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Historical Ecology of the San Diego Sport Fishery: Catch Composition, Species Trends, and Fishing Effort from 1959 to 2011

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Historical ecology of the San Diego sport fishery:
Catch composition, species trends, and fishing effort from 1959 to 2011

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by

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DEDICATION

This thesis is dedicated to anyone whose path to reaching their goals has been markedly non-linear.

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Abstract

Like ocean systems around the world, species targeted by the San Diego sportfishery are subject to myriad threats from human activity, with several species already showing documented decline. However, long-term fisheries datasets are often lacking, limiting natural resource managers' ability to appropriately manage these ecologically and economically important species. Therefore, this study used daily reports published in two Southern California newspapers to examine changes in catch composition, effort, and catch per unit effort (CPUE) from 1959-2011 for the San Diego commercial passenger fishing vessel (CPFV) sportfishery. This study then tested the relationship between those patterns and three large scale oceanographic conditions to provide insights into potential drivers of change. During the study period, composition of landings changed from being dominated by relatively few species in the 1960s and 1970s to a richer, and different, composition in the 1990s through 2010s. No species displayed a trend of increasing CPUE, while CPUE for several species (Bonito, Barracuda, and Mackerel) decreased across the study period and changes in large-scale oceanographic conditions alone did not explain the change. Despite the popularity of California Halibut in the sportfishing community, its CPUE appears to have stabilized at low levels, potentially making it an example of a shifting baseline. Meanwhile, *Sebastes spp* were strongly associated with cold water, suggesting it may be prudent to model expected responses of species within this genus to changing ocean temperatures associated with global climate change. The State of California has and will continue to invest in the management of its coastal marine resources. These actions will be both more effective and more cost-efficient when based on the best available information regarding the populations and habitats it seeks to protect. As this study has shown, analysis of CPFV landings, combined with oceanographic data and information on management and angler preferences, can provide an important tool to help understand what is happening in the populations of popular sportfishing species.

Chapter 1 – Background

Introduction

Recreational fisheries of Southern California, and San Diego in particular, are an important part of the region's economy and heritage. Over the past century, abundance and composition of these fisheries have fluctuated, due in part to myriad natural and anthropogenic stresses associated with the nearshore environment off a semi-arid and highly urbanized region. Understanding long-term community-level shifts in catch and insights into the drivers underlying those shifts are needed to better manage these fisheries, especially in the face of climate change. In addition to the economic and social values of recreational fishing, this industry has generated long-term catch datasets that, in some cases, are the best available data we have for evaluating community level shifts over long time scales. While catch data have limitations, such as the potential inability to untangle individual driving factors, the long-term nature of this dataset allows assessments of the influences of large temporal-scale oceanographic processes and management changes, and reduces biases associated with shifting baselines.

Sportfishing in San Diego: A brief history

Understanding changes in the recreational fisheries in the San Diego region is of particular interest because of the value of fishing to the economy and the heritage of the region. In the early 20th century, San Diego gained considerable notoriety as a destination for "rod and reel" sportfishing, attracting thousands of

recreational anglers each year (Palmer 1912). Commercial fishing in San Diego in the early part of the 20th century focused primarily on Albacore rather than other tuna species (Felando and Medina 2012) in part to avoid competition with the area's game fishing industry, which focused heavily on Bluefin Tuna (Palmer 1912). Today, recreational fishing contributes more than $4.6 billion to California's economic output (Southwick 2017) with two thirds of the state's marine fishing occurring between San Diego and Santa Barbara (Southwick 2009).

The commercial passenger fishing vessel (CPFV) industry has operated in southern California waters since at least the early 1900s, and in its early years was mostly the purview of a wealthy few (Young 1969). In the 1920s and 1930s, the CPFV fleet expanded considerably and by the mid-1950s boats were venturing into Mexican waters, targeting Yellowtail, White Seabass, Pacific Barracuda, billfish, and tuna species (Holts 1985). As the size, speed, and comfort of the CPFV boats increased during this time, boats were more easily able to target the Channel Islands, offshore banks, and the Coronado Islands (Holts 1985). Today, San Diego is often referred to as the "Saltwater Sportfishing Capital" of the western United States (Haugen 1990).

Shifting baselines and the need for historical data

Scientific studies are typically conducted over short time scales (less than ten years) and may be unlikely to detect patterns of ecological change associated with

long-term processes (Jackson 1997). This situation is exacerbated by the phenomenon known as shifting baselines (Pauly 1995, Dayton *et al.* 1998), which describes how science and society gradually become adjusted to changing systems. If an accurate baseline is known for a given system, it allows for the establishment of meaningful targets for restoration and conservation efforts. However, the acceptance of a shifted baseline as "normal" is often the case because some of the largest changes to natural systems (*e.g.,* population declines, habitat shifts) often happened before scientific data were collected regularly (Olsen 2002), and evidence of such changes may be available only in the form of anecdotes or historical data (Pauly 1995, Swetnam *et al.* 1999, Jackson *et al.* 2001). In the case of fisheries management, management schemes are often implemented after industrialized and/or intense recreational fishing has begun, and thus can serve to stabilize fish biomass at artificially low levels relative to true historic conditions (Myers and Worm 2003).

One way to mitigate the effects of shifting baselines is through the use of relatively longer-term studies, which (due to the rarity of long-term data sets) can require the use of historical data, often from non-traditional sources including photographs, logbook entries, newspaper reports, *etc* (e.g., Jackson *et al.* 2001, McClenachan 2009, Bellquist *et al.* 2016)*.* These sources can include quantitative, systematically collected historical data, which can provide indications of long-term changes where traditional data do not exist. While use of these types of data prohibits the construction of a randomized experimental design, and the method

of collection and quality may vary, it does not prevent the use of this information for scientific inquiry.

Numerous studies have successfully highlighted the strength and validity of historical data in rigorous ecological examinations (Jackson *et al.* 2001, Pitcher 2001, Sala *et al.* 2004, Saenz-Arroyo *et al.* 2005, McClenachan 2009, Bellquist *et al*. 2016, Fortibuoni *et al.* 2017), including specifically using information from captains' logs from commercial passenger fishing vessels in California to document, quantify, and analyze changes in fisheries targeted by recreational anglers (e.g., Dotson and Charter 2003, Erisman *et al.* 2011). However, this approach does affect the kinds of questions that can be asked and the way conclusions are framed. Despite potential shortcomings, historical data provide a window into past ecosystem conditions that otherwise may be unavailable to the modern investigator.

In the case of fisheries, it is important to note that landings data and other fisheries-dependent information come with their own suite of limitations (Bishop 2006). A particularly relevant limitation is the ability of fisheries-dependent data to mask hyperstability (wherein true abundance declines despite stable CPUE) in fisheries that target spawning aggregations, as has been demonstrated for key target species of the CPFV fishery in San Diego (Erisman *et al.* 2011). Therefore, information from these data must be combined with stock-assessments using fisheries-independent data sources to inform fisheries management strategies.

Nonetheless, historic landings data can offer an otherwise unavailable window into past conditions for species heavily targeted by the CPFV fleet in San Diego. Specifically, these data are able to provide information regarding trends in species composition and CPUE through time, as well as their potential association with large-scale oceanographic conditions that occur over long time scales (*e.g.*, Pacific decadal oscillations).

Impacts of fishing on fish populations: A brief review

Anthropogenic disturbances to the world's oceans are numerous, and include global climate change, habitat destruction, pollution/contamination, and fishing pressure (Bruland *et al.*1974, Zedler 1991, Dotson and Charter 2003, Gruber *et al.* 2012), with most documented impacts beginning in the late twentieth and early twenty-first centuries (Jackson *et al.* 2001). Because the current study uses data from the fishing industry to identify trends in species specifically targeted by sportfishing activities, the suite of possible impacts of fishing on fish populations is briefly reviewed here. Non-fisheries drivers of changes in fisheries composition and abundance (*e.g.,* changes in angler preference, oceanographic conditions, etc.) are discussed in Chapter 2.

Fishing can provide social and economic benefits (Pollnac and Poggie 2008, Southwick 2017) and in some cases may even benefit fish communities, for example by enhancing prey diversity and abundance through (mild) gear-disturbance, modulation of competitor species through a reduction in the

availability of prey (target species), and productivity inputs to ecosystems through bycatch discards (Martinez-Abrain *et al.* 2002, Gribble 2003, Zhou 2008, van Denderen *et al.* 2013). Despite these benefits, overfishing is often the reported cause of fisheries declines worldwide, perhaps because fishing has had direct effects on fisheries for longer than other widespread anthropogenic stressors (Jackson *et al.* 2001) and has the potential to seriously impact marine fisheries and their environments (Great Britain Royal Commission on Trawling 1885, Tegner and Dayton 2000, Jackson *et al*. 2001, Worm *et al.* 2006, Pauly *et al.* 1998, Pauly and Zeller 2016).

