FISHERIES INVENTORY AND UTILIZATION OF SAN DIEGO BAY, SAN DIEGO, CALIFORNIA FOR SURVEYS CONDUCTED IN APRIL AND JULY 2022

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1.0 EXECUTIVE SUMMARY

The Vantuna Research Group at Occidental College surveyed the estuarine fishes of San Diego Bay in April and July 2022 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, 19,630 (56 species) fishes weighing a total of 373.1 kilograms (kg) were recorded during April and July 2022. The most numerous species comprising 33.9 percent (%) of the catch was Slough Anchovy (*Anchoa delicatissima*), followed by Topsmelt (*Atherinops affinis*; 27.2%), Kelp Pipefish (*Syngnathus californiensis*; 8.3%), Giant Kelpfish (*Heterostichus rostratus*; 6.6%), and Arrow Goby (*Clevelandia ios*; 6.5%; Table 3). In terms of biomass, Round Stingrays (*Urobatis halleri*) dominated the catch comprising 35.4% of the biomass, followed by Spotted Sand Bass (*Paralabrax maculatofasciatus*; 16.1%), and Topsmelt (13.5%). These species are typically among the most dominant species in surveys of San Diego Bay.

Ecological Importance of Species

The principal fishes surveyed during these sampling periods as determined by the Ecological Index (E.I.) were the following species: Topsmelt, Round Stingray, Slough Anchovy, and Spotted Sandbass. Topsmelt ranked first (E.I. 4,060), Round Stingray ranked second (E.I. 3,880), Slough Anchovy ranked third (E.I. 3,278) and Spotted Sandbass ranked fourth (E.I. 1,730). Topsmelt, Round Stingray, and Spotted Sandbass were all found ubiquitously throughout the bay during both sampling periods, while only two Slough Anchovy were found in the North Ecoregion in July. Round Stingrays and Spotted Sandbass were dominant in terms of biomass, and Topsmelt and Slough Anchovies were dominant in terms of numerical abundance.

Best Estimates of Density and Standing Stock

The stock size estimate for 2022 was 28.7 million fishes. With an estimated surface area of 4,858 ha this gives an overall fish density 0.59 individuals/m^2 (Table 18). The highest estimates were of Slough Anchovy (13.08 million), Topsmelt (5.49 million), followed by Kelp Pipefish (2.79 million), Giant Kelpfish (2.44 million), and Shiner Perch (*Cymatogaster aggregata*; 1.19 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 552 MT or approximately 11.36 g/m^2, about 24% higher than the 2019 estimate and above average for all historical surveys. The highest biomass estimates were of Diamond Stingray (*Dasyatis dipterura*; 105.9 MT), followed by Round Stingray (103.8 MT), Spotted Sand Bass (91 MT), Topsmelt (88.2 MT), and Shovelnose Guitarfish (*Rhinobatos productus;* 33.3 MT). Round Stingray, Spotted Sand Bass and Topsmelt are typically in the top five biomass estimates from past surveys. Diamond Stingray is a historically atypical top biomass species, and this standing stock estimate is solely based upon the catch of just two individuals.

Banded Guitarfish (96 cm SL; 6.7 kg) captured in the South-Central Ecoregion by otter trawl during the April 2022 survey.

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 generally 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 and Slough Anchovy that were primarily found at small (juvenile) size classes (< 50 mm SL) appropriate for nesting birds in the area to feed their young. The typical timing for the recruitment of fishes to San Diego Bay begins in the spring and continues through the summer and this appears to be consistent in 2022. The biomass standing stock estimate for forage fish was 106.6 MT. During this study, 14 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 123 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. Eight species with primarily southern distributions were taken, including the largest Banded Guitarfish (*Zapteryx exasperata*; 96 cm SL; 6.7 kg) ever captured in 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 half (45.8%) 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 51.1% of the total catch in this survey.

Trends and Comparisons

The 2022 surveys represent an average catch compared to surveys conducted within last two decades and the biomass captured was slightly above average for all historical surveys. Total abundance was heavily influenced by large schools of forage fishes, as is common in historical surveys. Estimates of biomass were about average among all surveys in every ecoregion except the South Ecoregion, which reported the highest biomass catch at that ecoregion out of any sampling year at 109.8 kg. However, 52.2 kg of this total can be attributed to the catch of two large Diamond Stingrays and a large Shovelnose Guitarfish. The 2022 stock estimate was less than 35% of the mean number of individuals while the biomass standing stock estimate was 30% above average, again due to the catch of a few large elasmobranchs.

Overall, 2022 diversity estimates were variable among ecoregions and rank among historical values. The North and South-Central Ecoregions had above average diversity values, and the North-Central and South Ecoregions had slightly below average diversity values. Species richness for 2022 was average for the North-Central and South Ecoregions. The South-Central Ecoregion ranked third highest for any previous survey year and the North ranked the third lowest for any previous survey year. Community structure of fishes in April 2022 was most similar to that of the 2019 surveys and July was most similar to that of the 2008 surveys but neither were significantly different than any other survey performed in the 21st Century.

Two large female Diamond Stingrays (78 80 cm DW; 39.7 kg total weight) caught in the purse seine in the channel at the South Ecoregion during the July 2022 survey.

