FISHERIES INVENTORY AND UTILIZATION OF SAN DIEGO BAY, SAN DIEGO, CALIFORNIA FOR SURVEYS CONDUCTED IN APRIL AND JULY 2019

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TABLE OF CONTENTS

List of Tables iv

List of Figures v

1.0 Executive Summary 1

2.0 Introduction 4

3.0 Methods and Materials

3.1 Survey Locations 5

3.2 Ichthyofaunal Sampling 6

3.3 Water Quality Sampling 11

3.4 Data Analysis

3.4.1 Best Estimate of Density and Standing Stock 12

3.4.2 Community Analysis 13

4.0 Results and Discussion

4.1 Water Quality Parameters 14

4.2 Numerical Catch and Biomass 16

4.3 Species Diversity and Richness 24

4.4 Catch by Sampling Period and Ecoregion 25

4.5 Catch by Depth Strata and Subhabitats 29

4.6 Nursery Area Function 32

4.7 Ecological Importance of Species 33

4.8 Principle Species 35

4.9 Catch by Sampling Method 45

4.10 Best Estimates of Density and Standing Stock 52

4.11 Avian Forage Species 55

4.12 Fisheries Species 57

4.13 Southern Species Found in San Diego Bay 58

4.14 Indigenous Bay and Estuary Fishes 59

4.15 Invasive Species 60

4.16 Comparison of the Current and Historical April and July Surveys

4.16.1 Abundance, Biomass, and Stock Estimates 61

4.16.2 Community Metrics 65

4.16.3 Community Structure 68

5.0 Literature Cited 70

LIST OF TABLES

Table 1.	Lambert coordinates for San Diego Bay fisheries inventory	6
Table 2.	Estimates of aerial coverage of depth strata by ecoregion	12
Table 3.	Total abundance of fishes collected in San Diego Bay	18
Table 4.	Total biomass of fishes collected in San Diego Bay	19
Table 5.	Total abundance and biomass in the North Ecoregion	20
Table 6.	Total abundance and biomass in the North-Central Ecoregion	21
Table 7.	Total abundance and biomass in the South-Central Ecoregion	22
Table 8.	Total abundance and biomass in the South Ecoregion	23
Table 9.	Total abundance by sampling period	27
Table 10.	Total biomass by sampling period	28
Table 11.	Total abundance of fishes by depth strata	30
Table 12.	Total abundance by subhabitat	31
Table 13.	Percent of juveniles by species	32
Table 14.	Ecological Index of fishes	34
Table 15.	Total catch by sampling method	46
Table 16.	Total biomass by sampling method	49
Table 17.	Numerical and biomass density estimates by gear type	52
Table 18.	Best estimate of fish density and estimated stock size	53
Table 19.	Best estimate of biomass density and standing stock	54
Table 20.	Best estimate of avian forage fish species	56
Table 21.	Best estimate of fishery species	57
Table 22.	Panamic species from San Diego Bay	58
Table 23.	Abundance of Panamic species in San Diego Bay	59
Table 24.	Indigenous bay/estuarine species taken in San Diego Bay	59
Table 25.	Historical comparison of total catches	61
Table 26.	Historical comparison of abundance for top species	62
Table 27.	Historical comparison of total biomass	63
Table 28.	Historical comparison of biomass for top species	64
Table 29.	Historical comparison of stock/biomass standing stock estimates	65
Table 30.	Shannon diversity historical comparison	66
Table 31.	Species richness historical comparison	67

LIST OF FIGURES

Figure 1.	Sampling locations in San Diego Bay	5
Figure 2.	Sampling events for the North Ecoregion	8
Figure 3.	Sampling events for the North-Central Ecoregion	9
Figure 4.	Sampling events for the South-Central Ecoregion	10
Figure 5.	Sampling events for the South Ecoregion	11
Figure 6.	Summary of physical-chemical measurements by ecoregion	14
Figure 7.	Monthly rainfall in San Diego	15
Figure 8.	Catch of fishes by Ecoregion	16
Figure 9.	Catch of the five numerically dominant species by ecoregion	17
Figure 10.	Shannon diversity and species richness by ecoregion	24
Figure 11.	Shannon diversity and richness by sampling month	24
Figure 12.	Total abundance by sampling month	26
Figure 13.	Total biomass by sampling month	26
Figure 14.	Top 20 species ranked by Ecological Index	33
Figure 15.	Length frequency of Topsmelt	35
Figure 16.	Disc width frequency of Round Stingray	36
Figure 17.	Length frequency of Spotted Sand Bass	37
Figure 18.	Length frequency of Slough Anchovy	38
Figure 19.	Length frequency of Deepbody Anchovy	39
Figure 20.	Length frequency of Giant Kelpfish	40
Figure 21.	Length frequency of Shiner Perch	41
Figure 22.	Length frequency of Kelp Pipefish	42
Figure 23.	Length frequency of California Halibut	43
Figure 24.	Length frequency of Dwarf Perch	44
Figure 25.	Historical comparison of total catch	61
Figure 26.	Historical comparison of abundance for top species	62
Figure 27.	Historical comparison of total biomass	63
Figure 28.	Historical comparison of biomass for top species	64
Figure 29.	Historical comparison of Shannon diversity	66
Figure 30.	Historical comparison of species richness	67
Figure 31.	Historical comparison of fish community structure	68
Figure 32.	Relative mean abundance by fish community group	69

1.0 EXECUTIVE SUMMARY

The Vantuna Research Group at Occidental College surveyed the estuarine fishes of San Diego Bay in April and July 2019 for the Port of San Diego. The goals of the current study were to update previous studies, as well as quantify spatial and temporal utilization of the fishery populations in San Diego Bay. A summary of the results is as follows:

Composition and Abundance

During this study, 14,024 (45 species) fishes weighing a total of 271.5 kg were collected during April and July 2019. The most numerous species comprising 57.4% of the catch was Topsmelt (*Atherinops affinis*), followed by Slough Anchovy (*Anchoa delicatissima*; 9.0%), Deepbody Anchovy (*Anchoa compressa*; 7.4%), Dwarf Perch (*Micrometrus minimus*; 4.9%), and Giant Kelpfish (*Heterostichus rostratus*; 4.3%). In terms of biomass, Round Stingrays (*Urobatis halleri*) dominated the catch comprising 42.5% of the biomass, followed by Spotted Sand Bass (*Paralabrax maculatofasciatus*; 24.2%), and Topsmelt (8.4%). These species are typically among the most dominant species in surveys of San Diego Bay with the exception of Deepbody Anchovy which was only numerically dominant due to one school being captured in a single purse seine replicate.

Ecological Importance of Species

The principle fishes surveyed during these sampling periods as determined by the Ecological Index (E.I.) were the following species: Topsmelt, Round Stingray, Spotted Sand Bass, Slough Anchovy, and Deepbody Anchovy. Topsmelt ranked first (E.I. 6,572), Round Stingray ranked second (E.I. 4,606), and Spotted Sand Bass ranked third (E.I. 2,718). All three species were found ubiquitously throughout the bay during both sampling periods. Round Stingray and Spotted Sand Bass were dominant in terms of biomass, and Topsmelt was dominant in terms of numerical abundance. Slough Anchovy ranked fourth (E.I. 725) but was not present in the North Ecoregion during either sampling period. These species were followed by Deepbody Anchovy (E.I. 488), which were nearly all (98.6%) captured in a single purse seine replicate in the South-Central Ecoregion in July.

Best Estimates of Density and Standing Stock

The stock size estimate in 2019 was 18.3 million fishes, approximately half of the 2015 and 2016 estimates and the second lowest estimate ever behind 2012. With an estimated surface area of 4,858 ha this gives an overall fish density 0.38 individuals/m^2. The highest estimates were of Topsmelt (8.16 million), followed by Deepbody Anchovy (2.75 million), Slough Anchovy (2.19 million), Giant Kelpfish (1.09 million), and Shiner Perch (*Cymatogaster aggregata*; 0.815 million). As is typical, schooling and forage fishes dominated the stock estimate for the bay. The total best estimate of biomass standing stock was nearly 420 MT or approximately 8.64 g/m^2, about 35% higher than the 2016 estimate and above average for all historical surveys. The highest biomass estimates were of Round Stingray (136.5 MT), followed by Spotted Sand Bass (106.8 MT), Topsmelt (44.1 MT), Deepbody Anchovy (40.9 MT), and Bat Ray (*Myliobatis californica*; 17.0 MT). Round Stingray and Spotted Sand Bass are typically in the top five

biomass estimates from past surveys, but Deepbody Anchovy is a historically atypical top biomass species.

Avian Forage and Fisheries Species

Forage species are primarily surface-dwelling schooling fish that are accessible to diving avian predators, especially terns. Generally, forage fishes are small silvery-sided fishes that are found in large schools. These schooling fishes are not habitat-specific and move throughout the bay's ecosystem. Thirteen species of important forage fishes were captured during this study. The most abundant forage fishes were Topsmelt, Slough Anchovy, and Deepbody Anchovy. Topsmelt were primarily found at small (juvenile) size classes (<50 mm SL) appropriate for nesting birds to feed their young in the area. The typical timing for the recruitment of fishes to San Diego Bay begins in the spring and continues through the summer, but it appears this began much earlier in the year in 2019. The biomass standing stock estimate for forage fish was 106.7 MT. During this study, 13 important California recreational or commercial species were captured, the most abundant of which was Spotted Sand Bass. The standing stock estimate of fisheries species totaled 149.7 MT.

San Diego Bay as a Unique Fish Habitat and Nursery Area

San Diego Bay is known for being the northern edge of the range for many southern fishes that are not normally distributed in the Southern California Bight. Six species with primarily southern distributions were taken, including the largest Shortfin Corvina (*Cynoscion parvipinnis*; 48 cm SL) ever captured in the history of these surveys. These fishes were found almost exclusively in the southern half of the bay and none were captured in the North Ecoregion.

As the largest estuary in southern California, San Diego Bay provides critical habitat for bay and estuary fishes and continues to function as a nursery area for nearly two-thirds (65.2%) of those fishes. The high productivity rate coupled with the abundance of juvenile fishes in the bay highlights the importance of the bay as a nursery habitat. The bay contains extensive shallow water eelgrass habitat that supports a unique assemblage of juvenile and adult fishes that, in turn, support surrounding nearshore ecosystems. Juvenile fishes emigrate from the bay to offshore habitats, and important or endangered avian species utilize forage fishes in the bay. Southern California indigenous bay and estuary fishes represented 23.1% of the total catch in this survey.

Trends and Comparisons

While the 2019 surveys represent the fewest fishes ever captured in historical surveys, the biomass captured was only slightly below average. This is a product of not capturing large numbers of small individuals as is typical during April sampling, but instead capturing fewer, but larger, fish throughout the survey. This was particularly true in the South Ecoregion where fewer than 30% of the historical mean number of individuals was captured, but the biomass captured was the second highest ever recorded – more than 30% higher than average. Size structure of most species captured during the April sampling period was more typical of July sampling period catches (larger, fewer

young-of-the-year), potentially indicating a very early reproductive season for fishes in the bay.

Overall, 2019 Shannon Diversity estimates were variable among ecoregions and rank among historical values. The North and North-Central Ecoregions had the third and second lowest diversity values, respectively, of any sampling year. However, diversity values for the South-Central and South Ecoregions were the third highest of any sampling year. Species richness for 2019 was low overall (second lowest of any sampling year). Richness was the lowest ever recorded in both the North and North-Central Ecoregions and was tied for third lowest at both the South-Central and South Ecoregions for any survey period. Community structure of fishes was most similar to that of the 2012 surveys but was not statistically different than any other survey performed in the 21st Century.

Sunrise over the North Ecoregion in April 2019.

2.0 INTRODUCTION

The Vantuna Research Group at Occidental College surveyed the estuarine fishes of San Diego Bay in April and July 2019 for the Port of San Diego. The survey followed the protocols established from previous surveys (Allen 1999, Allen et al. 2002, Pondella et al. 2006, Pondella and Williams 2009a, Williams and Pondella 2012, Williams et al. 2015, Williams et al. 2016). The goals of the current study were to update the previous studies and address the following objectives:

1) Identify, determine, and quantify the utilization of the fishery populations in San Diego Bay

2) Identify habitats that support juvenile fish species and describe nursery utilization

3) Determine geographic and/or habitat areas of San Diego Bay that support significant populations of fish species utilized as forage by endangered avian species

4) Provide a comprehensive comparison of survey results to previous sampling years

In order to accomplish the objectives for these two sampling periods, we have documented the following parameters:

- ✓ Water quality parameters
- ✓ Fish species composition and abundance
  - Species diversity
  - Abundance by bay ecoregion
- ✓ Ecological importance of species
- ✓ Nursery area function
- ✓ Fish density and biomass estimates
  - Numerical and biomass density
  - Density and standing stock of avian forage species
  - Density and standing stock of fishery species
  - Panamic species unique to San Diego Bay
- ✓ Fish assemblage structure
- ✓ Historical comparisons
  - Diversity, Richness, Biomass, Abundance
  - Community structure

3.0 METHODS AND MATERIALS

3.1 Survey Locations

Four ecoregions of San Diego Bay were sampled and inventoried: North, North-Central, South-Central, and South (Figure 1, Table 1). These ecoregions were defined by Allen et al. (2002) and selected to adequately assess the status of all components of the ichthyofauna of the bay.

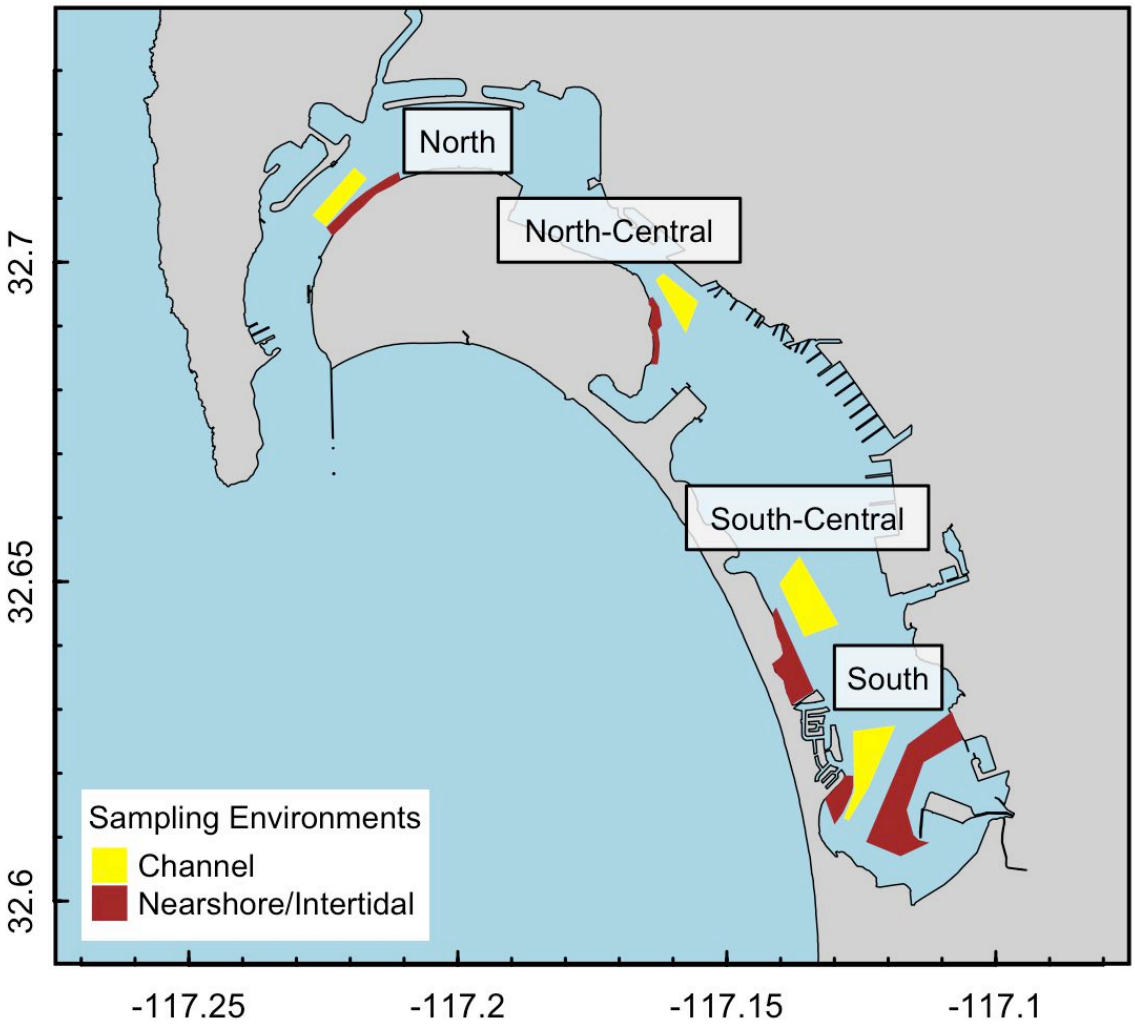


Figure 1. Sampling environment locations of the North, North-Central, South-Central, and South Ecoregions in San Diego Bay.

Table 1. Lambert Coordinates (Latitude, Longitude) for the San Diego Bay Fisheries Inventory and Utilization study, 2019.

Ecoregion	Site	Latitude	Longitude
North	Vegetated	32° 41' 50"	117° 13' 40"
	Non-Vegetated	32° 42' 45"	117° 12' 30"
North-Central	Vegetated	32° 41' 25"	117° 09' 50"
	Non-Vegetated	32° 41' 12"	117° 09' 45"
South-Central	Vegetated	32° 39' 05"	117° 08' 30"
	Non-Vegetated	32° 38' 48"	117° 08' 25"
South-Central	Vegetated	32° 37' 00"	117° 07' 45"
	Non-Vegetated	32° 36' 50"	117° 06' 45"

3.2 Ichthyofauna Sampling

Ichthyofauna sampling occurred during the spring and summer quarters of 2019 (April 6-7, April 13-14, and July 8-11, 2019). One ecoregion was sampled per day per sampling season. Collections were made off the 5-meter (m) *R/V Old Blue* and the 6.5-m *R/V Neoclinus*. At each ecoregion, the following five subhabitats were sampled: deep channel, nearshore non-vegetated, nearshore vegetated, intertidal non-vegetated, and intertidal vegetated.

Fish were sampled at each ecoregion using the following gear:

1) A 15.2-m x 1.8-m large seine equipped with a 1.8-m x 1.8-m x 1.8-m bag (1.2-centimeter [cm] mesh wings and 0.6-cm mesh in bag) was used to sample fishes in the intertidal subhabitat of each ecoregion at a depth of 0-2 meters. The net was set 15 m offshore parallel to the shoreline and pulled in shore, sampling an area of about 220 square meters (m^2) per haul. Three replicates per habitat were conducted for a total of six per ecoregion.

2) A 4.6-m x 1.2-m small seine with 3-mm mesh was utilized to collect fish in the shallow intertidal habitat of 0-0.5m depths. The small seine was pulled 10 m along shore and pivoted towards the shore, sampling an area of approximately 62 m^2. Three replicates per subhabitat were conducted for a total of six per ecoregion.

3) A 1-m^2 square enclosure constructed of metal pipe and canvas was used to survey small, burrow-inhabiting fish in shallow intertidal areas of the bay. The enclosure was randomly set within each subhabitat in a depth of 0.25-0.75 m. One liter of 9:1 isopropanol-2-quinoline solution was added to the enclosed water and then searched for 10 minutes using a 1-millimeter (mm) mesh dipnet. Three replicates per subhabitat were conducted for a total of six per ecoregion.

4) A 1.6-m beam trawl (4-mm mesh wings and 2-mm knotless mesh in the codend) was used to sample nearshore fish species. Standardized 10-minute tows were conducted sampling an area of approximately 290 m^2 per replicate. Three replicates per subhabitat were conducted for a total of six per ecoregion.

5) A 66-m x 6-m purse seine (1.2-cm mesh wings and 0.6-cm mesh bag) was used to sample fish species in the nearshore and channel subhabitats, sampling a total area of approximately 296 m^2 per replicate. Three replicates per subhabitat were conducted for a total of nine per ecoregion.

6) An 8-m semi-balloon otter trawl (2-cm mesh wings and 0.8-cm mesh codend) was used to survey fishes from the deepest portions of the channel subhabitat. Standardized 10-minute tows were conducted sampling a total area of approximately 2,417 m^2 per each replicate. Three replicates were conducted per ecoregion.

All fishes were identified and measured to the nearest centimeter (standard length [SL]) and gram using measuring boards and hanging scales or a digital balance. Most individuals were measured aboard the research vessels and returned to the water, though large catches of small individuals were returned to the laboratory for identification and measurement. Coordinates of each sampling effort were recorded for all sampling events. For otter and beam trawls the start and finish of each tow were recorded. The sampling events are plotted in Figures 2-5.

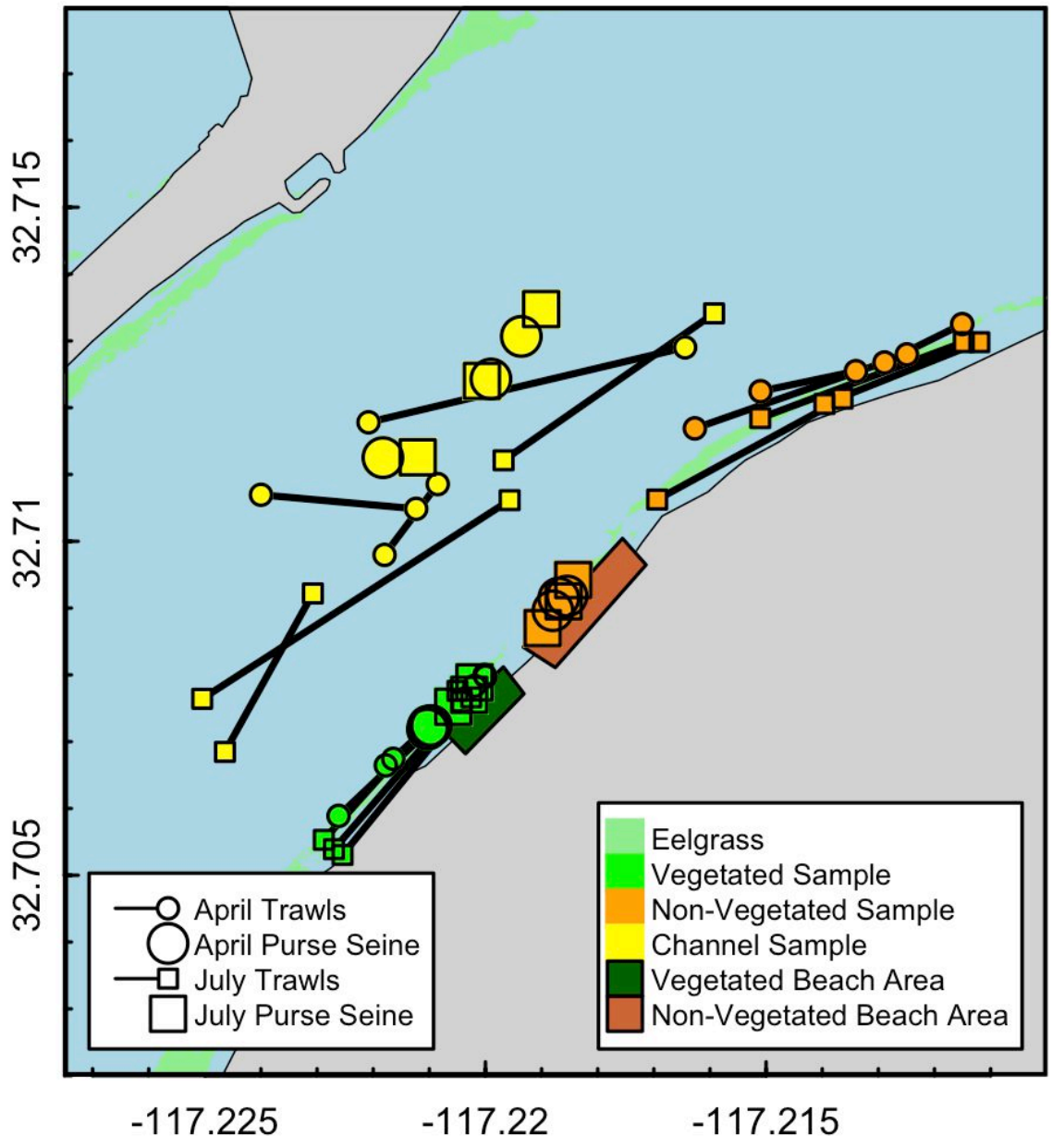


Figure 2. Sampling events for the North Ecoregion, 2019.

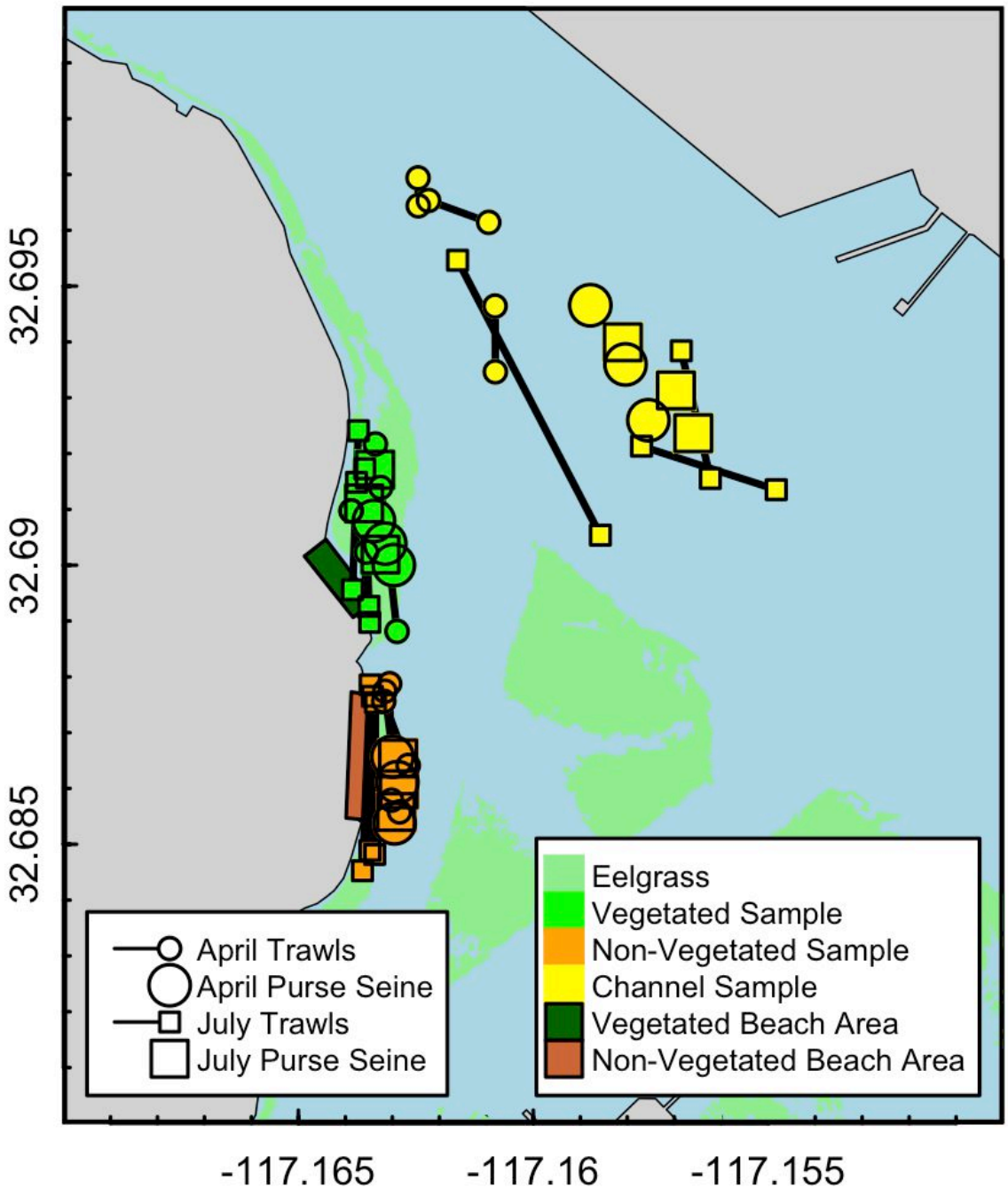


Figure 3. Sampling events for the North-Central Ecoregion, 2019.