In general, the majority of overfishing and its impacts have been attributed to industrial-scale fishing and to commercial fishing in general as opposed to recreational fishing, since the former have the capacity to capture far more individuals per unit time. Data reveal, however, that recreational fishing can also have substantial and lasting effects on fish populations (*e.g.,* Schroeder and Love 2002, Coleman *et al.* 2004, McClenachan 2009). This occurs through intensive capture in a relatively small area, capture of sensitive life stages/activities (e.g., mating, spawning, juvenile, largest/most fecund individuals) (Cooke and Gowx 2004), and/or catch-and-release mortality, which has been documented across taxa in geographically distinct systems and is especially pronounced in larger individuals with longer fight times (Millard *et al.* 2003, Heberer *et al*. 2010). Barotrauma, despite recompression efforts, remains a cause of catch and release mortality in *Sebastes* species, a popular target of the San Diego sportfishery,

including protected rockfish species whose stock relies heavily on mandatory fish release (Parker *et al.* 2006, Jarvis and Lowe 2008, Pribyl *et al.* 2012, Rankin *et al.* 2017, Bellquist *et al.* 2019). Additionally, recreational fishing can have a negative effect on often sensitive nearshore habitats themselves (Halpern *et al.* 2003) through noise, wake, and pollution associated with increased boat traffic and discarded fishing gear (hooks, line, lead weights) (Arlinghaus and Cooke 2009, Cowx 2002, McPhee *et al.* 2002).

The effects of fishing pressure on stocks depends in large part upon appropriate, science-based management that keeps current with changing conditions (Hilborn and Ovando 2014). Fisheries declines can occur in cases of uninformed, poor, or no management, and often when high fishing pressure occurs in concert with one or more other stressors (Jackson 2001, Valero and Waterhouse 2016, Santora *et al.* 2017). Effective and responsible fisheries management in turn requires scientific assessment of stocks, including an understanding of basic fishery biology, such as stock sizes, distributions, and maximum sustainable yield (MSY). Also needed is an understanding of relationships between fish stocks and long-term environmental fluctuations, such as climate change impacts and El Niño/Southern Oscillation (ENSO) events.

Need for this project

Previous studies (*e.g.*, Dotson and Charter 2003) used newspaper reports of landings from the California sportfishery to begin investigating long term trends

in fisheries targeted by CPFVs. However, there is need to expand the timeframe of investigation with additional years of data, as well as focus more closely on the San Diego sportfishery itself to investigate potential explanatory variables for patterns that emerge. The goal of this study was, therefore, to conduct a detailed examination of patterns in CPFV recreational fish stocks in San Diego over an extended time period, test the relationship between those patterns and a suite of environmental factors, and gain insight into possible fishery-independent controls on stocks.

Chapter 2 – Historical ecology of the San Diego sport fishery: Catch composition, species trends, and fishing effort from 1959 to 2011

Introduction

Recreational fishing in southern California

Recreational fishing contributes more than $4.6 billion to California's annual economic output (Southwick 2017), with two thirds of the state's marine fishing occurring between San Diego and Santa Barbara (Southwick 2009). In addition to the economic benefits of sportfishing, the sport provides social benefits including connecting people to nature, food provision, and recreation (Pollnac and Poggie 2008). Recreational fishing is particularly important in San Diego, known as the "Saltwater Sportfishing Capital" of the western United States (Haugen 1990), which has a commercial passenger fishing vessel (CPFV) fleet dating back to at least the early 1900s (Young 1969). In addition to shore-based and private boat recreational fishing, the large CPFV fleet operates out of four major landings based in Mission Bay and San Diego Bay (Parnell *et al.* 2010). Each chartered vessel typically carries between 30-50 anglers on half day, full day, overnight, twilight, and multi-day trips. While the overnight and multi-day trips visit offshore destinations (*e.g.,* the Coronado Islands), most half day and full day trips remain nearshore, particularly in the kelp beds off Point Loma and La Jolla (Parnell *et al.* 2010).

Like ocean ecosystems around the world, the southern California nearshore environment is subject to myriad threats from anthropogenic activities, including pollution, habitat destruction, climate change, and fishing pressure (Bruland *et al.* 1974, Zedler 1991, Jackson *et al.* 2001, Dotson and Charter 2003, Gruber *et al.* 2012). While commercial fishing removes more individuals per unit time, often resulting in stronger ecosystem consequences than recreational fishing, data suggest recreational fishing can also have substantial, negative, and lasting effects on fish populations (*e.g.,* Schroeder and Love 2002, Coleman *et al.* 2004, McClenachan 2009). However, there are many stressors influencing fish stocks (natural and anthropogenic, fishery-dependent and fishery-independent, acute and longer-term) and the effects of fishing pressure on stocks depend in large part upon appropriate, science-based management (Hilborn and Ovando 2014). Effective and responsible fisheries management in turn requires scientific assessment of stocks, including an understanding of relationships between fish stocks and long-term environmental fluctuations.

Several San Diego fisheries have experienced fluctuations and/or reductions in catch per unit effort that suggest possible changes in the fish populations through time (Limbaugh 1955, Jarvis *et al.* 2004, Miller and Erisman 2014, Valero and Waterhouse 2016). Of particular interest are fishes of economic importance, which not only contribute to the regional economy, but also encompass a variety of ecologically important functional groups. Understanding the patterns of change in fishery species and the relationship of these patterns to possible drivers (fishing

pressure, large-scale oceanographic conditions, and changing fishing regulations, including the implementation of marine protected areas) is needed to ensure effective management of these ecologically, economically, and socially important fisheries. This is especially true as the stresses associated with climate change intensify (Chavez *et al.* 2017).

Use of fishery catch data

Long-term fisheries biological datasets, often lacking due to the challenges associated with assessing population or stock sizes of species that cannot be easily observed, are another value of recreational fishing. Since 1936, the California Department of Fish and Wildlife (formerly California Department of Fish and Game) has required CPFV operators to report catch by species and the number of anglers onboard (Holts 1985). Starting in the early 1950s, these reports were published in several southern California newspapers, including the *Los Angeles Times* and the *San Diego Union Tribune*. Subsets of these data have been used to better understand changes in taxonomic representation, catch per unit effort (CPUE), total catch, and total effort through time for the California sportfishery, including San Diego (Dotson and Charter 2003). A previous study (Dotson and Charter 2003) analyzed data from 1959 through 1998 across California broadly but did not attempt to explain the patterns that emerged. Therefore, this updated analysis encompassed additional years of data, focusing specifically on the San Diego region, and investigated potential drivers of fisheries change.

Drivers of change in fisheries catch data

Fisheries catch data are not a direct approximation of population or stock sizes because they are also influenced by social and fishery-independent environmental drivers, such as species abundances, environmental conditions, management strategies, technological abilities, and social preferences (Pauly *et al.* 2013). In San Diego, catch data are likely influenced by changing preferences among anglers (Edwards 1992), changes in management strategies (Yoklavich *et al.* 2007), and fluctuations in large scale oceanographic conditions (Perry *et al.* 2005).

1. Angler preferences: Changes in preference through time may relate to changing demographics among the angling community, which may mirror changing demographics in the local community. For most of the history of the CPFV fleet, most anglers were relatively wealthy and were predominantly white males (Dewees *et al.* 1990). Throughout the 20th century, however, many of the wealthier anglers shifted to private boats and charters (Dewees *et al.* 1990), with the composition of CPFV clients potentially shifting to include a higher proportion of minority communities. With shifts in race and ethnicity, likely came shifts in preferences for target species (*e.g.,* Mintz and DuBois 2002, Moya 2004). Changing fishermen's preference may also simply be a matter of social trends, including the community's impression of the health value and safety of certain species (Edwards 1992, Burger and Gochfeld 2009, Carroll 2016) as well as the impact of popular culture

on consumer choice (Bestor 2000, Leschin-Hoar 2014). Finally, what may appear as a change in preference may actually be the result of improvements in fishing technology, particularly the increased availability of fish tracking technology or "fish finders" (Burden 2019). This change may appear in fisheries landings, such as an increase in highly migratory species (*e.g.*, billfishes, tunas) as anglers are able to target species other than those likely to appear in predictable aggregations (*e.g.,* spawning aggregations).

