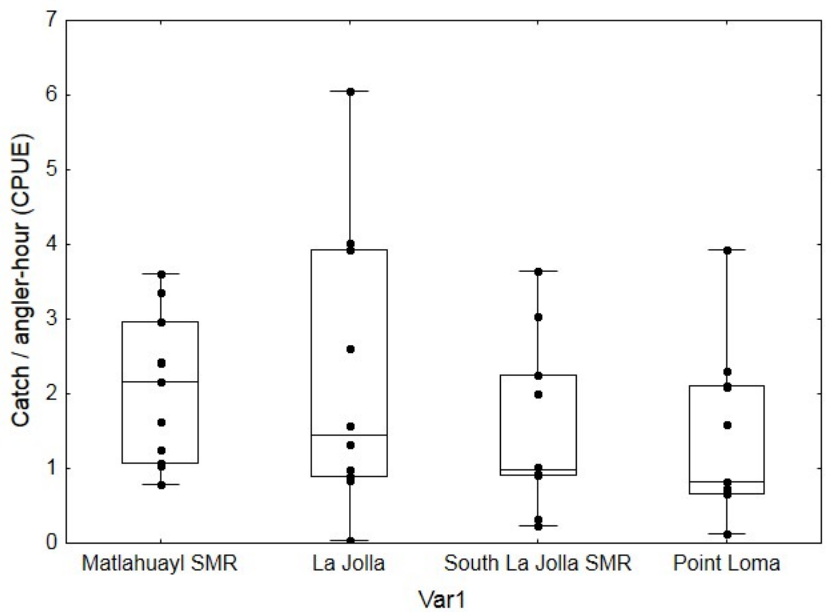

Figure 2. Kelp Bass CPUE across primary CPFV charter sites (only includes CPFV charters when Kelp Bass were the target species). Raw data points are overlaid onto boxplots at each site, which include Matlahuayl SMR (n = 11), La Jolla (n = 10), South La Jolla SMR (n = 10), and Point Loma (n = 11).

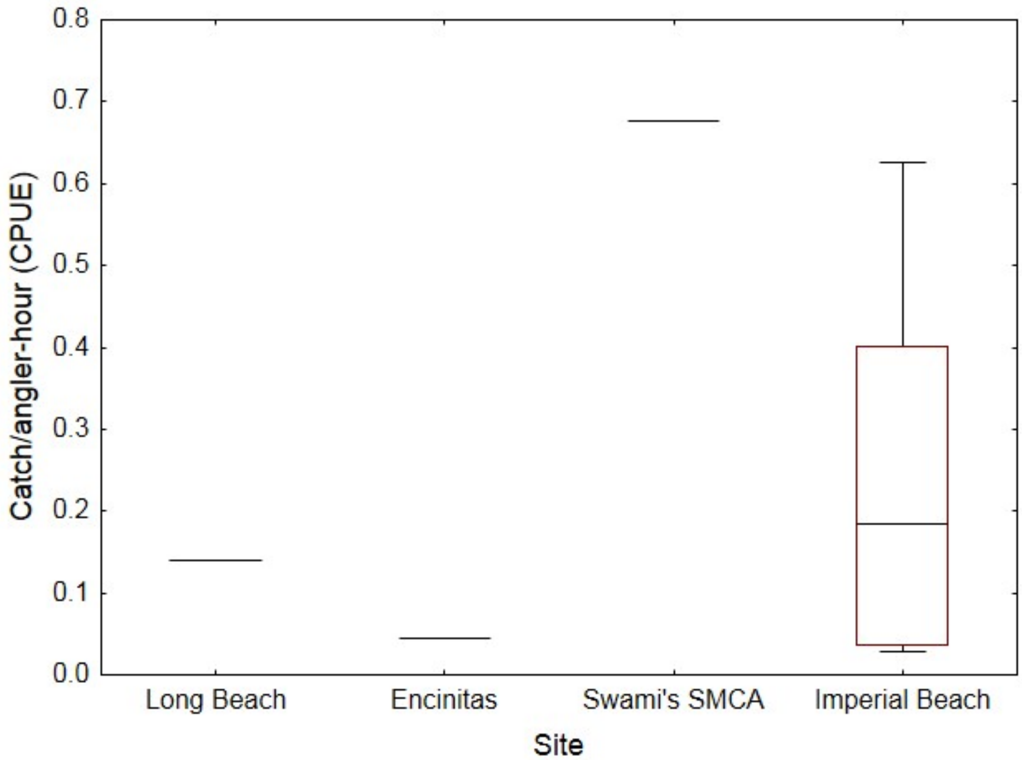

Figure 3. Barred Sand Bass CPUE across sites, which include Long Beach (n =1), Encinitas (n = 1), Swami's SMCA (n = 1), and Imperial Beach (n = 6).

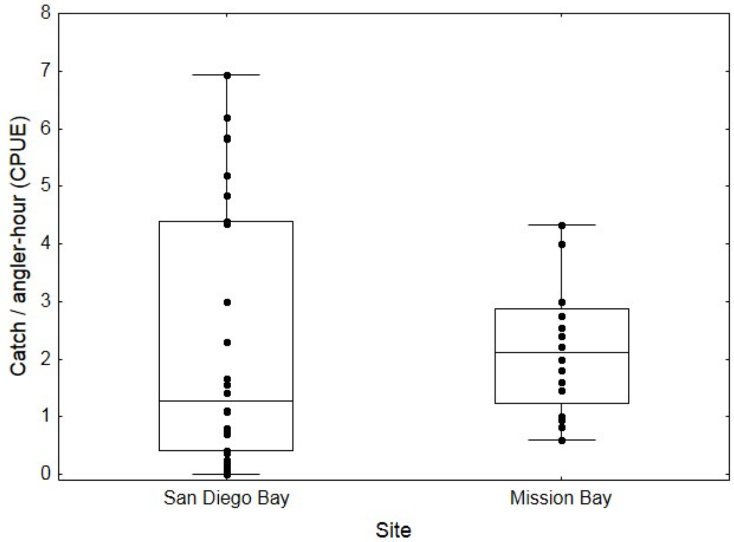

Figure 4. Spotted Sand Bass CPUE by site, which include San Diego Bay (n = 26) and Mission Bay (n = 16). Data are based on private vessel trips when Spotted Sand Bass were the target species.

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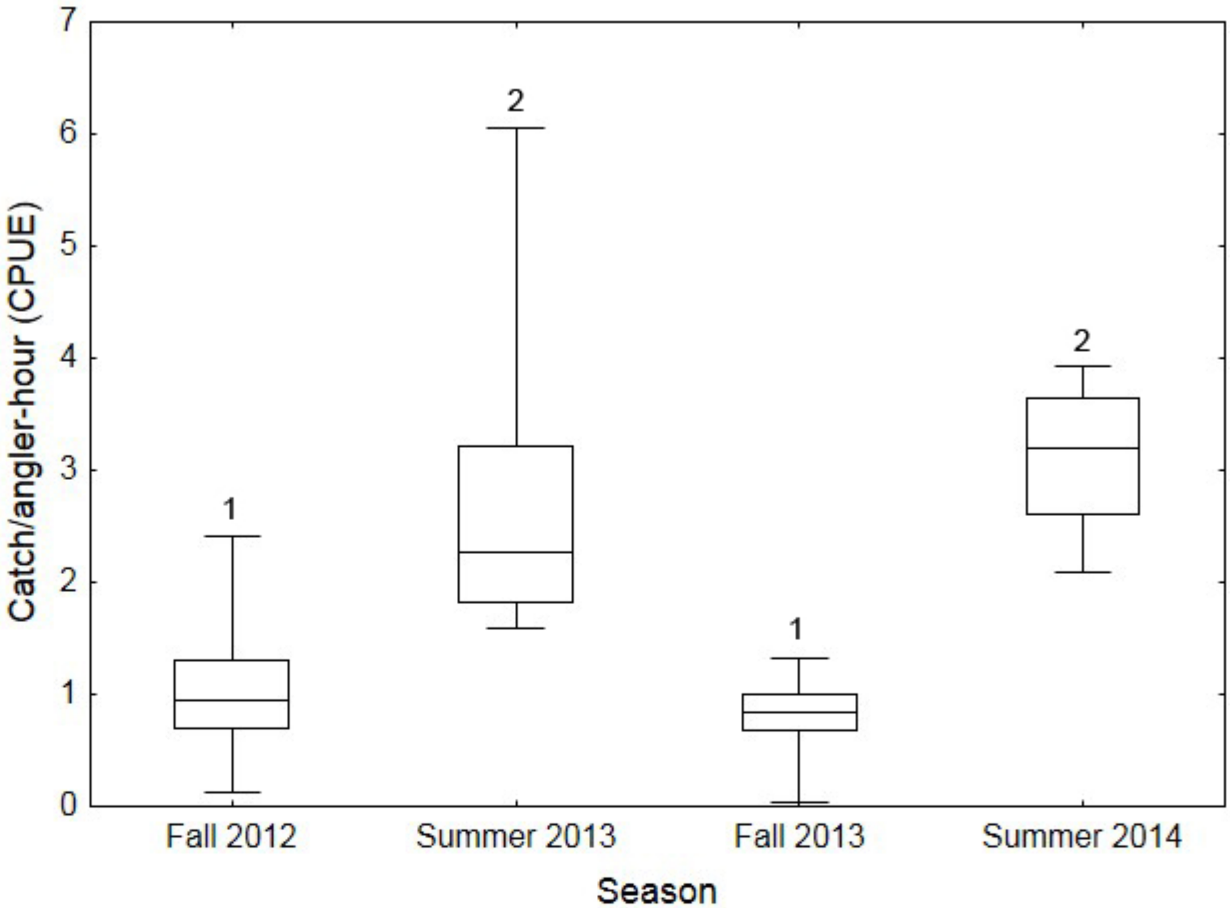

Figure 5. Boxplots of Kelp Bass CPUE by season, which includes fall 2012 (n = 11), summer 2013 (n = 8), fall 2013 (n = 12), and summer 2014 (n = 10). Fall trips were within Sept-Nov, and summer trips were within Jun-Aug periods. Numbers above each maximum represent groupings that resulted from Tukey's pairwise comparisons. Data only include CPFV charters when Kelp Bass were the target species.

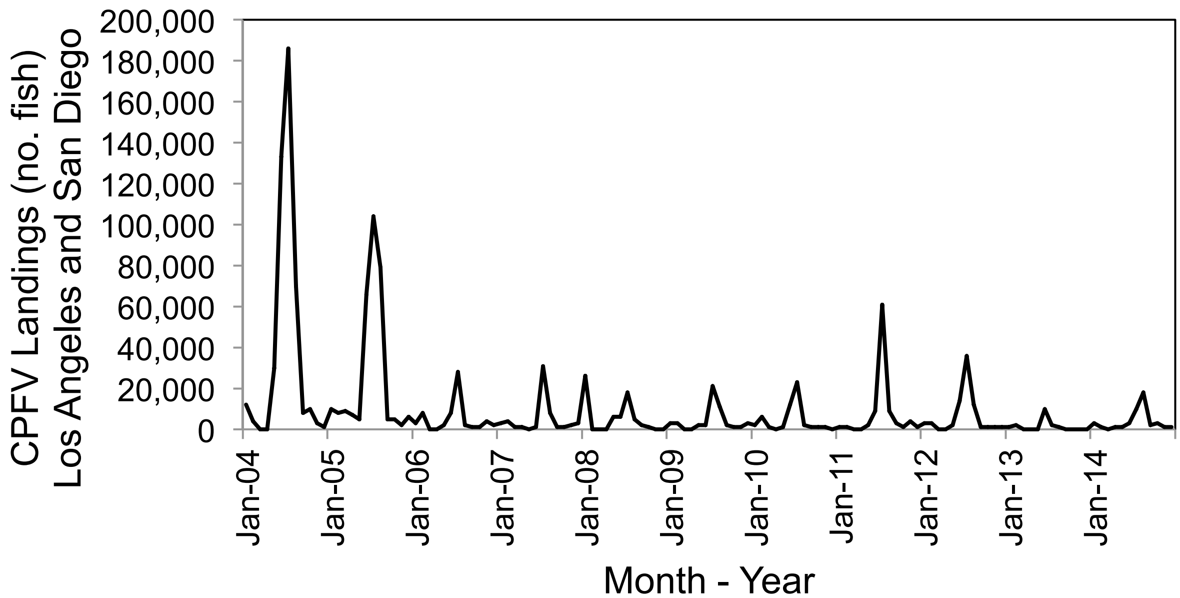

Figure 6. California Recreational Fisheries Survey (CFRS) estimates of monthly Barred Sand Bass landings aboard CPFVs based in Los Angeles and San Diego from Jan 2004 – Dec 2014.