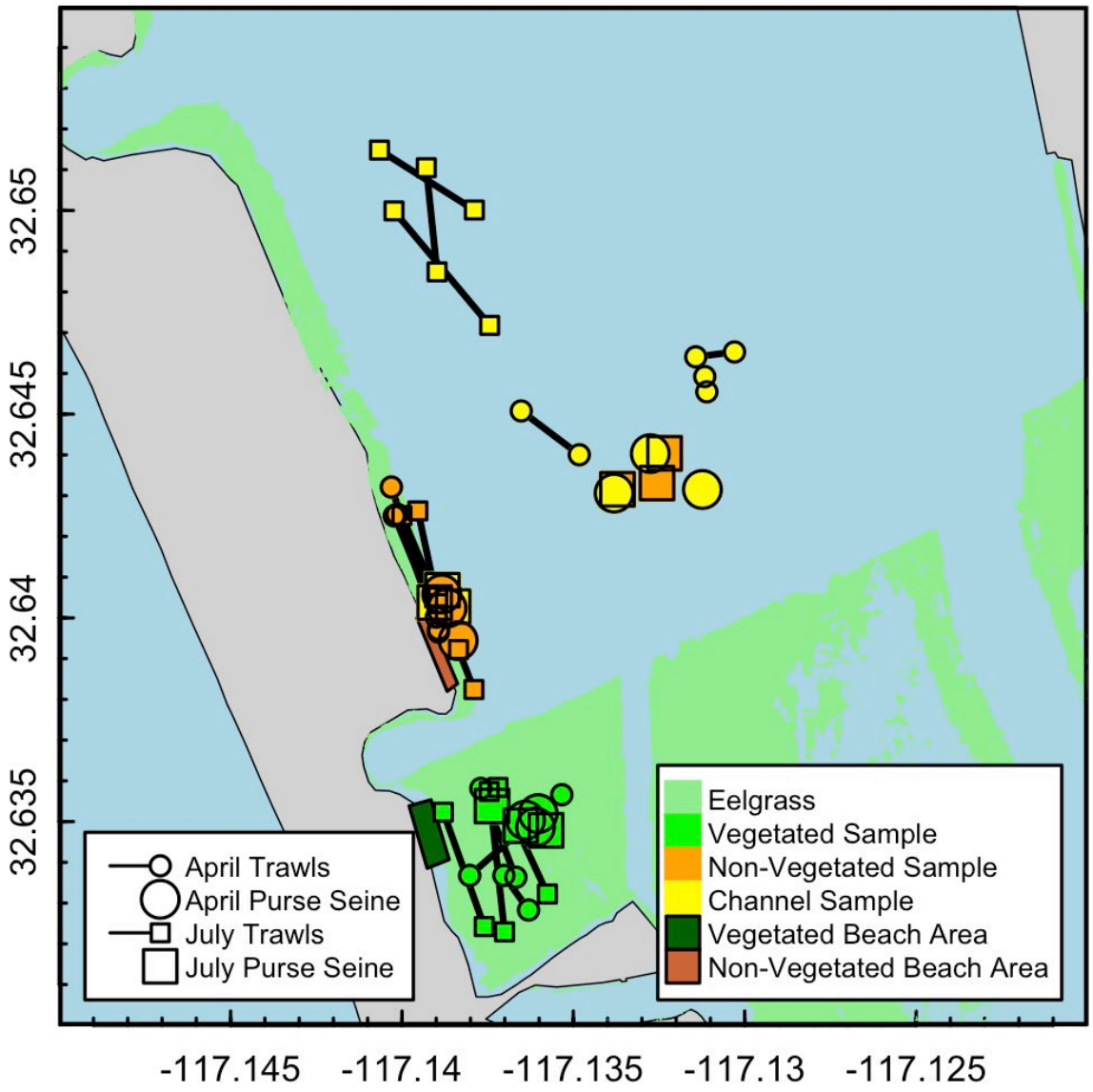


Figure 4. Sampling events for the South-Central Ecoregion, 2019.

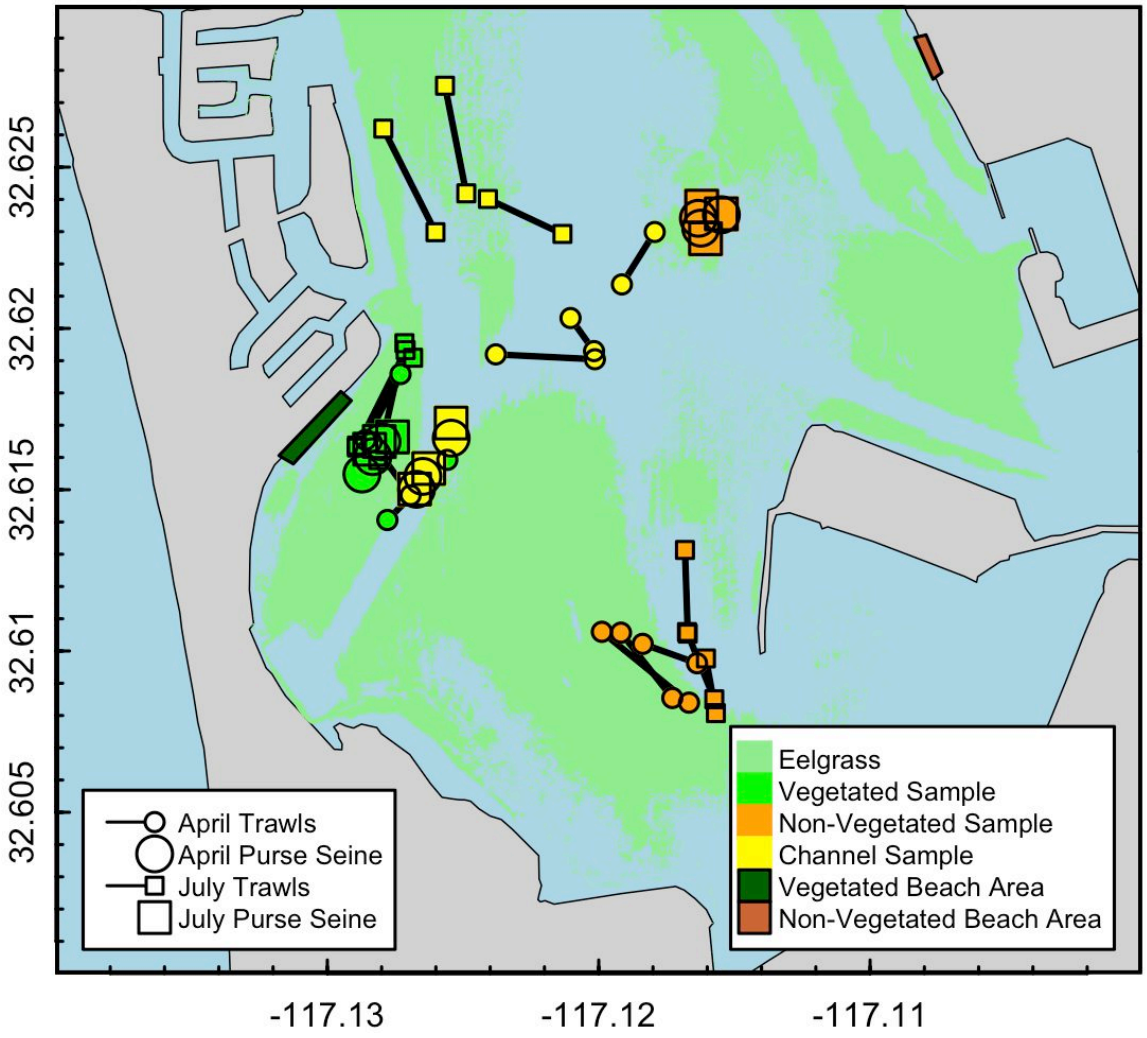


Figure 5. Sampling events for the South Ecoregion, 2019.

3.3 Water Quality Sampling

Water temperature (degrees Celsius [°C]), salinity (parts per thousand [ppt]), dissolved oxygen (milligrams per liter [mg/1]), and pH were measured during each sampling period and at each ecoregion using a Sea-Bird oceanographic profiler (Model SEACAT SBE 19*plus*V2) from *R/V Old Blue*. Downcast data from the 1-m surface bin where used to report these water quality values at the surface.

3.4 Data Analysis

3.4.1 Best Estimates of Density and Standing Stock

Density estimates used for the standing stock assessment were determined using the *Best Estimate of Density* within each Ecoregion. The best density and stock estimates were determined in the following manner:

1) Sample densities estimated by gear type for each species were averaged over all samples within the three depth strata (Intertidal, Nearshore, and Channel).
2) The maximum density for each species by gear type within each depth stratum was determined to be the *Best Estimate of Density* for that species within that depth stratum.
3) The proportional areal coverage of the three depth strata within the Ecoregion was determined previously by Allen et al. (2002) were used for the current study (Table 2). These areal proportions were then used to weight the *Best Estimate of Density* within the depth strata by species. A weighted average was then taken among these best estimates over the three depth strata for each species.
4) The sum of the weighted densities of all species represented *Best Estimate of Density* (numerical and biomass) for each depth stratum and Ecoregion was calculated.
5) Standing stock estimates were calculated by multiplying the best estimates by the total area of the individual Ecoregions and San Diego Bay as a whole.

Table 2. Estimates of area coverage of depth strata within each Ecoregion of San Diego Bay. Proportions and areas were used to weigh density and estimate standing stocks of fisheries.

% Area Ecoregion	Intertidal	Nearshore	Channel
North	6	33	60
North-Central	5	38	57
South-Central	3	61	36
South	4	84	13

Hectares/Habitat Ecoregion	Intertidal	Nearshore	Channel	TOTAL	% of Bay
North	61	327	593	982	20
North-Central	41	307	460	808	17
South-Central	51	1227	726	2005	41
South	40	890	133	1064	22
# Hectares	194	2751	1913	4858	
% Bay Area (Allen 2002)	4	57	39		

3.4.2 Community Structure

To characterize community-level temporal changes in fishes, we constructed a Bray-Curtis similarity matrix using the 'vegdist' function in the 'vegan' package (Oksanen et al. 2019) in R (R Core Team 2019). The matrix used fourth-root transformed taxon-specific abundance data summed across all replicates throughout the bay during each April and July. Significantly different fish community groups were determined using a cluster analysis with a SIMPROF test (alpha = 0.05) performed with the 'simprof' function in the 'clustsig' package (Clarke et al. 2008; Whitaker and Christman 2014.)

Jacob Eagleton holds a 48-cm Shortfin Corvina (*Cynoscion parvipinnis*) caught by purse seine in the South Ecoregion in July 2019.

4.0 RESULTS AND DISCUSSION

4.1 Water Quality Parameters

Sea surface temperature generally increased from north to south in the bay during both sampling periods, though the temperature was about 3-5 ºC warmer at each ecoregion during the July sampling period (Figure 6). Water temperature was also slightly above average in April and slightly below average in July. Dissolved oxygen was relatively consistent among Ecoregions. Salinity and pH increased slightly from north to south during the July sampling period but was consistent among ecoregions during the April sampling period. These physical-chemical results are typical of the bay and did not show effects of above-average winter rainfall.

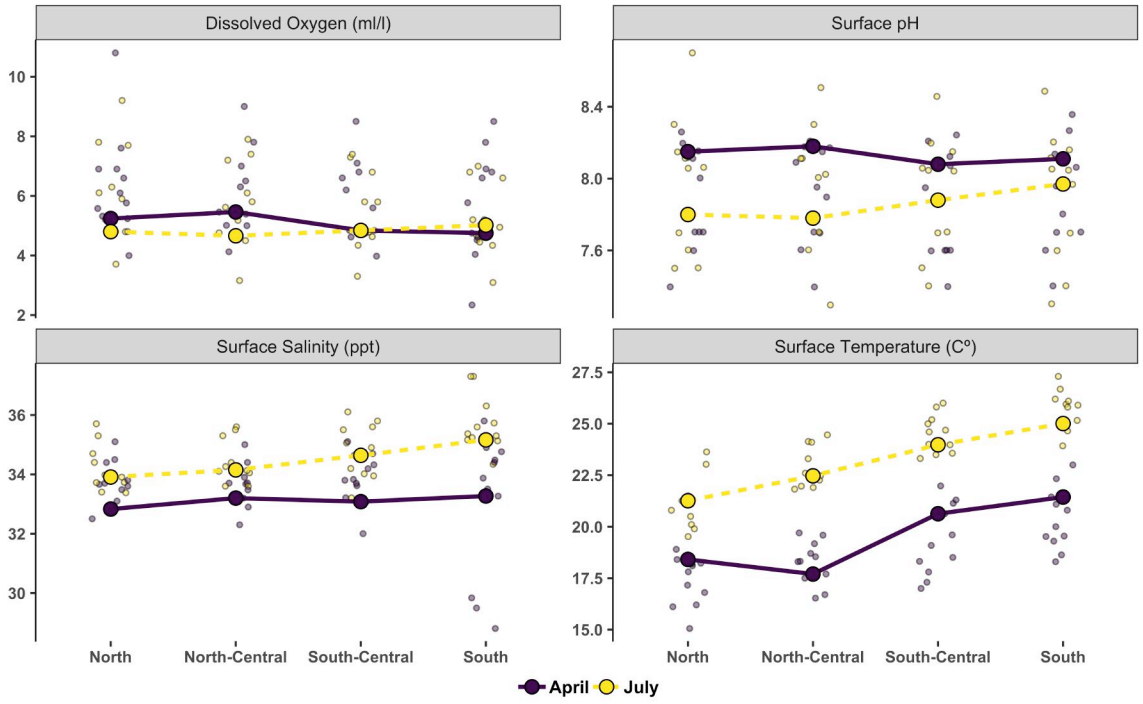


Figure 6. Summary of physical-chemical measurements by ecoregion in April and July 2019. To contextualize the 2019 results, values from previous surveys (1995-2016) are plotted as smaller, open points.

Salinity levels in San Diego Bay are subject to the effects of seasonal rainfall and evaporation. The bay is the receiving body of water for freshwater input from three watersheds (Pueblo San Diego, Sweetwater, and Otay) covering 1,150 square kilometers (km^2) of land, plus over 200 storm drain outfalls (San Diego County MS4 Co-permittees 2008). The South Ecoregion, where the Sweetwater and Otay Rivers meet the bay, has weak tidal currents, low mixing, and a small tidal prism compared to the other ecoregions (Wang et al. 1998) resulting in longer retention of freshwater signatures. However, most of the observed decreases in salinity in the South Ecoregion during the April surveys (e.g. 1998, 2012, 2015; Figure 6) were not during years where there is above average rainfall during Winter and early-Spring (e.g. 1995, 1998, 2005, 2019; Figure 7). This decoupling is due in part to the regulation of the Sweetwater and Otay Rivers by reservoirs that result in only rare releases of water into the rivers. By July, evaporation rates are typically higher than freshwater inflow creating hypersaline conditions regardless of winter precipitation levels (Peeling 1975).

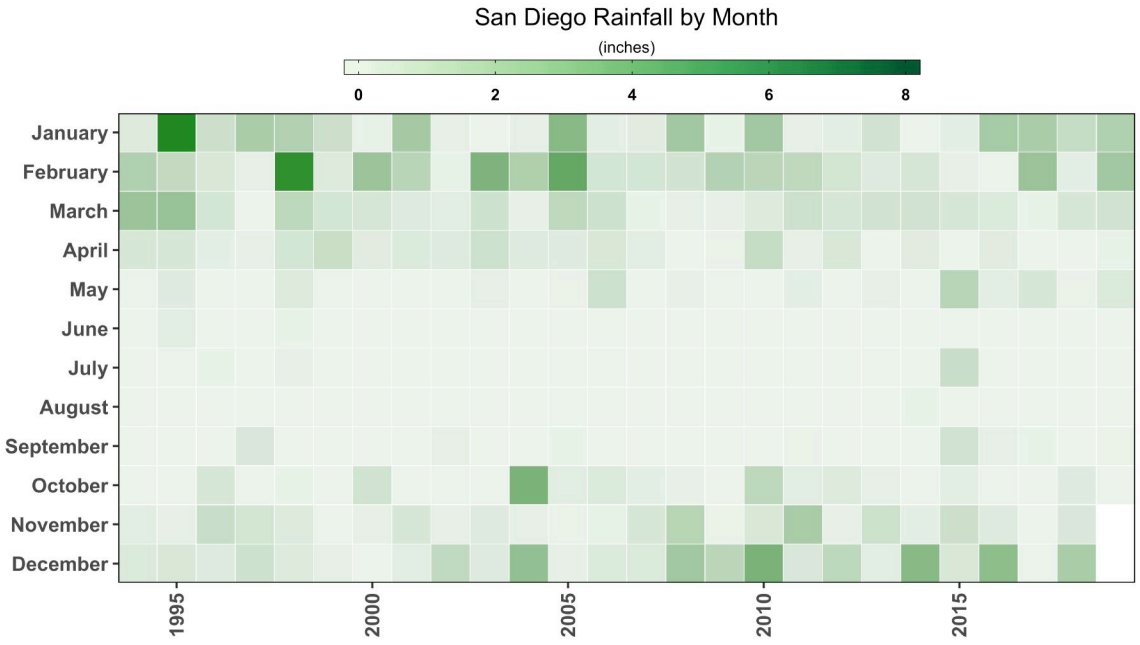


Figure 7. Monthly rainfall in San Diego from 1994-2019. Data are typically collected from National Weather Service rain gauges at San Diego International Airport (Lindbergh Field). Monthly totals were compiled by John S. Stokes III.

4.2 Numerical Catch and Biomass

During this study, 14,024 (45 species) fishes weighing a total of 271.5 kilograms (kg) were collected during April and July 2019. The most numerous species comprising 57.4 percent (%) of the catch was Topsmelt (*Atherinops affinis*), followed by Slough Anchovy (*Anchoa delicatissima*; 9.0%), Deepbody Anchovy (*Anchoa compressa*; 7.4%), Dwarf Perch (*Micrometrus minimus*; 4.9%), and Giant Kelpfish (*Heterostichus rostratus*; 4.3%; Table 3). In terms of biomass, Round Stingrays (*Urobatis halleri*) dominated the catch comprising 42.5% of the biomass, followed by Spotted Sand Bass (*Paralabrax maculatofasciatus*; 24.2%), and Topsmelt (8.4%; Table 4). These species are typically among the most dominant species in surveys of San Diego Bay with the exception of Deepbody Anchovies.

Total catch decreased from north to south (Figure 8) with differences in total fish abundance reflecting the differences in Topsmelt abundance. Abundance was greatest at the North Ecoregion (6,238; Table 5), followed by the North-Central Ecoregion (4,005; Table 6), South-Central Ecoregion (2,233; Table 7), and South Ecoregion (1,548; Table 8). Topsmelt dominated catches in the North (4,867) and North-Central (2,892) Ecoregions while Deepbody Anchovy (1,019) was the dominant species in the South-Central Ecoregion where 100% of the individuals were captured in a single purse seine replicate in July. Slough Anchovy (681) was the dominant species captured in the South Ecoregion.

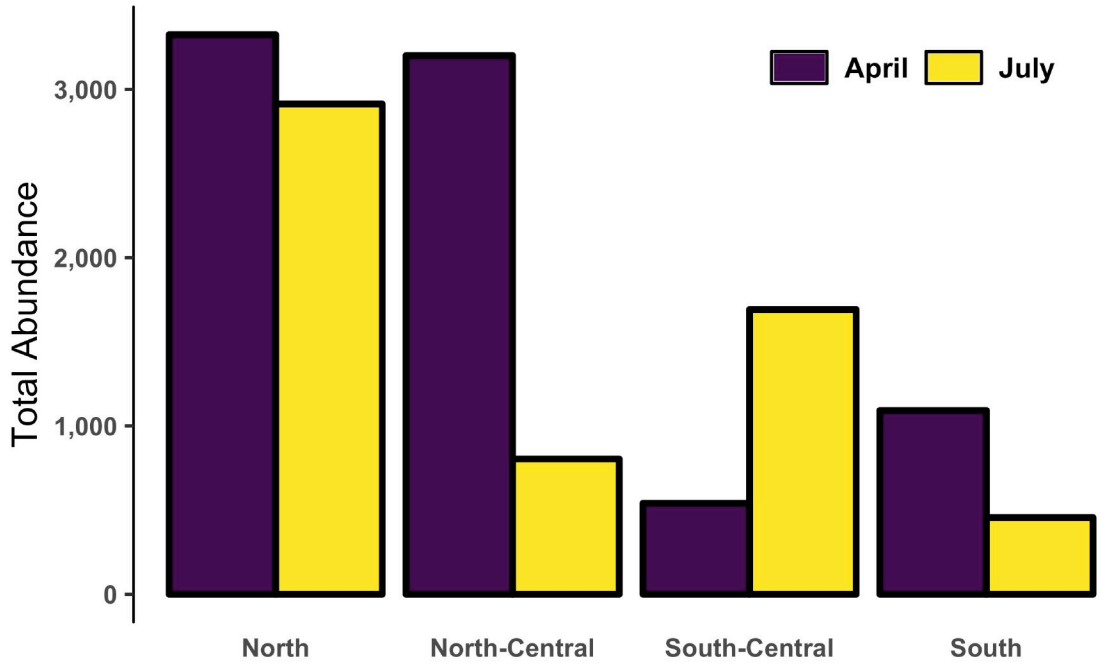


Figure 8. Total catch of San Diego Bay fishes by ecoregion, April and July 2019.

The catch of the five numerically dominant fishes had mixed patterns over the four ecoregions (Figure 9). Topsmelt were especially common in the northern half of the bay and Slough Anchovies were mostly captured in the southern half of the bay. Deepbody Anchovies were mostly limited to the South-Central Ecoregion where, 98.6% of all individuals caught in the entire survey were captured in a single purse seine replicate. Giant Kelpfish were found in all ecoregions and were a numerically dominant species in the North-Central Ecoregion. Dwarf Perch were limited to the North Ecoregion and were a numerically dominant species there.

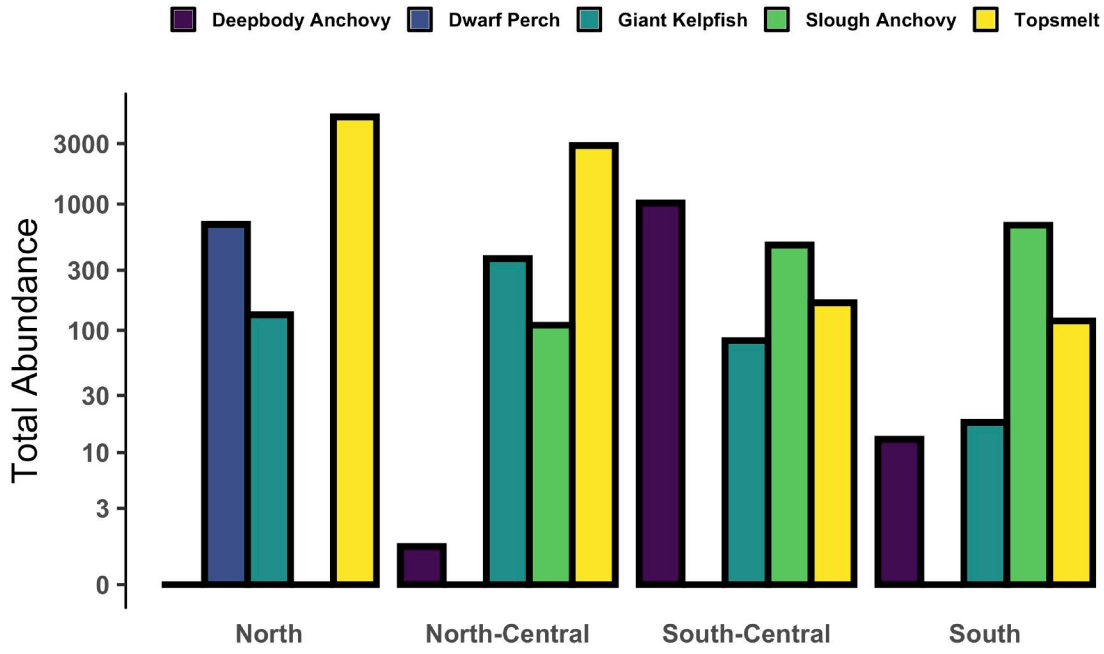


Figure 9. Total catch of the five numerically dominant species by ecoregion, 2019.

Round Stingrays had the highest catch in terms of biomass at three ecoregions (North, 30.9 kg; South-Central, 19.2 kg; South, 48.8 kg) and was second in biomass (16.6 kg) to Spotted Sand Bass (25.5 kg) in the North-Central Ecoregion. Spotted Sand Bass was also a dominant species in terms of biomass in the North (6.45 kg), South-Central (12.5 kg), and South (21.2 kg) Ecoregions. Topsmelt was a dominant species in terms of biomass in the North (14.3 kg) and North-Central (7.32 kg) Ecoregions. Deepbody Anchovies (15.2 kg) and Bat Rays (*Myliobatis californica*; 8.04 kg) were among the dominant species in the South-Central and South Ecoregions, respectively.