2. Fisheries management: Changes in management regimes can impact the composition of species in CPFV landings. In general, management rules fall into three broad categories:

   a. Species-specific regulations (*e.g.*, size limits; California's 1981 ban on commercial and recreational fishing of giant sea bass [*Stereolepis gigas*; Crooke 1992])

   b. Gear restrictions (*e.g.*, California's requirement that finfish only be taken using hook-and-line or by hand, with few exceptions [CDFW 2021])

   c. Area closures (*e.g.*, the enactment of California's Marine Life Protection Act of 1999, which enabled the creation of a system of marine reserves with various levels of fishing restrictions along the California coast [Kirlin *et al.* 2013])

In certain cases, species-specific management actions (particularly those that involve regional restrictions on fishing activity) have the

ability to protect a suite of species, which may thereby impact the
frequency of their occurrence in fisheries catch. For example, in
response to declines of Cowcod (*Sebastes levis*) resulting from
overfishing (Butler *et al.* 1999), the Pacific Fisheries Management
Council established two Cowcod Conservation Areas in 2001 where
fishing for groundfish is prohibited at certain depths (Yoklavich *et al.*
2007). Not only has this limited anglers' ability to target Cowcod, but
it has indirectly protected 50 additional species of rockfishes, as
evidenced by increases in the larvae of several rockfish species
(Thompson *et al.* 2017).

3. Oceanographic conditions: Large-scale oceanographic conditions
   including the El Niño/Southern Oscillation (ENSO), the Pacific
   Decadal Oscillation (PDO), and increasing ocean temperatures
   associated with climate change have the potential to drive changes in
   total population, species range, age structure, and other population
   dynamics (Lane 1965, Squire 1983, Perry *et al.* 2005). Because these
   conditions occur over long time scales, identifying their impact on fish
   populations requires long-term data sets that offer a window into
   historic conditions of focal species.

Project goal

Given the economic and social importance of recreational fishing in San Diego,
and the myriad factors affecting catch data, a better understanding is needed of the

long-term changes in recreational fishing catch, with insights into factors influencing those fluctuation, to inform fisheries management. The goal of this project, therefore, was to conduct a detailed examination of patterns in recreational fish stocks over an extended time period, test the relationship between those patterns and a suite of environmental factors, and gain insight into fishery-independent controls on stocks.

Methods

This study used daily catch and effort data from the San Diego CPFV fleet as reported in two local southern California newspapers, the *San Diego Union Tribune* (UT) and the *Los Angeles Times* (LAT), covering the period 1959-2011. Data for the period 1959-2003 were from an online database of LAT reports maintained by the National Marine Fisheries Service. Data for the period 2004-2011 were digitized by this project directly from UT microfilm (data from 2004-2011 were not available from the LAT as this newspaper stopped publishing Daily Ocean Fishing reports in 2003). Both newspapers sourced data directly from the same landings of the CPFV fleet in San Diego and previous studies (e.g., Erisman *et al.* 2011) similarly used CPFV data from two sources as one continuous database, as was done in this study. This resulted in a digital dataset from 1959-2011 with daily information regarding catch (broken down as the number of individuals per species/taxonomic group) as well as effort (including number of anglers and number of boats) for each San Diego CPFV landing. Fish reported as "released" were not included.

During this period, 147 taxonomic groups (usually species, but see note regarding *Sebastes and Paralabrax* genera) were reported. Usually, these groups were reported as a single species by common name, for instance Yellowtail (*Seriola dorsalis*), Bonito (*Sarda chiliensis*), and Pacific Mackerel (*Scomber japonicus*). Where possible each of the reported common names was assigned to a single scientific name, including in the cases of multiple common names as with Dorado/Dolphinfish (*Coryphaena hippurus*). However, there were two notable exceptions:

1. Rockfishes (*Sebastes spp.*) were rarely identified as individual species (*e.g.,* Salmon Grouper/Bocaccio), and were more frequently combined as "rockfish", "rock cod", "red rock fish", "reds", "red rock cod", and "vermillion rock fish". Though previous analysis of these data (Dotson and Charter 2003) suggested "rock cod" and "rock fish" may represent deep and shallow *Sebastes* species respectively, the current study does not assume such a distinction. When digitizing the data, the various names given to groups/sub-groups of *Sebastes* were included as reported. However, all designations for *Sebastes* were combined into one group for analysis due to low confidence in meaningful distinction between them. Therefore, this dataset is not a robust source for analyzing changes in particular *Sebastes* species through time, but only general trends in the genus.

2. Fishes from the genus *Paralabrax* were variously identified to species (*e.g.,* Kelp Bass/*P. clathratus,* Barred Sand Bass/*P. nebulifer*), or to

the group "bass". Again, these names were included as reported during the digitization of data but were combined into *Paralabrax spp.* for analysis. This was done primarily to maintain consistency with previous analyses of this dataset (e.g., Dotson and Charter 2003), which similarly combined the three *Paralabrax* species into one genus for analysis. Like with *Sebastes*, this grouping obfuscates potential patterns in the individual *Paralabrax* species that have been reported elsewhere (e.g., Erisman *et al.* 2011, Miller and Erisman 2014).

Because most designations in the dataset refer to a single species (rather than a genus as with *Sebastes* and *Paralabrax*), the term "species" is used in a description of the analysis and results below, even when referring to what are technically genera in the cases of *Sebastes* and *Paralabrax.*

Analyses

Daily catch and effort values were summed across landings and trip lengths to create one value of daily total effort and daily total catch per species, which was further summed to create monthly and annual total catch and effort values used in analyses described below. While previous studies (*e.g.*, Dotson and Charter 2003) examined raw catch data, this study standardized catch into catch per unit effort to overcome seasonal bias within the data (*i.e.,* higher effort during spring/summer). In this case, effort was identified as "angler-trip" and no distinction was made for various trip lengths. (Note: had effort been identified as "boat-trip" rather than

"angler-trip", the results would likely have emphasized the effects of larger party boats, which tend to stay closer to shore. Had effort been defined as "angler-day", separating out half, three-quarter, and full-day boat trips, it would likely have underemphasized the longer trips that target offshore species. Additionally, using "angler-trip" maintains consistency between this study and previous studies using similar datasets and methodologies.)

Changes in catch composition over time were examined using multivariate statistical analyses in which the averaged annual CPUE abundance data were grouped into (used as replicates in) seven broad, 8-yr (octadal) time periods: 1959-1966, 1967-1974, 1975-1982, 1983-1990, 1991-1998, 1999-2006, 2007-2011. These 8-yr intervals were chosen to reduce the effects of autocorrelation of the longer-lived species targeted by this fishery. The octadal time period groupings were chosen based on the result that the highest incidence (86%) of community composition differences occurred *between* 8-yr time periods (all but one pair of concurrent octades differed from each other; ANOSIM p≤0.05). Composition between time periods within the shorter intervals (2, 3, 4, 5, 6 and 7 yr intervals) and longer intervals (9, 10 and 11 yr intervals) differed less frequently than between the 8-yr time periods (only 0-60% of all pairwise comparisons within other time intervals were significantly different; ANOSIM p≤0.05).

Analysis of the summed and standardized data was conducted in three parts, as follows.

1. **Catch, effort, and CPUE through time**: Of the 147 species that appeared at least once in the 1959-2011 dataset, many appeared only very rarely (often only once). Therefore, a list of 21 focal species for analysis (Table 1) was established based on taxa meeting any of the following criteria: a) all of the top ten species within any year across entire time series, b) any species that appeared as >1% of the total catch in at least one octade, or c) three additional highly migratory species of interest to fisheries managers (bluefin tuna, bigeye tuna, tuna [unspecified]). These 21 species were then investigated for trends in total catch and CPUE through time.

2. **Changes in catch composition through time**: The 21 focal species (Table 1) were included for statistical analysis of differences in catch composition between octades. Similarities and differences in catch across octades were visualized using non-metric multidimensional scaling (nMDS; see Clarke 1993) on Bray-Curtis similarity indices of log (x+1) transformed, unstandardized CPUE data using R Statistical Platform (R Core Team 2013). For the nMDS analysis, six different random starting points with up to 1,000 steps were used. The stress values from the six runs were examined for stability to determine whether a global solution had been found.