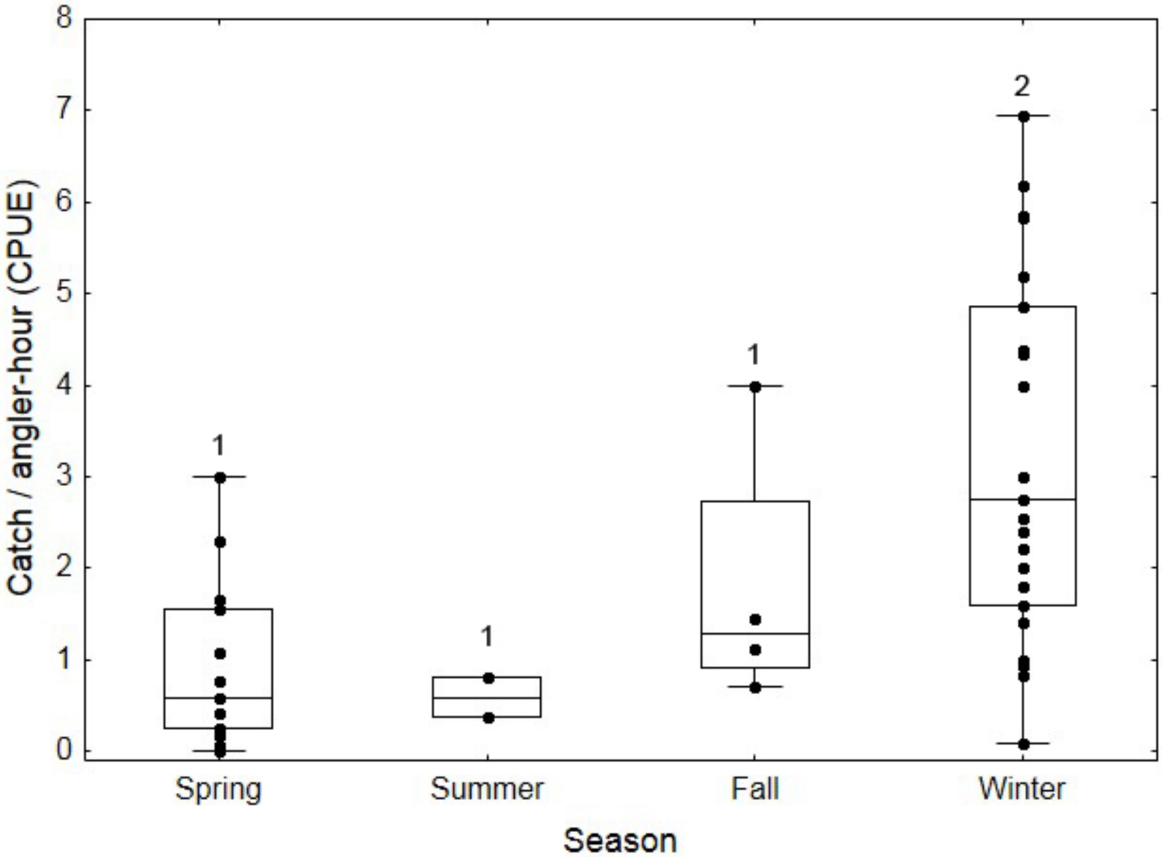

Figure 7. Boxplots of Spotted Sand Bass CPUE by season, spring (n = 13), summer (n = 2), fall (n = 4), and winter (n = 23). Numbers above each maximum represent groupings that resulted from Tukey's pairwise comparisons. Data only include private vessel trips in San Diego Bay and Mission Bay when Spotted Sand Bass were the target species.

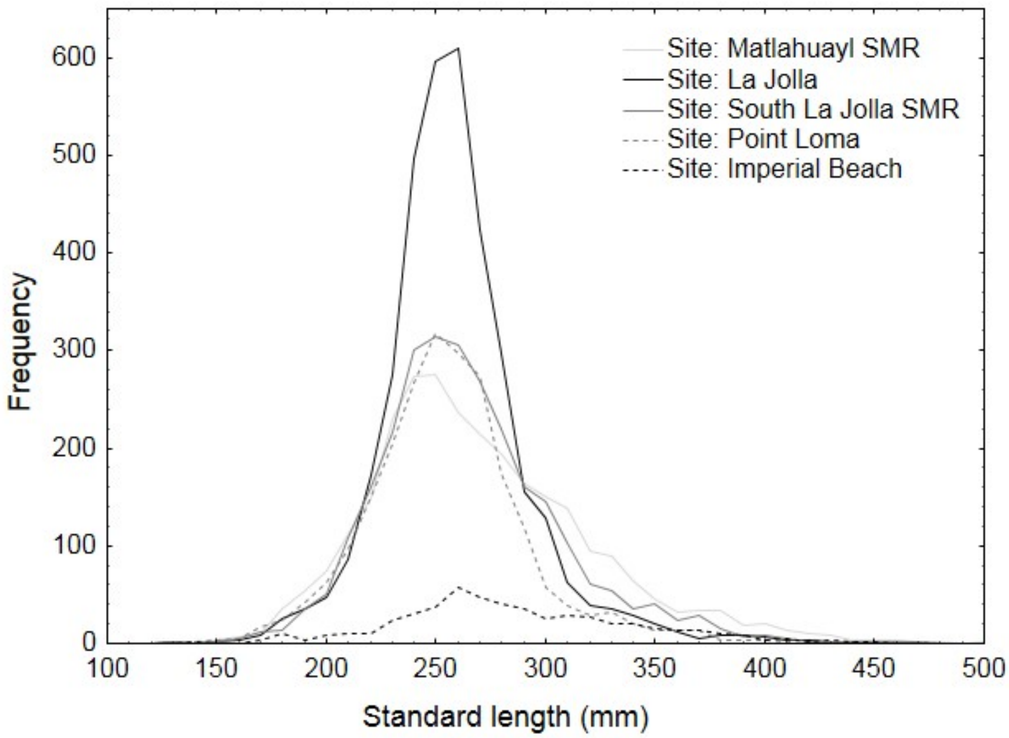

Figure 8. Kelp Bass length frequency distribution at the five primary sites off San Diego.

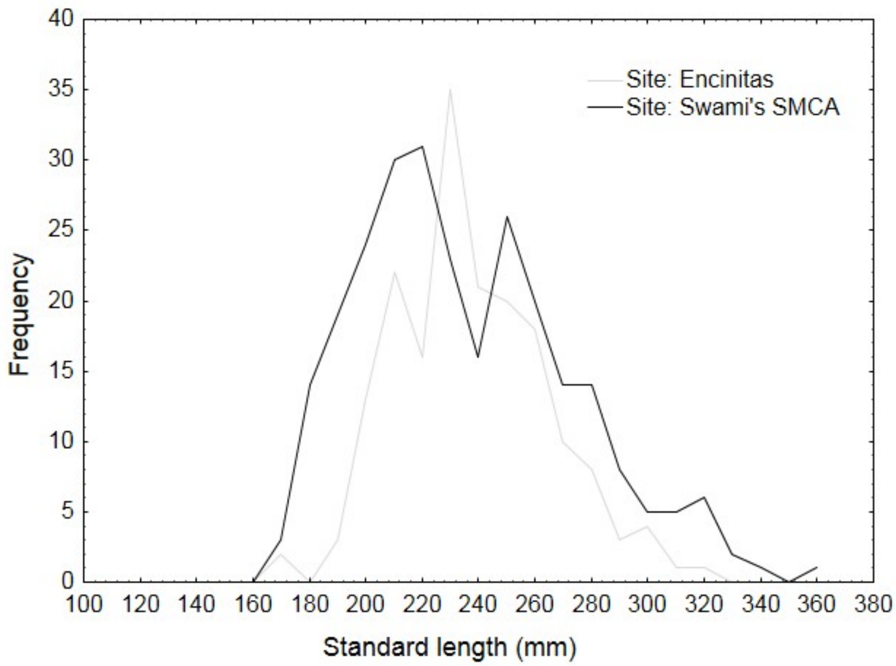

Figure 9. Kelp Bass length frequency by northern San Diego sites.

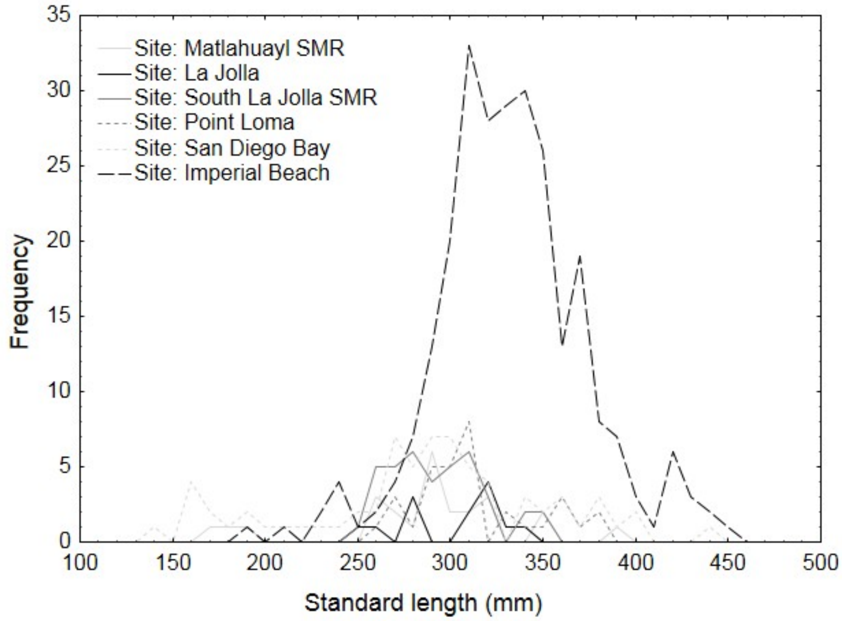

Figure 10. Barred Sand Bass length frequency by site.

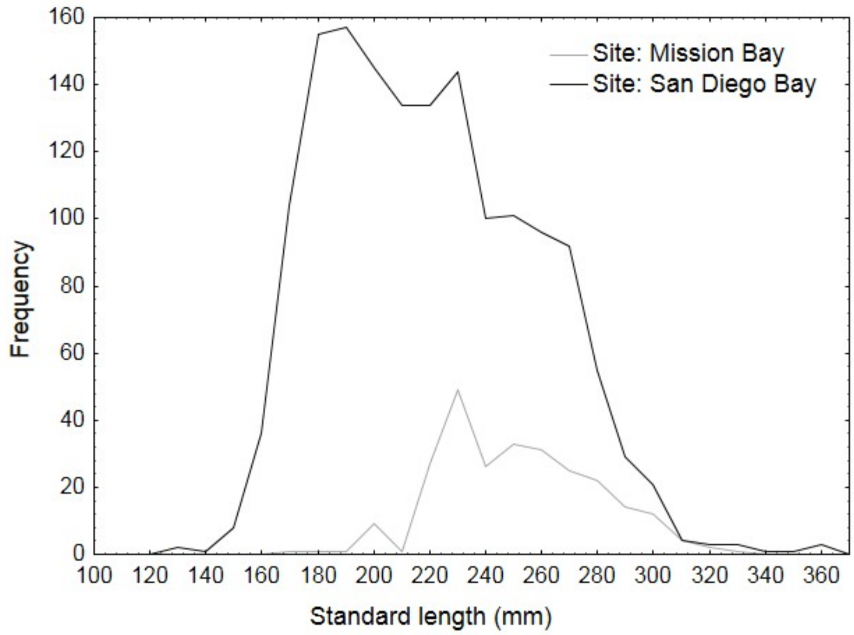

Figure 11. Spotted Sand Bass length frequency by site.

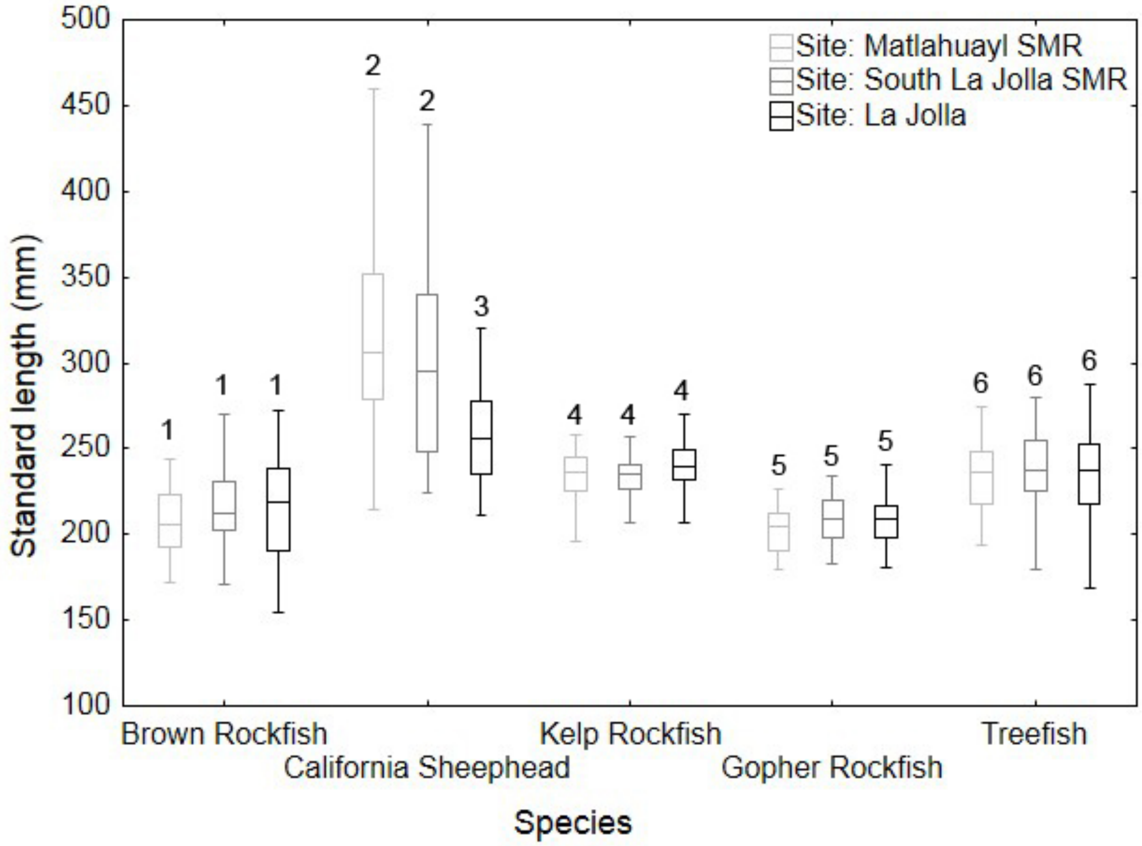

Figure 12. Boxplots showing size of the top five demersal bycatch species caught in the primary La Jolla sites. Numbers above each maximum represent groupings within each species that resulted from Tukey's pairwise comparisons.