Table 3. Total abundance of fishes collected in San Diego Bay during 2019 by ecoregion.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total	%
Atherinops affinis	Topsmelt	4,867	2,892	166	119	8,044	57.36
Anchoa delicatissima	Slough Anchovy		110	475	681	1,266	9.03
Anchoa compressa	Deepbody Anchovy		1	1,019	13	1,033	7.37
Micrometrus minimus	Dwarf Perch	691				691	4.93
Heterostichus rostratus	Giant Kelpfish	133	371	83	18	605	4.31
Cymatogaster aggregata	Shiner Perch	143	139	117	137	536	3.82
Urobatis halleri	Round Stingray	117	91	82	206	496	3.54
Syngnathus californiensis	Kelp Pipefish	82	65	121	163	431	3.07
Paralabrax maculatofasciatus	Spotted Sand Bass	37	155	81	147	420	2.99
Sardinops sagax	Pacific Sardine		77	1		78	0.56
Paralichthys californicus	California Halibut	33	12	14	5	64	0.46
Clevelandia ios	Arrow Goby	8	5	18	21	52	0.37
Hypsoblennius gentilis	Bay Blenny	20	17			37	0.26
Paralabrax nebulifer	Barred Sand Bass	1	27	6	1	35	0.25
Leuresthes tenuis	California Grunion	11	21			32	0.23
Pleuronichthys guttulatus	Diamond Turbot	6	4	14	5	29	0.21
Cynoscion parvipinnis	Shortfin Corvina		1	18	1	20	0.14
Halichoeres semicinctus	Rock Wrasse	19				19	0.14
Scomber japonicus	Pacific Chub Mackerel	14	1			15	0.11
Haemulon californiensis	Salema	1	10	1	2	14	0.10
Porichthys myriaster	Specklefin Midshipman	11		2		13	0.09
Symphurus atricaudus	California Tonguefish	10	1	1		12	0.09
Paralabrax clathratus	Kelp Bass	9	1			10	0.07
Albula gilberti	Cortez Bonefish			8	1	9	0.06
Leptocottus armatus	Pacific Staghorn Sculpin		1	2	6	9	0.06
Embiotoca jacksoni	Black Perch	8				8	0.06
Myliobatis californica	Bat Ray			2	6	8	0.06
Pleuronichthys ritteri	Spotted Turbot	8				8	0.06
Hippocampus ingens	Pacific Seahorse				4	4	0.03
Hyporhamphus rosae	California Halfbeak				4	4	0.03
Cheilotrema saturnum	Black Croaker		2	1		3	0.02
Gymnura marmorata	California Butterfly Ray				3	3	0.02
Fundulus parvipinnis	California Killifish				2	2	0.01
Scorpaena guttata	California Scorpionfish	2				2	0.01
Synodus lucioceps	California Lizardfish	2				2	0.01
Acanthogobius flavimanus	Yellowfin Goby	1				1	0.01
Atherinopsis californiensis	Jacksmelt			1		1	0.01
Dasyatis dipterura	Diamond Stingray				1	1	0.01
Gibbonsia elegans	Spotted Kelpfish	1				1	0.01
Ilypnus gilberti	Cheekspot Goby				1	1	0.01
Phanerodon furcatus	White Seaperch	1				1	0.01
Pleuronichthys decurrens	Curlfin Sole	1				1	0.01
Seriphus politus	Queenfish				1	1	0.01
Umbrina roncador	Yellowfin Croaker		1			1	0.01
Xystreurys liolepis	Fantail Sole	1				1	0.01
# of Species:	**45**	**6,238**	**4,005**	**2,233**	**1,548**	**14,024**	

Table 4. Total biomass (grams [g]) of fishes collected in San Diego Bay during 2019 by ecoregion.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total (g)	%
Urobatis halleri	Round Stingray	30,909	16,586	19,194	48,775	115,464	42.53
Paralabrax maculatofasciatus	Spotted Sand Bass	6,454	25,506	12,508	21,205	65,673	24.19
Atherinops affinis	Topsmelt	14,319	7,320	337	716	22,691	8.36
Anchoa compressa	Deepbody Anchovy		10	15,200	150	15,360	5.66
Myliobatis californica	Bat Ray			625	8,040	8,665	3.19
Albula gilberti	Cortez Bonefish			4,895	490	5,385	1.98
Cynoscion parvipinnis	Shortfin Corvina		700	4,300	108	5,108	1.88
Paralichthys californicus	California Halibut	3,710	385	473	129	4,697	1.73
Dasyatis dipterura	Diamond Stingray				4,200	4,200	1.55
Micrometrus minimus	Dwarf Perch	4,134				4,134	1.52
Sardinops sagax	Pacific Sardine		2,200	130		2,330	0.86
Gymnura marmorata	California Butterfly Ray				2,105	2,105	0.78
Cymatogaster aggregata	Shiner Perch	738	423	393	306.0	1,860	0.68
Halichoeres semicinctus	Rock Wrasse	1,838				1,838	0.68
Anchoa delicatissima	Slough Anchovy		153	703	876	1,732	0.64
Heterostichus rostratus	Giant Kelpfish	949	272	110	57	1,387	0.51
Porichthys myriaster	Specklefin Midshipman	871		505		1,376	0.51
Scomber japonicus	Pacific Chub Mackerel	1,200	118			1,318	0.49
Pleuronichthys guttulatus	Diamond Turbot	865	293	68	58	1,284	0.47
Paralabrax clathratus	Kelp Bass	805	4			809	0.30
Paralabrax nebulifer	Barred Sand Bass	19	395	143	51	608	0.22
Pleuronichthys ritteri	Spotted Turbot	514				514	0.19
Embiotoca jacksoni	Black Perch	501				501	0.18
Leuresthes tenuis	California Grunion	224	198			422	0.16
Syngnathus californiensis	Kelp Pipefish	117	145	57	102	421	0.16
Synodus lucioceps	California Lizardfish	255				255	0.09
Haemulon californiensis	Salema	19	120	12	39	190	0.07
Phanerodon furcatus	White Seaperch	190				190	0.07
Hypsoblennius gentilis	Bay Blenny	101	46			147	0.05
Scorpaena guttata	California Scorpionfish	140				140	0.05
Cheilotrema saturnum	Black Croaker		135	< 1		135	0.05
Hippocampus ingens	Pacific Seahorse				134	134	0.05
Symphurus atricaudus	California Tonguefish	95.0	25.0	3.0		123	0.05
Leptocottus armatus	Pacific Staghorn Sculpin		7	19	41	67	0.02
Atherinopsis californiensis	Jacksmelt			66		66	0.02
Umbrina roncador	Yellowfin Croaker		49			49	0.02
Seriphus politus	Queenfish				46	46	0.02
Pleuronichthys decurrens	Curlfin Sole	21				21	0.01
Clevelandia ios	Arrow Goby	2	3	5	9	19	0.01
Hyporhamphus rosae	California Halfbeak				15	15	0.01
Gibbonsia elegans	Spotted Kelpfish	10				10	< 0.01
Xystreurys liolepis	Fantail Sole	10				10	< 0.01
Fundulus parvipinnis	California Killifish				4	4	< 0.01
Acanthogobius flavimanus	Yellowfin Goby	3				3	< 0.01
Ilypnus gilberti	Cheekspot Goby				3	3	< 0.01
# of Species:	**45**	**69,011**	**55,092**	**59,745**	**87,658**	**271,506**	

Table 5. Total number of individuals and biomass (g) of fish species captured in the North Ecoregion, 2019.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Atherinops affinis	Topsmelt	4,867	78.02	14,319	20.75
Micrometrus minimus	Dwarf Perch	691	11.08	4,134	5.99
Cymatogaster aggregata	Shiner Perch	143	2.29	738	1.07
Heterostichus rostratus	Giant Kelpfish	133	2.13	949	1.38
Urobatis halleri	Round Stingray	117	1.88	30,909	44.79
Syngnathus californiensis	Kelp Pipefish	82	1.31	117	0.17
Paralabrax maculatofasciatus	Spotted Sand Bass	37	0.59	6,454	9.35
Paralichthys californicus	California Halibut	33	0.53	3,710	5.38
Hypsoblennius gentilis	Bay Blenny	20	0.32	101	0.15
Halichoeres semicinctus	Rock Wrasse	19	0.30	1,838	2.66
Scomber japonicus	Pacific Chub Mackerel	14	0.22	1,200	1.74
Leuresthes tenuis	California Grunion	11	0.18	224	0.32
Porichthys myriaster	Specklefin Midshipman	11	0.18	871	1.26
Symphurus atricaudus	California Tonguefish	10	0.16	95	0.14
Paralabrax clathratus	Kelp Bass	9	0.14	805	1.17
Clevelandia ios	Arrow Goby	8	0.13	2	< 0.01
Embiotoca jacksoni	Black Perch	8	0.13	501	0.73
Pleuronichthys ritteri	Spotted Turbot	8	0.13	514	0.74
Pleuronichthys guttulatus	Diamond Turbot	6	0.10	865	1.25
Scorpaena guttata	California Scorpionfish	2	0.03	140	0.20
Synodus lucioceps	California Lizardfish	2	0.03	255	0.37
Acanthogobius flavimanus	Yellowfin Goby	1	0.02	3	< 0.01
Gibbonsia elegans	Spotted Kelpfish	1	0.02	10	0.01
Haemulon californiensis	Salema	1	0.02	19	0.03
Paralabrax nebulifer	Barred Sand Bass	1	0.02	19	0.03
Phanerodon furcatus	White Seaperch	1	0.02	190	0.28
Pleuronichthys decurrens	Curlfin Sole	1	0.02	21	0.03
Xystreurys liolepis	Fantail Sole	1	0.02	10	0.01
# of Species:	**28**	**6,238**		**69,011**	

Table 6. Total number of individuals and biomass (g) of fish species captured in the North-Central Ecoregion, 2019.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Atherinops affinis	Topsmelt	2,892	72.21	7,320	13.29
Heterostichus rostratus	Giant Kelpfish	371	9.26	272	0.49
Paralabrax maculatofasciatus	Spotted Sand Bass	155	3.87	25,506	46.30
Cymatogaster aggregata	Shiner Perch	139	3.47	423	0.77
Anchoa delicatissima	Slough Anchovy	110	2.75	153	0.28
Urobatis halleri	Round Stingray	91	2.27	16,586	30.11
Sardinops sagax	Pacific Sardine	77	1.92	2,200	3.99
Syngnathus californiensis	Kelp Pipefish	65	1.62	145	0.26
Paralabrax nebulifer	Barred Sand Bass	27	0.67	395	0.72
Leuresthes tenuis	California Grunion	21	0.52	198	0.36
Hypsoblennius gentilis	Bay Blenny	17	0.42	46	0.08
Paralichthys californicus	California Halibut	12	0.30	385	0.70
Haemulon californiensis	Salema	10	0.25	120	0.22
Clevelandia ios	Arrow Goby	5	0.12	3	0.01
Pleuronichthys guttulatus	Diamond Turbot	4	0.10	293	0.53
Cheilotrema saturnum	Black Croaker	2	0.05	135	0.25
Anchoa compressa	Deepbody Anchovy	1	0.02	10	0.02
Cynoscion parvipinnis	Shortfin Corvina	1	0.02	700	1.27
Leptocottus armatus	Pacific Staghorn Sculpin	1	0.02	7	0.01
Paralabrax clathratus	Kelp Bass	1	0.02	4	0.01
Scomber japonicus	Pacific Chub Mackerel	1	0.02	118	0.21
Symphurus atricaudus	California Tonguefish	1	0.02	25	0.05
Umbrina roncador	Yellowfin Croaker	1	0.02	49	0.09
# of Species:	**23**	**4,005**		**55,092**	

Table 7. Total number of individuals and biomass (g) of fish species captured in the South-Central Ecoregion, 2019.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Anchoa compressa	Deepbody Anchovy	1,019	45.63	15,200	25.44
Anchoa delicatissima	Slough Anchovy	475	21.27	703	1.18
Atherinops affinis	Topsmelt	166	7.43	337	0.56
Syngnathus californiensis	Kelp Pipefish	121	5.42	57	0.10
Cymatogaster aggregata	Shiner Perch	117	5.24	393	0.66
Heterostichus rostratus	Giant Kelpfish	83	3.72	110	0.18
Urobatis halleri	Round Stingray	82	3.67	19,194	32.13
Paralabrax maculatofasciatus	Spotted Sand Bass	81	3.63	12,508	20.94
Clevelandia ios	Arrow Goby	18	0.81	5	0.01
Cynoscion parvipinnis	Shortfin Corvina	18	0.81	4,300	7.20
Paralichthys californicus	California Halibut	14	0.63	473	0.79
Pleuronichthys guttulatus	Diamond Turbot	14	0.63	68	0.11
Albula gilberti	Cortez Bonefish	8	0.36	4,895	8.19
Paralabrax nebulifer	Barred Sand Bass	6	0.27	143	0.24
Leptocottus armatus	Pacific Staghorn Sculpin	2	0.09	19	0.03
Myliobatis californica	Bat Ray	2	0.09	625	1.05
Porichthys myriaster	Specklefin Midshipman	2	0.09	505	0.85
Atherinopsis californiensis	Jacksmelt	1	0.04	66	0.11
Cheilotrema saturnum	Black Croaker	1	0.04	0.1	< 0.01
Haemulon californiensis	Salema	1	0.04	12	0.02
Sardinops sagax	Pacific Sardine	1	0.04	130	0.22
Symphurus atricaudus	California Tonguefish	1	0.04	3	0.01
# of Species:	**22**	**2,233**		**59,745**	

Table 8. Total number of individuals and biomass (g) of fish species captured in the South Ecoregion, 2019.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Anchoa delicatissima	Slough Anchovy	681	43.99	876	1.00
Urobatis halleri	Round Stingray	206	13.31	48,775	55.64
Syngnathus californiensis	Kelp Pipefish	163	10.53	102	0.12
Paralabrax maculatofasciatus	Spotted Sand Bass	147	9.50	21,205	24.19
Cymatogaster aggregata	Shiner Perch	137	8.85	306	0.35
Atherinops affinis	Topsmelt	119	7.69	716	0.82
Clevelandia ios	Arrow Goby	21	1.36	9	0.01
Heterostichus rostratus	Giant Kelpfish	18	1.16	57	0.07
Anchoa compressa	Deepbody Anchovy	13	0.84	150	0.17
Leptocottus armatus	Pacific Staghorn Sculpin	6	0.39	41	0.05
Myliobatis californica	Bat Ray	6	0.39	8,040	9.17
Paralichthys californicus	California Halibut	5	0.32	129	0.15
Pleuronichthys guttulatus	Diamond Turbot	5	0.32	58	0.07
Hippocampus ingens	Pacific Seahorse	4	0.26	134	0.15
Hyporhamphus rosae	California Halfbeak	4	0.26	15	0.02
Gymnura marmorata	California Butterfly Ray	3	0.19	2,105	2.40
Fundulus parvipinnis	California Killifish	2	0.13	4	< 0.01
Haemulon californiensis	Salema	2	0.13	39	0.04
Albula gilberti	Cortez Bonefish	1	0.06	490	0.56
Cynoscion parvipinnis	Shortfin Corvina	1	0.06	108	0.12
Dasyatis dipterura	Diamond Stingray	1	0.06	4,200	4.79
Ilypnus gilberti	Cheekspot Goby	1	0.06	3	< 0.01
Paralabrax nebulifer	Barred Sand Bass	1	0.06	51	0.06
Seriphus politus	Queenfish	1	0.06	46	0.05
# of Species:	**24**	**1,548**		**87,658**	

4.3 Shannon Diversity and Species Richness

The Shannon Diversity index (H'; Shannon 1948) was used to estimate diversity in San Diego Bay and provide a basis for comparison among ecoregions within the bay. Diversity was calculated for total catches by ecoregion and by sampling month. Species richness was low overall in 2019 but followed a typical spatial pattern with richness decreasing from north to south. Diversity, however, was lowest in the North Ecoregion and increased to the south (Figure 10). Species richness decreased slightly while H' increased from April to July 2019 (Figure 11). Both temporally and spatially, reduced H' values were due to the dominance of forage fishes.

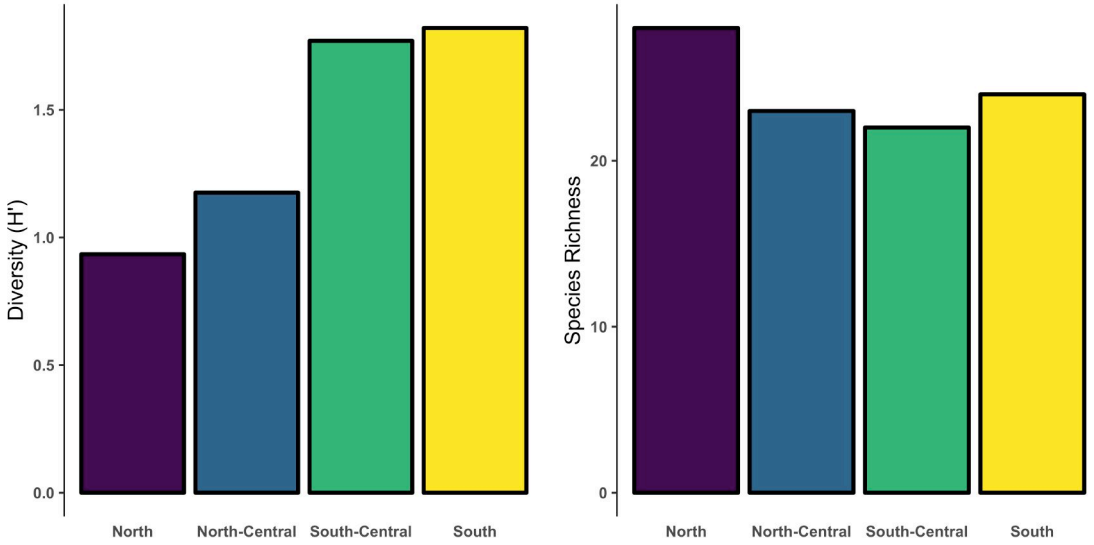


Figure 10. Shannon Diversity (H') and number of species (richness) of fishes taken in each San Diego Bay ecoregion, 2019.

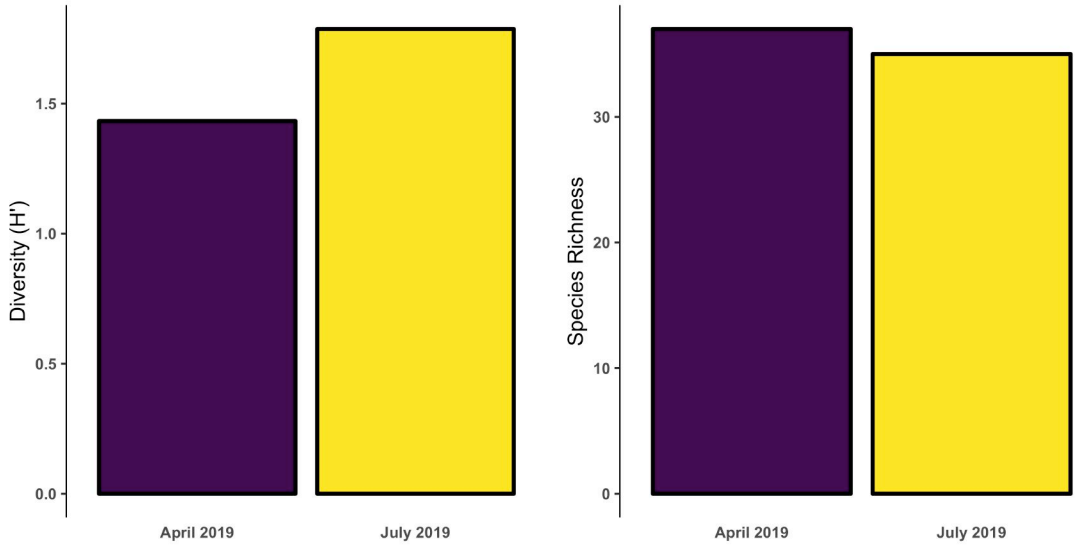


Figure 11. Shannon Diversity (H') and number of species (richness) of fishes taken in San Diego Bay by sampling month, 2019.

4.4 Catch by Sampling Ecoregion and Period

North Ecoregion – A total of 4,867 fishes belonging to 28 species and weighing 69.0 kg was collected in the North Ecoregion over two sampling periods in 2019 (Table 4). Topsmelt was by far the most frequently caught species (78.0%), followed by Dwarf Perch (11.1%), Shiner Perch (*Cymatogaster aggregata*; 2.29%), Giant Kelpfish (2.13%), and Round Stingray (1.88%). Round Stingray led in total biomass (44.8%), followed by Topsmelt (20.8%), Spotted Sand Bass (9.35%), Dwarf Perch (5.99%) and California Halibut (*Paralichthys californicus*; 5.38%)

North-Central Ecoregion - A total of 4,005 fishes belonging to 23 species and weighing 55.1 kg was collected in the North-Central Ecoregion in April and July, 2019 (Table 5). Topsmelt was by far the most abundant species (72.2%), followed by Giant Kelpfish (9.26%), Spotted Sand Bass (3.87%), Shiner Perch (3.47%), and Slough Anchovy (2.75%). Spotted Sand Bass led in total biomass (46.3%), followed by Round Stingray (30.1%), Topsmelt (13.3%), and Pacific Sardine (*Sardinops sagax;* 3.99%).

South-Central Ecoregion - A total of 2,233 fishes belonging to 22 species and weighing 59.7 kg was collected in the South-Central Ecoregion over the two sampling periods in 2019 (Table 6). Deepbody Anchovy was the most abundant species (45.6%), followed by Slough Anchovy (21.3%), Topsmelt (7.43%), Kelp Pipefish (*Syngnathus californiensis;* 5.42%), and Shiner Perch (5.24%). Round Stingray led in total biomass (32.1%), followed by Deepbody Anchovy (25.4%), Spotted Sand Bass (20.9%), Cortez Bonefish (*Albula gilberti*; 8.19%), and Shortfin Corvina (*Cynoscion parvipinnis*; 7.20%).

South Ecoregion - A total of 1,548 fishes belonging to 24 species and weighing 87.7 kg was collected in the South Ecoregion in April and July 2019 (Table 7). Slough Anchovy was the most abundant species (44.0%), followed Round Stingray (13.3%), Kelp Pipefish (10.5%), Spotted Sand Bass (9.50%), and Shiner Perch (8.85%). Round Stingray led in total biomass (55.6%), followed by Spotted Sand Bass (24.2%), and Bat Ray (9.2%).

In April 2019, 8,159 individuals comprised of 37 species of fishes were captured (Figure 12, Table 9). In July, the catch decreased to 5,865 fish and species richness decreased slightly to 35. Total biomass was greater in April (141.7 kg) than July (129.8 kg) (Figure 12, Table 10). From April to July there was a substantial decrease in total biomass in the North Ecoregion (Figure 13) presumably due to Topsmelt moving from the warm, protected waters towards the open ocean over this period. Biomass remained relatively steady at the other three ecoregions.

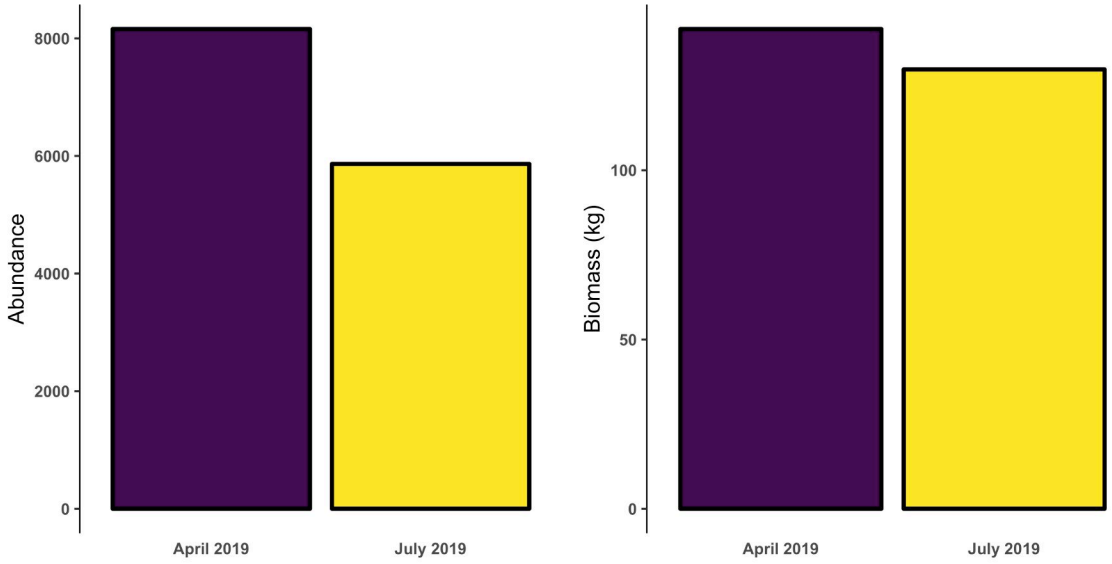


Figure 12. Total catch of fishes and biomass (kg) taken in San Diego Bay by sampling period, 2019.

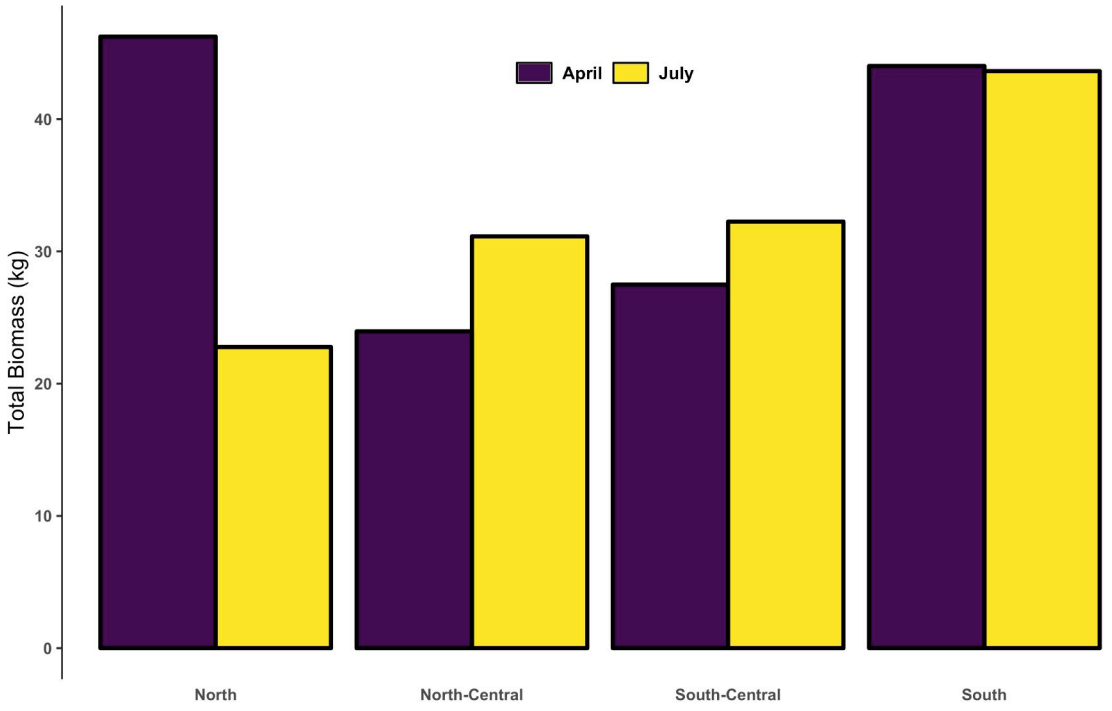


Figure 13. Biomass (kg) of San Diego Bay fishes taken by ecoregion, April and July 2019.

Table 9. Total abundance of fish species taken in San Diego Bay by sampling period, 2019.