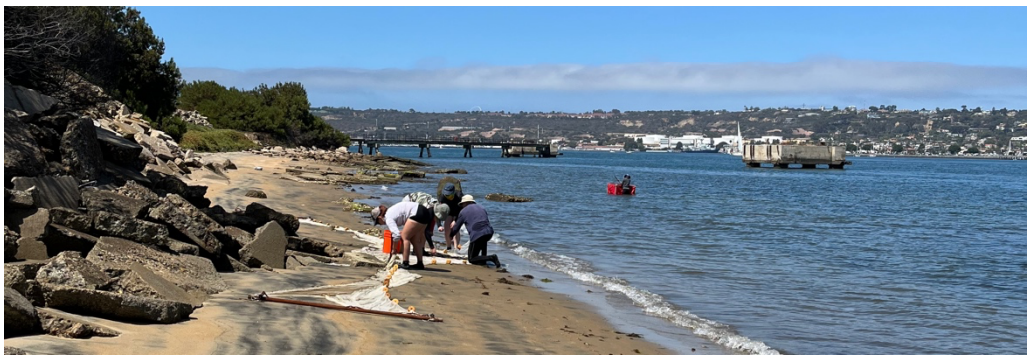
2.0 INTRODUCTION

The Vantuna Research Group at Occidental College surveyed the estuarine fishes of San Diego Bay in April and July 2022 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, Williams et al. 2019, Allen et al. 2022). 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

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.

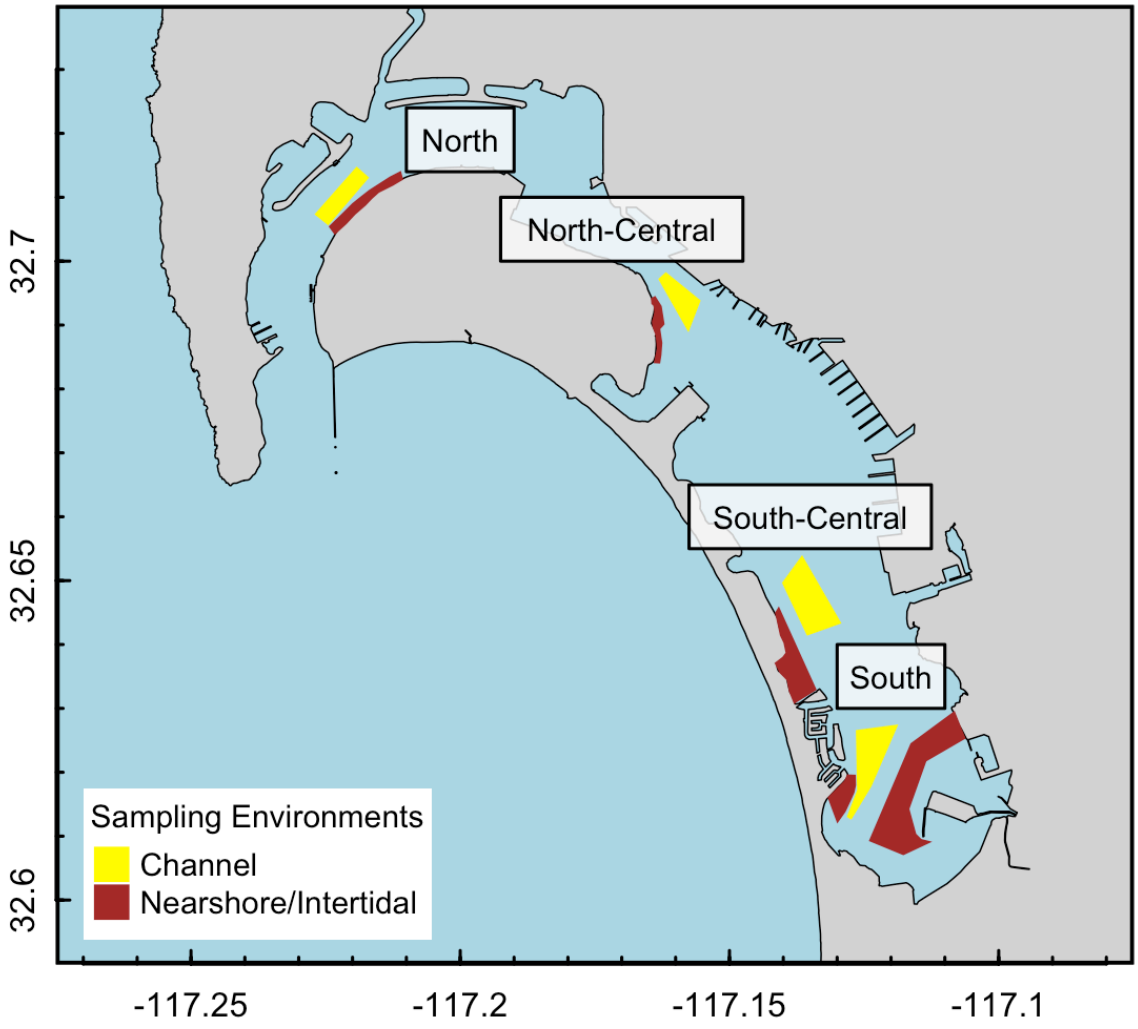


Figure 1. Sampling environment locations of the North, North-Central, South-Central, and South Ecoregions in San Diego Bay.

Table 1. Lambert Coordinates (Latitude, Longitude) for the San Diego Bay Fisheries Inventory and Utilization study, 2022.