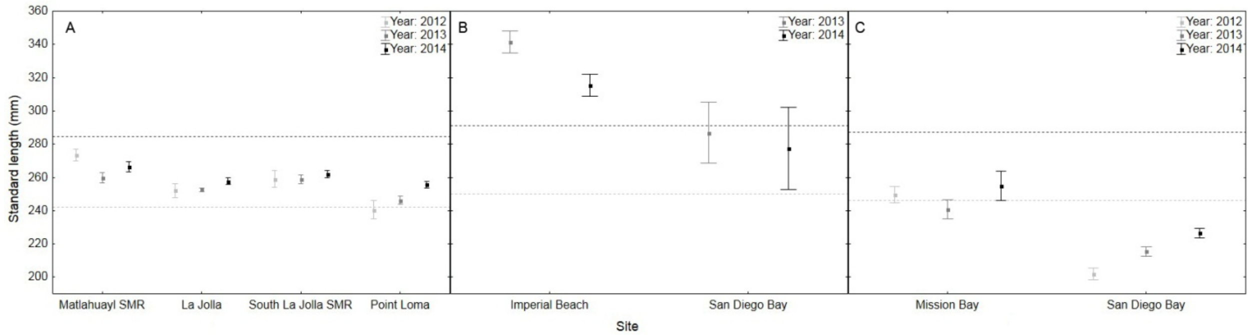

Figure 13. Mean (±95% CI) standard length of Kelp Bass (A), Barred Sand Bass (B), and Spotted Sand Bass (C) across primary sites during each of the three sampling years. The gray dashed lines mark the original minimum size limit in 2012 converted to standard length (12 inches total length), and the black dashed line represents the new increased minimum size limit (14 inches total length) that was implemented on March 1, 2013.

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PART II

Title: Movement and behaviors of three species of *Paralabrax* using both tag-recapture and acoustic telemetry methods in the coastal marine region of San Diego, California

Introduction

Scientifically informed spatial management initiatives can be successful for recovering and maintaining healthy fish stocks. A classic example of this is the well documented sockeye salmon (*Oncorhynchus nerka*) fishery in Bristol Bay, Alaska where record returns have recently been the product of both favorable environmental conditions and management policies informed by spatially explicit stock structure information (Hilborn et al. 2003). In California, spatial management policies were recently implemented in the form of a statewide network of marine protected areas (MPAs) from 2007-2012. This development process was based largely on lessons learned from the very first MPA network implementation process in California, which focused on the Northern Channel Islands in 2003 (Botsford et al. 2013, Gleason et al. 2013). Hamilton et al. 2010 conducted an evaluation of this MPA network, and found significantly greater densities and biomass, primarily of popularly fished species, inside the boundaries after only 5 years of protection. This is especially important given the social, economic, and ecological importance of fishing in California (NMFS 2013).

California has a 120-year documented history of recreational and commercial fishing (Ries 1997) with approximately 70% of the annual fishing effort occurring in southern California (CDFW 2014), yet the necessary science to inform local stock assessments is often limited, and the population status of some species is still unresolved. For example, recent debates regarding the population status of two species of *Paralabrax* in southern California have highlighted data deficiencies that still exist even among these extremely popular fisheries (Erisman et al. 2011, Jarvis et al. 2014a). These species represent ideal examples of the importance fish behavior in influencing fisheries management because they are heavily targeted and exhibit strong site fidelity (e.g., Lowe et al. 2003, Mason & Lowe 2010), and are thus among the most likely candidates to benefit from the spatial protection afforded by MPAs (Gell & Roberts 2003). Despite the importance of understanding fish movements, this information is still a primary source of uncertainty in assessing fish populations (Grüss et al. 2011). Data specific to movement patterns and habitat use of coastal demersal species in southern California is still limited to only a few species, frequently at only one or two sites (e.g., Lowe et al. 2003, Topping et al. 2005, Bellquist et al. 2008, Mason & Lowe 2010, McKinzie et al. 2014). Our limited knowledge of fish movements thus leads to inefficiencies in fisheries management, with an incomplete understanding of the effectiveness of MPAs and a failure to account for spawning habitats in fisheries management plans.

All three locally common species in the genus *Paralabrax*, Kelp Bass (*P. clathratus*), Barred Sand Bass (*P. nebulifer*), and Spotted Sand Bass (*P. maculatofasciatus*) are ecologically, economically, and socially important in southern California and Mexico. California Commercial Passenger Fishing Vessel (CPFV) logbooks indicate that Kelp Bass and Barred Sand Bass are likely among the top three most frequently landed species during the entire documented history of California recreational fishing (Hill and Schneider 1999), with approximately 45.3 million fish landed from 1936-2008. Jarvis et al. 2014a note that private boaters land an additional 31% of all three species combined. In total, recreational angling and harvest of these species have a broad range of biological and economic impacts in California. The angling community thus cares deeply about gaining the necessary data to ensure the long-term health of the stocks, and being a part of the fisheries management process (Sholz et al. 2004).

Our goal was to measure movement patterns of all three species of *Paralabrax* in the San Diego coastal area within a network of MPAs, while most studies typically focus on movement within individual MPAs. .To do this, we used tag-recapture methods to assess coarse-scale movements for all three species, and acoustic telemetry to generate a more detailed spatial and temporal record of the behaviors of both Kelp Bass and Barred Sand Bass. Acoustic telemetry was not used for Spotted Sand Bass because this species inhabits bays and estuaries, which are separate from the coastal rocky reefs inhabited by Kelp Bass and Barred Sand Bass. Using the telemetry data, we assessed the movement and behavioral patterns of the two species in the context of reproductive season and spatial management in Southern California, and provide estimates of the proportional use or reserves, and frequency of spillover. Spillover in this case is defined as any individuals crossing from MPAs to areas open to fishing, independent of the influences of conspecific densities. Using both tag-recapture and acoustic telemetry, we provide an estimate of the extent of protections afforded by reserves off of La Jolla, and characterize the temporal extent and spatial location of Barred Sand Bass spawning behaviors.

Methods

Study Sites

Our study sites were located primarily along coastal San Diego County, one of the three primary centers of recreational fishing in California, which also include Los Angeles and San Francisco. While we tagged a small number of individuals off Los Angeles and Orange Counties, our primary tagging sites from north to south consisted of Matlahuayl State Marine Reserve (SMR), La Jolla, South La Jolla SMR, Mission Bay, Point Loma, San Diego Bay, and Imperial Beach (Fig. 1). Matlahuayl SMR has been protected from all fishing since 1971, while the South La Jolla SMR was implemented in January 2012. The La Jolla, Point Loma, Mission Bay, and San Diego Bay sites have always been open to recreational fishing. Mission Bay was historically a tideland that was dredged and reshaped into a recreation area in the late 1940s. Similarly, San Diego Bay has undergone substantial anthropogenic and urban modifications, with 37% of the shoreline owned and 19.8% of the total land and water area occupied by the U.S. Navy (San Diego Bay Integrated Natural Resources Management Plan, 2013, pg. 221). Traditionally, Barred Sand Bass spawning aggregations occur at the Imperial Beach site from June-August (Jarvis et al. 2010). Collectively, these sites represent a broad range of angler-targeted habitats and locations with differing spatial protections.

Tagging Methods

Movement patterns were measured using both tag-recapture methods and acoustic telemetry. Our tag-recapture methods consisted of standard Floy® T-Bar Anchor tags applied with Avery Dennison Mark III tagging guns. In total, we tagged 16,013 individuals of the three bass species combined over a 2 year period. Of these, we double-tagged 673 Kelp Bass in order to measure tag loss rates. Each tag was inserted in the dorsal musculature between the pterygiophores beneath the anterior portion of the dorsal fin (cite). Printed on each tag was the individual ID number as well as a phone number for reporting recaptures. We also created a website (www.cooperativefishtagging.org) and a freely available smartphone application (CatchReporter) for anglers to report tagged fish. Floy tag retention rates were measured by double-tagging a subsample of Kelp Bass, and recording subsequent recaptures of these individuals that had either both or only one tag remaining.

The acoustic telemetry approach consisted of Vemco model V13 coded acoustic transmitters, which only measure presence/absence near a receiver, and V13AP coded acoustic transmitters, which measure presence/absence, acceleration, and depth. Transmitters reported randomly within 100-200sec intervals, yielding an approximate battery life of 440-480 days after correcting for time of deployment. Fish were surgically fitted with either the V13 or V13AP transmitters using methods that mirrored other local telemetry studies (e.g., Lowe et al. 2003, Topping et al. 2005, Bellquist et al. 2008, Mason & Lowe 2010, McKinzie et al. 2013) under approved IACUC protocol S12116. After release, each tagged fish was detected by an array of 44 Vemco VR2W acoustic receivers attached to subsurface moorings at fixed locations (Fig. 2, www.LaJollaArray.org). Detections from coded transmitters provided receiver-specific presence/absence data, and for a subset of tags, depth and tag acceleration profiles at 2-minute intervals.

Data Analysis

Tag-recapture data were collected for all three bass species directly aboard the CPFV tagging charters and private boat trips, as well as from tag reports by recreational anglers. Anglers had the choice of reporting tags by calling the phone number printed on the tag, entering the tag information on the project website, or by submitting the information with a new smartphone application that we developed (CatchReporter). Recapture data were used to measure coarse-scale movement and recapture rates between sites both within the La Jolla kelp bed (encompassed by the array) and outside the La Jolla sites. We used linear regression to analyze the log of total distance traveled with respect to time at liberty and individual size at the time of tagging. Measurements of distance traveled were only possible when recapture locations had reliable latitude-longitude coordinates associated with them. Frequency distributions of time at liberty, distance traveled, and tag-recapture locations were generated, and logistic regression was used to estimate Floy® Tag loss rates over time based on recaptures of double-tagged individuals.

Acoustic telemetry data were used to measure seasonal movements of both Kelp Bass and Barred Sand Bass throughout the La Jolla kelp bed. All acoustic data were download managed in the Vemco NUE software. Analysis of variance and Tukey's post hoc tests were used to test for seasonal effects on depth and acceleration. The percent of detections at each receiver were plotted using a Geographic Information System (GIS), and split between seasons to show spatial changes in detection patterns for each species. The proportion of detections for each individual was also measured as a proxy for time spent inside/outside MPA boundaries.

Results

A total of 12,581 Kelp Bass, 1,079 Barred Sand Bass, and 2,353 Spotted Sand Bass were Floy tagged from Oct 2012 – Sep 2014 at 11 sites from Long Beach, California south to the U.S. - Mexico border. However, the majority of individuals were tagged at the primary sites off San Diego County (Fig. 1). A total of 1362 kelp bass, 49 Barred Sand Bass, and 90 Spotted Sand Bass recaptures were recorded during this period, with site-specific recapture rates ranging from 0-17.5% (Table 1). Among the Kelp Bass, 1,207 fish were recaptured once, 132 were recaptured twice, 22 were recaptured three times, and 1 individual was recaptured 4 times during the study period. Times at liberty among recaptures ranged from ~1 minute to 733 days (Figures 2-4), with

60 individuals recaptured on the same day they were tagged. In addition, a total of 41 Kelp Bass and 26 Barred Sand Bass were tagged with coded acoustic transmitters at the three La Jolla sites, which contained an array of 43 underwater acoustic receivers attached to fixed subsurface moorings (Fig. 5).

Tag Loss Rates

A total of 673 Kelp Bass were double tagged across multiple sites, and 113 of these were recaptured with one or both tags still attached. .Logistic regression revealed that the probability of Floy tag loss was related to time at liberty ($p < 0.001$). After 1 year at liberty, the probability of tag retention was approximately 80.8%, and decreased to 62% after 1.5 years, and 50% after 1.75 years (Fig. 6). Tag retention rates were not estimated for Barred Sand Bass or Spotted Sand Bass.