		2019			
Scientific Name	**Common Name**	**April**	**July**	**Total**	**%**
Atherinops affinis	Topsmelt	5,357	2,687	8,044	57.36
Anchoa delicatissima	Slough Anchovy	641	625	1,266	9.03
Anchoa compressa	Deepbody Anchovy	1	1,032	1,033	7.37
Micrometrus minimus	Dwarf Perch	136	555	691	4.93
Heterostichus rostratus	Giant Kelpfish	497	108	605	4.31
Cymatogaster aggregata	Shiner Perch	445	91	536	3.82
Urobatis halleri	Round Stingray	254	242	496	3.54
Syngnathus californiensis	Kelp Pipefish	264	167	431	3.07
Paralabrax maculatofasciatus	Spotted Sand Bass	233	187	420	2.99
Sardinops sagax	Pacific Sardine	78		78	0.56
Paralichthys californicus	California Halibut	32	32	64	0.46
Clevelandia ios	Arrow Goby	23	29	52	0.37
Hypsoblennius gentilis	Bay Blenny	31	6	37	0.26
Paralabrax nebulifer	Barred Sand Bass	24	11	35	0.25
Leuresthes tenuis	California Grunion	32		32	0.23
Pleuronichthys guttulatus	Diamond Turbot	21	8	29	0.21
Cynoscion parvipinnis	Shortfin Corvina	1	19	20	0.14
Halichoeres semicinctus	Rock Wrasse	7	12	19	0.14
Scomber japonicus	Pacific Chub Mackerel	14	1	15	0.11
Haemulon californiensis	Salema	12	2	14	0.10
Porichthys myriaster	Specklefin Midshipman	4	9	13	0.09
Symphurus atricaudus	California Tonguefish	2	10	12	0.09
Paralabrax clathratus	Kelp Bass	7	3	10	0.07
Albula gilberti	Cortez Bonefish	6	3	9	0.06
Leptocottus armatus	Pacific Staghorn Sculpin	8	1	9	0.06
Embiotoca jacksoni	Black Perch	3	5	8	0.06
Myliobatis californica	Bat Ray	6	2	8	0.06
Pleuronichthys ritteri	Spotted Turbot	3	5	8	0.06
Hippocampus ingens	Pacific Seahorse	4		4	0.03
Hyporhamphus rosae	California Halfbeak	4		4	0.03
Cheilotrema saturnum	Black Croaker		3	3	0.02
Gymnura marmorata	California Butterfly Ray	3		3	0.02
Fundulus parvipinnis	California Killifish		2	2	0.01
Scorpaena guttata	California Scorpionfish	1	1	2	0.01
Synodus lucioceps	California Lizardfish		2	2	0.01
Acanthogobius flavimanus	Yellowfin Goby	1		1	0.01
Atherinopsis californiensis	Jacksmelt		1	1	0.01
Dasyatis dipterura	Diamond Stingray	1		1	0.01
Gibbonsia elegans	Spotted Kelpfish	1		1	0.01
Ilypnus gilberti	Cheekspot Goby		1	1	0.01
Phanerodon furcatus	White Seaperch	1		1	0.01
Pleuronichthys decurrens	Curlfin Sole		1	1	0.01
Seriphus politus	Queenfish	1		1	0.01
Umbrina roncador	Yellowfin Croaker		1	1	0.01
Xystreurys liolepis	Fantail Sole		1	1	0.01
	Total:	**8,159**	**5,865**	**14,024**	
	# of Species:	37	35		

Table 10. Total biomass (g) of fish species taken in San Diego Bay by sampling period, 2019.

		2019			
Scientific Name	**Common Name**	**April**	**July**	**Total**	**%**
Urobatis halleri	Round Stingray	50,731	64,733	115,464	42.53
Paralabrax maculatofasciatus	Spotted Sand Bass	35,308	30,365	65,673	24.19
Atherinops affinis	Topsmelt	20,396	2,295	22,691	8.36
Anchoa compressa	Deepbody Anchovy	10	15,350	15,360	5.66
Myliobatis californica	Bat Ray	8,040	625	8,665	3.19
Albula gilberti	Cortez Bonefish	3,540	1,845	5,385	1.98
Cynoscion parvipinnis	Shortfin Corvina	700	4,408	5,108	1.88
Paralichthys californicus	California Halibut	3,431	1,266	4,697	1.73
Dasyatis dipterura	Diamond Stingray	4,200		4,200	1.55
Micrometrus minimus	Dwarf Perch	1,772	2,362	4,134	1.52
Sardinops sagax	Pacific Sardine	2,330		2,330	0.86
Gymnura marmorata	California Butterfly Ray	2,105		2,105	0.78
Cymatogaster aggregata	Shiner Perch	1,290	570	1,860	0.68
Halichoeres semicinctus	Rock Wrasse	239	1,599	1,838	0.68
Anchoa delicatissima	Slough Anchovy	792	940	1,732	0.64
Heterostichus rostratus	Giant Kelpfish	665	722	1,387	0.51
Porichthys myriaster	Specklefin Midshipman	1,237	139	1,376	0.51
Scomber japonicus	Pacific Chub Mackerel	1,200	118	1,318	0.49
Pleuronichthys guttulatus	Diamond Turbot	708	576	1,284	0.47
Paralabrax clathratus	Kelp Bass	742	67	809	0.30
Paralabrax nebulifer	Barred Sand Bass	302	306	608	0.22
Pleuronichthys ritteri	Spotted Turbot	265	249	514	0.19
Embiotoca jacksoni	Black Perch	328	173	501	0.18
Leuresthes tenuis	California Grunion	422		422	0.16
Syngnathus californiensis	Kelp Pipefish	247	175	421	0.16
Synodus lucioceps	California Lizardfish		255	255	0.09
Haemulon californiensis	Salema	151	39	190	0.07
Phanerodon furcatus	White Seaperch	190		190	0.07
Hypsoblennius gentilis	Bay Blenny	52	95	147	0.05
Scorpaena guttata	California Scorpionfish	5	135	140	0.05
Cheilotrema saturnum	Black Croaker		135	135	0.05
Hippocampus ingens	Pacific Seahorse	134		134	0.05
Symphurus atricaudus	California Tonguefish	40	83	123	0.05
Leptocottus armatus	Pacific Staghorn Sculpin	60	7	67	0.02
Atherinopsis californiensis	Jacksmelt		66	66	0.02
Umbrina roncador	Yellowfin Croaker		49	49	0.02
Seriphus politus	Queenfish	46		46	0.02
Pleuronichthys decurrens	Curlfin Sole		21	21	0.01
Clevelandia ios	Arrow Goby	8	11	19	0.01
Hyporhamphus rosae	California Halfbeak	15		15	0.01
Gibbonsia elegans	Spotted Kelpfish	10		10	< 0.01
Xystreurys liolepis	Fantail Sole		10	10	< 0.01
Fundulus parvipinnis	California Killifish		4	4	< 0.01
Acanthogobius flavimanus	Yellowfin Goby	3		3	< 0.01
Ilypnus gilberti	Cheekspot Goby		3	3	< 0.01
	Total:	**141,713**	**129,794**	**271,506**	
	# of Species:	37	35		

4.5 Catch by Depth Strata and Subhabitats

Of the three bay depth strata (intertidal, nearshore, and channel) the greatest catch of fishes was in the intertidal strata (6,315 individuals from 24 species; Table 11). 5,876 fishes from 33 species were captured in the nearshore, and 1,833 fishes from 24 species were captured in the channel. A total of 8,076 fishes was taken in vegetated areas of the nearshore and intertidal (Table 12) comprised of 28 of the 45 species captured during the 2019 surveys. 4,115 fishes, from 33 species were caught in the nearshore and intertidal non-vegetated areas.

Purse seine being pulled aboard R/V Neoclinus from the channel in the South-Central Ecoregion in July 2019.

Table 11. Total abundance of fish species taken from San Diego Bay by depth strata, 2019.

		Depth Strata				
Scientific Name	**Common Name**	**Channel**	**Intertidal**	**Nearshore**	**Total**	**%**
Atherinops affinis	Topsmelt	278	5,480	2,286	8,044	57.36
Anchoa delicatissima	Slough Anchovy	124	206	936	1,266	9.03
Anchoa compressa	Deepbody Anchovy	1,032	1		1,033	7.37
Micrometrus minimus	Dwarf Perch		334	357	691	4.93
Heterostichus rostratus	Giant Kelpfish		39	566	605	4.31
Cymatogaster aggregata	Shiner Perch	4	11	521	536	3.82
Urobatis halleri	Round Stingray	159	12	325	496	3.54
Syngnathus californiensis	Kelp Pipefish	1	115	315	431	3.07
Paralabrax maculatofasciatus	Spotted Sand Bass	59	5	356	420	2.99
Sardinops sagax	Pacific Sardine	78			78	0.56
Paralichthys californicus	California Halibut	25	14	25	64	0.46
Clevelandia ios	Arrow Goby		38	14	52	0.37
Hypsoblennius gentilis	Bay Blenny	1	5	31	37	0.26
Paralabrax nebulifer	Barred Sand Bass		9	26	35	0.25
Leuresthes tenuis	California Grunion		3	29	32	0.23
Pleuronichthys guttulatus	Diamond Turbot	10	18	1	29	0.21
Cynoscion parvipinnis	Shortfin Corvina	17		3	20	0.14
Halichoeres semicinctus	Rock Wrasse			19	19	0.14
Scomber japonicus	Pacific Chub Mackerel	15			15	0.11
Haemulon californiensis	Salema			14	14	0.10
Porichthys myriaster	Specklefin Midshipman	3		10	13	0.09
Symphurus atricaudus	California Tonguefish	2		10	12	0.09
Paralabrax clathratus	Kelp Bass			10	10	0.07
Albula gilberti	Cortez Bonefish	7		2	9	0.06
Leptocottus armatus	Pacific Staghorn Sculpin		9		9	0.06
Embiotoca jacksoni	Black Perch		5	3	8	0.06
Myliobatis californica	Bat Ray	2	1	5	8	0.06
Pleuronichthys ritteri	Spotted Turbot	7		1	8	0.06
Hippocampus ingens	Pacific Seahorse	1		3	4	0.03
Hyporhamphus rosae	California Halfbeak		4		4	0.03
Cheilotrema saturnum	Black Croaker	2		1	3	0.02
Gymnura marmorata	California Butterfly Ray	1	1	1	3	0.02
Fundulus parvipinnis	California Killifish		2		2	0.01
Scorpaena guttata	California Scorpionfish	2			2	0.01
Synodus lucioceps	California Lizardfish	2			2	0.01
Acanthogobius flavimanus	Yellowfin Goby			1	1	0.01
Atherinopsis californiensis	Jacksmelt		1		1	0.01
Dasyatis dipterura	Diamond Stingray			1	1	0.01
Gibbonsia elegans	Spotted Kelpfish			1	1	0.01
Ilypnus gilberti	Cheekspot Goby		1		1	0.01
Phanerodon furcatus	White Seaperch			1	1	0.01
Pleuronichthys decurrens	Curlfin Sole			1	1	0.01
Seriphus politus	Queenfish			1	1	0.01
Umbrina roncador	Yellowfin Croaker		1		1	0.01
Xystreurys liolepis	Fantail Sole	1			1	0.01
	Total:	**1,833**	**6,315**	**5,876**	**14,024**	
	# of Species:	24	24	33		

Table 12. Total abundance of fish species taken from San Diego Bay by subhabitat, 2019.

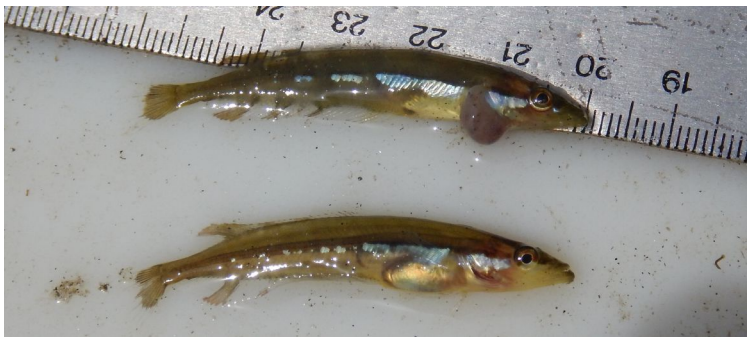
		Subhabitat				
Scientific Name	Common Name	Channel	Non-Vegetated	Vegetated	Total	%
Atherinops affinis	Topsmelt	278	1,986	5,780	8,044	57.36
Anchoa delicatissima	Slough Anchovy	124	730	412	1,266	9.03
Anchoa compressa	Deepbody Anchovy	1,032		1	1,033	7.37
Micrometrus minimus	Dwarf Perch		254	437	691	4.93
Heterostichus rostratus	Giant Kelpfish		293	312	605	4.31
Cymatogaster aggregata	Shiner Perch	4	253	279	536	3.82
Urobatis halleri	Round Stingray	159	69	268	496	3.54
Syngnathus californiensis	Kelp Pipefish	1	210	220	431	3.07
Paralabrax maculatofasciatus	Spotted Sand Bass	59	143	218	420	2.99
Sardinops sagax	Pacific Sardine	78			78	0.56
Paralichthys californicus	California Halibut	25	27	12	64	0.46
Clevelandia ios	Arrow Goby		21	31	52	0.37
Hypsoblennius gentilis	Bay Blenny	1	25	11	37	0.26
Paralabrax nebulifer	Barred Sand Bass		19	16	35	0.25
Leuresthes tenuis	California Grunion		6	26	32	0.23
Pleuronichthys guttulatus	Diamond Turbot	10	5	14	29	0.21
Cynoscion parvipinnis	Shortfin Corvina	17	1	2	20	0.14
Halichoeres semicinctus	Rock Wrasse		12	7	19	0.14
Scomber japonicus	Pacific Chub Mackerel	15			15	0.11
Haemulon californiensis	Salema		10	4	14	0.10
Porichthys myriaster	Specklefin Midshipman	3	10		13	0.09
Symphurus atricaudus	California Tonguefish	2	7	3	12	0.09
Paralabrax clathratus	Kelp Bass		4	6	10	0.07
Albula gilberti	Cortez Bonefish	7	2		9	0.06
Leptocottus armatus	Pacific Staghorn Sculpin		4	5	9	0.06
Embiotoca jacksoni	Black Perch		4	4	8	0.06
Myliobatis californica	Bat Ray	2	6		8	0.06
Pleuronichthys ritteri	Spotted Turbot	7	1		8	0.06
Hippocampus ingens	Pacific Seahorse	1	3		4	0.03
Hyporhamphus rosae	California Halfbeak		4		4	0.03
Cheilotrema saturnum	Black Croaker	2	1		3	0.02
Gymnura marmorata	California Butterfly Ray	1		2	3	0.02
Fundulus parvipinnis	California Killifish			2	2	0.01
Scorpaena guttata	California Scorpionfish	2			2	0.01
Synodus lucioceps	California Lizardfish	2			2	0.01
Acanthogobius flavimanus	Yellowfin Goby		1		1	0.01
Atherinopsis californiensis	Jacksmelt			1	1	0.01
Dasyatis dipterura	Diamond Stingray		1		1	0.01
Gibbonsia elegans	Spotted Kelpfish			1	1	0.01
Ilypnus gilberti	Cheekspot Goby			1	1	0.01
Phanerodon furcatus	White Seaperch			1	1	0.01
Pleuronichthys decurrens	Curlfin Sole		1		1	0.01
Seriphus politus	Queenfish		1		1	0.01
Umbrina roncador	Yellowfin Croaker		1		1	0.01
Xystreurys liolepis	Fantail Sole	1			1	0.01
	Total:	**1,833**	**4,115**	**8,076**	**14,024**	
	# of Species:	24	33	28		

4.6 Nursery Area Function

San Diego Bay continues to be a nursery area for over half of the fishes found there. Approximately 65% of all fishes sampled in San Diego Bay were juveniles (Table 13). The most abundant juveniles (Topsmelt, Arrow Goby, Giant Kelpfish) are all critical commercial and/or forage fish species. The high catch of juvenile fishes in the bay highlights the continued importance of San Diego Bay as a nursery area for bay, estuarine, and nearshore species.

Table 13. Percent of juveniles taken of the top 20 species of fish from San Diego Bay, 2019.

Scientific Name	Common Name	Juveniles	Total Abundance	% Juvenile
Hypsoblennius gentilis	Bay Blenny	37	37	100.00
Clevelandia ios	Arrow Goby	49	52	94.23
Heterostichus rostratus	Giant Kelpfish	569	605	94.05
Haemulon californiensis	Salema	13	14	92.86
Atherinops affinis	Topsmelt	7,166	8,044	89.09
Paralabrax nebulifer	Barred Sand Bass	30	35	85.71
Cymatogaster aggregata	Shiner Perch	414	536	77.24
Micrometrus minimus	Dwarf Perch	502	691	72.65
Pleuronichthys guttulatus	Diamond Turbot	21	29	72.41
Paralichthys californicus	California Halibut	36	64	56.25
Syngnathus californiensis	Kelp Pipefish	204	431	47.33
Halichoeres semicinctus	Rock Wrasse	6	19	31.58
Urobatis halleri	Round Stingray	21	496	4.23
Leuresthes tenuis	California Grunion	1	32	3.13
Paralabrax maculatofasciatus	Spotted Sand Bass	7	420	1.67
Anchoa delicatissima	Slough Anchovy	2	1,266	0.16
Anchoa compressa	Deepbody Anchovy	0	1,033	0.00
Sardinops sagax	Pacific Sardine	0	78	0.00
Cynoscion parvipinnis	Shortfin Corvina	0	20	0.00
Scomber japonicus	Pacific Chub Mackerel	0	15	0.00
		9,078	**13,917**	**65.23**



Juvenile Giant Kelpfish captured by large seine from the South-Central Ecoregion in April 2019.

4.7 Ecological Importance of Species

An index of ecological importance was also calculated to estimate the relative importance of each species within the bay assemblage. An Ecological Index (E.I.) was determined using the total catch for each species during this study and incorporated three significant ecological variables: % Number, % Weight, and % Frequency of Occurrence, by ecoregion and month (E.I. = (% Number + % Weight) * % Frequency of Occurrence; Table 14; Figure 14). This index is indicative of the importance of each species to the energy flow within the San Diego Bay ecosystem. Topsmelt ranked first (E.I. 6,572), Round Stingray ranked second (E.I. 4,606), and Spotted Sand Bass ranked third (E.I. 2,718). All three species were found ubiquitously throughout the bay during both sampling periods. Round Stingray and Spotted Sand Bass were dominant in terms of biomass, and Topsmelt was dominant in terms of numerical abundance. Slough Anchovy ranked fourth (E.I. 725) but was not present in the North Ecoregion during either sampling period. These species were followed by Deepbody Anchovy (E.I. 488), which were nearly all (98.6%) captured in a single purse seine replicate in the South-Central Ecoregion in July.

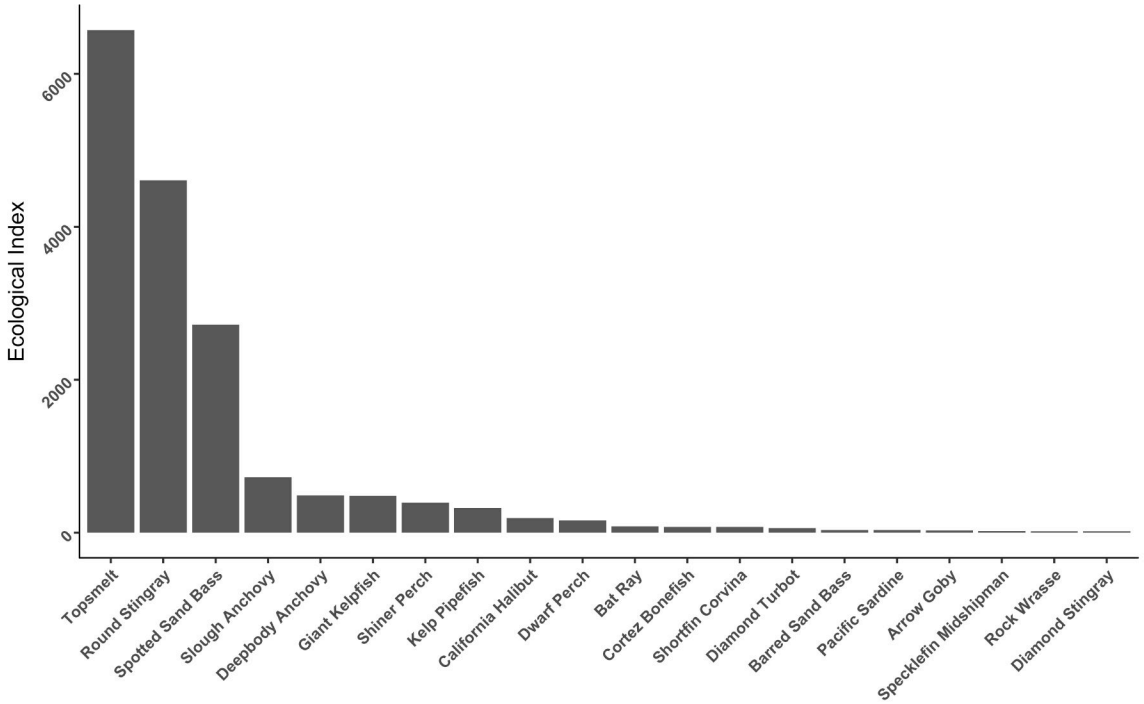


Figure 14. Top 20 species of San Diego Bay fishes ranked by Ecological Index, 2019.

Table 14. Relative abundance, relative biomass, frequency of occurrence, and Ecological Index (E.I.) of San Diego Bay fishes, 2019.

Scientific Name	Common Name	Abundance %	Biomass %	Frequency of Occurance	Ecological Index
Atherinops affinis	Topsmelt	57.36	8.36	100.0	6571.61
Urobatis halleri	Round Stingray	3.54	42.53	100.0	4606.40
Paralabrax maculatofasciatus	Spotted Sand Bass	2.99	24.19	100.0	2718.31
Anchoa delicatissima	Slough Anchovy	9.03	0.64	75.0	724.90
Anchoa compressa	Deepbody Anchovy	7.37	5.66	37.5	488.37
Heterostichus rostratus	Giant Kelpfish	4.31	0.51	100.0	482.49
Cymatogaster aggregata	Shiner Perch	3.82	0.68	87.5	394.35
Syngnathus californiensis	Kelp Pipefish	3.07	0.16	100.0	322.84
Paralichthys californicus	California Halibut	0.46	1.73	87.5	191.29
Micrometrus minimus	Dwarf Perch	4.93	1.52	25.0	161.25
Myliobatis californica	Bat Ray	0.06	3.19	25.0	81.21
Albula gilberti	Cortez Bonefish	0.06	1.98	37.5	76.78
Cynoscion parvipinnis	Shortfin Corvina	0.14	1.88	37.5	75.90
Pleuronichthys guttulatus	Diamond Turbot	0.21	0.47	87.5	59.47
Paralabrax nebulifer	Barred Sand Bass	0.25	0.22	75.0	35.51
Sardinops sagax	Pacific Sardine	0.56	0.86	25.0	35.36
Clevelandia ios	Arrow Goby	0.37	0.01	75.0	28.32
Porichthys myriaster	Specklefin Midshipman	0.09	0.51	37.5	22.47
Halichoeres semicinctus	Rock Wrasse	0.14	0.68	25.0	20.31
Dasyatis dipterura	Diamond Stingray	0.01	1.55	12.5	19.43
Hypsoblennius gentilis	Bay Blenny	0.26	0.05	50.0	15.90
Scomber japonicus	Pacific Chub Mackerel	0.11	0.49	25.0	14.81
Paralabrax clathratus	Kelp Bass	0.07	0.30	37.5	13.85
Gymnura marmorata	California Butterfly Ray	0.02	0.78	12.5	9.96
Leuresthes tenuis	California Grunion	0.23	0.16	25.0	9.59
Haemulon californiensis	Salema	0.10	0.07	50.0	8.49
Symphurus atricaudus	California Tonguefish	0.09	0.05	50.0	6.54
Pleuronichthys ritteri	Spotted Turbot	0.06	0.19	25.0	6.16
Embiotoca jacksoni	Black Perch	0.06	0.18	25.0	6.04
Leptocottus armatus	Pacific Staghorn Sculpin	0.06	0.02	37.5	3.33
Cheilotrema saturnum	Black Croaker	0.02	0.05	25.0	1.78
Scorpaena guttata	California Scorpionfish	0.01	0.05	25.0	1.65
Synodus lucioceps	California Lizardfish	0.01	0.09	12.5	1.35
Hippocampus ingens	Pacific Seahorse	0.03	0.05	12.5	0.97
Phanerodon furcatus	White Seaperch	0.01	0.07	12.5	0.96
Hyporhamphus rosae	California Halfbeak	0.03	0.01	12.5	0.43
Atherinopsis californiensis	Jacksmelt	0.01	0.02	12.5	0.39
Umbrina roncador	Yellowfin Croaker	0.01	0.02	12.5	0.31
Seriphus politus	Queenfish	0.01	0.02	12.5	0.30
Fundulus parvipinnis	California Killifish	0.01	< 0.01	12.5	0.20
Pleuronichthys decurrens	Curlfin Sole	0.01	0.01	12.5	0.19
Gibbonsia elegans	Spotted Kelpfish	0.01	< 0.01	12.5	0.14
Xystreurys liolepis	Fantail Sole	0.01	< 0.01	12.5	0.14
Acanthogobius flavimanus	Yellowfin Goby	0.01	< 0.01	12.5	0.10
Ilypnus gilberti	Cheekspot Goby	0.01	< 0.01	12.5	0.10

4.8 Principle species

Topsmelt (*Atherinops affinis*)

Topsmelt was ranked first by the Ecological Index and were found during both sampling periods and at all ecoregions, depth strata and subhabitats, though the vast majority were caught in the intertidal depth strata. These mostly juvenile fish (89.1%) were nearly three times as abundant in the vegetated (5,780) versus non-vegetated (1,986) subhabitats. They were the most abundant fish in the survey comprising 57.4% of the catch, but only 8.36% of the biomass due to their relatively small size. Their size frequency distribution (Figure 15) in April showed a pattern typically more consistent with that of July, suggesting that the reproductive season for Topsmelt occurred earlier than normal in 2019. No adults were observed in July.