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 2022 (April 2-3, April 8-10, and July 18-21, 2022). One ecoregion was sampled per day per sampling season. Collections were made off the 7.6-meter (m) *DV Obscurus* and the 6.5-m *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.

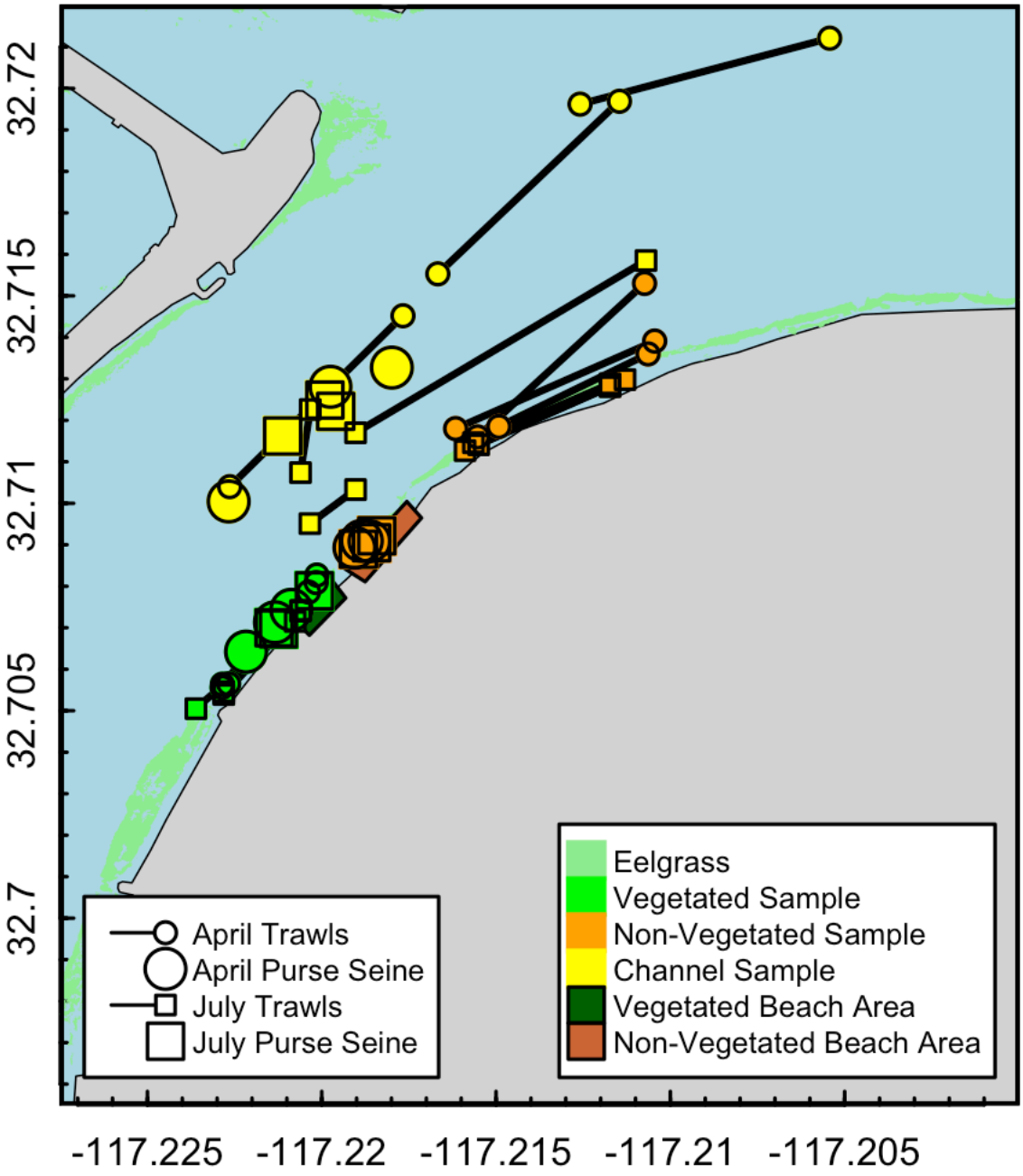


Figure 2. Sampling events for the North Ecoregion, 2022.