Table 1: Focal species/genera used in CPUE and catch composition analysis	
Common Name	**Scientific Name**
Bocaccio (Salmon Grouper)	*Sebastes paucispinis*
California Halibut	*Paralichthys californicus*
California Sheephead	*Semicossyphus pulcher*
California Yellowtail	*Seriola dorsalis*
Dorado (dolphinfish)	*Coryphaena hippurus*
Giant (Humboldt) Squid	*Dosidicus gigas*
Kelp/Calico Bass, Sand Bass	*Paralabrax* spp
Lingcod	*Ophiodon elongatus*
Ocean whitefish	*Caulolatilus princeps*
Pacific Barracuda	*Sphyraena argentea*
Pacific Bonito	*Sarda chiliensis*
Pacific Mackerel	*Scomber japonicus*
Rockfish (unspecified)	*Sebastes* spp
Sculpin (CA Scorpionfish)	*Scorpaena guttata*
Skipjack	*Euthynnus pelamis*
Tuna (unspecified)	*Thunnus spp.*
Tuna, Albacore	*Thunnus alalunga*
Tuna, Bigeye	*Thunnus obesus*
Tuna, Bluefin	*Thunnus orientalis*
Tuna, Yellowfin	*Thunnus albacares*
White sea bass	*Atractoscion nobilis*

Table 1: List of 21 focal species/genera (narrowed down from 147 species reported from 1959-2011) for the analysis of change in catch and CPUE from 1959-2011, based on the following criteria: one of the top ten species within any year across entire time series, appeared as >1% of the total catch in at least one octade, and was one of three highly migratory species of interest to fisheries managers (Bluefin Tuna, Bigeye Tuna, Tuna [unspecified]).

Stress is a measure of how well the solution (in this case the two-dimensional nMDS plots) represents the distances between the data, and only analyses with stress values of <0.2 were used. Stress values <0.1 are "good" and <0.2 are "usable" (Clarke 1993). Significance

testing for differences in catch composition between octades was completed using an analysis of similarity (ANOSIM; Clark 1993). The significance levels of resultant pairwise comparisons were determined using sequential Bonferroni-adjusted alphas. Analyses of species dissimilarities between time periods, and the particular species contributing to the dissimilarity, were carried out using SIMPER (Clark 1993). The SIMPER results specify which species are responsible for the ANOSIM results by comparing the average abundances of species between groups. The average dissimilarity between samples from the groups is computed and then broken down into contributions from each species. Those species with high average terms relative to the standard deviation are important in the differentiation of groups.

3. **Relationships with oceanographic conditions:** Using results from the ANOSIM and SIMPER analyses to identify which species were responsible for driving changes between octades, eight species were chosen for investigating the possible relationship between their CPUE and large-scale oceanographic conditions. Three additional economically valuable species were also included. Possible relationships between current and time-lagged oceanographic variables (temperature, PDO, and ENSO) and CPUE (log+1 transformed) were tested with forward, stepwise multiple regressions using JMP Pro 13 Statistical Software. Variables included in the model met the criteria of

$p \leq 0.05$. Data sources for the oceanographic conditions were as follows:

- ENSO values are as reported from the Oceanic Niño Index, which is the running, 3-month mean sea surface temperature (SST) anomaly for the Niño 3.4 region. Data were accessed via http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears2011.shtml.

- PDO values are as reported from NOAA's National Centers for Environmental Information (NCEI) index, which is based on NOAA's extended reconstruction of SSTs (ERSST Version 4; Huang *et al.* 2014). These data were accessed via https://www.ncdc.noaa.gov/teleconnections/pdo/

- Sea surface temperature values are as reported for La Jolla/Scripps Pier by the Scripps Institution of Oceanography (SIO)'s Shore Stations Program. Data are provided by the Shore Stations Program at SIO and were accessed via https://scripps.ucsd.edu/programs/shorestations/shore-stations-data/data-sio/

Results

Catch, effort, and CPUE through time

Total annual catch (total fish recorded), effort (total annual angler-trips recorded), and catch per unit effort (CPUE; fish per angler-trip) varied from 1959-2011 (Figure 1). However, variability in all three (CPUE, catch, and effort) tended to be lower during the second half of the period compared to the first (Table 2). From 1987 onward, total catch experienced a net decline ($r^2 = -0.43$, $p = 0.032$), even while effort and CPUE generally leveled off during that same period (Figure 1).

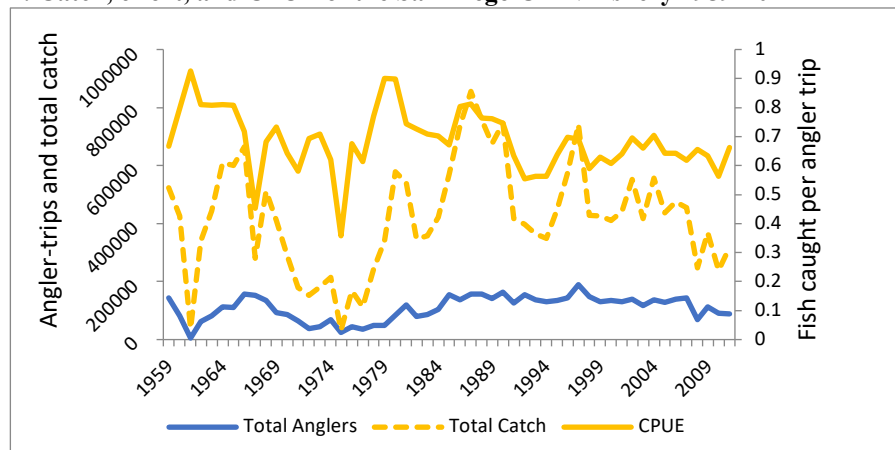**Figure 1: Catch, effort, and CPUE of the San Diego CPFV fishery 1959-2011**

Figure 1: Total catch, effort, and catch per unit effort (CPUE) of the San Diego CPFV fishery through time. Catch is reported as the total number of individual fish reported. Effort is the total angler-trips for that year. CPUE is calculated as the number of fish per angler-trip and has been log+1 transformed.

Table 2: Mean and Standard Deviation of Catch, Effort, and CPUE through time

		1959-1984	1985-2011
Effort (angler-trips)	**Mean**	**81,300**	**134,892**
	Std. Dev.	*39,980*	*24,353*
Catch (total fish)	**Mean**	**346,483**	**496,627**
	Std. Dev.	*180,980*	*163,338*
CPUE	**Mean**	**0.7135**	**0.6606**
	Std. Dev.	*0.1272*	*0.0710*

Table 2: Annual mean and standard deviation of effort (total annual angler-trips recorded), total catch (total annual fish recorded), and CPUE (fish per angler-trip) for the period 1959-1984 as compared to 1985-2011.

Of the 21 focal species investigated for trends through time, all displayed variability in both catch and CPUE (Appendix A), with several trends emerging (Figure 2). The CPUE of some species appeared cyclical (*e.g.*, *Paralabrax, Sebastes*), while others decreased through time (*e.g.*, Bonito, Mackerel, and Barracuda). Several displayed relatively high variability (*e.g.*, Albacore and Yellowtail). Other species peaked early in the dataset and then stabilized relatively low (*e.g.*, Halibut), and several species did not appear in abundance until the second half of the data set (*e.g.*, Dorado, Yellowfin Tuna, and Giant Squid).