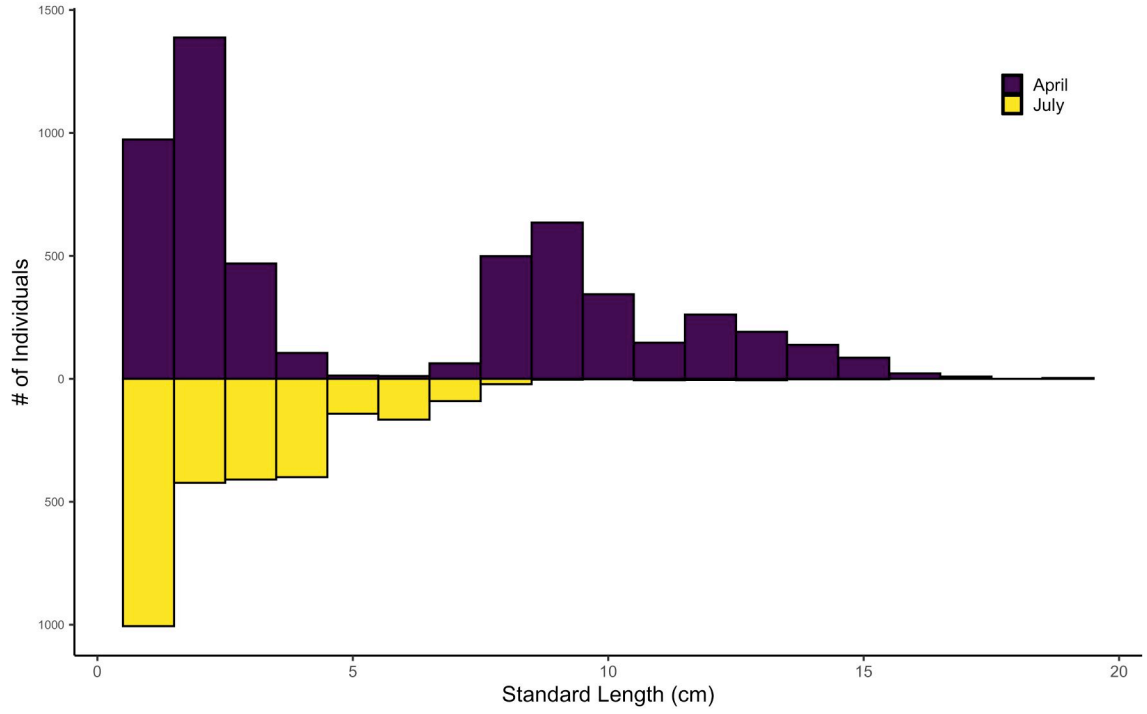


Figure 15. Total number of Topsmelt individuals by standard length (cm) from San Diego Bay, April and July 2019.

Round Stingray (*Urobatis halleri*)

The second highest ranked species in terms of ecological importance in 2019 was the Round Stingray. This species was ubiquitous throughout the bay during these surveys, and were found in all sampling periods, ecoregions, depth strata and subhabitats. While only consisting of 3.54% of the total individuals captured in the 2019 surveys, those individuals accounted for 42.5% of the biomass. The sizes of captured Round Stingrays were widely stratified, representative of its entire size range, and showed growth of juveniles and sub-adults between the April and July sampling periods (Figure 16). Round Stingrays were caught primarily in the channel and nearshore depth strata, with just a few individuals captured in the intertidal. While they were observed in all four ecoregions, the highest catches were in the South Ecoregion.

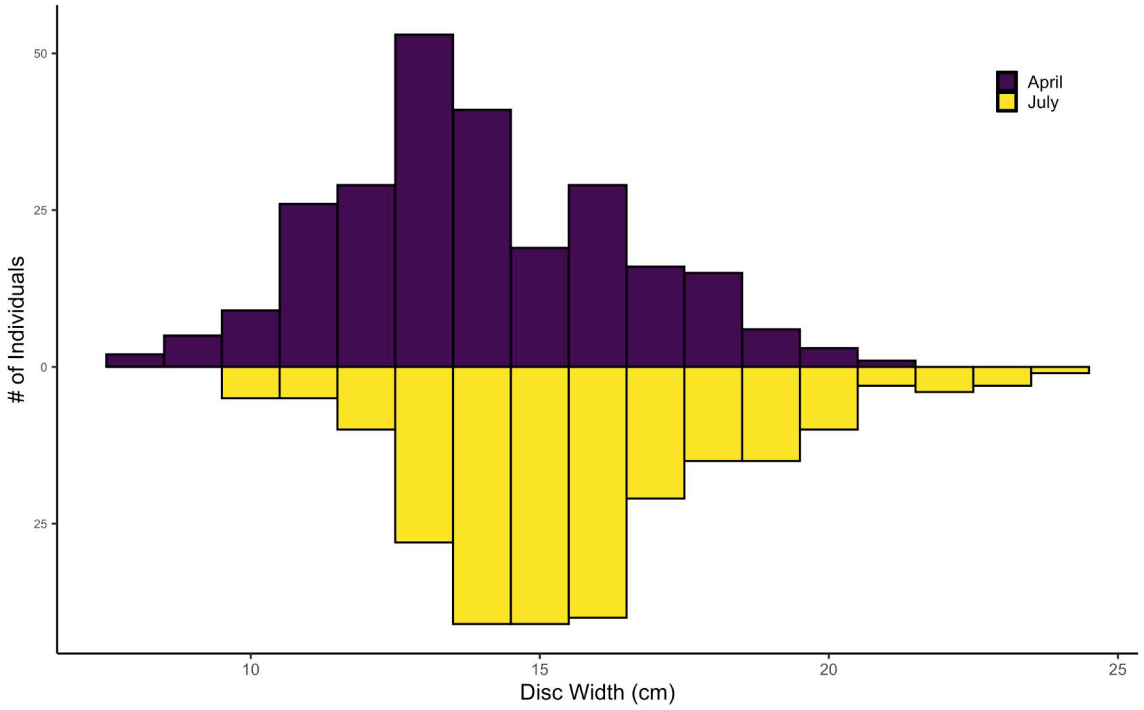
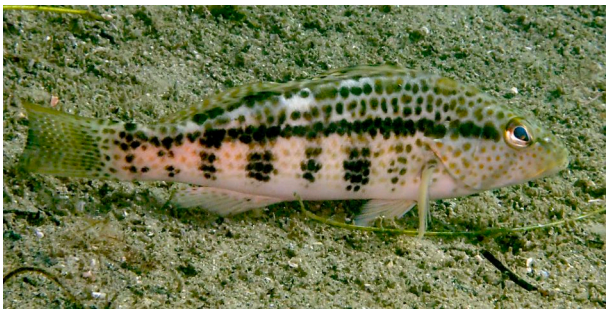


Figure 16. Total number of Round Stingray individuals by disc width (cm) from San Diego Bay, April and July 2019.

Spotted Sand Bass (*Paralabrax maculatofasciatus*)



Spotted Sand Bass are the ubiquitous mesocarnivore in San Diego Bay. In 2019, they ranked third in Ecological Index – a product of having the second highest biomass despite only having the ninth highest numerical abundance. Like the Topsmelt and Round Stingray that rank higher, this species was ubiquitous throughout the bay during these surveys, and were found in all sampling periods, ecoregions, depth strata and subhabitats. This important recreational fish species primarily utilizes bays and estuaries along the southern California coastline. Unlike previous years, there was no bimodal size distribution (Figure 17) during either sampling period and very few juveniles were present. Similar to Topsmelt, the April distribution is more typical of a July distribution, in this case representing either an extremely early reproductive season or a failed recruitment year for Spotted Sand Bass.

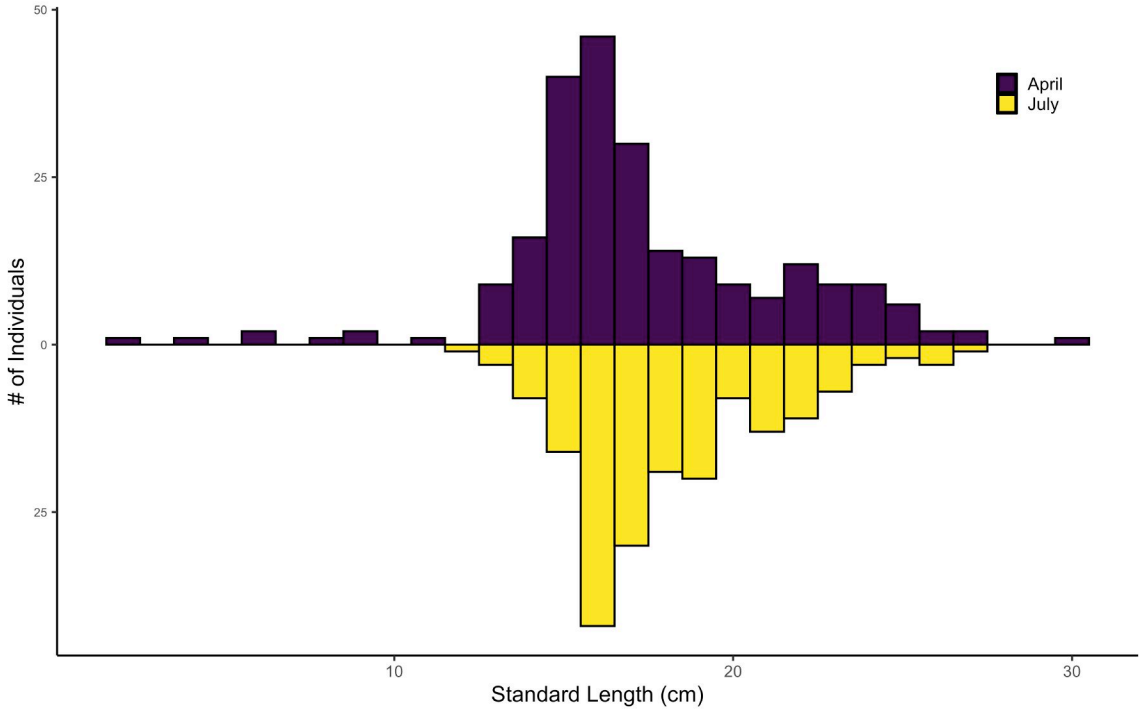


Figure 17. Total number of Spotted Sand Bass individuals by standard length (cm) from San Diego Bay, April and July 2019.

Slough Anchovy (*Anchoa delicatissima*)

Slough Anchovy ranked as the fourth most ecologically important fish species in San Diego Bay. This species was ubiquitous throughout the bay except for the North Ecoregion where it was not captured during either survey. They were found in all depth strata and subhabitats. They only had the fifteenth highest biomass of all fishes captured in 2019 but were the second most abundant species captured during the surveys. Nearly all (99.8%) captured individuals were of adult size, with no change in size distribution between the April and July sampling periods (Figure 18). The bay is a well-known nursery area for this critical forage species and there were no doubt a significant number of juveniles of this species utilizing the bay, however juvenile Slough Anchovy are exceptionally narrow-bodied and are unlikely to be captured through most sampling methods employed.

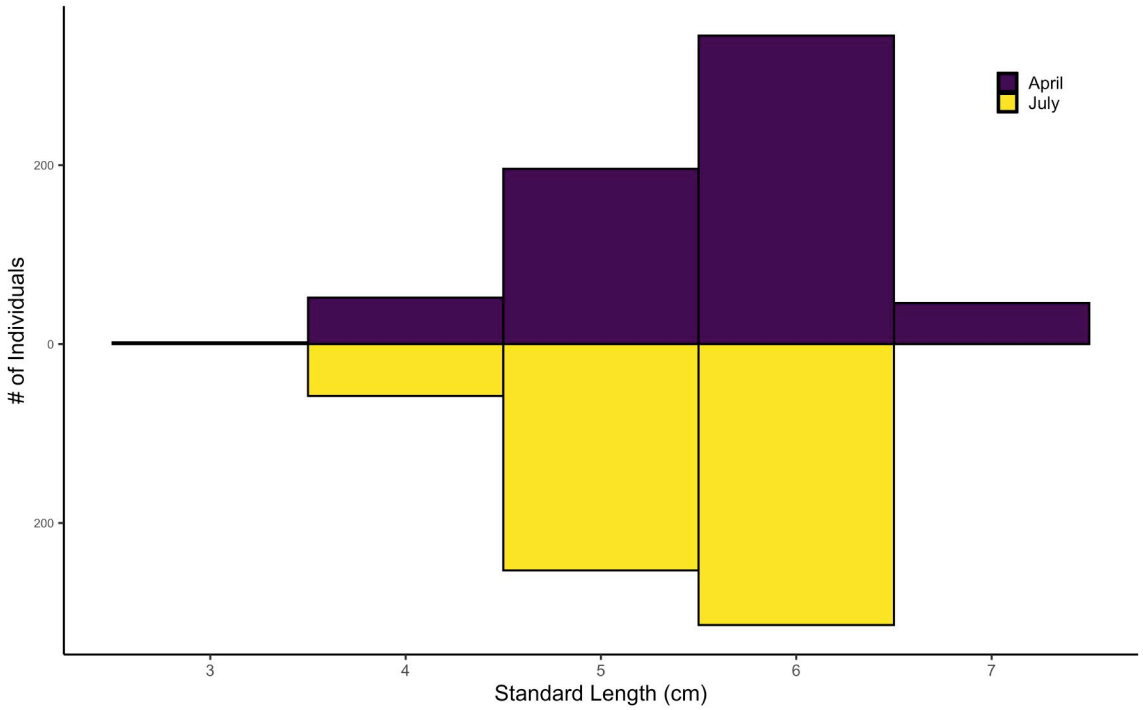


Figure 18. Total number of Slough Anchovy individuals by standard length (cm) from San Diego Bay, April and July 2019.

Deepbody Anchovy (*Anchoa compressa*)

Deepbody Anchovy ranked fifth in Ecological Index. Despite being ranked so highly, this species was almost entirely limited to the Channel subhabitat during this study. In fact, 98.6% of the individuals caught were from one purse seine replicate in the South-Central Ecoregion in July, and every individual was of adult size (Figure 19). Such a catch undoubtedly skews stock estimates and calculations of ecological importance, however as one of the rare species in the bay that almost exclusively inhabits the water column in the channel, it is difficult to assess their numbers accurately.

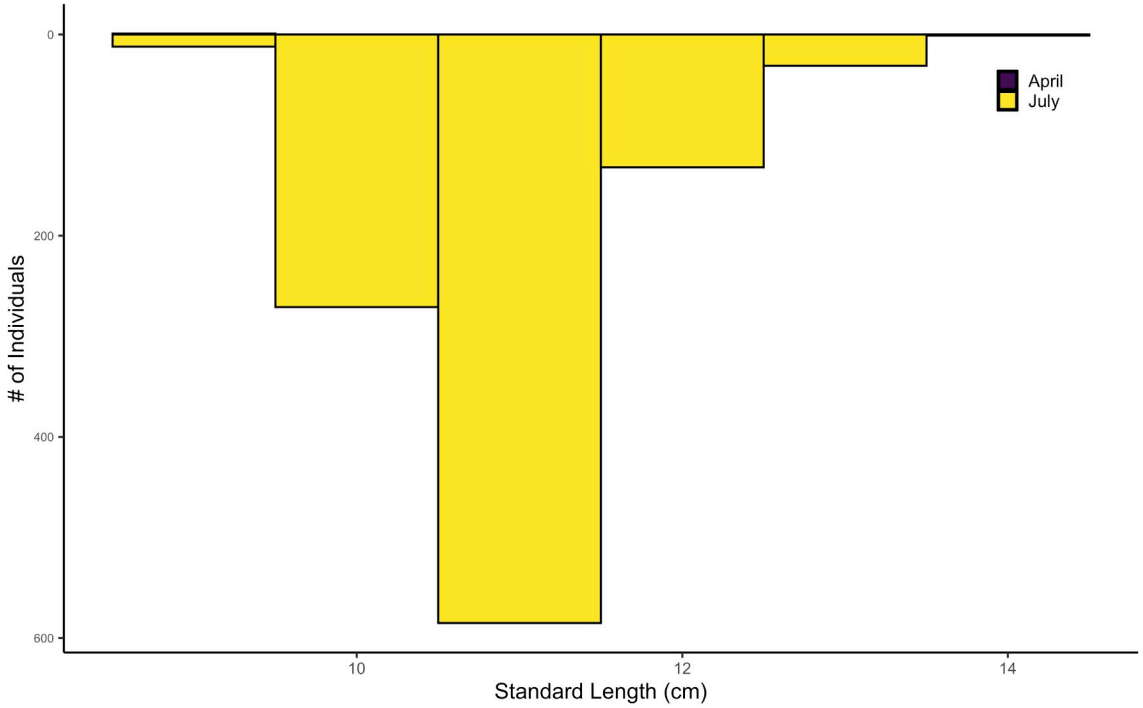


Figure 19. Total number of Deepbody Anchovy individuals by standard length (cm) from San Diego Bay, April and July 2019.

Giant Kelpfish (*Heterostichus rostratus*)

Giant Kelpfish ranked sixth in Ecological Index and were present during each sampling period in all ecoregions. They were found in both vegetated and non-vegetated habitats in the nearshore and intertidal depth strata, however, 15 times the number of individuals were taken in the nearshore strata (566) than the intertidal (39). 94.1% of the Giant Kelpfish captured were juveniles, and all individuals were less than 22 cm SL. There was a stark shift in distribution of size classes (Figure 20) from April to July suggesting a strong winter recruitment event, high juvenile mortality, and rapid growth between sampling events. This observed growth is consistent with that of previous surveys and fits within parameters for juvenile growth rates as estimated by a recent otolith ageing study (Winston et al. 2018).

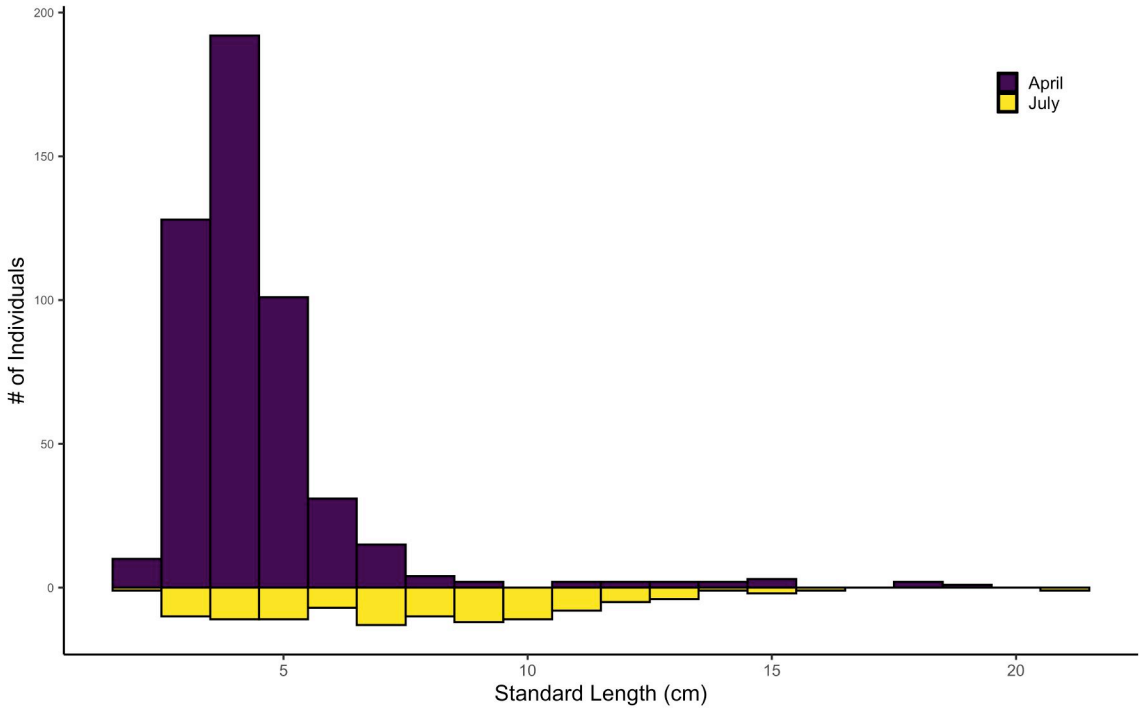


Figure 20. Total number of Giant Kelpfish individuals by standard length (cm) from San Diego Bay, April and July 2019.

Shiner Perch (*Cymatogaster aggregata*)

Shiner Perch ranked seventh by the Ecological Index and were found during both sampling periods and at all ecoregions except the South Ecoregion in July. They were caught almost exclusively in the nearshore subhabitat. These mostly juvenile fish (77.2%) were the sixth most abundant fish in the survey comprising 3.82% of the catch, but less than 1% of the biomass due to their small size. Their size frequency distributions (Figure 21) suggested a recruitment event prior to the April sampling efforts, and heavy natural mortality with slight growth between April and July. This distribution pattern is similar to that of other survey years.

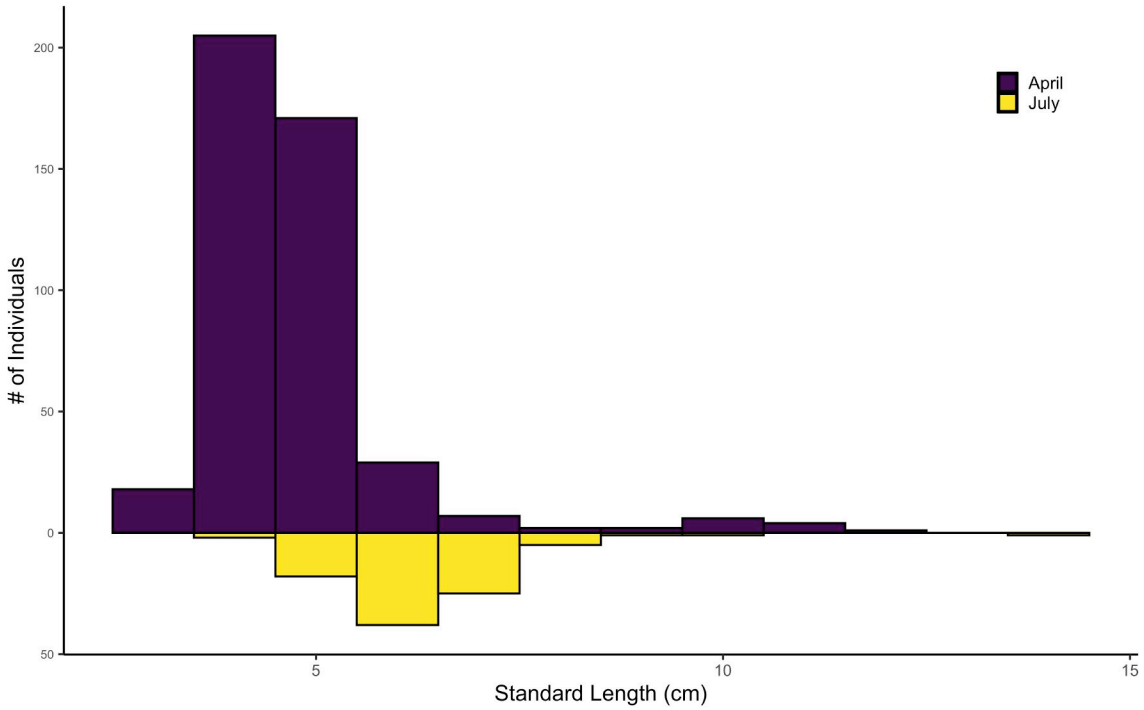


Figure 21. Total number of Shiner Perch individuals by standard length (cm) from San Diego Bay, April and July 2019.

Kelp Pipefish (*Syngnathus californiensis*)

Though these long, narrow fishes only accounted for 0.16% of the biomass captured in 2019, Kelp Pipefish ranked eighth in Ecological Index by accounting for 3.07% of the total abundance and being caught in all ecoregions during both survey periods. They were caught in all depth strata and habitats including a single individual in the channel subhabitat. More than 73% of the individuals were captured in the nearshore subhabitat and showed no apparent preference for vegetated versus non-vegetated habitat. A uniform size distribution belied the fact that nearly half (47.3%) of the individuals captured were juveniles (Figure 22), but the sharp increase in mean size from April to July supported the idea that this species grows quickly.

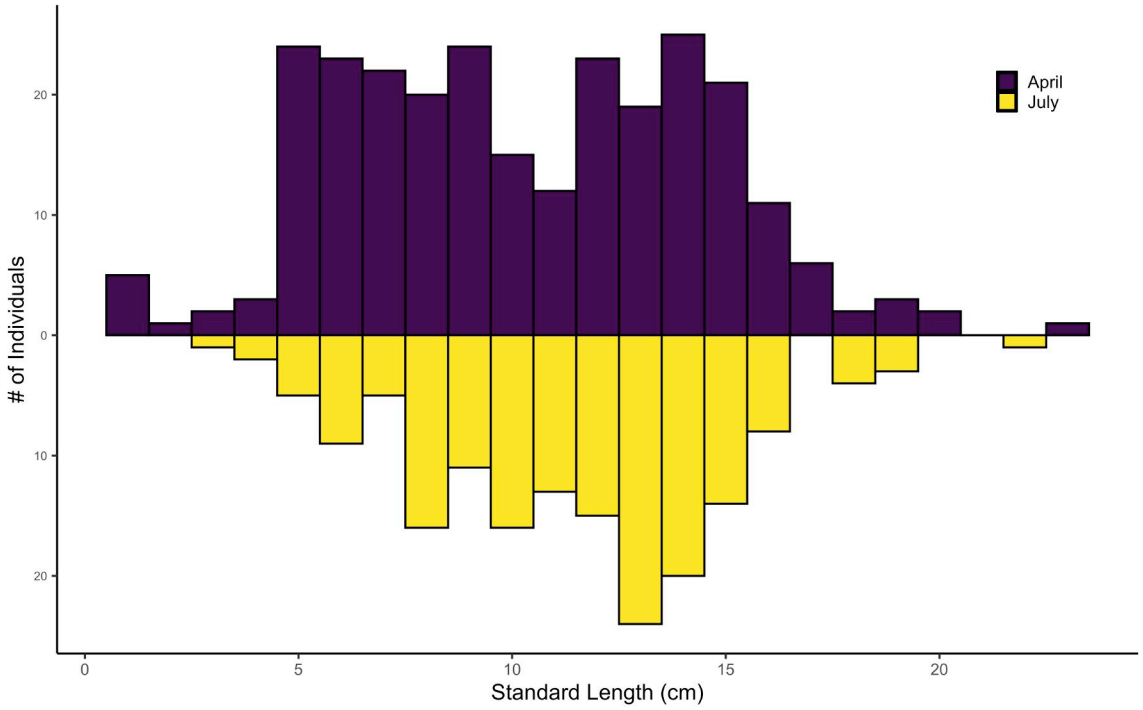


Figure 22. Total number of Kelp Pipefish individuals by standard length (cm) from San Diego Bay, April and July 2019.

California Halibut (*Paralichthys californicus*)

While not a frequently caught species (0.46% of the total catch), Calfornia Halibut ranked ninth in Ecological Index as a product of being caught at all ecoregions, all depth strata, and all subhabitats, and ranking eighth in biomass (1.7%). About 56% of the individuals were juveniles and only one fish would have been considered legal for recreational fishing purposes (Figure 23), but that fish alone weighed 2.5 kg – more than half of the total biomass of this species.