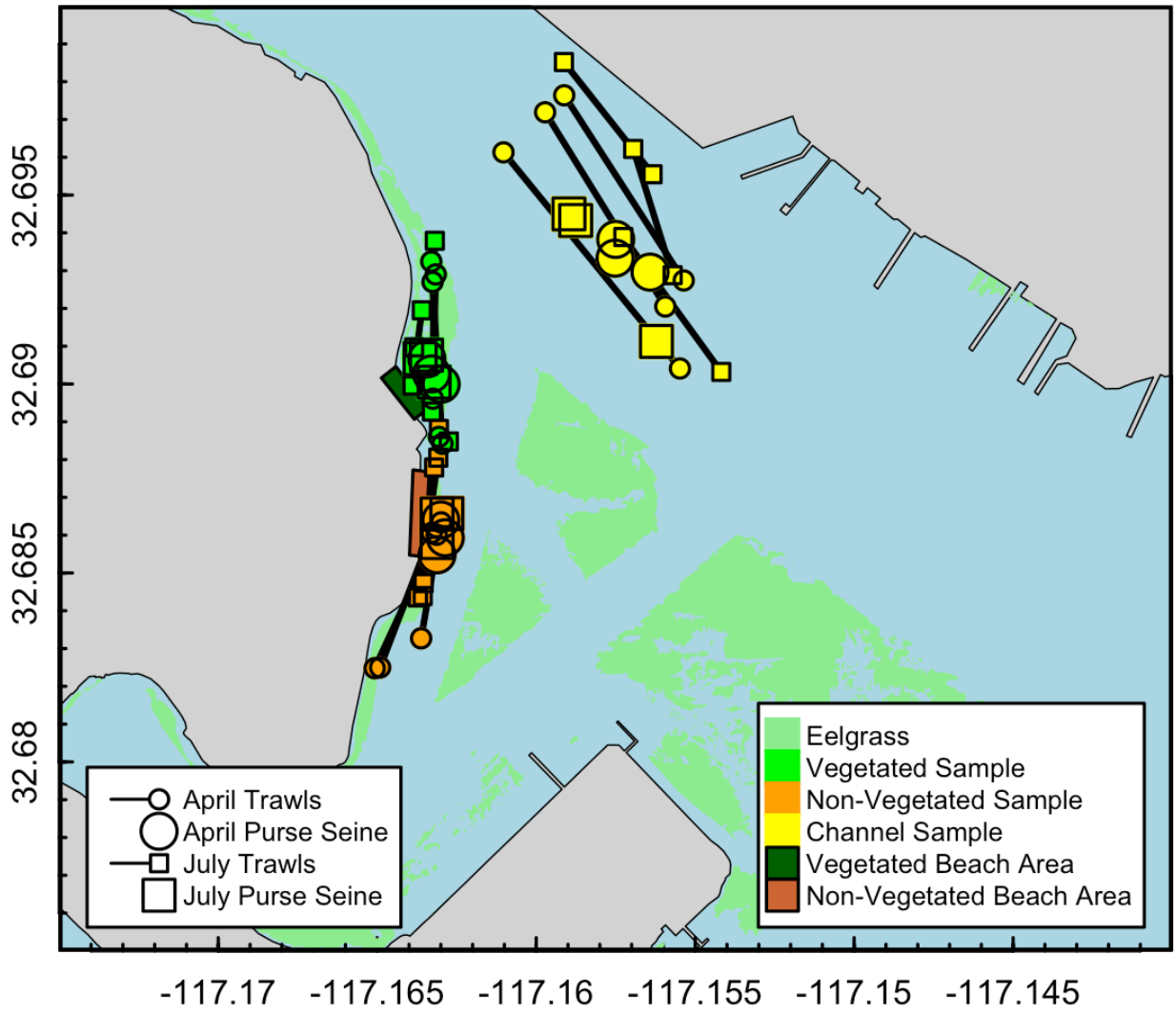


Figure 3. Sampling events for the North-Central Ecoregion, 2022.