Movement based on tag-recapture

Tag recapture analyses show limited movements for all three bass species overall, with the majority of individuals recaptured at the site of original tagging (Tables 2-4). However, several instances of movement between sites were reported. For example, among the Kelp Bass recaptures that were originally tagged inside the Matlahuayl SMR, approximately 14.8% (71/481) were recaptured outside the SMR boundaries (3 of these were recaptured as far away as San Clemente, California). In comparison, among the 517 recaptures that were originally tagged in La Jolla (open to fishing), only 1.9% (10/517) were recaptured inside the adjacent Matlahuayl SMR boundaries. However, there is a much greater probability of fishing being recaptured outside the SMR boundaries because the area is open to fishing, and is subject to recaptures from the fishing community. Thus, if only data from tagging charters are taken into account (i.e. if we standardize for fishing effort), then 3.1% of fish that were tagged inside the SMR were recaptured outside, while 5.8% that were tagged outside the SMR were recaptured back inside the boundaries. The farthest distance recorded among all three species was a Barred Sand Bass that was tagged at Shelter Island in San Diego Bay, and recaptured 95.4 km away off Dana Point (Table 3). All Spotted Sand Bass were recaptured in the same bay they were originally tagged (Table 4). Kelp Bass showed no relationship between time at liberty and either total distance traveled (Fig. 7, $F = 2.47$, $df = 1$, $p = 0.12$) or standard length ($F= 2.89$, $df = 1$, $p = 0.09$), and almost 86.2% of individuals were recaptured within 1km of their tagging location, regardless of time at liberty (Fig. 8). Barred Sand Bass also showed no relationship between distance traveled and either time at liberty ($F = 3.20$, $df = 1$, $p = 0.08$) or standard length ($F = 2.15$, $df = 1$, $p = 0.15$), although relatively few recaptures were reported with reliable spatial information to allow travel distance calculations (Fig. 9). Spotted Sand Bass showed no significant relationship between distance traveled and either time at liberty (Fig. 10, $F= 3.03$, $df = 1$, $p = 0.09$) or standard length ($F = 3.17$, $df= 1$, $p = 0.08$), and no individuals traveled between San Diego Bay and Mission Bay. Only 42.6% (640) of our total recaptures were recorded directly on CPFV tagging charters, while the remaining 57.4% (861) were reported by the recreational fishing community. Of the tags reported by anglers, 13.1% of these were reported directly to the SIO researcher via community contacts that we developed during the course of the project.

Movement and behavior based on acoustic telemetry

Acoustic telemetry results provide additional detail to movement analyses for both Kelp Bass and Barred Sand Bass. Both species showed distinct seasonal differences in depth utilization (Fig. 11). Kelp Bass used shallower depths from Jun-Aug in both 2013 and 2014 relative to winter months, although these vertical summer movements were shallower in 2013 than 2014. Barred Sand Bass also showed shallower depth use with greater variability during the summer, but the time period of these vertical movements ranged from Apr-Aug, and was generally deeper than for Kelp Bass. In addition, from Sep 2014 – Jan 2015 (outside spawning season), Barred Sand Bass depth remained relatively shallow, but decreased in monthly variability. Seasonal differences are also apparent for both species with respect to acceleration (Fig. 12), which we assume to reflect the general activity levels of individuals. Both species showed greater activity during the summer months of both 2013 and 2014, and Kelp Bass showed slightly greater activity than Barred Sand Bass for almost every month. Variability in activity was generally similar for both species across all months.

In addition to vertical and behavioral measurements, seasonal horizontal movement was measured for both species between the three La Jolla sites. Kelp Bass did not show strong seasonal differences in detections at specific receivers. However, Barred Sand Bass showed southward movements during late spring and early summer to the southern end of the South La Jolla SMR, which is an area dominated by broad sand flats adjacent to kelp forest habitat (Fig. 13). Two example individuals are shown to migrate from northern La Jolla to the South La Jolla SMR (Fig. 13a), and from central La Jolla to the South La Jolla SMR (Fig. 13b). Upon reaching this broad sand flat, both individuals began vertical movements (and greater acceleration) that are consistent with known spawning behaviors (McKinzie et al. 2014). One individual only showed vertical behavior for a brief period of time (Fig. 13a), likely because this fish was primarily using an area just outside the detection range of the receivers. However, the other individual showed strong vertical movements from early June to late August, which gives an estimate of potential spawning duration for this individual. This duration is consistent with spawning estimates from batch fecundity analyses (Jarvis et al. 2014b). Detections for both species decreased at the end of 2014 because this was the projected end date of the transmitter batteries.

Kelp Bass showed the majority of time spent within the sites where they were originally tagged (Fig. 14), while Barred Sand Bass exhibited more regular movements between the La Jolla Sites (Fig. 15). Figure 14a shows 11/15 Kelp Bass that were tagged inside the Matlahuayl SMR were detected over 90% of the time inside the SMR, while the remaining 4 individuals showed regular movements to adjacent outside areas. Conversely, Fig. 15c shows Barred Sand Bass that were tagged inside the South La Jolla SMR showed a much broader range of percent detections inside vs. outside the SMR. While spatial patterns in detections are largely dependent upon where individuals were initially tagged, we achieved relatively even spatial distribution of tags deployed (Fig. 5a). Overall, Kelp Bass and Barred Sand Bass showed 72.7% and 15.7% of all detection inside the SMRs, respectively (Table 5).

Discussion

Understanding fish movement patterns is essential for fisheries management, especially given the relatively recent development of spatially explicit stock assessment models that are beginning to inform new marine spatial planning initiatives (Hilborn 2012). Past stock assessments for demersal species in southern California often assumed no movement among individuals (e.g., Key et al. 2005), but studies are showing that some species travel much farther than originally thought. For example, Hanan & Curry 2012 found that nine species of rockfish

(*Sebastes sp*.) were recaptured greater than 50km from their initial tagging site in southern California. Such information provides a more complete knowledge base of fish behaviors that can be used to inform fisheries management more effectively.

While fine-scale movement patterns have been studied for kelp bass (Lowe et al. 2003) and barred sand bass (Mason and Lowe 2010), these studies were both conducted at the same individual MPA site at Santa Catalina Island. A benefit of conducting similar research along the mainland coast was that it allowed us to measure movement patterns relative to a network of MPAs rather than a single MPA. In addition, habitat and bathymetric characteristics differ between the islands and the mainland, so movement patterns of these two species are likely to be different between the two regions. Barred Sand Bass are also generally more abundant along the mainland coast, so research focusing on mainland movements represents additionally valuable information about the stock. Jarvis et al. 2010 used tag-recapture data from both the 1960s and 1990s to document seasonal spawning aggregations of Barred Sand Bass along the mainland. In addition McKinzie et al. 2013 used acoustic telemetry to measure fine-scale spawning and non-spawning behaviors of Barred Sand Bass at one of these aggregations sites off Huntington Beach, California. However, the data from these two studies were collected while the Barred Sand Bass were still following traditional spawning behavior at historically consistent aggregation sites. In both 2013 and 2014 there was a virtual absence of spawning aggregations at the traditional sites in southern California.

Our tag-recapture results varied by species and by site, with the greatest success being achieved largely with Kelp Bass in the La Jolla and Point Loma sites, and with Spotted Sand Basses in San Diego Bay. Overall recapture rates were 10.83% for Kelp Bass, 4.54% for Barred Sand Bass, and 3.82% for Spotted Sand Bass, and these rates are growing because we are still collecting new recapture reports from anglers. Floy tag retention rates were sufficiently high to measure movements over relatively long time periods for Kelp Bass (almost 2 years), but retention rates were not measured for the other two congeners. Given that 60 Kelp Bass were recaptured on the same day they were tagged, and that time at liberty was as short as ~1 minute, it appears that catch-and-release fishing imposes surprisingly low stress on the species. On the other hand, at least some individuals are adversely impacted by harvest, with 1.7% suffering initial mortality upon capture, and an additional 3.1% succumbing over an extended period of time.

The vast majority of Kelp Bass were recaptured within 1km of their tagging site regardless of time at liberty. Collyer and Young 1953 reported the first known tag-recapture results for Kelp Bass, and found similarly limited movements among the majority of recaptured Kelp Bass. Young 1963 also found similar results, with 364/458 individuals recaptured at the same site as initial tagging. In our study, movements relative to the Matlahuayl SMR boundaries showed similarly low rates of between-site movement for Kelp Bass. While most results a show limited scale of movement for Kelp Bass, several individuals in our study traveled up to 80km from the initial tagging site. Kelp Bass are not known to migrate such distances for spawning purposes, and there was no relationship between individual size and distance traveled, so the reasons behind these rare but distant movements remain unclear.

Annual spawning migrations are exhibited by Barred Sand Bass, and their spawning aggregation sites are highly predictable, well-documented, and heavily targeted by recreational fishing fleets (Turner et al. 1969; Feder et al. 1974; Love et al. 1996a,b; Jarvis et al. 2010). The primary aggregation site off San Diego is the broad sand flat off the coast of Imperial Beach and Tijuana, Mexico (Jarvis et al. 2010). Our sampling effort was designed to take advantage of this aggregation site, and tag a large number of individuals with relatively few trips during the spawning season. However, Barred Sand Bass exhibited a virtual absence of traditional spawning behavior during the summer in 2013 and 2014, not only in this aggregation site, but in all known southern California sites (e.g., Imperial Beach, San Onofre, Huntington Beach flats, Santa Monica Bay, and Ventura Flats). As a result, the majority of Barred Sand Bass were tagged at isolated rocky reefs off Imperial Beach during the spawning season (summer), and in San Diego Bay outside the spawning season (winter). Our tag-recapture results did show the majority of movement occurring between Imperial Beach, San Diego Bay, and Point Loma, so it is possible that individuals that make up the spawning aggregation at Imperial Beach generally come from the three sites combined. However, sample sizes are too low for a definitive conclusion. This is cause for serious concern given not only the susceptibility of aggregating species to overfishing, but also that fishing has already caused the depletion of other fishes that exhibit similarly predictable aggregating behaviors in other places (Sadovy & Eklund 1999, Sala et al. 2001, Whaylen et al. 2004).

While tag-recapture methods were not as successful as we hoped for quantifying movements at the Imperial Beach spawning site, acoustic telemetry methods did shed light on potential spawning behaviors in southern La Jolla. Seventy percent of Barred Sand Bass tagged with acoustic transmitters showed clear affinity for an area just south of the South La Jolla SMR during their known spawning season (Jarvis et al. 2014b). This area is a broad sand flat adjacent to kelp forest habitat, which is consistent with the depth and habitat at other known spawning aggregation sites. Some of these fish traveled from as far away as Matlahuayl SMR directly to this area, and upon arrival, all individuals performed daily vertical migrations in the water column with greater acceleration rates. All of these behaviors are consistent with known spawning behaviors at other known spawning sites (McKinzie et al. 2014). Kelp Bass also exhibited vertical migrations, but this occurred at areas around the entire La Jolla kelp bed, and there were clear differences between the two species in vertical behaviors. Kelp Bass ascended high in the water column during the spawning season in June and July, with a consistent vertical separation from the benthic substrate during these months. This was based on the depth of the tagged individual relative to the known depths surrounding each receiver where fish were detected. Barred Sand Bass also rose vertically in the water column during their spawning period but consistently returned to the bottom, i.e. did not remain high in the water column for extended periods of time like Kelp Bass. If Barred Sand Bass were spawning in this area, then this is the first quantitative documentation to our knowledge of this spawning aggregation site, which is partially protected by the boundaries of the South La Jolla SMR. In winter of 2014-2015, it appears as though Barred Sand Bass remain high in the water column, but these individuals simply moved to shallower areas while staying near the bottom.

Despite our findings of a potentially new spawning aggregation site, Barred Sand Bass did not form their traditional aggregation off Imperial Beach during our sampling period. Rather, smaller aggregations were located by the CPFV fleet and heavily targeted in the Point Loma and Imperial Beach kelp forests. The aggregation site in south La Jolla may be another of these smaller aggregation sites that apparently occurred in the absence of the larger primary aggregation site. This new shift in spawning behavior may be a result of significant declines in landings since 2005 (Jarvis et al. 2014), and should be addressed by management agencies in both California and Mexico. Aburto-Oropeza et al. 2008 note that Barred Sand Bass are a commercially important species targeted along the Baja California coast, and it is essential to understand whether other aggregation sites in Baja are exhibiting similar trends to those in southern California.

The array of acoustic receivers distributed throughout the three La Jolla sites allowed us to assess the protections afforded individuals by the existing MPA network. Kelp Bass exhibited very limited movement between the three La Jolla sites, with most individuals being detected almost entirely at the site where they were initially tagged. Barred Sand Bass exhibited greater rates of exchange between inside and outside sites, suggesting that the MPA network in La Jolla affords less protection for Barred Sand Bass than for Kelp Bass. This is especially true given that much of the spawning aggregation behaviors observed for Barred Sand Bass occurred just outside of the South La Jolla SMR. The trans-boundary movements of individuals documented in this study may or may not represent instances of density-dependent spillover, but fish of both species are clearly leaving the MPA boundaries for varying periods of time.

Spotted Sand Bass exhibit complex spawning behaviors and spatial variation in protogynous hermaphroditism (Hastings 1989, Allen et al. 1995, Hovey & Allen 2000). Allen et al. 1995 suggest that Spotted Sand Bass form spawning aggregations at the entrance of bays and estuaries during late spring and summer, although their sources are primarily anecdotal. While we did find areas within San Diego Bay that were characterized by exceptionally high catch rates, these areas were sampled outside the summer spawning season. In San Diego Bay, tagged fish from the southern portion of the bay were generally smaller and caught at shallower depths, while larger individuals were caught in the northern portion and in deeper channels. This segregation of size classes may be due to an ontogenetic shift from shallow eelgrass (*Zostera marina*) flats to deeper channel habitats. A more prolonged and intensive mark-recapture study would be required to definitively demonstrate this shift.