Figure 2: CPUE through time for eleven example species
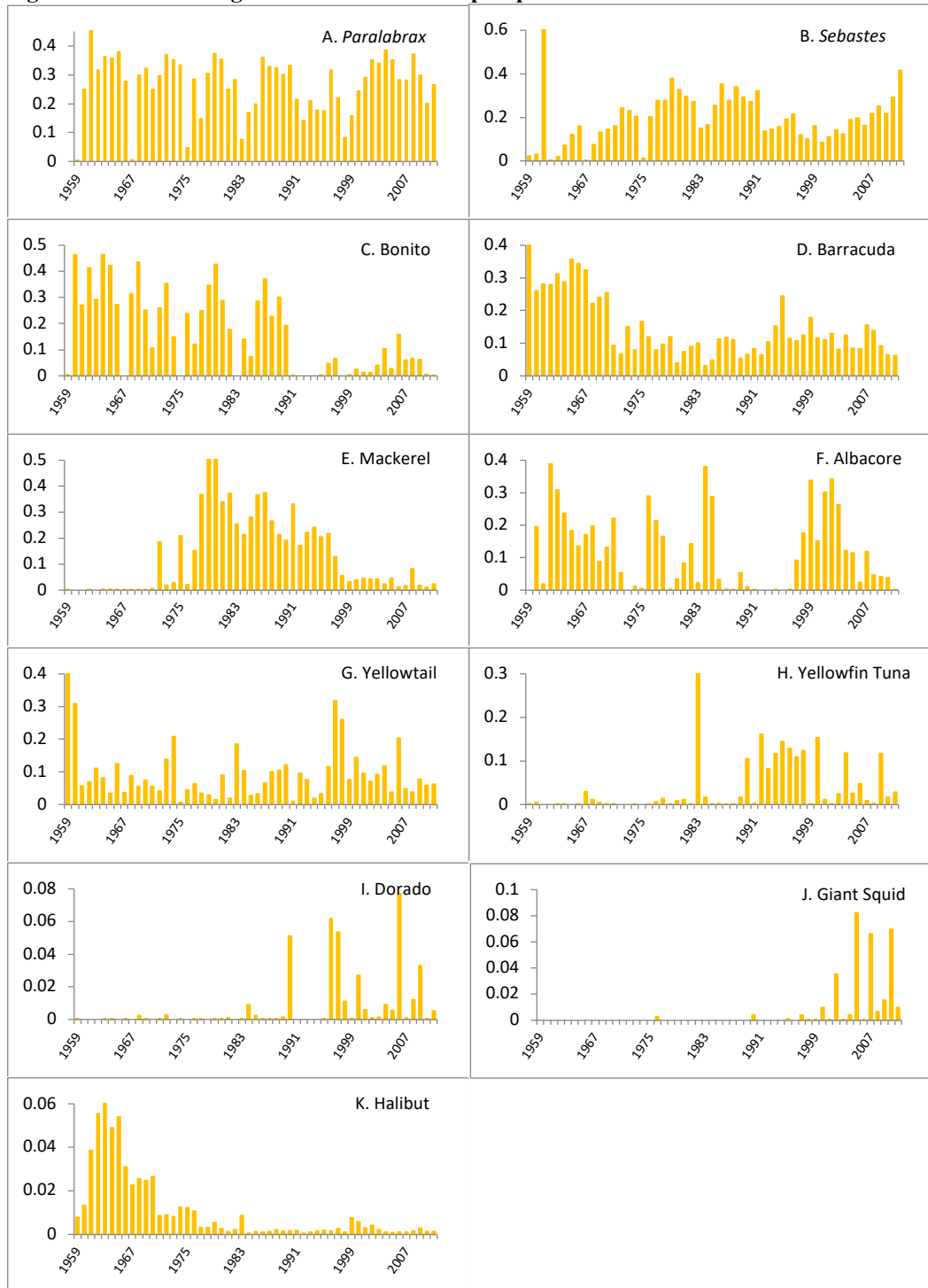
Figure 2: Annual CPUE (log+1 transformed) from 1959-2011 of 11 example focal species investigated for trends in catch and CPUE through time.

Changes in catch composition through time

Overall, the diversity of landings (*i.e.,* the number species appearing during various time periods) increased through time ($r^2 = 0.82$, p<0.01; Figure 3). The suite of species appearing in the catch during the first three octades (1959-1982) was dominated by seven species that made up over 95% of the catch, while 11-12 species made up at least 95% of the catch in the last four octades (1983-2011).

Figure 3: Catch composition through time
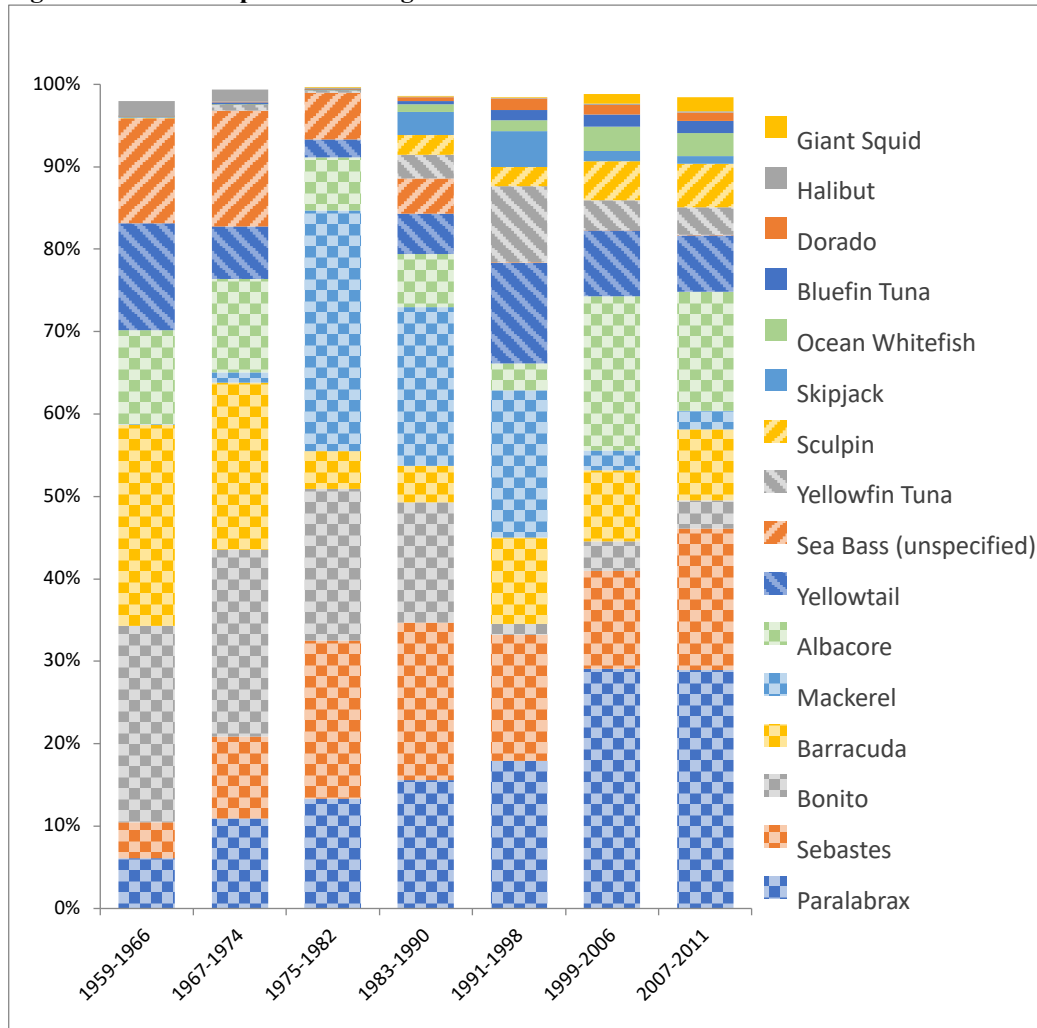
Figure 3: Each species of fish recorded during each octade is displayed as a percentage of total catch for that octade. Because species representing <1% of the total catch are not displayed, each octade does not sum to exactly 100%.

In terms of catch composition, octades tended to be most like their neighboring octade (Figure 4), with two general groups emerging: the late50s – early80s (cooler colors) and the mid80s – early10s (warmer colors).

Figure 4: nMDS plot of catch composition through time
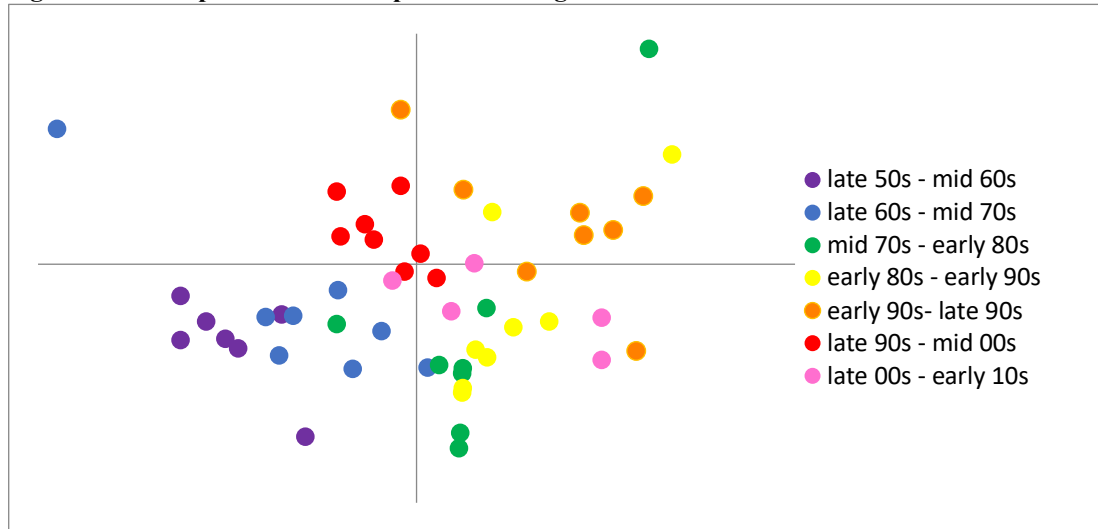
Figure 4: Non-metric multidimensional scaling plot of San Diego CPFV catch composition during each of seven octades from 1959-2011. Stress value = 0.18.