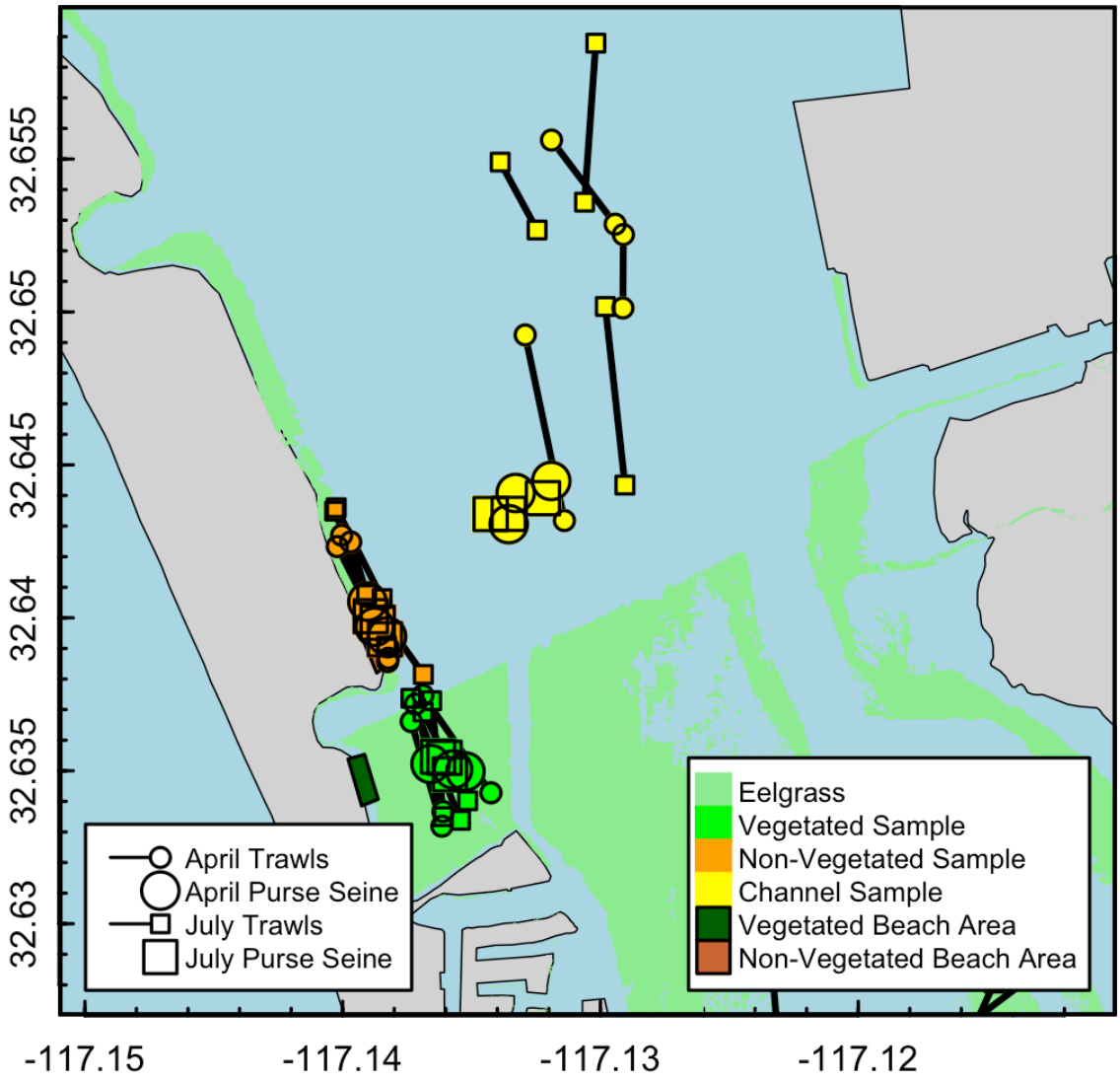


Figure 4. Sampling events for the South-Central Ecoregion, 2022.

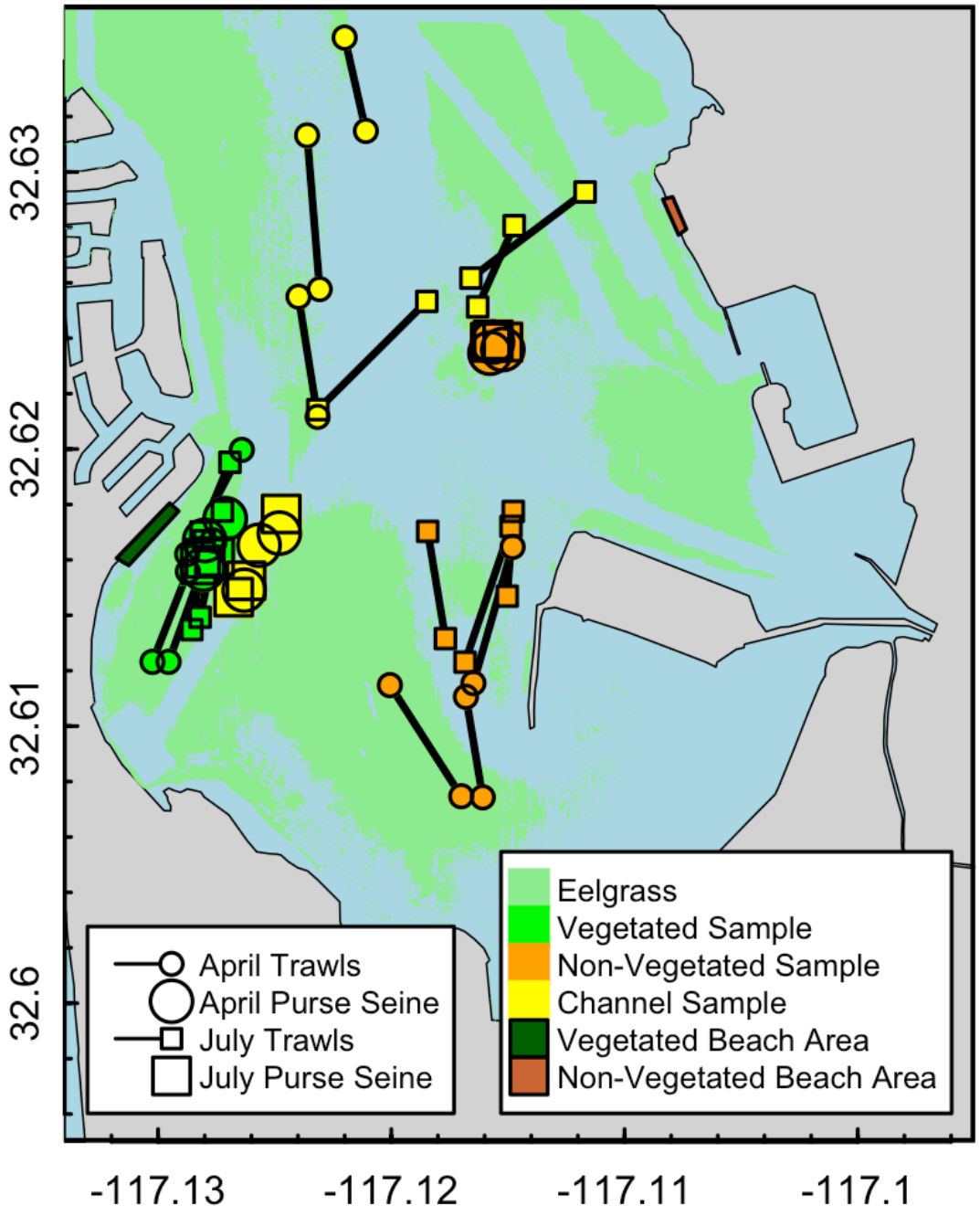


Figure 5. Sampling events for the South Ecoregion, 2022.