The success of this project was largely due to our collaborative partnerships with the southern California fishing community, the California Department of Fish and Wildlife, and the San Diego Oceans Foundation. The level of cooperation between these stakeholder groups yielded significant benefits, especially with respect to data quality and quantity, as well as strong collaborative relationships for future projects. Our final recapture rates show that 57.4% of our total recaptures were reported by the recreational fishing community. The support we received from the recreational fishing community with respect to tagging efforts and recapture reporting was thus fundamental to our success, and the Sportfishing Association of California was a strong facilitator of this collaborative progress.

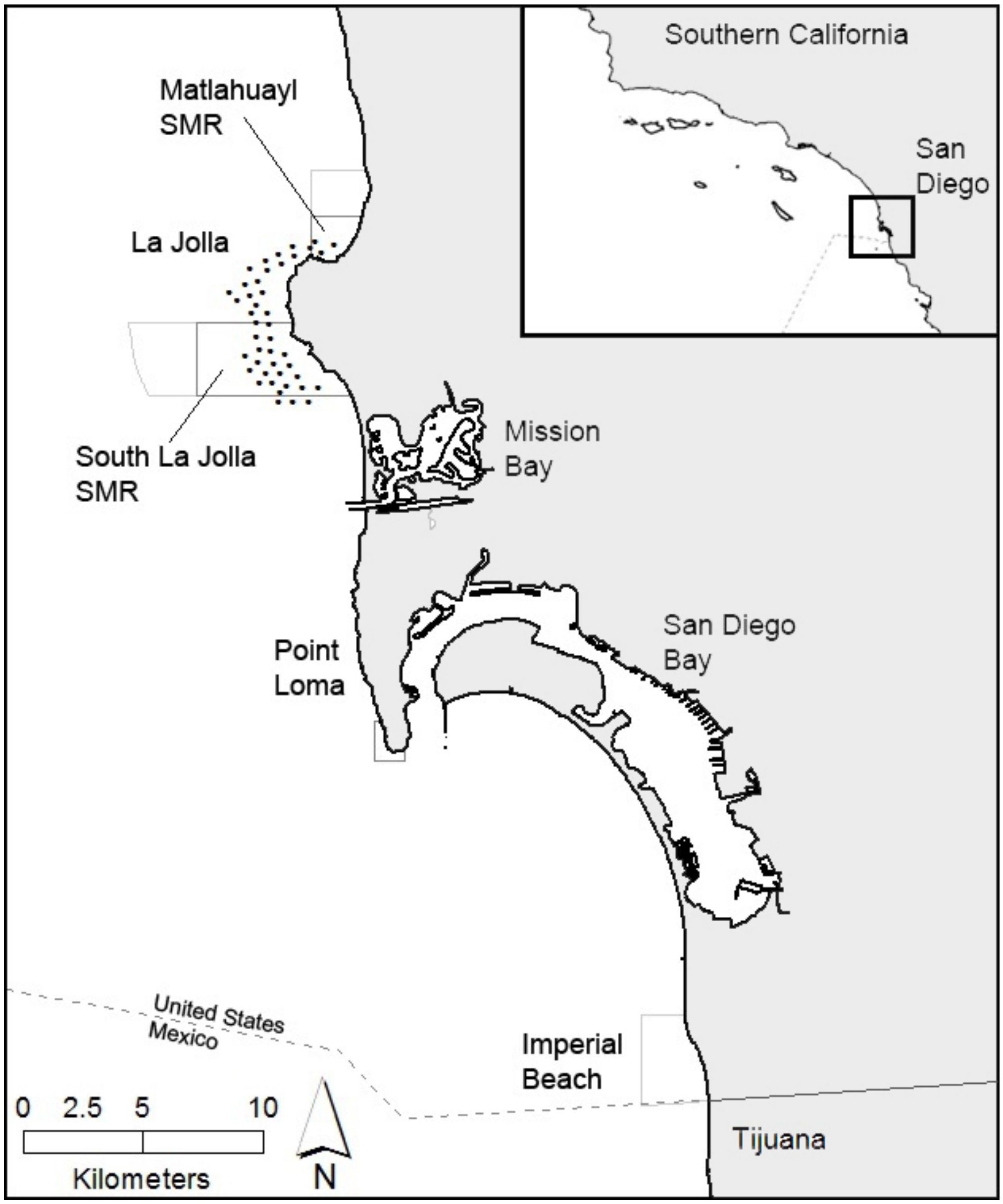

Figure 1. Site map of the San Diego coastal area. Gray solid lines represent MPA boundaries, specifically the Matlahuayl and South La Jolla SMRs. The gray dashed line represents the U.S.-Mexico maritime border. Black dots in the three La Jolla sites represent fixed locations of Vemco VR2w acoustic receivers attached to subsurface moorings.

	Kelp Bass		Barred Sand Bass		Spotted Sand Bass	
Site	Tagged	Recapture Rate	Tagged	Recapture Rate	Tagged	Recapture Rate
LB	82	4.88	37	2.70		
NB					22	9.09
NC	452	8.41	70	2.86		
M	2766	15.18	25	4.00		
LJ	3523	15.38	13	7.69		
SLJ	2670	1.80	35	2.86		
MB	185	9.19	15	6.67		
MBy	4	0	1	0	363	6.34
PL	2300	9.83	40	17.50		
SDB	71	4.23	577	3.99	1968	3.30
IB	528	4.17	266	4.14		
Total	12581	10.83	1079	4.54	2353	3.82

Table 1. Total number of individuals tagged and percent recapture rates for each of the three species by tagging site. Sites include Long Beach (LB), Newport Bay (NB), north San Diego County (NC), Matlahuayl SMR (M), La Jolla (LJ), South La Jolla SMR (SLJ), Mission Beach (MB), Mission Bay (MBy), Point Loma (PL), San Diego Bay (SDB), and Imperial Beach (IB).

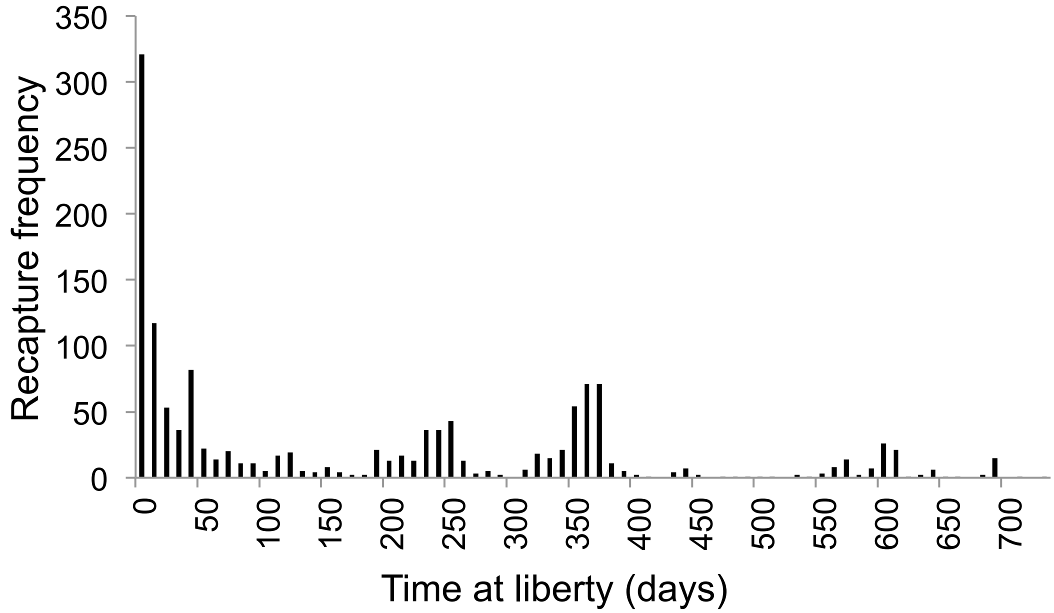

Figure 2. Kelp bass recapture frequency. Data only include the most recent recapture for each individual.

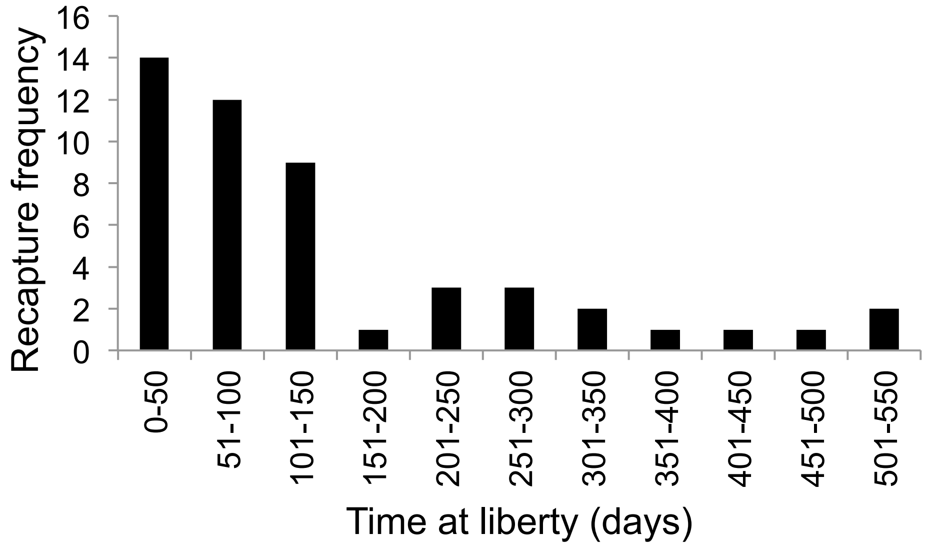

Figure 3. Barred sand bass recapture frequency. Data only include the most recent recapture for each individual (excluding tournaments).

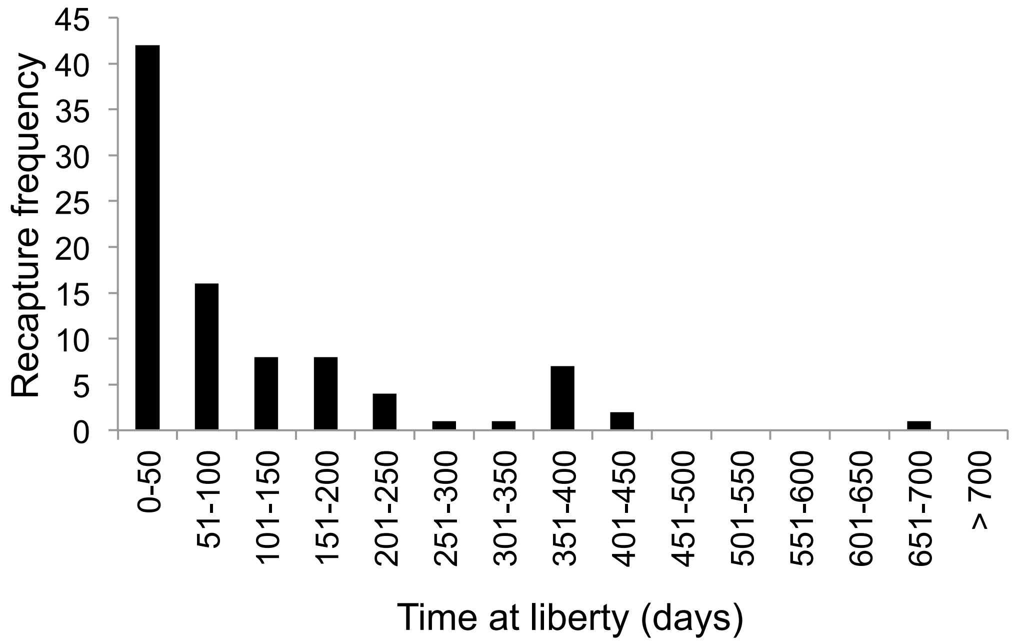

Figure 4. Spotted sand bass recapture frequency. Data only include the most recent recapture for each individual (excluding tournaments)