Overall, each octade tended to be most similar to the octades immediately before/after, with catch composition generally differing more with increasing length of time between octades (Table 3). The main exception to this trend was that the catch composition of the early-90's was the most distinct of any octade. This dissimilarity was driven by generally higher abundances of Yellowtail and Yellowfin Tuna in the early-90s as compared to other octades, and lower abundances of Bonito, Barracuda, Albacore, and *Paralabrax*. Between the late-50s and late-60s (the first two octades), Bonito, Barracuda, Albacore, and

Paralabrax abundances all decreased, while *Sebastes* abundance increased. The

trend of increased *Sebastes* abundance, decreased Bonito, Barracuda and

Albacore and *Paralabrax* abundance continued to drive octadal dissimilarity

throughout the time series, with fluctuations and generally more minor

contributions of six other species. Several species experienced pulses in catch

abundance in the middle of this time period (*e.g.,* Mackerel abundance increased

from the late-60s to the mid-70s and decreased thereafter). Similarly, Yellowtail

and Yellowfin Tuna abundance increased between the mid-70s to early-90s, and

decreased again in the final three octades (early-90s through late-00s).

Table 3: Octadal Similarity			
Time Periods	ANOSIM pairwise p	Dissimilarity (%)	Species contributing >10% of the variability (SIMPER)
Late 50s, Late 60s	*0.022*	37.7	-BO, +Seb, -B, -A, -Par
Late 60s, Mid 70s	*0.003*	42.74	+M, =BO, +Seb, -Par, +A
Mid 70s, Early 80s	0.236	35.27	-M, -BO, -A, =Par, =Seb, +Y
Early 80s, Early 90s	*0.006*	40.73	-BO, -A, -Par, -Seb, +YT, -M, +Y
Early 90s, Late 90s	*0.001*	43.42	+A, -M, +Par, -Y, -YT, +Seb
Late 90s, Late 00s	*0.006*	32.63	-A, +Seb, -Par, -Y, -YT, -BO, -B
Late 50s, Late 00s	*0.003*	57.5	-BO, +Seb, -B, -A, -Y, -Par

Table 3: Results of ANOSIM and SIMPER analyses for pairwise comparisons of catch composition between temporally adjacent octades. Pairwise p values that are significant compared to sequential Bonferroni adjusted alpha are shown in bold italics. Symbols (+, -, =) indicate whether the species' average abundance increased, decreased or stayed about the same between the earlier and later time period.: A= Albacore Tuna, B= Barracuda, BO=Bonito, M= Mackerel, Par= Paralabrax, Seb= Sebastes, Y= Yellowtail, YT= Yellowfin Tuna

Relationships with oceanographic conditions

All eleven species investigated were found to be associated with at least one

oceanographic condition (all P and p = <0.0001; Table 4). Abundances of all

species tested, with the exception of Mackerel, were correlated with temperature,

either contemporaneous temperature or temperature lagged by six months to a

year. Abundance of *Sebastes* was strongly and negatively associated with

contemporaneous temperature (R^2 = -0.42), while Albacore was positively

associated with contemporaneous temperature (r^2 = 0.22).

Table 4: CPUE and Oceanographic Conditions

Response variable	R^2	F	n	df	Independent variable(s)	r^2
Albacore	0.22	158.9	613	1,611	Temp (contemp.)	--
Barracuda	-0.06	38.5	607	1,605	Temp (6 month lag)	--
Bonito	0.17	26.7	541	4,536	Current PDO	0.14
					Temp (6 month lag)	-0.10
					ENSO (5 year lag)	-0.17
					ENSO (6 year lag)	-0.05
Dorado	0.10	69.5	613	1,611	Temp (contemp.)	--
Giant Squid	0.09	27.5	589	2,586	Temp (6 month lag)	0.03
					Temp (2 year lag)	0.06
Halibut	-0.04	26.6	613	1,611	Temp (contemp.)	--
Mackerel	0.20	77.9	601	2,598	Current PDO	0.15
					PDO (1 year lag)	0.08
Paralabrax	0.06	19.8	601	2,598	Temp (contemp.)	0.08
					Temp (1 year lag)	-0.03
Sebastes	-0.42	447.7	613	1,611	Temp (contemp.)	--
Yellowtail	0.12	82.8	613	1,611	Temp (contemp.)	--
Yellowfin	0.10	64.4	613	1,611	Temp (contemp.)	--

Table 4: Relationship between CPUE and oceanographic conditions. "Contemp." refers to contemporaneous temperature, or the average temperature during the same month as the CPUE. All P and p values <0.0001.

Dorado, Yellowtail, and Yellowfin were all moderately positively correlated with contemporaneous temperature (r^2 = 0.10, 0.12, and 0.10 respectively). Barracuda, Halibut, *Paralabrax* were only weakly negatively associated with temperature (R^2 = -0.06, -0.04, and -0.06 respectively). Two species, Bonito and Mackerel, were weakly positively correlated with PDO values, with Bonito associated with contemporaneous PDO (r^2 = 0.14), and Mackerel correlated with both contemporaneous PDO values (r^2 = 0.15) and the prior year's PDO values (r^2 = 0.08). ENSO values from five and six years prior also helped explain the variability in Bonito CPUE values (r^2 = -0.17 and -0.05, respectively), while no other species was found to be correlated with ENSO.

Discussion

Though total effort of the San Diego commercial passenger fishing vessel (CPFV) fleet did not change markedly during the second half of the twentieth century (this study, CDFW 2001), the landings themselves changed in terms of both catch composition and catch per unit effort of several individual species. Composition of fisheries landings from this fleet changed from being dominated by relatively few species in the 1960s and 1970s to a richer, and different, composition in the 1990s and 2010s. There were gradual, cyclic, and (in some cases) rapid shifts in catch composition occurring throughout this period, with major changes from a catch dominated by Barracuda, Yellowtail, Albacore, and Bonito to catch dominated by *Paralabrax* and *Sebastes*, with a larger suite of species making up the remainder of catch.

Several species did not appear until later in the dataset, with Dorado and Yellowtail perhaps explained by the ENSO event of 1982-1983 as both species were associated with warmer waters. That ENSO event, and the warmer water temperatures it brought, has been associated with a potential "faunal shift" in 1983-1984 identified by previous studies (*e.g.,* Miller and McGowan 2013). The current study similarly identified the early 1980s as a period of change: the early 1980s is when the diversity of catch increased (*i.e.*, more species started to appear in the landings data) and octades separated into roughly pre- and post- 1980s associations. One possible driver of this pattern could be increasing sea surface temperatures, whose annual mean rose above the 1919-present long-term mean beginning in the early 1980s (Rasmussen *et al.* 2019).

Of the 21 focal species investigated, only eight drove the majority of differences in catch composition across the dataset. These species (Albacore Tuna, Barracuda, Bonito, Mackerel, *Paralabrax, Sebastes*, Yellowtail, Yellowfin Tuna) display various patterns of variability and abundance in the catch data through time (Table 6), with certain species also displaying an association with large-scale oceanographic conditions. For several of the 21 focal species (specifically Yellowtail, Yellowfin Tuna, Dorado, Albacore, Giant Squid), large scale patterns in abundance are difficult to interpret from this dataset. In some cases (e.g., Giant Squid, Dorado), this is due to their appearing very late in the data or in other cases (e.g., Yellowfin Tuna, Albacore) appearing in relatively stable (if variable) catch

totals (though note that variability of several of these species is associated with large scale oceanographic conditions, as described below).

Species displaying an overall pattern of CPUE decline

Notably, no species displayed a trend of generally increasing CPUE through time, while CPUE for several species (Bonito, Barracuda, and Mackerel) decreased across the study period. Based on improvements in fishing technologies, a decrease in CPUE of these three species suggests changes in angler preferences, management restrictions, and/or changes in the underlying populations and their distributions.

Changes in large-scale oceanographic conditions did not completely explain the overall decrease in these three species. Bonito was highly cyclical and correlated with both PDO and ENSO values, which are both also cyclical. However, correlations with PDO and ENSO do not explain the directional trend in Bonito because neither PDO nor ENSO values displayed directional long-term trends. Similarly, though Mackerel was positively associated with PDO, that association does not explain the overall directionality of change. Bonito and Barracuda were weakly negatively associated with temperature, which increased slightly during this time, which could potentially explain some of the observed reduction in their CPUE. In the case of Mackerel (which was not found to be associated with temperature), this temperature change does not help explain the reduction in its CPUE.