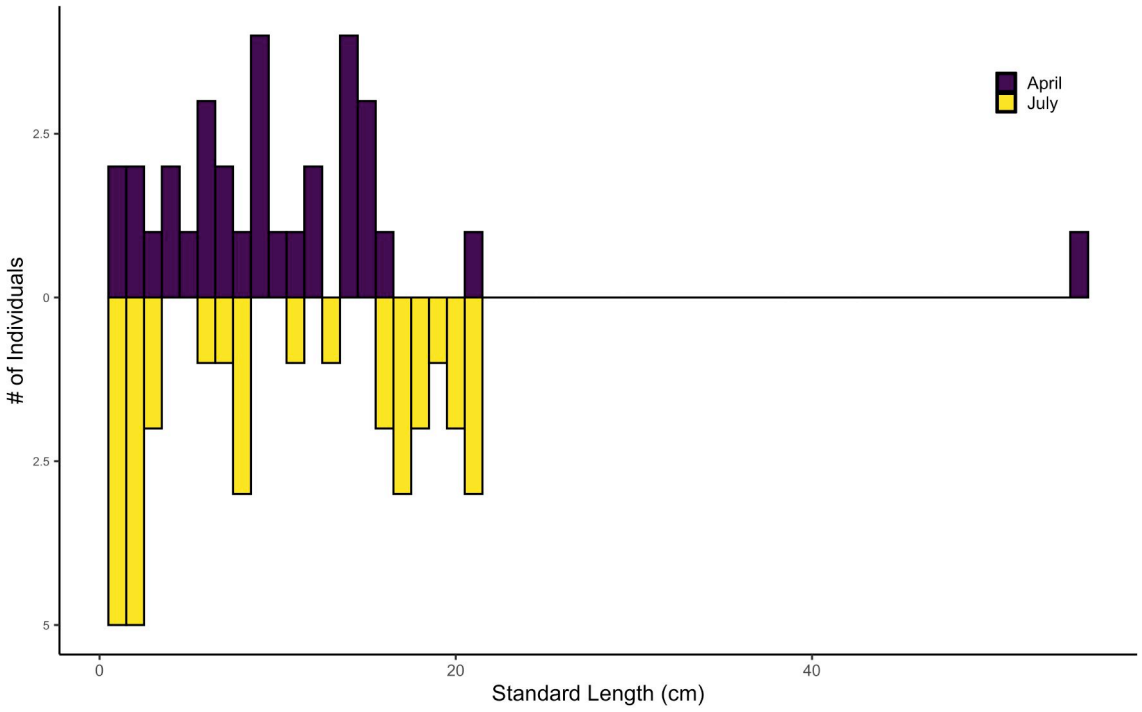


Figure 23. Total number of California Halibut individuals by standard length (cm) from San Diego Bay, April and July 2019.

Dwarf Perch (*Micrometrus minimus*)

Dwarf Perch ranked tenth in terms of Ecological Index, because it was the fourth most frequent catch (4.93%) with the tenth highest biomass (3.0%) during the 2019 surveys. It was only caught in the North Ecoregion, but during both survey periods, and in all subhabitats and depth strata except for the channel. As opposed to Shiner Perch, this viviparous species appears to have reproduced sometime between the April and July sampling periods as there were far fewer adults and a far greater number of juveniles in July (Figure 24).

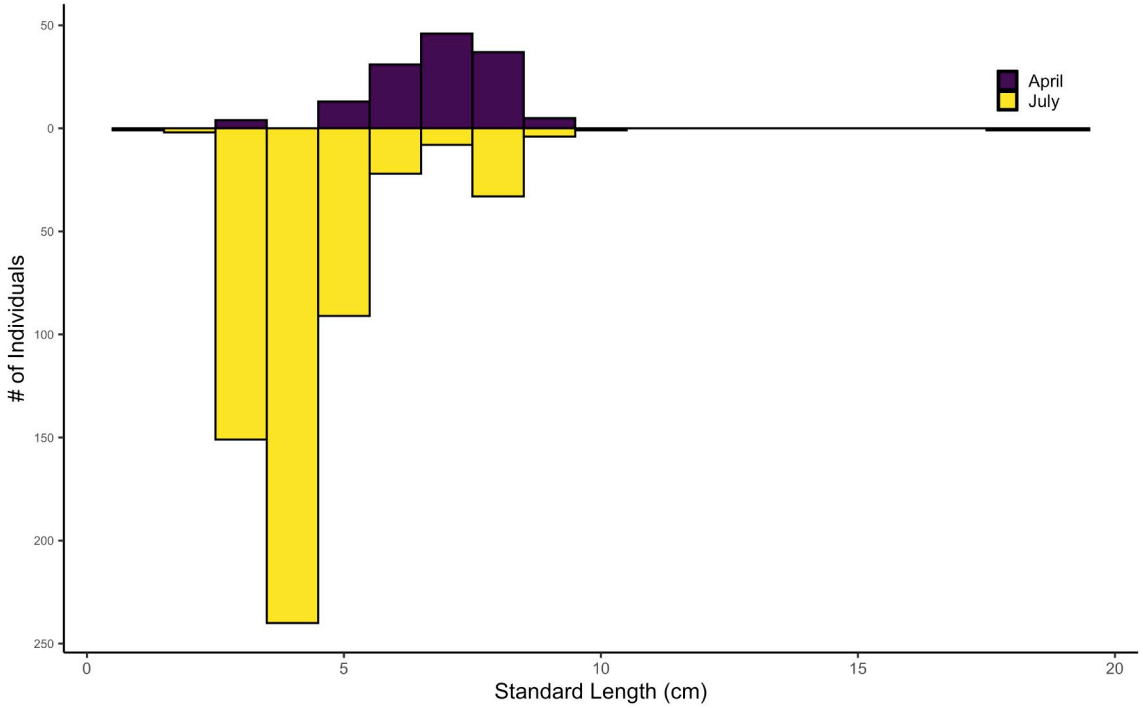


Figure 24. Total number of Dwarf Perch individuals by standard length (cm) from San Diego Bay, April and July 2019.

4.9 Catch by Sampling Method

The greatest number of species were collected in the purse seines (30 species), followed by large seine (23), beam trawl (21), otter trawl (15), small seine (11), and square enclosure (3; Tables 15 and 16). The purse seine captured the greatest number of fish, catching a total of 5,966, a number greatly influenced by large schools of anchovies and Topsmelt. There was an unusually large catch in the small seine (4,695), most of which were newly settled Topsmelt, and there were moderate catches in the large seine (1,610) and beam trawl (1,487), a relatively low catch in the otter trawl (256), and only 10 fish in the square enclosure (Table 15). The greatest amount of biomass was also captured in the purse seine (195.0 kg), with high biomass also captured in the otter trawl (36.4 kg) and beam trawl (29.6 kg). The large seine (9.14 kg) and small seine (1.30 kg) captured lower amounts of biomass, and the square enclosure captured only 20.5 g of fishes (Table 16).

The purse seine was most effective at sampling the schooling fishes (Slough Anchovy, Northern Anchovy, Topsmelt). The beam trawl was most effective for catching benthic nearshore and eelgrass fishes (Kelp Pipefish, Giant Kelpfish, Shiner Perch, Dwarf Perch). The square enclosure was largely ineffective in 2019 but was slightly more effective than in previous years. The beach seines were most effective at catching juvenile Topsmelt and Dwarf Perch. The top species caught in the otter trawls was Round Stingray. The highest density of fishes was captured in the small seine (1.578 individuals/m^2) followed by the purse seine (0.280 individuals/m^2; Table 17). The purse seines and beam trawls produced the highest biomass density values (9.151 g/m^2 and 2.126 g/m^2, respectively). The square enclosures captured the smallest amount of biomass (0.427 g/m^2).

Transporting the square enclosure along the beach in the North-Central Ecorgeion, July 2019.

Table 15. Total catch (number of individuals) of fish species taken in San Diego Bay in 2019 by sampling method.

PURSE SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Atherinops affinis	Topsmelt	2,563	42.96
Anchoa delicatissima	Slough Anchovy	1,060	17.77
Anchoa compressa	Deepbody Anchovy	1,032	17.30
Cymatogaster aggregata	Shiner Perch	417	6.99
Paralabrax maculatofasciatus	Spotted Sand Bass	317	5.31
Urobatis halleri	Round Stingray	231	3.87
Micrometrus minimus	Dwarf Perch	103	1.73
Sardinops sagax	Pacific Sardine	78	1.31
Leuresthes tenuis	California Grunion	29	0.49
Cynoscion parvipinnis	Shortfin Corvina	20	0.34
Heterostichus rostratus	Giant Kelpfish	19	0.32
Scomber japonicus	Pacific Chub Mackerel	15	0.25
Haemulon californiensis	Salema	14	0.23
Halichoeres semicinctus	Rock Wrasse	13	0.22
Syngnathus californiensis	Kelp Pipefish	12	0.20
Albula gilberti	Cortez Bonefish	9	0.15
Myliobatis californica	Bat Ray	7	0.12
Paralabrax clathratus	Kelp Bass	6	0.10
Paralabrax nebulifer	Barred Sand Bass	5	0.08
Hippocampus ingens	Pacific Seahorse	3	0.05
Paralichthys californicus	California Halibut	3	0.05
Embiotoca jacksoni	Black Perch	2	0.03
Dasyatis dipterura	Diamond Stingray	1	0.02
Gibbonsia elegans	Spotted Kelpfish	1	0.02
Hypsoblennius gentilis	Bay Blenny	1	0.02
Phanerodon furcatus	White Seaperch	1	0.02
Pleuronichthys guttulatus	Diamond Turbot	1	0.02
Porichthys myriaster	Specklefin Midshipman	1	0.02
Seriphus politus	Queenfish	1	0.02
Symphurus atricaudus	California Tonguefish	1	0.02
# of Species:	**30**	**5,966**	

BEAM TRAWL			
Scientific Name	**Common Name**	**Abundance**	**%**
Heterostichus rostratus	Giant Kelpfish	547	36.79
Syngnathus californiensis	Kelp Pipefish	303	20.38
Micrometrus minimus	Dwarf Perch	254	17.08
Cymatogaster aggregata	Shiner Perch	104	6.99
Urobatis halleri	Round Stingray	104	6.99
Paralabrax maculatofasciatus	Spotted Sand Bass	52	3.50
Hypsoblennius gentilis	Bay Blenny	31	2.08
Paralichthys californicus	California Halibut	22	1.48
Paralabrax nebulifer	Barred Sand Bass	21	1.41
Clevelandia ios	Arrow Goby	14	0.94
Porichthys myriaster	Specklefin Midshipman	9	0.61
Symphurus atricaudus	California Tonguefish	9	0.61
Halichoeres semicinctus	Rock Wrasse	6	0.40
Paralabrax clathratus	Kelp Bass	4	0.27
Acanthogobius flavimanus	Yellowfin Goby	1	0.07
Atherinops affinis	Topsmelt	1	0.07
Cheilotrema saturnum	Black Croaker	1	0.07
Embiotoca jacksoni	Black Perch	1	0.07
Gymnura marmorata	California Butterfly Ray	1	0.07
Pleuronichthys decurrens	Curlfin Sole	1	0.07
Pleuronichthys ritteri	Spotted Turbot	1	0.07
# of Species:	**21**	**1,487**	

Table 15 (continued).

LARGE SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Atherinops affinis	Topsmelt	936	58.14
Micrometrus minimus	Dwarf Perch	297	18.45
Anchoa delicatissima	Slough Anchovy	205	12.73
Heterostichus rostratus	Giant Kelpfish	34	2.11
Syngnathus californiensis	Kelp Pipefish	23	1.43
Clevelandia ios	Arrow Goby	18	1.12
Pleuronichthys guttulatus	Diamond Turbot	18	1.12
Paralichthys californicus	California Halibut	13	0.81
Urobatis halleri	Round Stingray	12	0.75
Cymatogaster aggregata	Shiner Perch	10	0.62
Paralabrax nebulifer	Barred Sand Bass	9	0.56
Leptocottus armatus	Pacific Staghorn Sculpin	8	0.50
Paralabrax maculatofasciatus	Spotted Sand Bass	5	0.31
Embiotoca jacksoni	Black Perch	4	0.25
Hyporhamphus rosae	California Halfbeak	4	0.25
Hypsoblennius gentilis	Bay Blenny	4	0.25
Leuresthes tenuis	California Grunion	3	0.19
Fundulus parvipinnis	California Killifish	2	0.12
Anchoa compressa	Deepbody Anchovy	1	0.06
Atherinopsis californiensis	Jacksmelt	1	0.06
Ilypnus gilberti	Cheekspot Goby	1	0.06
Myliobatis californica	Bat Ray	1	0.06
Umbrina roncador	Yellowfin Croaker	1	0.06
# of Species:	**23**	**1,610**	

SMALL SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Atherinops affinis	Topsmelt	4,540	96.70
Syngnathus californiensis	Kelp Pipefish	92	1.96
Micrometrus minimus	Dwarf Perch	37	0.79
Clevelandia ios	Arrow Goby	15	0.32
Heterostichus rostratus	Giant Kelpfish	5	0.11
Anchoa delicatissima	Slough Anchovy	1	0.02
Cymatogaster aggregata	Shiner Perch	1	0.02
Embiotoca jacksoni	Black Perch	1	0.02
Gymnura marmorata	California Butterfly Ray	1	0.02
Leptocottus armatus	Pacific Staghorn Sculpin	1	0.02
Paralichthys californicus	California Halibut	1	0.02
# of Species:	**11**	**4,695**	

Table 15 (continued).

OTTER TRAWL			
Scientific Name	**Common Name**	**Abundance**	**%**
Urobatis halleri	Round Stingray	149	58.20
Paralabrax maculatofasciatus	Spotted Sand Bass	46	17.97
Paralichthys californicus	California Halibut	25	9.77
Pleuronichthys guttulatus	Diamond Turbot	10	3.91
Pleuronichthys ritteri	Spotted Turbot	7	2.73
Cymatogaster aggregata	Shiner Perch	4	1.56
Porichthys myriaster	Specklefin Midshipman	3	1.17
Cheilotrema saturnum	Black Croaker	2	0.78
Scorpaena guttata	California Scorpionfish	2	0.78
Symphurus atricaudus	California Tonguefish	2	0.78
Synodus lucioceps	California Lizardfish	2	0.78
Gymnura marmorata	California Butterfly Ray	1	0.39
Hippocampus ingens	Pacific Seahorse	1	0.39
Syngnathus californiensis	Kelp Pipefish	1	0.39
Xystreurys liolepis	Fantail Sole	1	0.39
# of Species:	**15**	**256**	

SQUARE ENCLOSURE			
Scientific Name	**Common Name**	**Abundance**	**%**
Clevelandia ios	Arrow Goby	5	50.0
Atherinops affinis	Topsmelt	4	40.0
Hypsoblennius gentilis	Bay Blenny	1	10.0
# of Species:	**3**	**10**	

Table 16. Total biomass (g) of fish species taken from San Diego Bay in 2019 by sampling method.

PURSE SEINE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	68,380	35.06
Paralabrax maculatofasciatus	Spotted Sand Bass	53,959	27.67
Atherinops affinis	Topsmelt	20,098	10.31
Anchoa compressa	Deepbody Anchovy	15,350	7.87
Myliobatis californica	Bat Ray	8,400	4.31
Albula gilberti	Cortez Bonefish	5,385	2.76
Cynoscion parvipinnis	Shortfin Corvina	5,108	2.62
Dasyatis dipterura	Diamond Stingray	4,200	2.15
Paralichthys californicus	California Halibut	2,527	1.30
Sardinops sagax	Pacific Sardine	2,330	1.19
Halichoeres semicinctus	Rock Wrasse	1,654	0.85
Cymatogaster aggregata	Shiner Perch	1,567	0.80
Anchoa delicatissima	Slough Anchovy	1,440	0.74
Scomber japonicus	Pacific Chub Mackerel	1,318	0.68
Paralabrax clathratus	Kelp Bass	774	0.40
Micrometrus minimus	Dwarf Perch	639	0.33
Leuresthes tenuis	California Grunion	358	0.18
Pleuronichthys guttulatus	Diamond Turbot	335	0.17
Porichthys myriaster	Specklefin Midshipman	255	0.13
Haemulon californiensis	Salema	190	0.10
Phanerodon furcatus	White Seaperch	190	0.10
Paralabrax nebulifer	Barred Sand Bass	126	0.06
Heterostichus rostratus	Giant Kelpfish	122	0.06
Syngnathus californiensis	Kelp Pipefish	118	0.06
Hippocampus ingens	Pacific Seahorse	105	0.05
Seriphus politus	Queenfish	46	0.02
Embiotoca jacksoni	Black Perch	23	0.01
Hypsoblennius gentilis	Bay Blenny	11	0.01
Gibbonsia elegans	Spotted Kelpfish	10	0.01
Symphurus atricaudus	California Tonguefish	3	< 0.01
# of Species:	**30**	**195,021**	

BEAM TRAWL			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	18,195	61.47
Paralabrax maculatofasciatus	Spotted Sand Bass	6,028	20.36
Gymnura marmorata	California Butterfly Ray	1,600	5.41
Micrometrus minimus	Dwarf Perch	1,459	4.93
Heterostichus rostratus	Giant Kelpfish	909	3.07
Paralabrax nebulifer	Barred Sand Bass	259	0.87
Cymatogaster aggregata	Shiner Perch	221	0.74
Syngnathus californiensis	Kelp Pipefish	213	0.72
Halichoeres semicinctus	Rock Wrasse	184	0.62
Paralichthys californicus	California Halibut	147	0.50
Porichthys myriaster	Specklefin Midshipman	139	0.47
Symphurus atricaudus	California Tonguefish	80	0.27
Hypsoblennius gentilis	Bay Blenny	62	0.21
Paralabrax clathratus	Kelp Bass	35	0.12
Embiotoca jacksoni	Black Perch	21	0.07
Pleuronichthys decurrens	Curlfin Sole	21	0.07
Pleuronichthys ritteri	Spotted Turbot	19	0.06
Clevelandia ios	Arrow Goby	5.5	0.02
Acanthogobius flavimanus	Yellowfin Goby	3.0	0.01
Atherinops affinis	Topsmelt	1.5	0.01
Cheilotrema saturnum	Black Croaker	0.1	0.00
# of Species:	**21**	**29,600**	

Table 16 (continued).

LARGE SEINE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	2,729	29.86
Atherinops affinis	Topsmelt	1,887	20.64
Micrometrus minimus	Dwarf Perch	1,855	20.29
Paralabrax maculatofasciatus	Spotted Sand Bass	475	5.20
Embiotoca jacksoni	Black Perch	342	3.74
Heterostichus rostratus	Giant Kelpfish	334	3.65
Anchoa delicatissima	Slough Anchovy	290	3.17
Myliobatis californica	Bat Ray	265	2.90
Paralabrax nebulifer	Barred Sand Bass	223	2.44
Paralichthys californicus	California Halibut	208	2.28
Pleuronichthys guttulatus	Diamond Turbot	100	1.09
Atherinopsis californiensis	Jacksmelt	66	0.72
Cymatogaster aggregata	Shiner Perch	65	0.71
Leuresthes tenuis	California Grunion	64	0.70
Leptocottus armatus	Pacific Staghorn Sculpin	57	0.62
Hypsoblennius gentilis	Bay Blenny	56	0.61
Umbrina roncador	Yellowfin Croaker	49	0.54
Syngnathus californiensis	Kelp Pipefish	36	0.39
Hyporhamphus rosae	California Halfbeak	15	0.16
Anchoa compressa	Deepbody Anchovy	10	0.11
Clevelandia ios	Arrow Goby	8	0.09
Fundulus parvipinnis	California Killifish	4	0.04
Ilypnus gilberti	Cheekspot Goby	3	0.03
# of Species:	**23**	**9,141**	

SMALL SEINE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Atherinops affinis	Topsmelt	703	54.20
Gymnura marmorata	California Butterfly Ray	205	15.81
Micrometrus minimus	Dwarf Perch	181	13.96
Embiotoca jacksoni	Black Perch	115	8.87
Syngnathus californiensis	Kelp Pipefish	53	4.09
Heterostichus rostratus	Giant Kelpfish	23	1.77
Leptocottus armatus	Pacific Staghorn Sculpin	10	0.77
Clevelandia ios	Arrow Goby	4	0.27
Anchoa delicatissima	Slough Anchovy	2	0.15
Cymatogaster aggregata	Shiner Perch	1	0.08
Paralichthys californicus	California Halibut	1	0.04
# of Species:	**11**	**1,297**	

Table 16 (continued).

OTTER TRAWL			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	26,160	71.81
Paralabrax maculatofasciatus	Spotted Sand Bass	5,211	14.30
Paralichthys californicus	California Halibut	1,814	4.98
Porichthys myriaster	Specklefin Midshipman	982	2.70
Pleuronichthys guttulatus	Diamond Turbot	849	2.33
Pleuronichthys ritteri	Spotted Turbot	495	1.36
Gymnura marmorata	California Butterfly Ray	300	0.82
Synodus lucioceps	California Lizardfish	255	0.70
Scorpaena guttata	California Scorpionfish	140	0.38
Cheilotrema saturnum	Black Croaker	135	0.37
Symphurus atricaudus	California Tonguefish	40	0.11
Hippocampus ingens	Pacific Seahorse	29	0.08
Xystreurys liolepis	Fantail Sole	10	0.03
Cymatogaster aggregata	Shiner Perch	6	0.02
Syngnathus californiensis	Kelp Pipefish	2	0.01
# of Species:	**15**	**36,428**	

SQUARE ENCLOSURE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Hypsoblennius gentilis	Bay Blenny	18	87.8
Clevelandia ios	Arrow Goby	1.5	7.3
Atherinops affinis	Topsmelt	1.0	4.9
# of Species:	**3**	**20.5**	

Table 17. Comparison of mean densities and biomass densities by gear type and sampling year for San Diego Bay. Values were calculated for years that were sampled in April and July and only includes data from those sampling months.

	Year	Beam Trawl	Otter Trawl	Purse Seine	Large Seine	Small Seine	Square Enclosure
Density (#/m^2)	*1995*	0.188	0.021	3.937	0.589	4.037	3.646
	1996	0.170	0.009	8.205	0.658	8.699	6.396
	1997	0.106	0.013	0.844	0.532	2.369	4.208
	1998	0.037	0.003	1.995	0.427	0.403	4.000
	2005	0.145	0.032	0.569	0.676	0.439	0.708
	2008	0.223	0.006	0.390	0.171	0.702	0.542
	2012	0.386	0.008	0.122	0.366	1.659	0.708
	2015	0.184	0.028	0.705	0.219	0.869	0.146
	2016	0.189	0.009	0.495	0.177	1.873	0.146
	2019	0.107	0.004	0.280	0.152	1.578	0.208

	Year	Beam Trawl	Otter Trawl	Purse Seine	Large Seine	Small Seine	Square Enclosure
Biomass Density (g/m^2)	*1995*	3.455	2.229	10.44	0.816	0.527	1.681
	1996	2.433	1.772	16.92	0.887	1.172	0.433
	1997	1.170	1.844	6.195	1.504	0.300	0.409
	1998	1.610	0.591	7.083	1.013	0.059	0.604
	2005	5.137	1.426	5.580	1.684	0.217	0.196
	2008	3.572	0.624	3.910	1.314	0.256	12.32
	2012	7.199	1.026	7.949	1.502	1.044	2.065
	2015	2.578	1.583	11.01	1.367	0.462	0.010
	2016	2.188	1.288	6.356	0.764	0.390	0.019
	2019	2.126	0.628	9.151	0.866	0.436	0.427

4.10 Best Estimates of Density and Standing Stock

The best estimate for the total stock size was 18,321,764 fishes (Table 18). With an estimated surface area of 4,858 ha (Table 2) this gives an overall fish density 0.38 individuals/m^2 (Table 18). The highest estimates were of Topsmelt (8.16 million), Deepbody Anchovy (2.75 million), Slough Anchovy (2.19 million), followed by Giant Kelpfish (1.09 million), and Shiner Perch (0.815 million). As is typical, schooling and forage fishes dominated the stock estimate for the bay.

The total best estimate of biomass standing stock was about 420 metric tons (MT) (Table 19). This gives an overall estimate of 8.64 g/m^2, about 35% higher than the 2016 estimate and above average for all historical surveys (Williams et al. 2016). The highest biomass estimates were of Round Stingray (136.5 MT), followed by Spotted Sand Bass (106.8 MT), Topsmelt (44.1 MT), Deepbody Anchovy (40.9 MT), and Bat Ray (17.0 MT). Round Stingray and Spotted Sand Bass are typically in the top five biomass estimates from past surveys, but Deepbody Anchovy is a historically atypical top biomass species.

Table 18. Best estimate of densities (#/m^2) and stock estimates, April and July 2019.

		Best Estimate of Density (#/m^2) Depth Strata				
Scientific Name	**Common Name**	**Channel**	**Intertidal**	**Nearshore**	**Weighted Mean**	**Stock Estimate (#)**
Atherinops affinis	Topsmelt	0.03913	1.52554	0.16082	0.16795	8,159,182
Anchoa compressa	Deepbody Anchovy	0.14527	0.00009		0.05666	2,752,504
Anchoa delicatissima	Slough Anchovy	0.01745	0.01941	0.06588	0.04513	2,192,640
Heterostichus rostratus	Giant Kelpfish		0.00322	0.03930	0.02253	1,094,386
Cymatogaster aggregata	Shiner Perch	0.00007	0.00095	0.02935	0.01679	815,856
Syngnathus californiensis	Kelp Pipefish	0.00002	0.03091	0.02177	0.01365	663,147
Paralabrax maculatofasciatus	Spotted Sand Bass	0.00183	0.00047	0.02140	0.01293	628,070
Micrometrus minimus	Dwarf Perch		0.02813	0.01825	0.01153	559,926
Urobatis halleri	Round Stingray	0.00257	0.00114	0.01555	0.00991	481,590
Clevelandia ios	Arrow Goby		0.10417	0.00101	0.00474	230,266
Sardinops sagax	Pacific Sardine	0.01098			0.00428	208,024
Hypsoblennius gentilis	Bay Blenny	0.00014	0.02083	0.00223	0.00216	104,818
Leuresthes tenuis	California Grunion		0.00028	0.00204	0.00117	57,071
Paralichthys californicus	California Halibut	0.00043	0.00123	0.00158	0.00112	54,321
Cynoscion parvipinnis	Shortfin Corvina	0.00239		0.00021	0.00105	51,185
Paralabrax nebulifer	Barred Sand Bass		0.00085	0.00151	0.00089	43,431
Scomber japonicus	Pacific Chub Mackerel	0.00211			0.00082	40,005
Haemulon californiensis	Salema			0.00099	0.00056	27,285
Halichoeres semicinctus	Rock Wrasse			0.00091	0.00052	25,336
Albula gilberti	Cortez Bonefish	0.00099		0.00014	0.00046	22,567
Porichthys myriaster	Specklefin Midshipman	0.00005		0.00065	0.00039	18,883
Symphurus atricaudus	California Tonguefish	0.00003		0.00065	0.00038	18,557
Myliobatis californica	Bat Ray	0.00028	0.00009	0.00035	0.00031	15,263
Paralabrax clathratus	Kelp Bass			0.00042	0.00024	11,694
Pleuronichthys guttulatus	Diamond Turbot	0.00017	0.00170	0.00007	0.00018	8,527
Hippocampus ingens	Pacific Seahorse	0.00002		0.00021	0.00013	6,173
Embiotoca jacksoni	Black Perch		0.00038	0.00014	0.00010	4,634
Pleuronichthys ritteri	Spotted Turbot	0.00012		0.00007	0.00009	4,276
Gymnura marmorata	California Butterfly Ray	0.00002	0.00034	0.00007	0.00006	2,969
Cheilotrema saturnum	Black Croaker	0.00003		0.00007	0.00005	2,642
Acanthogobius flavimanus	Yellowfin Goby			0.00007	0.00004	1,989
Pleuronichthys decurrens	Curlfin Sole			0.00007	0.00004	1,989
Dasyatis dipterura	Diamond Stingray			0.00007	0.00004	1,949
Gibbonsia elegans	Spotted Kelpfish			0.00007	0.00004	1,949
Phanerodon furcatus	White Seaperch			0.00007	0.00004	1,949
Seriphus politus	Queenfish			0.00007	0.00004	1,949
Leptocottus armatus	Pacific Staghorn Sculpin		0.00076		0.00003	1,472
Hyporhamphus rosae	California Halfbeak		0.00038		0.00002	736
Scorpaena guttata	California Scorpionfish	0.00003			0.00001	653
Synodus lucioceps	California Lizardfish	0.00003			0.00001	653
Fundulus parvipinnis	California Killifish		0.00019		0.00001	368
Xystreurys liolepis	Fantail Sole	0.00002			0.00001	327
Atherinopsis californiensis	Jacksmelt		0.00009		< 0.00001	184
Ilypnus gilberti	Cheekspot Goby		0.00009		< 0.00001	184
Umbrina roncador	Yellowfin Croaker		0.00009		< 0.00001	184
	Grand Totals:	**0.22420**	**1.74135**	**0.38606**	**0.37713**	**18,321,764**

Table 19. Best estimate of biomass densities (g/m^2) and standing stock, April and July 2019.