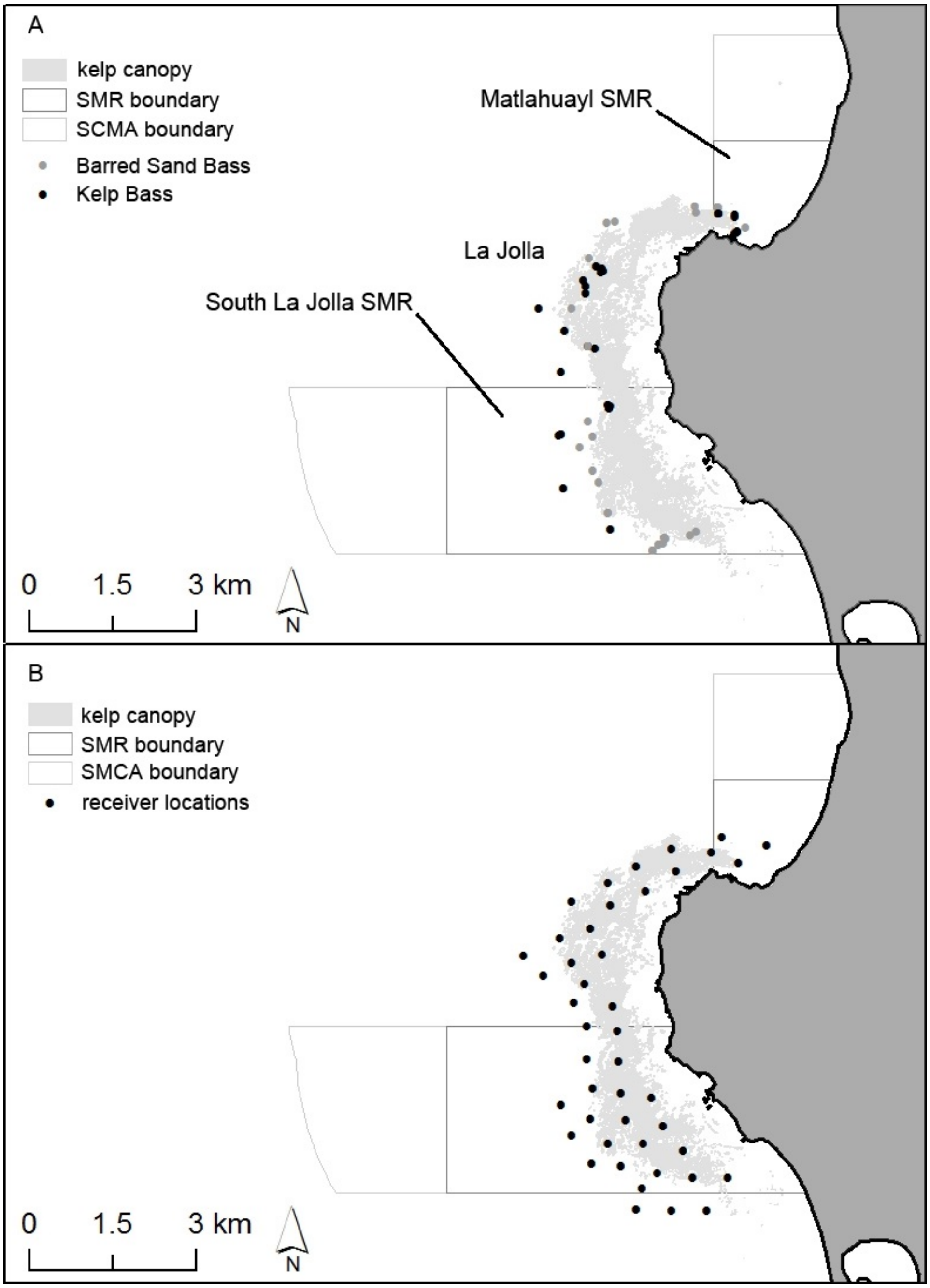

Figure 5. Map of acoustic transmitter deployment locations for Kelp Bass and Barred Sand Bass (a), and map of the array of acoustic receivers at the three La Jolla sites (b). The dark gray area represents land, and the light gray polygon represents the average spatial extent of the La Jolla kelp forest. In panel A, the black and gray dots represent acoustic tagging locations of Kelp Bass and Barred Sand Bass, respectively. In panel B, each black dot represents the location of a Vemco VR2W acoustic receiver attached to a subsurface mooring.

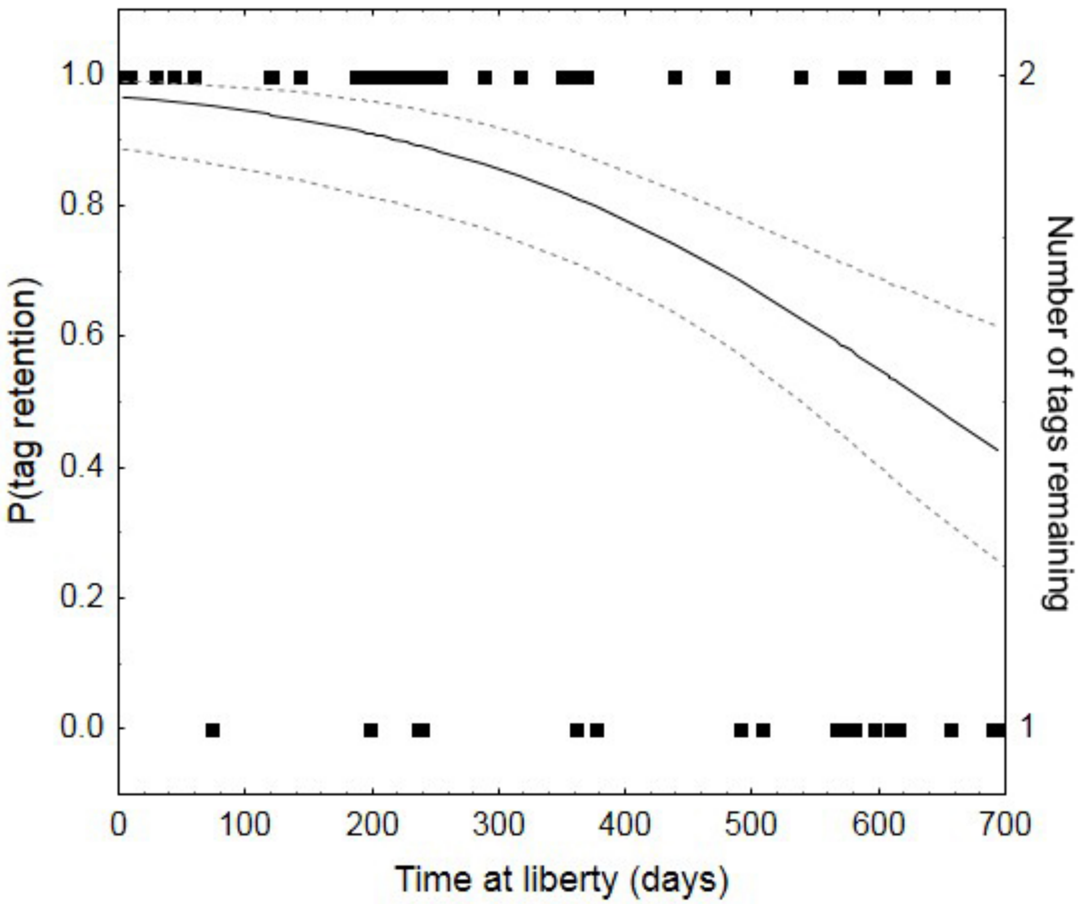

Figure 6. Logistic regression results showing the probability of tag retention over time among double-tagged kelp bass. The solid black line represents the predicted values of tag retention probability, and the dotted lines represent upper and lower 95% confidence limits. Black points along the top and bottom are shown relative to the secondary (right) Y-axis, and represent double-tagged individuals that were recaptured with both tags and only one tag remaining, respectively.

		Recapture Sites											
	Site	LB	SC	NC	M	LJ	SLJ	MB	MBy	PL	SDB	IB	Unk	Total
Tagging Sites	LB	4												4
	SC													0
	NC			33						2				35
	M		3	4	409	60	1	1	2				1	481
	LJ			1	10	465	7	3	3	3			25	517
	SLJ		1			14	40	2	1	1			2	61
	MB					1		5		1				7
	MBy													0
	PL		1		1	2				214		1	7	226
	SDB										3			3
	IB									5		21	2	28
	Total	4	5	38	420	542	48	11	6	226	3	22	37	1362

Table 2. Kelp Bass recapture frequencies for the following tagging and recapture sites: Long Beach (LB), San Clemente (SC), north San Diego County (NC), Matlahuayl SMR (M), La Jolla (LJ), South La Jolla SMR (SLJ), Mission Beach (MB), Mission Bay (MBy), Point Loma (PL), San Diego Bay (SDB), Imperial Beach (IB), and unknown location (Unk).

		Recapture Site												
	Site	LB	DP	NC	M	LJ	SLJ	MB	Mby	PL	SDB	IB	Unk	Total
Tagging Site	LB	1												1
	DP													
	NC			1										1
	M				1									1
	LJ					1								1
	SLJ						1							1
	MB							1						1
	Mby													
	PL													
	SDB		1							6	20	5	1	33
	IB									1	3	6		10
	Total	1	1	1	1	1	1	1		7	23	11	1	49

Table 3. Barred Sand Bass recapture frequencies for the following tagging and recapture sites: Long Beach (LB), Dana Point (DP), north San Diego County (NC), Matlahuayl SMR (M), La Jolla (LJ), South La Jolla SMR (SLJ), Mission Beach (MB), Mission Bay (MBy), Point Loma (PL), San Diego Bay (SDB), Imperial Beach (IB), and unknown location (Unk).

		Recapture Site			
	Site	NB	MBy	SDB	Total
Tagging Site	NB	2			2
	MBy		22		22
	SDB			65	65
	Total	2	22	65	89

Table 4. Spotted Sand Bass recapture frequencies for the following tagging and recapture sites: Newport Bay (NB), Mission Bay (MBy), and San Diego Bay (SDB). No individuals were recorded traveling between these sites.

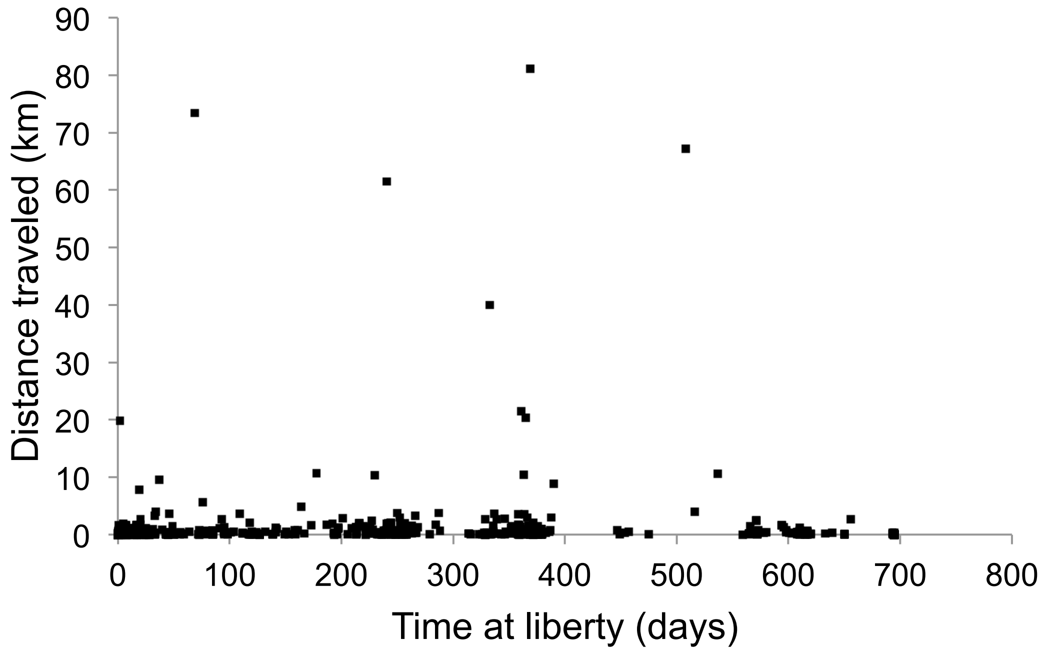

Figure 7. Total distance traveled by kelp bass.

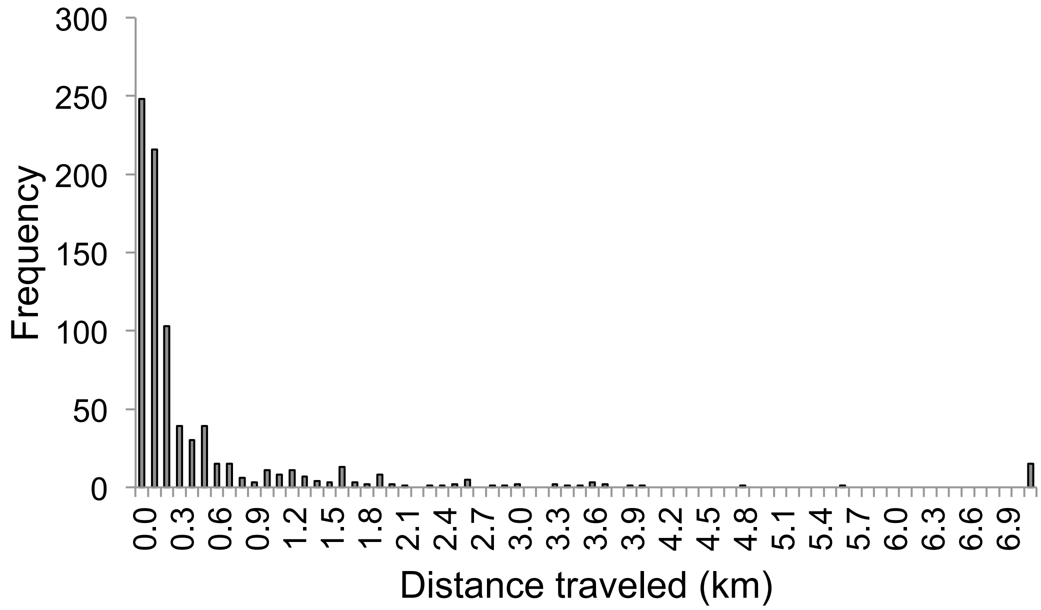

Figure 8. Frequency distribution of total distance traveled by kelp bass.