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 *DV Obscurus*. Downcast data from the 1-m surface bin were used to report these water quality values at the surface.

Large seine at the South-Central Ecoregion in the non-vegetated subhabitat in July 2022.

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. 2022) in R (R Core Team 2022). 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.)

Un-sorted catch from an otter trawl net in the North Ecoregion during the April 2022 survey.

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 2-5 ºC warmer at each ecoregion during the July sampling period (Figure 6). Water temperature was slightly above average in April. In July, water was slightly below average in the North and North-Central ecoregions and slightly above average in the South-Central and South ecoregions. Dissolved oxygen was relatively consistent among ecoregions. Surface salinity increased slightly from north to south during the July sampling period but was consistent among ecoregions during the April sampling period. Surface pH was consistent among ecoregions for both sampling periods. These physical-chemical results are typical of the bay and did not show effects of below-average winter rainfall.

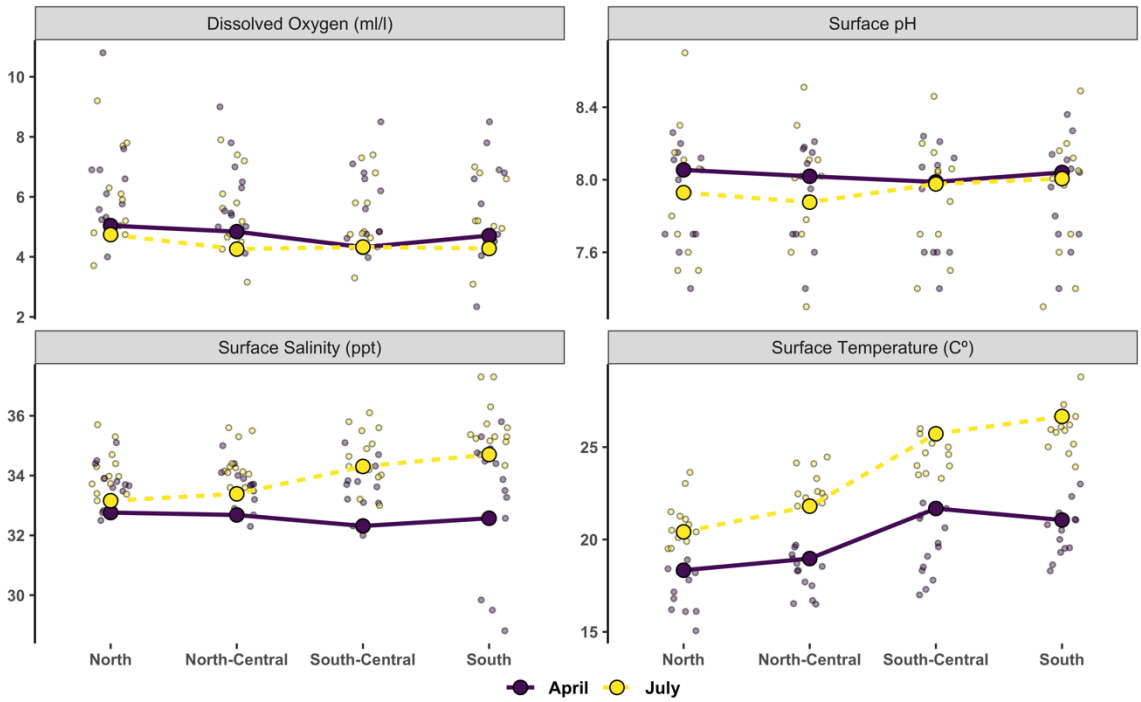


Figure 6. Summary of physical-chemical measurements by ecoregion in April and July 2022. To contextualize the 2022 results, values from previous surveys (1995-2019) are plotted as smaller, open points.

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).