		Best Estimate of Density (g/m^2) Depth Strata					
Scientific Name	**Common Name**	**Channel**	**Intertidal**	**Nearshore**	**Weighted Mean**	**Stock Estimate (kg)**	**Stock Estimate (MT)**
Urobatis halleri	Round Stingray	0.45097	0.25843	4.60318	2.81003	136,511	136.5
Paralabrax maculatofasciatus	Spotted Sand Bass	0.30039	0.04498	3.64759	2.19808	106,783	106.8
Atherinops affinis	Topsmelt	0.87725	0.23622	0.97593	0.90786	44,104	44.1
Anchoa compressa	Deepbody Anchovy	2.16075	0.00095		0.84273	40,940	40.9
Myliobatis californica	Bat Ray	0.10557	0.02509	0.53843	0.34908	16,958	17.0
Albula gilberti	Cortez Bonefish	0.56799		0.09502	0.27568	13,392	13.4
Cynoscion parvipinnis	Shortfin Corvina	0.38007		0.16948	0.24483	11,894	11.89
Dasyatis dipterura	Diamond Stingray			0.29561	0.16850	8,186	8.19
Sardinops sagax	Pacific Sardine	0.32798			0.12791	6,214	6.21
Paralichthys californicus	California Halibut	0.03127	0.01970	0.17786	0.11436	5,556	5.56
Scomber japonicus	Pacific Chub Mackerel	0.18553			0.07236	3,515	3.52
Gymnura marmorata	California Butterfly Ray	0.00517	0.06888	0.11494	0.07029	3,415	3.41
Micrometrus minimus	Dwarf Perch		0.17566	0.10481	0.06677	3,244	3.24
Halichoeres semicinctus	Rock Wrasse			0.11641	0.06636	3,224	3.22
Cymatogaster aggregata	Shiner Perch	0.00010	0.00616	0.11029	0.06315	3,068	3.07
Anchoa delicatissima	Slough Anchovy	0.02590	0.02746	0.08840	0.06159	2,992	2.99
Heterostichus rostratus	Giant Kelpfish		0.03163	0.06527	0.03847	1,869	1.87
Paralabrax clathratus	Kelp Bass			0.05448	0.03105	1,508	1.51
Pleuronichthys guttulatus	Diamond Turbot	0.01464	0.00947	0.02358	0.01953	949	0.95
Hypsoblennius gentilis	Bay Blenny	0.00155	0.37500	0.00445	0.01814	881	0.88
Porichthys myriaster	Specklefin Midshipman	0.01693		0.01795	0.01683	818	0.82
Leuresthes tenuis	California Grunion		0.00606	0.02520	0.01460	709	0.71
Paralabrax nebulifer	Barred Sand Bass		0.02112	0.01861	0.01145	556	0.56
Syngnathus californiensis	Kelp Pipefish	0.00003	0.01781	0.01527	0.00943	458	0.46
Haemulon californiensis	Salema			0.01337	0.00762	370	0.37
Phanerodon furcatus	White Seaperch			0.01337	0.00762	370	0.37
Hippocampus ingens	Pacific Seahorse	0.00050		0.00739	0.00441	214	0.21
Pleuronichthys ritteri	Spotted Turbot	0.00853		0.00136	0.00411	199	0.20
Symphurus atricaudus	California Tonguefish	0.00069		0.00575	0.00354	172	0.17
Embiotoca jacksoni	Black Perch		0.03864	0.00162	0.00247	120	0.12
Seriphus politus	Queenfish			0.00324	0.00185	90	0.09
Synodus lucioceps	California Lizardfish	0.00440			0.00171	83	0.08
Clevelandia ios	Arrow Goby		0.03125	0.00040	0.00148	72	0.07
Scorpaena guttata	California Scorpionfish	0.00241			0.00094	46	0.05
Cheilotrema saturnum	Black Croaker	0.00233		0.00001	0.00091	44	0.04
Pleuronichthys decurrens	Curlfin Sole			0.00151	0.00086	42	0.04
Gibbonsia elegans	Spotted Kelpfish			0.00070	0.00040	19	0.02
Atherinopsis californiensis	Jacksmelt		0.00625		0.00025	12	0.01
Leptocottus armatus	Pacific Staghorn Sculpin		0.00540		0.00022	10	0.01
Umbrina roncador	Yellowfin Croaker		0.00464		0.00019	9	0.01
Acanthogobius flavimanus	Yellowfin Goby			0.00022	0.00012	6	0.01
Xystreurys liolepis	Fantail Sole	0.00017			0.00007	3	< 0.01
Hyporhamphus rosae	California Halfbeak		0.00142		0.00006	3	< 0.01
Fundulus parvipinnis	California Killifish		0.00038		0.00002	1	< 0.01
Ilypnus gilberti	Cheekspot Goby		0.00028		0.00001	1	< 0.01
	Grand Totals:	**5.47115**	**1.41288**	**11.31169**	**8.63793**	**419,630**	**419.6**

4.11 Avian Forage Species

Forage species are primarily surface-dwelling schooling fish that are accessible to diving avian predators, especially terns. Generally, forage fishes are small silvery-sided fishes that are found in large schools. These schooling fishes are generally not habitat specific and move throughout the bay's ecosystem. Thirteen species of important forage fishes (as defined in Pondella and Williams 2011) were captured during this study. The most abundant forage fishes were Topsmelt, Slough Anchovy, and Deepbody Anchovy. Topsmelt were primarily found at small (juvenile) size classes (<50 mm SL) appropriate for nesting birds to feed their young in the area. The typical timing for the recruitment of fishes to San Diego Bay begins in the spring and continues through the summer, but it appears this began much earlier in the year in 2019. The biomass standing stock estimate for forage fish was 106.7 MT. When estimating by ecoregion, values were highest at the South-Central Ecoregion (66.5 MT) which was driven almost entirely by one catch of Deepbody Anchovy. This was followed by the North Ecoregion (32.3 MT), the North-Central Ecoregion (14.0 MT), and the South Ecoregion (3.4 MT; Table 20).

Surf scoter (*Melanitta perspicillata*) swimming near Sweetwater Marsh.

Table 20. Best estimate of biomass standing stock for forage fish species by ecoregion, 2019.

Ecoregion	Scientific Name	Common Name	Depth Strata			Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
			Channel	Intertidal	Nearshore			
North	*Atherinops affinis*	Topsmelt	2.87162	0.49530	2.33587	2.55224	25,063	25.1
	Scomber japonicus	Pacific Chub Mackerel	0.67568			0.41216	4,047	4.05
	Micrometrus minimus	Dwarf Perch		0.70265	0.41925	0.18051	1,773	1.77
	Cymatogaster aggregata	Shiner Perch		0.01061	0.19088	0.06363	625	0.62
	Heterostichus rostratus	Giant Kelpfish		0.09697	0.16868	0.06148	604	0.60
	Leuresthes tenuis	California Grunion		0.02424	0.04505	0.01632	160	0.16
	Clevelandia ios	Arrow Goby			0.00057	0.00019	2	< 0.01
		Grand Total:		**1.32977**	**3.16030**	**3.28654**	**32,274**	**32.3**
North-Central	*Atherinops affinis*	Topsmelt	0.59122	0.43616	1.42652	0.90088	7,279	7.28
	Sardinops sagax	Pacific Sardine	1.23874			0.70608	5,705	5.71
	Cymatogaster aggregata	Shiner Perch		0.01061	0.11064	0.04257	344	0.34
	Scomber japonicus	Pacific Chub Mackerel	0.06644			0.03787	306	0.31
	Heterostichus rostratus	Giant Kelpfish		0.02727	0.05402	0.02189	177	0.18
	Leuresthes tenuis	California Grunion			0.05574	0.02118	171	0.17
	Anchoa delicatissima	Slough Anchovy		0.05492	0.00169	0.00339	27	0.03
	Clevelandia ios	Arrow Goby			0.00086	0.00033	3	< 0.01
	Anchoa compressa	Deepbody Anchovy		0.00379		0.00019	2	< 0.01
		Grand Total:	**1.89640**	**0.53275**	**1.64948**	**1.73439**	**14,014**	**14.0**
South-Central	*Anchoa compressa*	Deepbody Anchovy	8.55856			3.08108	61,776	61.78
	Anchoa delicatissima	Slough Anchovy		0.05492	0.15709	0.09748	1,954	1.95
	Cymatogaster aggregata	Shiner Perch		0.00152	0.07658	0.04676	937	0.94
	Atherinops affinis	Topsmelt		0.04167	0.07123	0.04470	896	0.90
	Sardinops sagax	Pacific Sardine	0.07320			0.02635	528	0.53
	Heterostichus rostratus	Giant Kelpfish		0.00076	0.03089	0.01887	378	0.38
	Clevelandia ios	Arrow Goby		0.08333	0.00014	0.00259	52	0.05
	Atherinopsis californiensis	Jacksmelt		0.02500		0.00075	15	0.02
		Grand Total:	**8.63176**	**0.20720**	**0.33593**	**3.31857**	**66,537**	**66.5**
South	*Anchoa delicatissima*	Slough Anchovy	0.10360		0.19482	0.17517	1,864	1.86
	Atherinops affinis	Topsmelt	0.04617	0.14242	0.07010	0.06988	744	0.74
	Cymatogaster aggregata	Shiner Perch	0.00041	0.00189	0.06306	0.05247	558	0.56
	Anchoa compressa	Deepbody Anchovy	0.08446			0.01098	117	0.12
	Heterostichus rostratus	Giant Kelpfish		0.00152	0.00760	0.00637	68	0.07
	Clevelandia ios	Arrow Goby		0.04167		0.00167	18	0.02
	Hyporhamphus rosae	California Halfbeak		0.00568		0.00023	2	0.00
	Fundulus parvipinnis	California Killifish		0.00152		0.00006	1	0.00
		Grand Total:	**0.23465**	**0.19470**	**0.33559**	**0.31683**	**3,371**	**3.4**

4.12 Fisheries Species

During this study, 15 species were captured that have importance in either the recreational or commercial fisheries in California. The most abundant fisheries species were Spotted Sand Bass, Pacific Sardine, and California Halibut. Including all ecoregions, standing stock estimates of fisheries species totaled 149.7 MT. Like the forage fishes, when estimating by ecoregion values were greatest at the South-Central Ecoregion (71.4 MT), this time driven by Spotted Sand Bass, Cortez Bonefish, and Shortfin Corvina. Stock estimates were next highest in the South Ecoregion (93.2 MT) and the North-Central Ecoregion (26.6 MT), both driven almost exclusively by Spotted Sand Bass. The North Ecoregion had the smallest stock estimate at 13.0 MT (Table 21).

Table 21. Best estimate of biomass standing stock for recreational/commercial fishery species by ecoregion, 2019.

			Depth Strata					
Ecoregion	Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
North	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.04244		1.54279	0.53501	5,254	5.3
	Scomber japonicus	Pacific Chub Mackerel	0.67568			0.41216	4,047	4.05
	Paralichthys californicus	California Halibut	0.08254		0.70383	0.28261	2,775	2.78
	Paralabrax clathratus	Kelp Bass			0.21791	0.07191	706	0.71
	Embiotoca jacksoni	Black Perch		0.15457	0.00648	0.01141	112	0.11
	Scorpaena guttata	California Scorpionfish	0.00965			0.00589	58	0.06
	Paralabrax nebulifer	Barred Sand Bass		0.00720		0.00043	4	< 0.01
		Grand Total:	**0.81031**	**0.16177**	**2.47100**	**1.31943**	**12,957**	**13.0**
North-Central	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.01931	0.03333	6.33305	2.41923	19,547	19.55
	Sardinops sagax	Pacific Sardine	1.23874			0.70608	5,705	5.71
	Cynoscion parvipinnis	Shortfin Corvina			0.19707	0.07489	605	0.61
	Scomber japonicus	Pacific Chub Mackerel	0.06644			0.03787	306	0.31
	Paralichthys californicus	California Halibut	0.01358	0.01250	0.03851	0.02300	186	0.19
	Paralabrax nebulifer	Barred Sand Bass		0.06742	0.05086	0.02270	183	0.18
	Cheilotrema saturnum	Black Croaker	0.00931			0.00531	43	0.04
	Umbrina roncador	Yellowfin Croaker		0.01856		0.00093	7	0.01
	Paralabrax clathratus	Kelp Bass			0.00115	0.00044	4	< 0.01
		Grand Total:	**1.34738**	**0.13182**	**6.62064**	**3.29044**	**26,587**	**26.6**
South-Central	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.62387	0.10227	2.47128	1.73515	34,790	34.79
	Albula gilberti	Cortez Bonefish	1.99606		0.38007	0.95042	19,056	19.06
	Cynoscion parvipinnis	Shortfin Corvina	1.52027		0.45045	0.82207	16,483	16.48
	Sardinops sagax	Pacific Sardine	0.07320			0.02635	528	0.53
	Paralabrax nebulifer	Barred Sand Bass		0.00985	0.02356	0.01467	294	0.29
	Paralichthys californicus	California Halibut	0.02565	0.03561	0.00169	0.01133	227	0.23
	Cheilotrema saturnum	Black Croaker			0.00003	0.00002	0	< 0.01
		Grand Total:	**4.23905**	**0.14773**	**3.32708**	**3.56001**	**71,378**	**71.4**
South	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.57770	0.04432	4.24324	3.59877	38,291	38.29
	Albula gilberti	Cortez Bonefish	0.27590			0.03587	382	0.38
	Cynoscion parvipinnis	Shortfin Corvina			0.03041	0.02524	269	0.27
	Paralabrax nebulifer	Barred Sand Bass			0.01436	0.01192	127	0.13
	Seriphus politus	Queenfish			0.01295	0.01075	114	0.11
	Paralichthys californicus	California Halibut	0.00331	0.03068		0.00166	18	0.02
		Grand Total:	**0.85691**	**0.07500**	**4.30096**	**3.68419**	**39,200**	**39.2**

4.13 Southern (Panamic) Species Found in San Diego Bay

San Diego Bay is known for being the northern edge of the range for many southern fishes that are not normally distributed in the Southern California Bight. As an example, at least 25 northern range extensions have been reported from the bay (Table 22). During this study, six species [Cortez Bonefish, California Butterfly Ray (*Gymnura marmorata*), Pacific Seahorse (*Hippocampus ingens*), California Halfbeak (*Hyporhamphus rosae*), Diamond Stingray (*Dasyatis dipterura*), and the largest Shortfin Corvina (48 cm SL) captured in these surveys] with primarily southern distributions were taken (Table 23). These fishes were found almost exclusively in the southern half of the bay and none were captured in the North Ecoregion.

Table 22. Panamic species previously recorded in San Diego Bay.

Scientific Name	Common Name	First Recorded SDB Collection Date	Citation
Albula gilberti	Cortez Bonefish	prior to 1918	Starks (1918)
Caranx caballus	Green Jack	1857	Girard (1858)
Caranx caninus	Pacific Crevalle Jack	16 Mar 1972	Miller and Lea (1972)
Caranx vinctus	Cocinero	12 Aug 1997	Lea and Rosenblatt (2000)
Caranx sexfasciatus	Bigeye Trevally	Nov 1990	Lea and Walker (1995)
Cetengraulis mysticetus	Anchoveta	1980-1986	Duffy (1987)
Chanos chanos	Milkfish	22 Mar 1982	Duffy and Bernard (1985)
Chaetodon humeralis	Threebanded Butteflyfish	1857	Girard (1858)
Ctenogobius sagittula	Longtail Goby	1907	Lea and Rosenblatt (2000)
Cynoscion parvipinnis	Shortfin Corvina	common	Jordan and Gilbert (1880)
Dasyatis dipterura	Diamond Stingray	1880 (type locale)	Jordan and Gilbert (1880)
Elops affinis	Machete	30 Dec 1997	Lea and Rosenblatt (2000)
Gymnura marmorata	California Butterfly Ray	1864 (type locale)	Cooper (1864)
Haemulon flaviguttatum	Cortez Grunt	May 1991	Lea and Rosenblatt (1992)
Hippocampus ingens	Pacific Seahorse	1855 (type locale)	Girard (1858)
Hyporhamphus rosae	California Halfbeak	1880 (type locale)	Jordan and Gilbert (1880)
Lobotes pacificus	Pacific Tripletail	5 Nov 1997	Lea and Rosenblatt (2000)
Mugil curema	White Mullet	25 May 1985	Lea et al. (1988)
Polydactylus approximans	Blue Bobo	Dec 1997	Lea and Rosenblatt (2000)
Pseudupeneus grandisquamous	Bigscale Goatfish	15 Jul 1998	Lea and Rosenblatt (2000)
Scomberomorus sierra	Pacific Sierra	Dec 1995	Williams et al. (2011)
Selene brevoorii	Mexican Lookdown	Feb 1993	Lea and Walker (1995)
Sphyrna lewini	Scalloped Hammerhead	Apr 1997	Lea and Rosenblatt (2000)
Strongylura exilis	California Needlefish	common	Fitch and Lavenberg (1975)
Zapteryx exasperata	Banded Guitarfish	1880 (type locale)	Jordan and Gilbert (1880)

Pacific Seahorses caught by purse seine in the South Ecoregion in July 2019.

Table 23. Abundance of Panamic species collected in San Diego Bay by ecoregion, April and July 2019.

		Ecoregions							
		North		North-Central		South-Central		South	
Scientific Name	Common Name	*April*	*July*	*April*	*July*	*April*	*July*	*April*	*July*
Albula gilberti	Cortez Bonefish					5	3	1	
Cynoscion parvipinnis	Shortfin Corvina			1			18		1
Dasyatis dipterura	Diamond Stingray							1	
Gymnura marmorata	California Butterfly Ray							3	
Hippocampus ingens	Pacific Seahorse							4	
Hyporhamphus rosae	California Halfbeak							4	

4.14 Indigenous Bay and Estuary Fishes

As the largest estuary in southern California, San Diego Bay provides critical habitat for bay and estuary fishes and continues to function as a nursery area for nearly two-thirds (65.2%) of those fishes. The high productivity rate coupled with the abundance of juvenile fishes in the bay highlights the importance of the bay as a nursery habitat. The bay contains extensive shallow water eelgrass habitat that supports a unique assemblage of juvenile and adult fishes that, in turn, support surrounding nearshore ecosystems. Juvenile fishes emigrate from the bay to offshore habitats, and important or endangered avian species utilize forage fishes in the bay. Southern California indigenous bay and estuary fishes represented 23.1% of the total catch in this survey (Table 24).

Table 24. Indigenous bay/estuarine species taken in San Diego Bay by ecoregion in 2019.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total	%
Anchoa delicatissima	Slough Anchovy	110	475	681		1,266	39.05
Anchoa compressa	Deepbody Anchovy	1	1,019	13		1,033	31.86
Syngnathus californiensis	Kelp Pipefish	65	121	163	82	431	13.29
Paralabrax maculatofasciatus	Spotted Sand Bass	155	81	147	37	420	12.95
Clevelandia ios	Arrow Goby	5	18	21	8	52	1.60
Hypsoblennius gentilis	Bay Blenny	17			20	37	1.14
Fundulus parvipinnis	California Killifish			2		2	0.06
Ilypnus gilberti	Cheekspot Goby			1		1	0.03
	Total % of catch:	**5.7%**	**42.8%**	**46.0%**	**9.5%**		**23.1%**

4.15 Invasive Species

In addition to being a warm-water refuge for southern species, San Diego Bay is also a major port-of-entry and commercial shipping hub. Releases of ballast water and trans-Pacific transportation of hull fouling organisms and their associated hitchhikers into historically disturbed habitat provides ideal opportunities for invasive species, such as Yellowfin Goby (*Acanthogobius flavimanus*) and Chameleon Goby (*Tridentiger trigonocephalus*) to establish themselves in the bay. Though ballast water exchange in the bay has been regulated to help reduced the threat since 2000, these species were established prior to the implementation of these regulations. The Yellowfin Goby was first described inside tidal marshes of the South Ecoregion by Williams et al. (1998) and has been reported in many brackish and freshwater areas in California where they pose a threat to native fish species as predators. Although the low-salinity requirements of this species appear to limit its expansion potential, no eradication or control efforts for this invasive have been successful (Molnar et al. 2008). Williams et al. (1998) recommended management actions that reduce off-season freshwater inflows and return tidal action to impounded saltmarsh areas in order to favor native species and prevent further spread of exotics.

The Chameleon Goby was first captured in San Diego Bay in January 1995 during the Allen et al. (2002) survey, and subsequently described with additional records by Pondella and Chinn (2005). Despite the possibility of competing with native species for habitat, this invader has not become enough of a problem to require management action, and there are no known natural controls in California's marine environment (Molnar et al. 2008). Ironically, the Chameleon Goby may be controlled by Yellowfin Goby predation (Meng et al. 1994).

During the 2012 survey, sampling yielded both of those species: three Yellowfin Gobies and 18 Chameleon Gobies. Given the widespread nature of Chameleon Goby throughout the bay during those surveys (captured in the channel, nearshore vegetated, and nearshore non-vegetated areas, in all ecoregions but the North), we reported that there may be a sustained invasion and self-recruiting population of Chameleon Goby within the bay (Williams and Pondella 2012). However, no Chameleon Gobies were caught in 2015, 2016, or 2019 (Williams et al. 2015, Williams et al. 2016). The only Yellowfin Goby encountered in 2015 was a single partially digested individual that was regurgitated by a Spotted Sand Bass in the South Ecoregion. Two Yellowfin Gobies were caught in the South Ecoregion in 2016, and only one was captured in 2019 in the North Ecoregion. The paucity of Yellowfin and Chameleon Gobies may be a product of heavy predation, low reproductive success, or simply more effective filtering of ballast water. Rainfall in Winter 2018-2019 likely produced favorable conditions for both of these species as both species thrive in fresh to brackish water environments. However, any advantage was not noticeable given the infrequent capture of either species.

4.16 Comparison of the Current and Historical April and July Surveys

4.16.1 Abundance, Biomass, and Stock Estimates

Total catch and biomass from the April and July 2019 sampling periods were also compared to values from 1995-1998, 2005, 2008, 2012, 2015, and 2016. While the 2019 surveys represent the fewest fishes ever captured in historical surveys, the biomass captured was only slightly below average (Tables 25-28; Figures 25-28). This is a product of not capturing large numbers of small individuals as is typical during April sampling, but instead capturing fewer, but larger, fish throughout the survey. This was particularly true in the South Ecoregion where fewer than 30% of the historical mean number of individuals was captured, but the biomass captured was the second highest ever recorded – more than 30% higher than average. Consequently, the 2019 stock estimate was less than 20% of the mean number of individuals while the biomass standing stock estimate was nearly average (98.8% of the mean; Table 29).

Table 25. Total abundance by sampling year. Results were calculated for years that were sampled in April and July and only includes data from those sampling months.

	Sampling Years									
Ecoregion	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**	**2019**
North	59,178	91,176	8,978	14,486	4,237	7,233	4,244	10,240	5,158	6,238
North-Central	19,523	112,964	8,718	11,603	12,539	3,354	5,645	5,874	7,932	4,005
South-Central	22,403	3,623	10,659	8,267	2,346	2,666	3,422	4,789	3,001	2,233
South	5,063	3,153	4,735	14,738	5,337	2,438	3,952	3,240	5,036	1,548
Total:	**106,167**	**210,916**	**33,090**	**49,094**	**24,459**	**15,691**	**17,263**	**24,143**	**21,127**	**14,024**

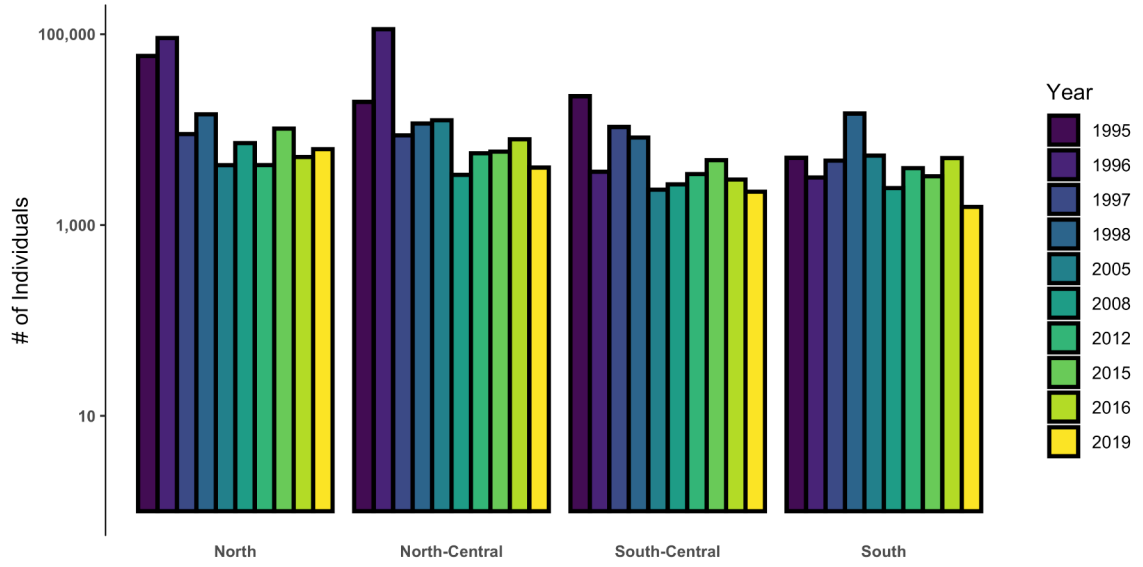


Figure 25. Total abundance by ecoregion and sampling year. Results were calculated for years that were sampled in April and July and only includes data from those sampling months.