It is unclear whether changes in angler preference could explain the observed declines in the relative contribution of these species to the catch totals of the CPFV fleet. Consistent with Mackerel not appearing in the dataset until the early 1970s, Mackerel were not historically a favored target of anglers in California (Young 1969), and the literature does not demonstrate a change in preference for Mackerel through time. Rather, recreational catch of Mackerel has remained a low (<5%), but relatively stable, proportion of total landings since at least 1983 (Crone and Hill 2015). While some anecdotal reports suggest a reduction in the popularity of Barracuda in recent decades (Monterey Bay Aquarium 2019), others suggest their popularity remains high (Allen 2014, CA Sea Grant 2021). Finally, in the case of Bonito, the near disappearance of the species from landings data in the early 1990s is unlikely to be explained by changing preferences, since Bonito are regularly ranked as one of the 15 most sought after species by recreational fishermen in southern California (CDFW 2001).

Changes in CPFV clientele demographics (*i.e.*, race, ethnicity, income level) and concordant differences in seafood preferences (Mintz and DuBois 2002, Moya 2004) may have contributed to shifts in catch composition. While CPFV clientele was overwhelmingly (>90%) composed of well educated, white men with relatively high incomes as of 1990 (Dewees *et al.* 1990), there are anecdotal reports of changing demographics amongst CPFV anglers, including increased proportions of non-white anglers, since then (T.S. Talley, pers.comm., July 29, 2021).

In addition to changes in angler preference and the effects of large-scale oceanographic conditions (which do not fully explain CPUE reductions Mackerel, Bonito, and/or Barracuda), changes in management regimes also have the potential to affect landings data and are summarized for each species below:

1. Mackerel: In terms of management, Pacific Mackerel (*Scomber japonicus*) has had a complex history. Commercial fishing of Mackerel in California intensified in the early part of the twentieth century (c. 1930s), after which harvests underwent long-term decline until reaching record lows in the 1970s (Crone and Hill 2015). At that time, the state implemented a short-lived moratorium on the commercial fishery, which coincided with high CPUE for Mackerel in this study's dataset (c. 1972). From that highpoint, Mackerel CPUE of the CPFV fleet has exhibited a steady decline, with no major changes in management strategies other than the initiation of a harvest control rule of 18,200 metric tons in 2001 for the commercial fishery (PFMC 2011). The decline documented in this study is consistent with declines identified in the commercial fishery, including prior to the initiation of the harvest control rule, as well as recent fisheries-independent stock assessments (Crone *et al.* 2009, Crone and Hill 2015).

   Because neither changing preferences nor large scale oceanographic conditions explain the marked decline in Mackerel CPUE identified by this study, and because this decline is mirrored by and commercial landings and

stock assessments (Crone *et al.* 2009, Crone and Hill 2015), it is likely that the decline in CPFV CPUE reflects a true decline in the biomass of this species. However, given the relatively small contribution of recreational fishing to the overall landings of Pacific Mackerel (<5% in most years [Crone and Hill 2015]), it is likely that sportfishing catch reflects, rather than significantly contributes to, this decline.

2. Barracuda: In the case of California Barracuda (*Sphyraena argentea*), changes in management strategies are more likely to explain the significant reduction in CPFV landings that occurred in the late 1960s/early 1970s, after which the species remained relatively depressed, though relatively stable, in catch totals. In the 1930s and 1940s, take of Barracuda by southern California sportfishermen rivaled that of take from the commercial fishery (Pinkas 1966). During the post-World War II boom years, recreational take contributed 70-85% of total take for this species and by the mid-1960s this species was considered a mainstay of the CPFV fleet (Pinkas 1966). However, fisheries managers in the late 1950s noticed that concerning reductions in Barracuda CPUE in southern California had begun in 1947 and recommended size limits for both the commercial and recreational fisheries. That size limit (28 inches TL), along with a 10 fish bag limit, is still in place today (CDFW 2021).

Because the main change to Barracuda management coincided with the period of reduction of Barracuda in the CPFV catch documented by this study, it is likely that the reductions in CPFV CPUE of Barracuda are an artifact of that management regime. Importantly, though, the true status of the Barracuda population is poorly known, due to a lack of data and assessment (CDFW 2001).

3. Bonito: The third species to display an overall reduction in CPUE through time in this study is Pacific Bonito (*Sarda chiliensis*), which, in addition to being highly cyclical, all but disappeared in the CPFV catch beginning in the early 1990s. While significant effort has gone into understanding energetics and morphological characteristics of this species (*e.g.,* Magnuson and Prescott 1966, Ellerby *et al.* 2000, Sepulveda *et al.* 2003), relatively little effort has been undertaken to document overall population dynamics and/or stock condition. The limited information available about condition of the California Bonito stock comes from the California Department of Fish and Wildlife (CDFW). Per guidelines established as part of California' Marine Life Management Act of 1998, CDFW completes regular status reports for the major fisheries of the state, beginning with a baseline report in 2001 and followed by updates through 2003, 2006, 2008, and 2011 (CDFW 2013).

Though Bonito was included in the 2001 baseline report and the 2008 update, it does not appear in any of the other reports, including the most recent one.

The baseline report indicated "precipitous" decreases in recreational Bonito landings between 1980-1998, as well as reductions in commercial landings during the second half of the twentieth century. The decline in commercial landings was largely attributed to low market value and restrictions on foreign vessels in Mexican nearshore waters beginning in the early 1980s, where 50-90% of landed Bonito was taken from the period 1943-1958 and 1975-1978 (CDFW 2001). Despite these restrictions, CPFV effort in Mexican waters peaked in 1984-1985 and 1997-1998.

The recreational decline was attributed to a variety of factors, including a shift of the recreational fishery towards more desirable tuna species, changes in distributions due to oceanographic changes, and an overall decline in stock abundance (CDFW 2001). Though CDFW's baseline report did not quantify the relationship between Bonito and large-scale conditions, the current study does not fully support the Department's conclusion. PDO, ENSO, and temperature jointly explain roughly 17% of the variability in Bonito catch. However, this serves only to explain the strongly cyclical nature of Bonito landings, not the relative absence in CPFV CPUE beginning in 1990 identified here despite periods of warm water conditions that provide favorable conditions for Bonito survival (CDFW 2001). A shift towards more desirable species may explain some of this trend, particularly Yellowtail, Yellowfin Tuna, Dorado, and to some degree Albacore, which were found here to have relatively higher CPUEs in the period 1990-2011 as compared to previous

years. However, most southern California CPFV fishing trips in U.S. waters have been found not to target any particular species (CDFW 2001). Given this, it is likely that the declines identified by the baseline report and the 2008 update, as well as the near absence of Bonito from post-1990 CPFV landings identified here, are attributable to a reduction in stock abundance.

The last stock assessment for Bonito occurred in 1982, after which a minimum size and weight limit were instituted for both the commercial and recreational fisheries, though up to 50% of the recreational 10-fish bag limit can be undersized individuals (CDFW 2021). Given that the majority of change in CPFV CPUE occurred post-1990, an updated stock assessment is highly recommended. While recreational fishing accounts for the majority of take for this species (as opposed to commercial fishing), factors other than fishing pressure (*e.g.*, prey availability) may also account for declines in stock abundance. The relationship between declines in Bonito CPUE should be evaluated against abundance of anchovies, sardines, and other forage fish species targeted by Bonito in southern California. Bonito are currently included in the federal Highly Migratory Species Fishery Management Plan as a "monitored" species (*i.e.*, it is not actively managed on a federal level), and if fisheries-independent data and/or stock assessments support the declines documented here, it may be valuable to consider stronger management of this species.

Other Trends

Beside the three species displaying overall declines in CPUE, three additional

species/groups displayed trends of note during the period analyzed by this study:

Halibut, *Sebastes spp*, and *Paralabrax spp*.

1. Halibut: California Halibut (*Paralichthys californicus*) appeared in relatively

    high abundance during the first ten years of this data set (1959-1970),

    experienced a reduction during the following ten years, and has been nearly

    absent since 1977. Consistent with this, a 2011 stock assessment identified a

    depleted stock during the whole timeframe modeled (1971-2011), with the

    2011 population modeled at only 14% of the historic spawning biomass

    (Maunder *et al.* 2011). Low recruitment was identified as a potential

    indication that additional management action is necessary to reduce the risk of

    a fishery collapse, though no specific actions were recommended.