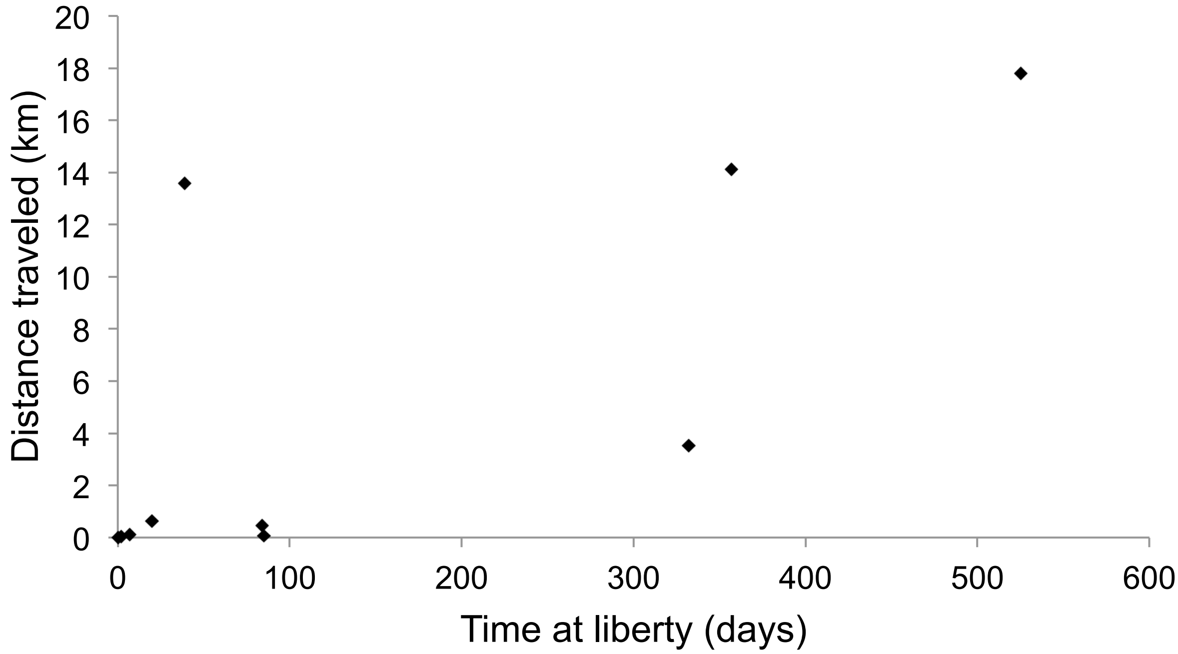

Figure 9. Total distance traveled by barred sand bass (excluding tournaments). One individual traveled 95.4 km over 59 days, but was not included in the figure for the purposes of viewing the other points.

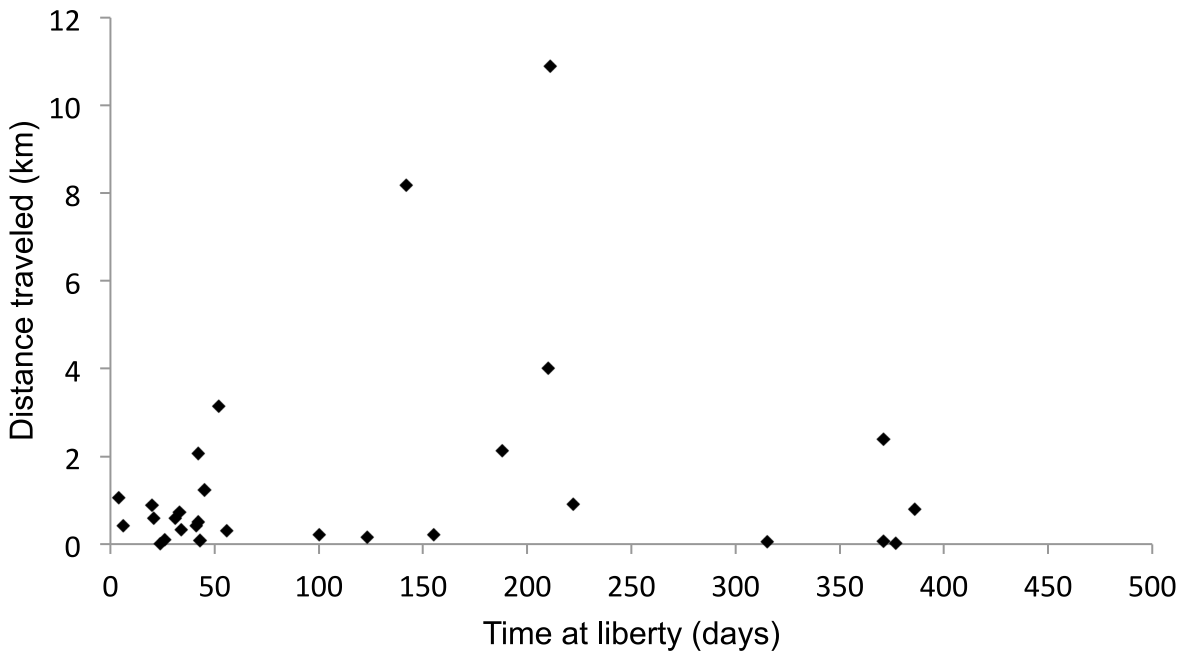

Figure 10. Total distance traveled by spotted sand bass (excluding tournaments).

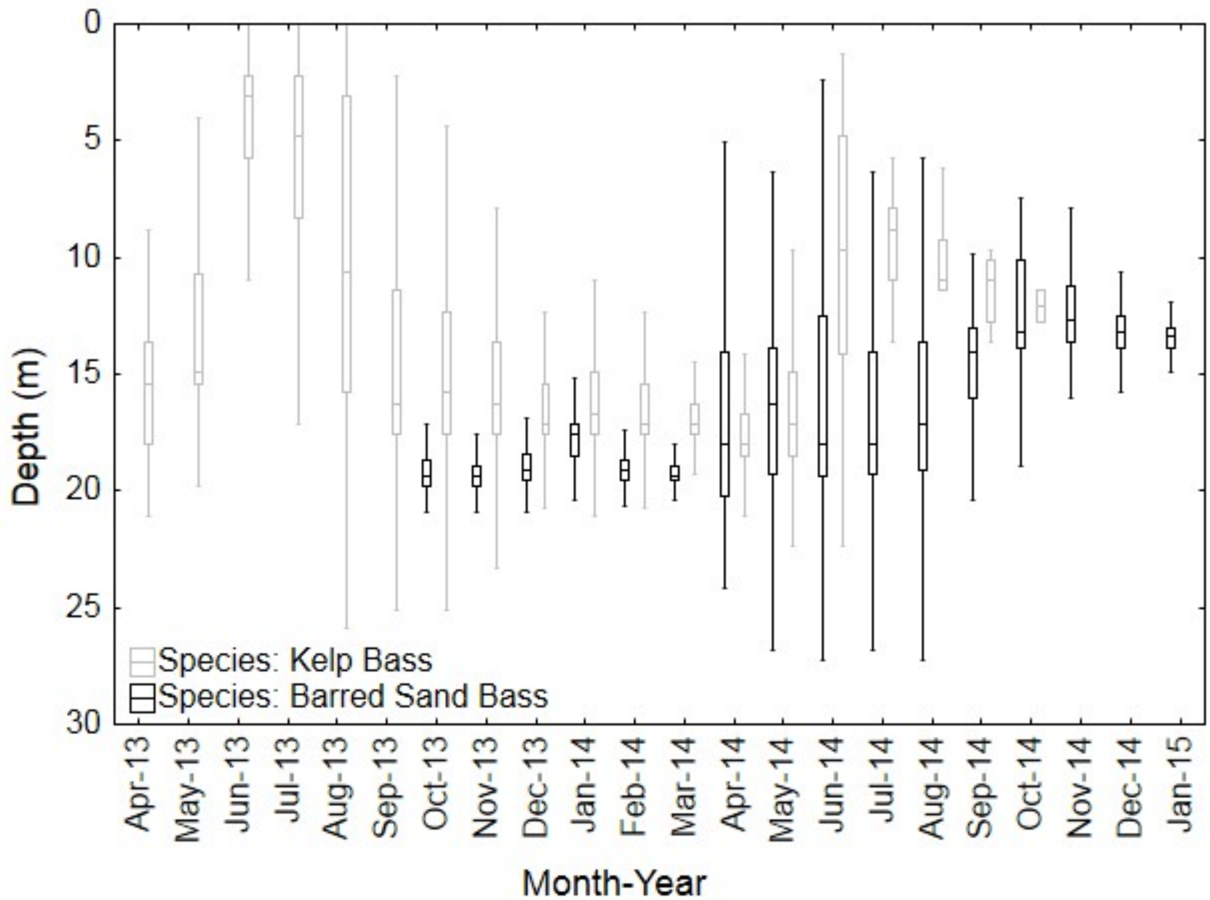

Figure 11. Boxplots showing depth utilization by month for both Kelp Bass and Barred Sand Bass in the three La Jolla sites.

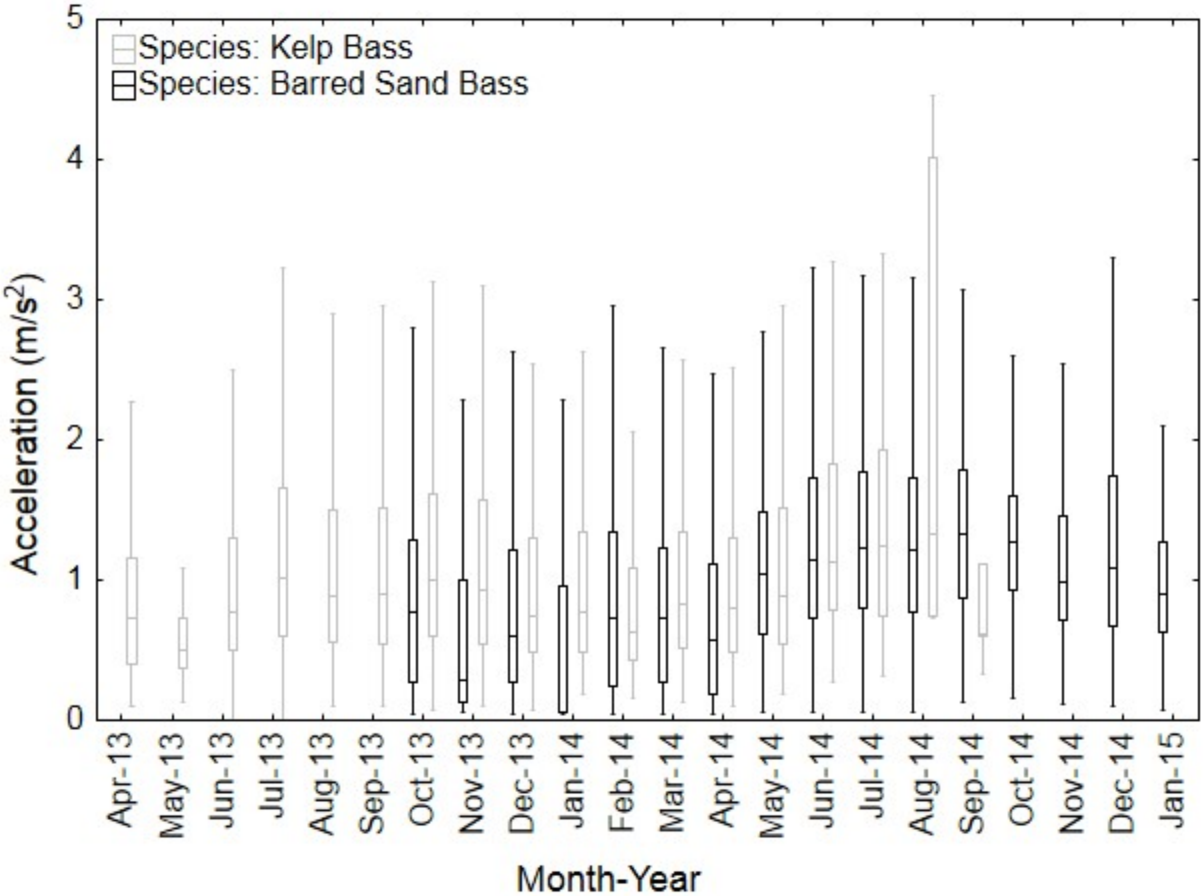

Figure 12. Boxplots showing median acceleration by month for both Kelp Bass and Barred Sand Bass in the three La Jolla sites.