Table 26. Total abundance by sampling year. Results were calculated for years that were sampled in April and July and only includes data from those sampling months.

	Sampling Years									
Common Name	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**	**2019**
Northern Anchovy	52,389	147,173	3	8,373	1,397	10	0	6,666	1,205	0
Topsmelt	25,272	33,915	12,917	9,232	7,448	3,393	6,529	2,024	4,136	8,044
Slough Anchovy	16,821	16,616	11,029	27,790	11,219	5,538	1,566	7,957	8,825	1,266
Shiner Perch	3,998	3,222	2,794	336	1,180	1,700	2,174	915	199	536
California Grunion	0	739	3,136	1,123	186	0	0	1,608	965	32
Arrow Goby	401	339	104	73	62	927	2,438	629	1,749	52
Deepbody Anchovy	69	221	29	5	2	72	17	80	30	1,033
Other	7,217	8,691	3,078	2,162	2,965	4,051	4,539	4,264	4,018	3,061

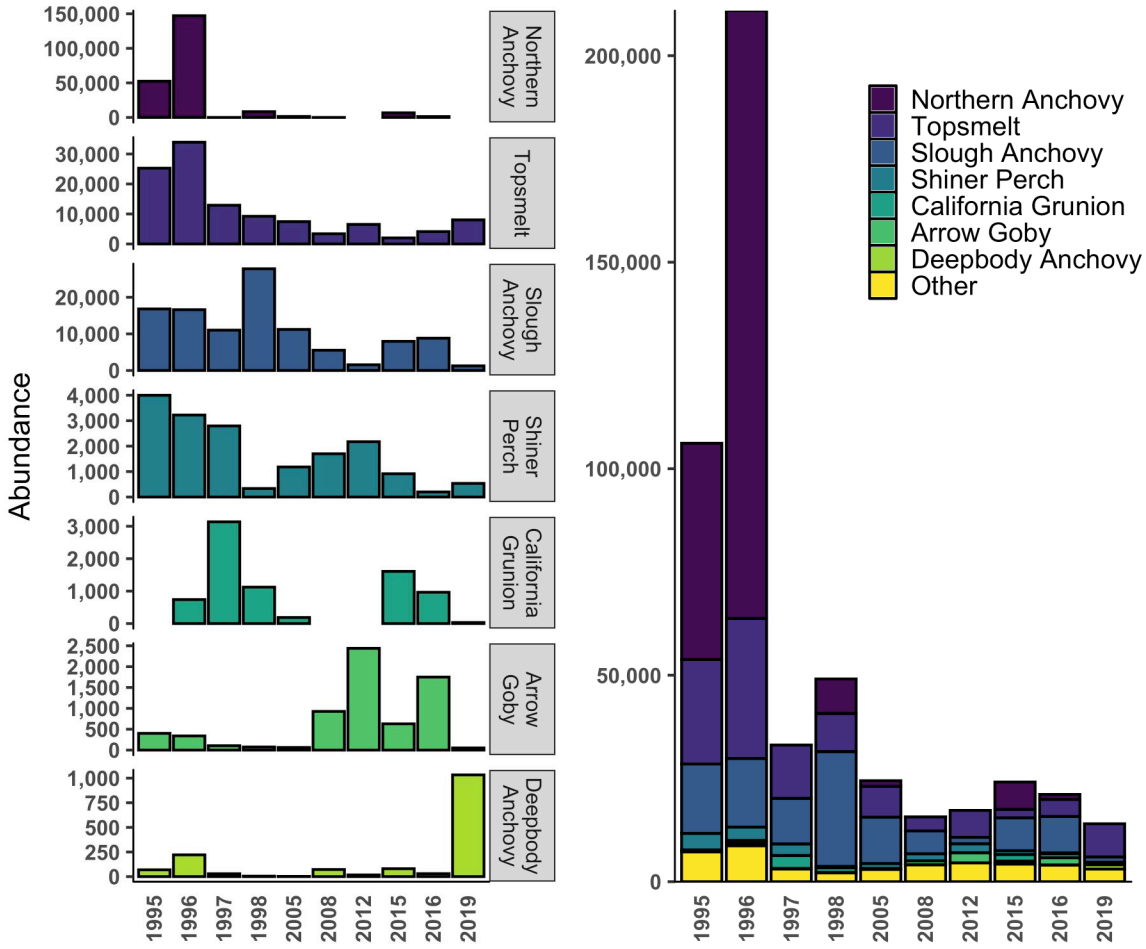


Figure 26. Total abundance of the most frequently caught species by sampling year. Results were calculated for years that were sampled in April and July and only includes data from those sampling months.

Table 27. Total biomass (kg) of fishes captured during April and July surveys by ecoregion.

	Sampling Years									
Ecoregion	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**	**2019**
North	111.9	195.4	70.1	58.7	58.9	36.5	119.7	112.8	83.2	69.0
North-Central	97.2	192.3	88.4	74.4	121.0	55.3	83.0	120.9	65.3	55.1
South-Central	111.8	46.6	65.4	33.2	34.2	43.7	70.7	69.2	49.2	59.7
South	89.2	75.8	48.2	52.3	77.4	49.0	74.8	75.3	52.2	87.7
Total:	**410.0**	**510.1**	**272.1**	**218.6**	**291.6**	**184.5**	**348.2**	**378.2**	**249.9**	**271.5**

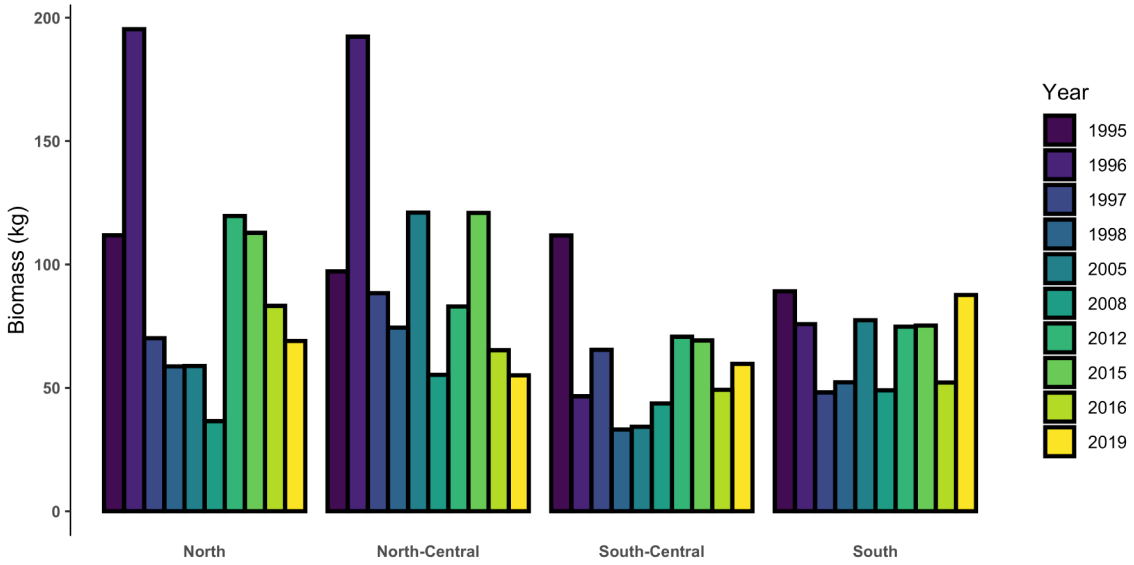


Figure 27. Total biomass (kg) of fishes captured during April and July surveys by ecoregion.

Table 28. Total biomass (kg) of the highest biomass fishes captured during April and July surveys by species and sampling year.

	Sampling Years									
Common Name	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**	**2016**
Round Stingray	79.1	63.5	77.2	25.9	109.8	60.9	134.2	129.9	110.9	115.5
Spotted Sand Bass	59.9	29.7	33.5	42.2	36.3	47.3	62.3	50.8	28.2	65.7
Northern Anchovy	49.7	178.9	0.0	9.5	3.0	0.0	0.0	50.9	29.0	0.0
Slough Anchovy	45.7	30.1	19.3	66.0	17.4	10.2	2.4	14.7	14.8	1.7
Topsmelt	22.9	20.5	44.4	20.5	12.1	10.3	11.4	4.7	4.6	22.7
Bat Ray	26.3	37.2	0.0	0.5	36.5	0.0	31.3	26.2	4.6	8.7
Barred Sand Bass	38.3	40.2	10.6	4.7	4.7	2.7	2.2	5.6	7.5	0.6
California Butterfly Ray	0.0	0.0	0.0	8.6	2.1	5.1	15.5	51.2	2.4	2.1
Other	88.2	109.9	87.1	40.7	69.7	48.0	88.9	44.1	47.9	54.6

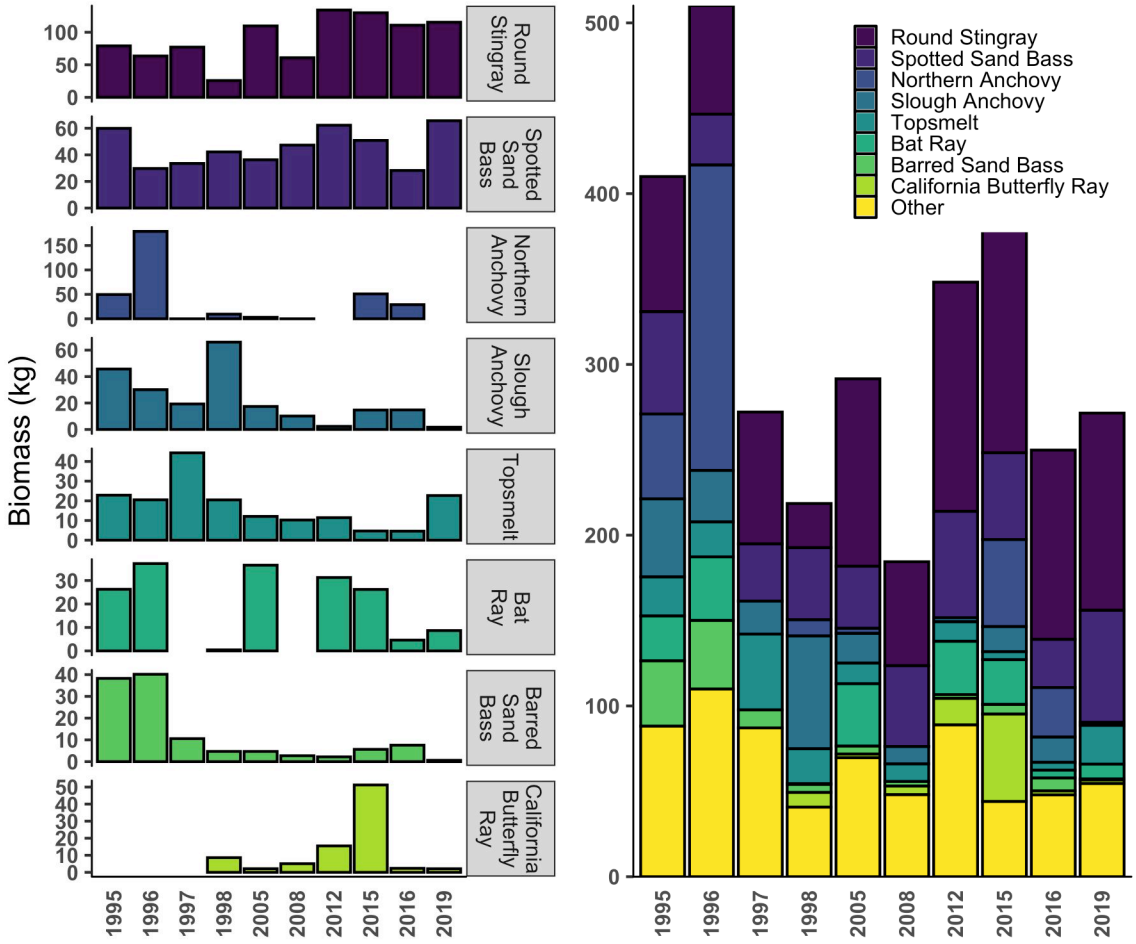


Figure 28. Total biomass (kg) of the highest biomass fishes captured during April and July surveys, shown by species over time (left) and as a proportion of the annual catch (right).

Table 29. Stock estimates and biomass standing stock by sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

Survey Year (source)	Stock Estimate (#)	Standing Stock (kg)
1995 (Allen et al. 2002)	178,106,064	513,340
1996 (Allen et al. 2002)	368,102,566	769,855
1997 (Allen et al. 2002)	49,326,442	302,962
1998 (Allen et al. 2002)	101,099,343	349,989
2005 (Pondella et al. 2006)	31,258,743	343,308
2008 (Pondella and Williams 2009a)	24,805,106	249,398
2012 (Williams and Pondella 2012)	16,180,679	465,376
2015 (Williams et al. 2015)	35,545,986	518,885
2016 (Williams et al. 2016)	30,173,603	311,227
2019 (Present Study)	18,321,764	419,630

4.16.2 Community Metrics

Shannon Diversity (H') and species richness values were determined for April and July from the previous surveys (Allen 1999, Pondella et al. 2006, Pondella and Williams 2009a, Williams and Pondella 2012, Williams et al. 2015, Williams et al. 2016) to allow direct comparisons of the data sets. The 1995-1998 survey years were used for the comparison because these were the only years from Allen et al. (2002) where both April and July were sampled. Overall, 2019 H' estimates were variable among ecoregions and rank among historical values. The North and North-Central Ecoregions had the third and second lowest diversity values, respectively, of any sampling year. However, diversity values for the South-Central and South Ecoregions were the third highest of any sampling year (Table 26, Figure 25). Species richness for 2019 was the lowest ever recorded in both the North and North-Central Ecoregions and was tied for third lowest at both the South-Central and South Ecoregions for any survey period (Table 27; Figure 26).

R/V Old Blue heading to the South-Central Ecoregion in April 2019.

Table 30. Shannon diversity (H') values by sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

	Sampling Years									
Ecoregion	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**	**2019**
North	0.74	0.90	1.34	1.42	1.77	1.72	1.56	1.43	1.94	0.93
North-Central	1.75	0.93	1.50	1.25	1.36	1.62	1.63	1.81	1.61	1.18
South-Central	1.32	1.72	1.13	0.37	1.77	1.88	1.92	1.41	1.51	1.77
South	1.93	1.84	1.35	0.59	1.06	2.03	1.84	1.71	1.61	1.82
Total:	**1.46**	**1.04**	**1.65**	**1.31**	**1.65**	**2.05**	**2.02**	**2.05**	**2.00**	**1.69**

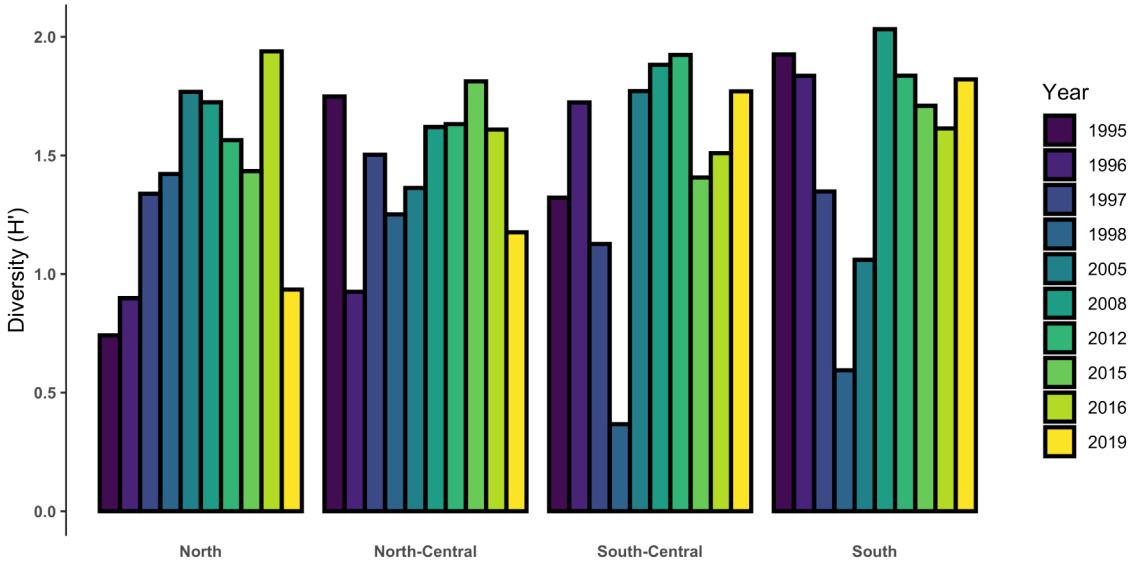


Figure 29. Shannon diversity (H') values by ecoregion and sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

Table 31. Species richness values by sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

	Sampling Years									
Ecoregion	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**	**2019**
North	35	42	29	34	38	33	30	35	40	28
North-Central	32	33	31	26	38	27	37	35	33	23
South-Central	31	23	27	22	25	23	32	27	21	22
South	34	24	26	30	23	25	29	23	31	24
Total:	**53**	**54**	**42**	**51**	**57**	**48**	**52**	**52**	**55**	**45**

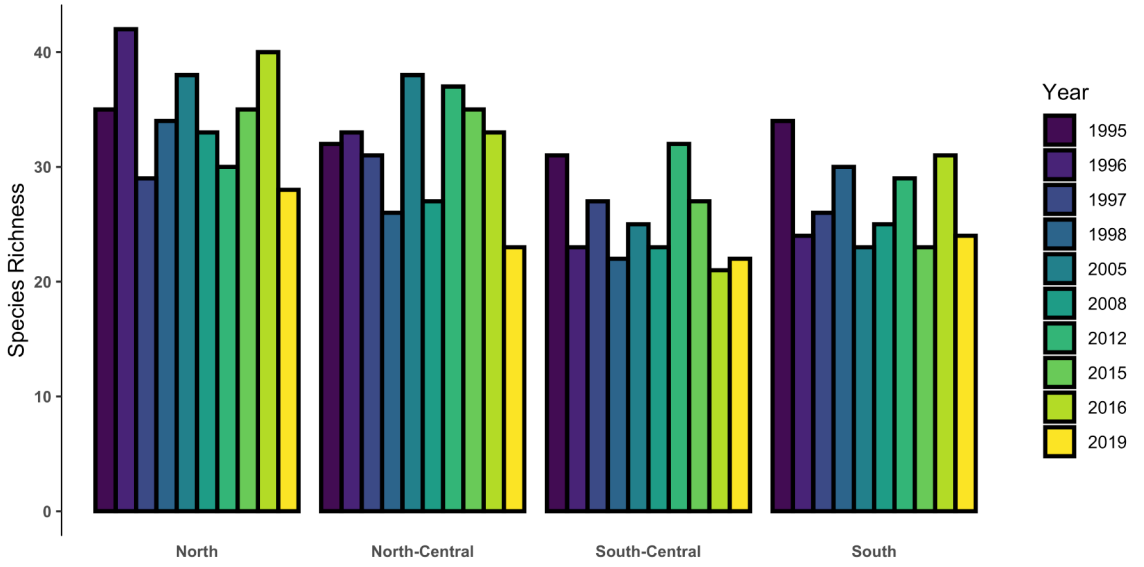


Figure 30. Species richness values by ecoregion and sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

4.16.3 Community Structure

Six significantly different groups (a-f) were determined by cluster analysis of fish communities for each survey period (Figure 31). The driving species behind each community group can be visualized in Figure 32, where circles are scaled to mean abundance by community group of eleven typical San Diego Bay fish taxa. Sampling periods prior to, during, and after the 1997-1998 El Niño event showed the strongest differentiation from most other surveys. The April and July 1997 sampling periods form their own distinct fish community (group 'f'), driven by comparatively higher catch of Pacific Sardine and California Grunion. After substantial rainfall during the winter of 1997-1998, the catch in April 1998 (group 'a') was dominated by Topsmelt, but also had large catches of Striped Mullet (*Mugil cephalus*) and Cortez Bonefish, two estuarine residents that thrive in brackish water. Relatively little else was captured during that survey. By July 1998, the fish community returned to a typical mid-1990's July pattern (group 'd') where Northern Anchovy (*Engraulis mordax*) dominated the catch.

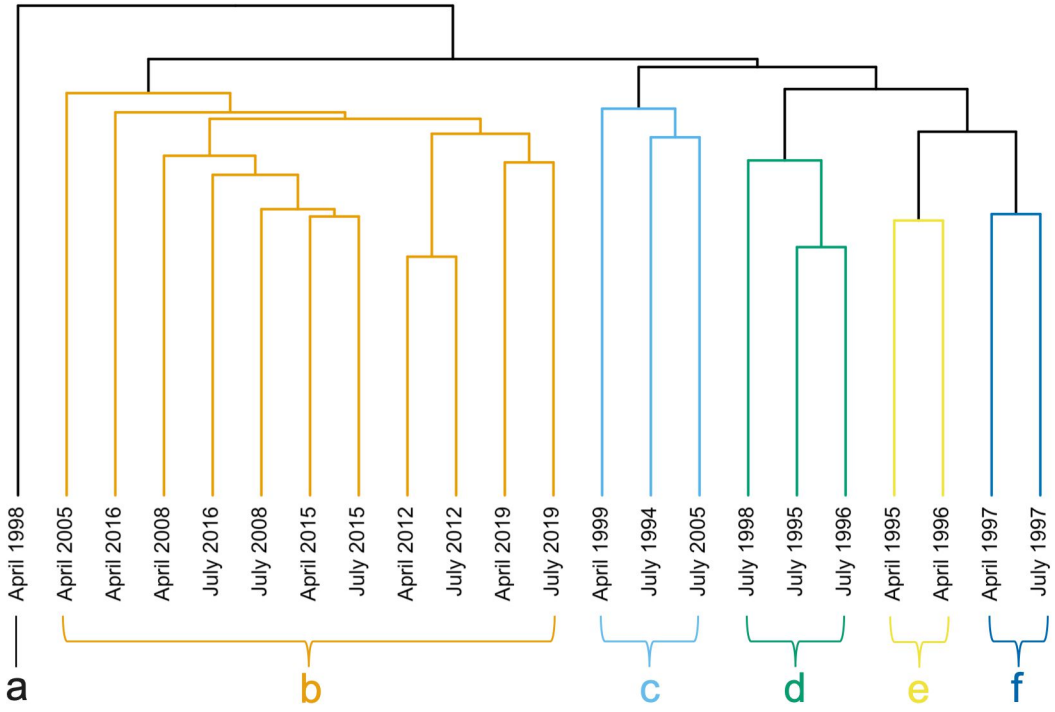


Figure 31. Fish communities for the twenty-two April and July surveys were clustered in this tree. Branch distances shown in this diagram represent the relative similarity of stations to each other using Bray-Curtis distances and group-average linkage. Significantly different (SIMPROF, α = 0.05) fish communities are indicated by letters (a-f) and color groupings.

In spite of the intensity of the 2015-2016 El Niño event, all four sampling periods (April 2015-July 2016) clustered into the largest group ('b'), as did both April and July of 2019. Community structure of fishes in 2019 was most similar to that of the 2012 surveys but was not statistically different than any other survey performed in the 21st Century.

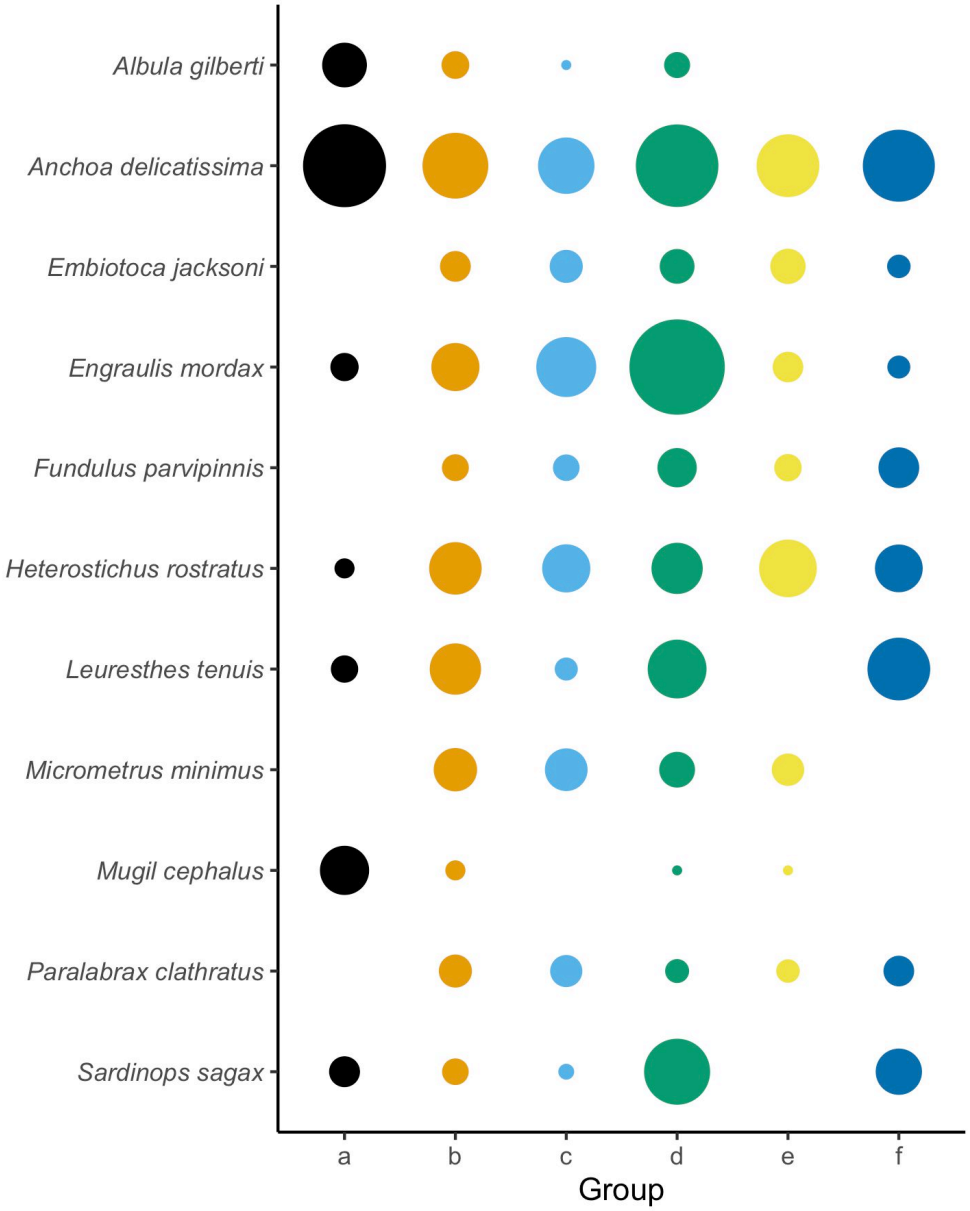


Figure 32. Relative mean abundance (circles scaled to value) per sampling period for select fish taxa in San Diego Bay by community group (as identified in Figure 30).

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Sam Soule ('18) with a Cortez Bonefish caught by purse seine in the South Ecoregion in April 2019.