    In fact, this species has a long history of management in the state of

    California, dating back to 1911 when trammel nets were outlawed in state

    waters (Schultze 2011). Between 1913 and the 1970s, various methods of

    commercial fishing were intermittently barred either temporally or spatially

    (Schultze 2011). In 1971, a recreational size limit of 22 inches total length

    was established along with a five-fish bag limit (Schultze 2011). These limits

    are still in place today (CDFW 2021), however there has been no evidence for

    a resulting increase in Halibut population in either the 2011 stock assessment

or this study. Given their co-incidence, it is likely that the 1971 recreational size limits were the cause of the initial reduction of Halibut CPUE from the San Diego CPFV identified here (beginning in 1971) but not the near-absence of Halibut beginning in 1977.

In addition to fishing pressure, Halibut have historically been impacted negatively by coastal development, which has tended to destroy the coastal bays and estuaries on which juvenile Halibut rely (Fodrie *et al.* 2009). Heavy dredging and filling of coastal wetlands in the late 1960s may have influenced CPFV landings of the later 1970s, as this species can live up to 30 years and recruits to the fishery at between 4-6 years of age (Haugen 1990). The combination of the limits placed on recreational fishing, as well as the passage of the California Coastal Act and the establishment of the California Coastal Commission (both of which limited continued filling and dredging along the California coast) likely helped to stabilize Halibut populations from further reductions after the late 1970s. However, the fact that CPFV landings have failed to rebound, even to levels seen following the 1971 recreational catch limits, along with the findings of the 2011 stock assessment, suggest it may be worthwhile to revisit commercial regulations and/or stock enhancement strategies. The California Department of Fish and Wildlife and the California Ocean Science Trust are currently developing an updated 2020 Stock Assessment for this species, which will hopefully provide guidance for updated management recommendations.

Despite their near absence from the CPFV landings in San Diego, Halibut

remain popular among the sportfishing community (Zieralski 2009, Hendricks

2014). Because their CPUE has been relatively stable for the past several

decades (this study), this may combine with their popularity to create a

reduced sense of concern for the status of the stock. For example, the state of

California's baseline fishery status report in 2001 stated, "California halibut

catches have been remarkably stable over the last two decades" as a contrast

to species whose catches have declined. In addition to the impact of shifting

baselines on fisheries managers, the effects are also seen in public perception

of Halibut, as when relatively high CPUE gets reported in local newspapers as

a "comeback" (e.g., Williams 1987), even though the CPUE is still only a

very small fraction of historic recreational catch totals (this study). Taken

within the historic context (stock assessment, this study), it is clear that

Halibut CPUE has stabilized at especially low levels compared to historic

baselines, making Halibut an excellent example of shifting baselines'

potentially negative effect on conservation and management of natural

resources.

2. *Sebastes* and *Paralabrax*: The CPUE of both the genera evaluated, *Sebastes*

   (rock fishes) and *Paralabrax* (kelp bass, sand bass), remained relatively stable

   in the recreational CPUE of the CPFV fleet in San Diego during the period

   investigated. While analyzing these two groups to genus, rather than species,

is consistent with previous analyses (Dotson and Charter 2003), this limits what can be interpreted from the apparent stability of these genera in this dataset. Importantly, other studies (*e.g.,* Erisman *et al.* 2011, Miller and Erisman 2014) have found significant declines in *P. clathratus* that would not be evident in this study due to this grouping.

Despite strong, clear cyclical patterns in the CPUE of both genera, CPUE of neither group is correlated with the cyclical oceanographic conditions (ENSO and PDO) found to explain a significant portion of variability in catch for several other species analyzed here. This may be surprising given that other studies (*e.g.,* Charter and Sandknop 2000) have found an association between ENSO and larval *Sebastes* abundance. Again, individual species within *Sebastes* and/or *Paralabrax* may in fact be strongly associated with oceanographic conditions (as was identified in species-level analysis that found landing and CPUE reductions through time for several *Sebastes* species [Jarvis *et al*. 2004]), but this was not evident at the genus level. Though neither *Sebastes* nor *Paralabrax* were correlated with ENSO or PDO in this study, temperature explained a measure of variability in both genera. In the case of *Paralabrax,* the association is weak, with temperature (contemporaneous and 1 year lag) explaining only 6% of the variability in catch. By contrast, temperature explains 42% of the variability in *Sebastes*, with colder temperatures associated with higher catch totals. This is consistent

with previous studies (e.g., Jarvis *et al.* 2004), based on fisheries dependent and fisheries independent data for specific rock fish species.

The association of *Sebastes* species with cold water has long been documented in scientific literature (*e.g.*, Ainley *et al.* 1993, Laidig *et al.* 2007), though mostly from the perspective of larvae abundance and juvenile recruitment. Given this strong and well-documented association between *Sebastes* and cold water, it may be prudent to model expected responses of this genus to changing ocean temperatures associated with global climate change, and with consideration of the recently documented links between MPAs and increases in the larvae of several rockfishes historically targeted for fishing (Thompson *et al.* 2017). Given the strongly cyclical nature of the CPUE for these species, and considering the susceptibility of larvae to temperature, management strategies may also be worth investigating to see if an adaptive model based on current ecosystem or stock conditions would be more appropriate than the currently fixed catch limits in place today. However, given that this study only analyzed these groups to the genus level, and because management can differ greatly from species to species, further investigation into more specific patterns of abundance would be valuable.

In the case of *Paralabrax*, the apparent stability of CPUE identified by this study should be considered within the context of other reports documenting a decline in at least one *Paralabrax* species (*P. clathratus*) (Thompson *et al.*

2017), as well as recent studies documenting "hyperstability" of the two *Paralabrax* species targeted by the CPFV fishery in San Diego. Hyperstability, a process by which CPUE can remain high even while a species experiences decline in true abundance, has been documented as being particularly prevalent in nearshore coastal species whose life history involves regular, predictable spawning aggregations including *Paralabrax nebulifer and P. clathratus* (Erisman *et al.* 2011).

Importance of Oceanographic Variables

Of the eleven species investigated for a relationship with oceanographic conditions, all were found to be associated with at least one of the three large scale oceanographic conditions examined here (temperature, PDO, and ENSO). For several of these species, this was despite no overall trend in abundance in the CPFV landings. In nearly all cases, contemporaneous or recent past temperature explained the most variability (with the exception of Bonito and Mackerel, whose associations with PDO and ENSO were discussed previously). In the cases of Barracuda, Halibut, and *Paralabrax*, the association was fairly weak, with temperature explaining between 4-6% of the variability. In these cases, it is likely that another variable (*e.g.,* availability of prey items) is responding strongly to temperature, which then affects the target species. For other species, though, temperature explains a relatively large percentage of variability in CPUE – upwards of 42% for *Sebastes*, 22% for Albacore, 17% for Bonito, and around 10% for Dorado, Giant Squid, Yellowtail, and Yellowfin tuna. For all but one of

these species (*Sebastes*), temperature is associated with an increase in CPUE. However, it is unlikely that contemporaneous temperature (or even a 6-month lagged temperature) is directly affecting the underlying populations. Instead, temperature is likely affecting their range, with warmer water bringing migratory species like tunas farther north and increasing their availability to the San Diego CPFV fleet. While this is not news to the fishing community, documenting this type of association within the context of changing ocean waters can be informative for natural resource managers. As species' ranges change with rising sea surface temperatures, it will become increasingly important to avoid overfishing in the face of local abundance despite potentially overall declining stocks (Chavez *et al.* 2017).

Conclusions

Efforts to protect and manage coastal marine resources of California will be both more effective and more cost-efficient when based on the best available information regarding focal populations and habitats. As this study has shown, analysis of CPFV landings can provide an important tool to help understand what is happening in the populations of popular sportfishing species. In some cases, such as California Halibut, this analysis can help underscore previously identified patterns and provide additional support for necessary management actions in recreational and/or commercial fishing. In other cases, such as Bonito, these analyses highlight patterns of decline that have so far not instigated active management. Such analyses also support the use of quantitative, non-traditional

data sets in investigating ecological patterns, particularly in cases where

minimizing the effects of shifting baselines can improve restoration targets.

However, data gaps exist for interpreting causes of identified patterns (*e.g.*, social

data on angler demographics and preferences) and opportunities exist for better

understanding the impact of management actions on target species (*e.g.*,

collaborative fisheries programs to collect data regarding catch sizes, locations,

timing, bycatch, *etc.*). While it is important to combine fisheries dependent

historical analyses with fisheries-independent investigations to fully understand

the population dynamics of particular species of interest, this study helps tease out

some of the longer-term trends not always available through the use of modern

scientific data alone.

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Appendix A: Catch and CPUE for all 21 focal species

Total annual catch (orange line, right axis) and CPUE (grey bars, left axis) 1959-2011. Note CPUE is log+1 transformed and catch is presented in the thousands.