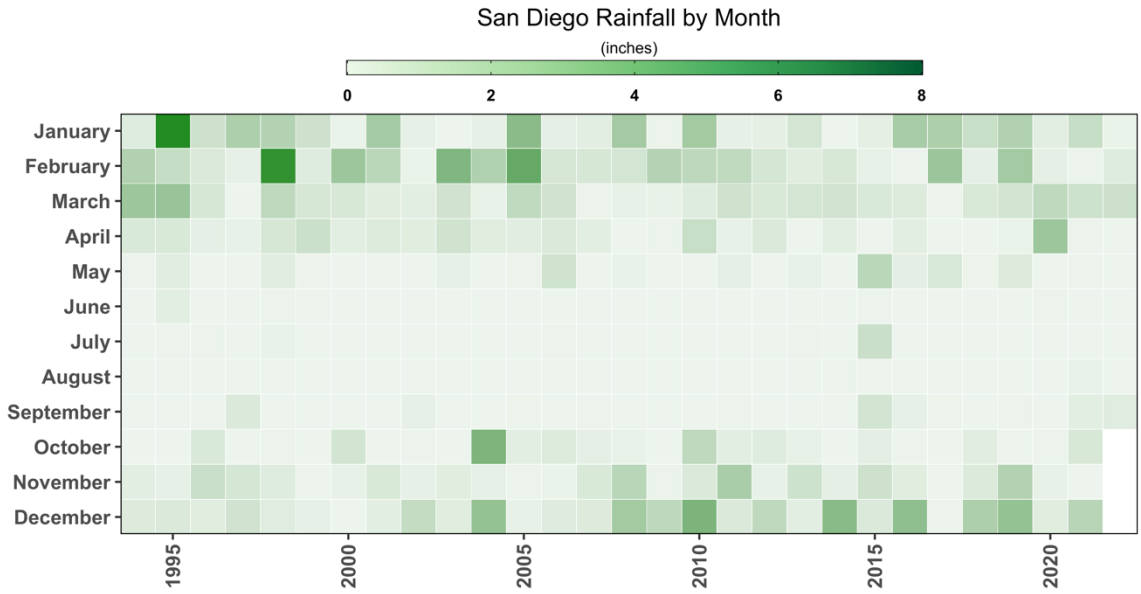


Figure 7. Monthly rainfall in San Diego from 1994-2022. Data are typically collected from National Weather Service rain gauges at San Diego International Airport (Lindbergh Field). Monthly totals were compiled by John S. Stokes III**.**

4.2 Numerical Catch and Biomass

During this study, 19,630 (56 species) fishes weighing a total of 373.1 kilograms (kg) were recorded during April and July 2022. The most numerous species comprising 33.9 percent (%) of the catch was Slough Anchovy (*Anchoa delicatissima*), followed by Topsmelt (*Atherinops affinis*; 27.2%), Kelp Pipefish (*Syngnathus californiensis*; 8.3%), Giant Kelpfish (*Heterostichus rostratus*; 6.6%), and Arrow Goby (*Clevelandia ios*; 6.5%; Table 3). In terms of biomass, Round Stingrays (*Urobatis halleri*) dominated the catch comprising 35.4% of the biomass, followed by Spotted Sand Bass (*Paralabrax maculatofasciatus*; 16.1%), and Topsmelt (13.5%; Table 4). These species are typically among the most dominant species in surveys of San Diego Bay.

Total catch was highest in the South-Central Ecoregion in April and in the North-Central Ecoregion in July (Figure 8) with differences in total fish abundance reflecting the differences in Topsmelt and Slough Anchovy abundance. Abundance was greatest at the North-Central Ecoregion (5,408; Table 6), followed by the South-Central Ecoregion (5,365; Table 7), North Ecoregion (4,759; Table 5), and South Ecoregion (4,098; Table 8). Topsmelt dominated catches in the North (2,482) and North-Central (2,412) Ecoregions, while Slough Anchovy was the dominant species in the South-Central (3,074) and South (1,820) Ecoregions.

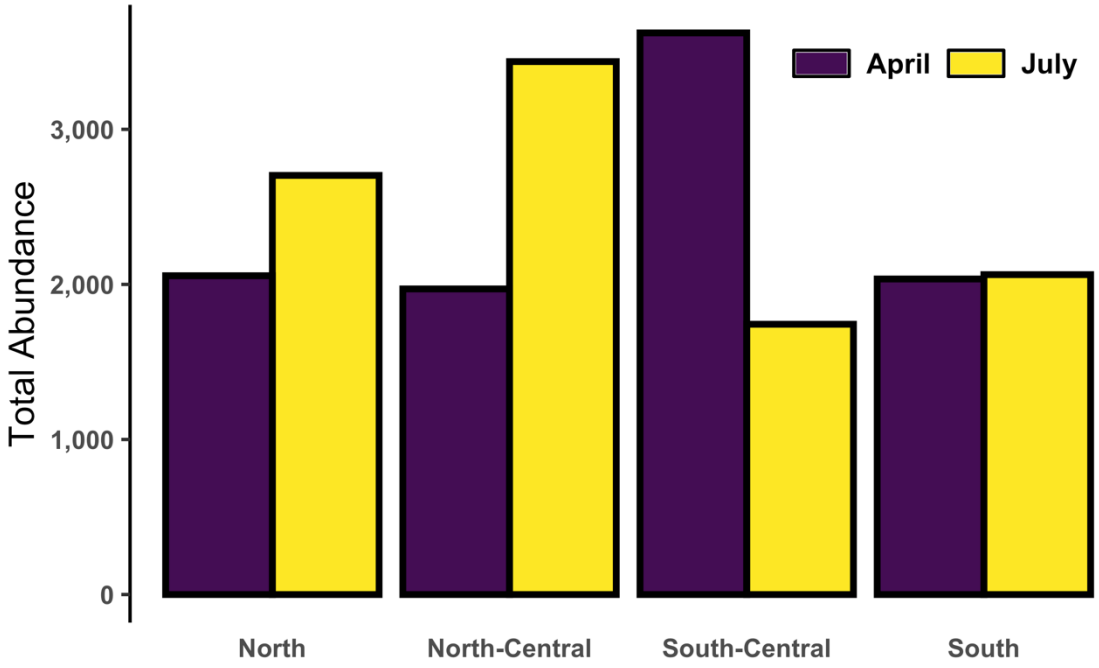


Figure 8. Total catch of San Diego Bay fishes by ecoregion, April and July 2022.

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. Giant Kelpfish were more numerically dominant in the North and North-Central Ecoregions while Arrow Gobies were more dominant in the South-Central and South Ecoregions. Both Kelp Pipefish were a numerically dominant species in all ecoregions. All five species were represented in each ecoregion.