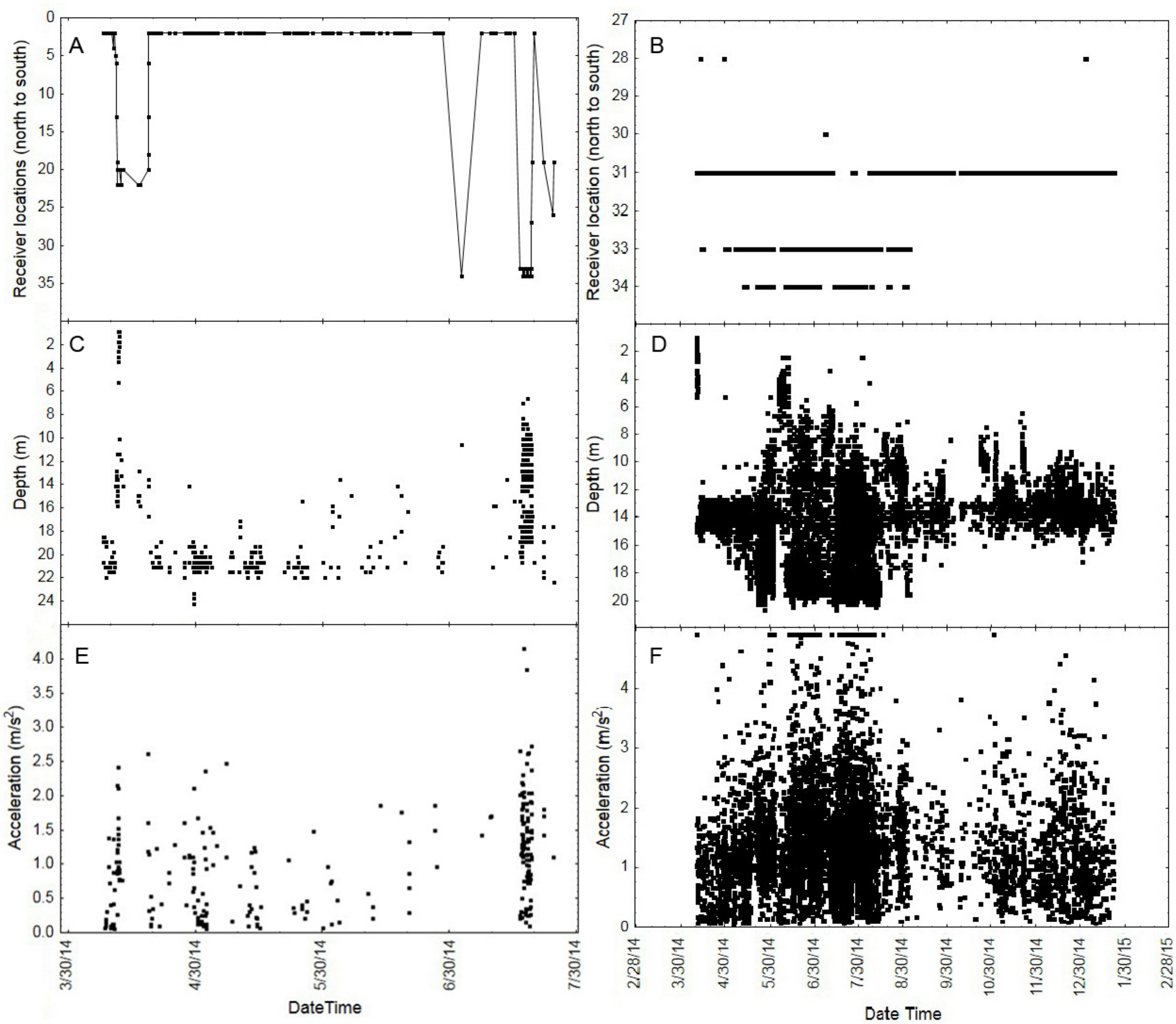

Figure 13. Horizontal movement, depth use, and acceleration of two individual Barred Sand Bass. Individual 1 is represented by panels A, C, and E, and individual 2 is represented by panels B, D, and F. The top panels show horizontal movement between receiver locations from north to south, the middle panels represent individual depth detections at each day/time, and the bottom panels represent individual acceleration detections at each day/time.

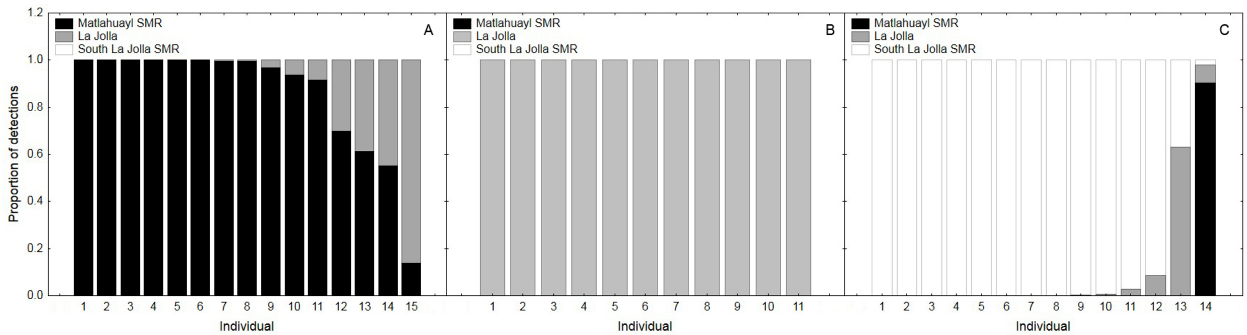

Figure 14. The proportion of detections at each of the three La Jolla Sites for Kelp Bass that were initially tagged in the Matlahuayl SMR (a), in La Jolla (b), and in the South La Jolla SMR (c).

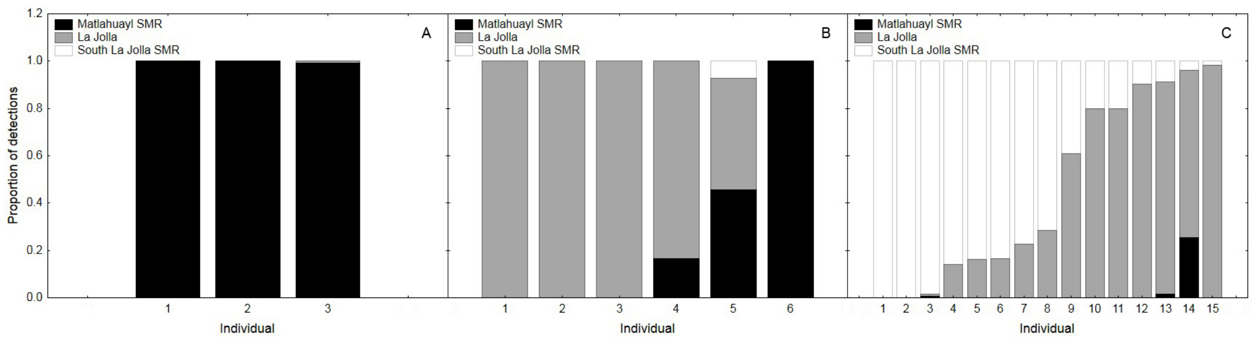

Figure 15. The proportion of detections at each of the three La Jolla sites for Barred Sand Bass that were initially tagged in the Matlahuayl SMR (a), in La Jolla (b), and in the South La Jolla SMR (c).

	Total Detections		Percent Detections	
Species	Kelp Bass	Barred Sand Bass	Kelp Bass	Barred Sand Bass
Inside	250,797	24,169	72.7	15.7
Outside	94,394	129,447	27.3	84.3
Total	345,191	153,616		

Table 5. The total number of detections and percentage of detections for each species both inside and outside the two MPAs in La Jolla.

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Long-term recommendations

The California Department of Fish and Wildlife recently implemented a coast-wide network of MPAs to protect marine species, increase abundances and biodiversity, and improve fisheries. The CDFW also implemented new regulations to improve specifically the bass populations in response to long-term declines in Kelp Bass population metrics, and recent but precipitous declines in Barred Sand Bass population metrics. We formed our recommendations in the context of these recent regulatory changes.

Our project results indicate that the recent increase in minimum size limit (from 12in to 14in total length) is likely yielding positive results for Kelp Bass and Spotted Sand Bass. Signs of growth following the new regulations are evident, particularly for Kelp Bass in the most heavily fished areas. These regulations thus appear to be functioning as intended, and the fish that were 12 inches in length during the beginning of the study should begin recruiting into the fishery based on the new 14in minimum size limit in 2016. Spotted Sand Bass may take longer because they reach much smaller maximum sizes, and have slower size-specific growth rates than Kelp Bass. Barred Sand Bass grow very similarly to Kelp Bass, but they do not show similar positive signs in response to the increased minimum size limits. The decreased bag limits will likely have the greatest positive impact on Kelp Bass and Barred Sand Bass because Spotted Sand Bass are largely a catch-and-release fishery. Barred Sand Bass, however, are of serious concern because landings declined precipitously begging in 2005-2006, and leading up to the establishment of decreased bag limits. These declines have also coincided with the almost complete disappearance of spawning aggregations at the 5 primary sites in southern California during our 2012-2014 sampling period, and again during the 2015 spawning season. Most of the new coastal MPAs are relatively large, and are thus likely to benefit both Kelp Bass and Barred Sand Bass based on our movement estimates. However, only one of these MPAs (South La Jolla SMR) appears to encompass a Barred Sand Bass spawning aggregation lite. This spawning site was undocumented at the time of reserve implementation. Unfortunately, this spawning site is likely much smaller than the other 5 known sites, and it is only partially protected by the MPA boundaries (although future studies should focus on improving our understanding of the geographic and demographic scope of this site). Given the significant population declines and drastic changes in / disappearance of spawning behavior, we recommend that the recreational fishing community consider a three-month seasonal closure for Barred Sand Bass from June – August in California state waters beginning in 2016.

Financial report: 2012-2014

Budgeted

Category	2012-2013	2013-2014	Total
Total Salaries and Wages	$35,248	$8,620	$43,868
Tuition Remission	$21,683	-	$21,683
Supplies	$105,389	$47,084	$152,473
Domestic Travel	$440	$440	$880
Total Direct Costs	$162,760	$56,144	$218,904
Indirect Costs	$12,742	$8,081	$20,823
Total Direct and Indirect Costs	$175,502	$64,225	**$239,727**

Actual

Category	2012-2013	2013-2014	Total
Total Salaries and Wages	$26,782	$17,838	$44,620
Tuition Remission	$18,360	$4,292	$22,652
Supplies	$94,717	$55,613	$150,330
Domestic Travel	$484	-	$484
Total Direct Costs	$140,343	$77,743	$218,086
Indirect Costs	$14,226	$6,710	$20,936
Total Direct and Indirect Costs	$154,569	$84,452	$239,022

Difference from budgeted amount: -0.3%
Cost-share rate: 31.6%

List of publications and outreach efforts
Three manuscripts for publication in peer reviewed scientific journals are currently in preparation. These will likely be available during summer of 2016.

Publications in newspapers/magazines/online
Johnson. C. Jul 3, 2012. Sportfishers to help researchers study marine bass off San Diego. Western Bass.

Bowen, W. Oct, 2012. Scripps researchers enlist the curious in fish-tagging project. La Jolla Light.

McDonell, P. Nov 2, 2012. Scientific Anglers. Western Outdoor News.

Landesfeind, E. Nov 15, 2012. California saltwater bass tagging program. BD Outdoors.

Brody, Ambrosia. May 17, 2013. Meet Lyall Bellquist—Tracking SoCal's saltwater bass. The Log: California's Boating and Fishing News.
Landesfeind, E. Aug 8, 2013. Saltwater bass tagging program follow up. BD Outdoors

Bowen, W. Nov 4, 2013. On a tagging mission. San Diego Downtown News.

Zieralski, E. Nov 15, 2013. Catch-and-release fishing fueling bass study. San Diego Union Tribune.

Bowen, W. Nov 15, 2013. Sportfishing boat in La Jolla Cove tags bass for sustainability study. La Jolla Light.

Lawler, R. Mar, 2014. Ten thousand tagged bass waiting to be caught. Pacific Coast Sportfishing.

Lawler, R. Oct, 2014. Calico bass tagging program: a success. Pacific Coast Sportfishing.
Fischer, P. Feb 1, 2015. Fish tagging project off the coast of San Diego. Clairemont Times.

Radio interviews:
2013. Soundcloud (Burditt & Maestre), Emerging Technologies: Lyall Bellquist

2013. Phil Friedman Outdoors.

2013. Let's Talk Hook-Up.

Jun 15, 2014. Let's Talk Hook-Up.

Fishing Trade Shows:
2013-2014. Fred Hall Fishing and Boat Show booths, Long Beach and Del Mar, California.

Television Shows:
Fowlkes, M. 2015. Inside Sportfishing (2 episodes), Fox Sports West.

Project website
www.cooperativefishtagging.org

Facebook
Coastal Angler Tagging Cooperative

Smartphone "app"
CatchReporter

Data handling and availability
Our intent is to publish the studies outlined above as primary research in peer-reviewed journals (within two years of project completion), and include the associated data as a digital appendix. This approach to publication is rapidly becoming standard practice in the ecological and fisheries sciences, and many journals no require authors to provide data along with published studies.

Project media
We received media coverage via newspaper articles in the San Diego Union Tribune, San Diego Downtown News, La Jolla Light, Clairemont Times, and Western Outdoor News. We also conducted radio interviews on two radio stations that broadcast throughout southern California, and produced two television episodes on Fox Sports West, Inside Sportfishing. Acoustic recordings are available on the radio show website (www.hookup1090.com/show-archive) as well as https://soundcloud.com/emerging-technologies/state-of-our-oceans-lyall. Project photographs are available on the Facebook page for the Coastal Angler Tagging Cooperative.