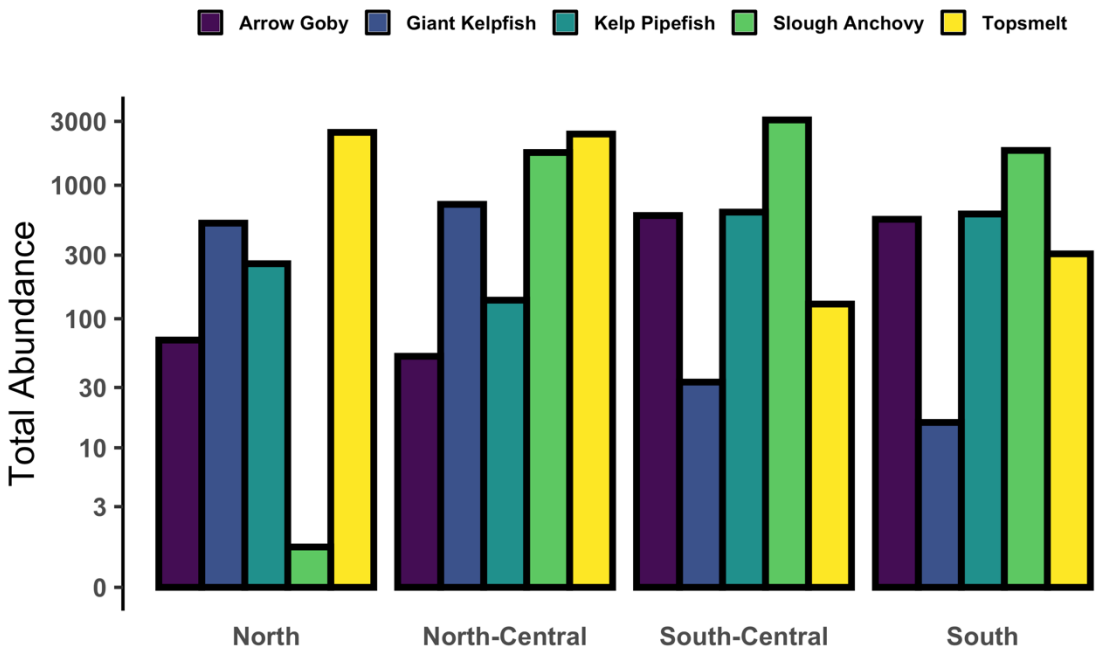


Figure 9. Total catch of the five numerically dominant species by ecoregion, 2022.

Round Stingrays had the highest catch in terms of biomass at three ecoregions (North, 47.2 kg; North-Central, 15 kg; South-Central, 41.6 kg) and was second in biomass (28.6 kg) to Diamond Stingrays (*Dasyatis dipterura*; just two individuals totaling 39.7 kg) in the South Ecoregion. Spotted Sand Bass was also a dominant species in terms of biomass in all ecoregions: North (17.4 kg), North-Central (12.4 kg), South-Central (16.7 kg), and South (13.6 kg) Ecoregions. Topsmelt was a dominant species in terms of biomass in the North (37.4 kg) and North-Central (8.1 kg) Ecoregions. Slough Anchovies were among the dominant species in the North-Central (4.4 kg) and South-Central (5.9 kg) Ecoregions. Single individuals of Shovelnose Guitarfish (*Rhinobatos productus*; 12.5 kg) in the South Ecoregion and Banded Guitarfish (*Zapteryx exasperata*; 6.7 kg) in the South-Central Ecoregion were also biomass-dominant species.

Table 3. Total abundance of fishes collected in San Diego Bay during 2022 by ecoregion.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total	%
Anchoa delicatissima	Slough Anchovy	1	1,756	3,074	1,820	6,651	33.88
Atherinops affinis	Topsmelt	2,482	2,412	129	307	5,330	27.15
Syngnathus californiensis	Kelp Pipefish	259	138	630	610	1,637	8.34
Heterostichus rostratus	Giant Kelpfish	521	720	33	16	1,290	6.57
Clevelandia ios	Arrow Goby	69	52	594	557	1,272	6.48
Cymatogaster aggregata	Shiner Perch	185	105	352	363	1,005	5.12
Micrometrus minimus	Dwarf Perch	723				723	3.68
Urobatis halleri	Round Stingray	173	76	232	172	653	3.33
Paralabrax maculatofasciatus	Spotted Sand Bass	50	52	76	63	241	1.23
Porichthys myriaster	Specklefin Midshipman	96	1	2		99	0.50
Pleuronichthys guttulatus	Diamond Turbot		3	45	28	76	0.39
Fundulus parvipinnis	California Killifish			1	71	72	0.37
Atherinopsis californiensis	Jacksmelt	59	8			67	0.34
Anchoa compressa	Deepbody Anchovy		1	57	3	61	0.31
Paralichthys californicus	California Halibut	11	10	32	6	59	0.30
Leuresthes tenuis	California Grunion	47	2			49	0.25
Quietula y-cauda	Shadow Goby		2	9	34	45	0.23
Seriphus politus	Queenfish			44		44	0.22
Hypsoblennius gentilis	Bay Blenny	12	22		2	36	0.18
Cynoscion parvipinnis	Shortfin Corvina		13	8	5	26	0.13
Embiotoca jacksoni	Black Perch	20				20	0.10
Pleuronichthys ritteri	Spotted Turbot	11	8	1		20	0.10
Albula gilberti	Cortez Bonefish			5	11	16	0.08
Cheilotrema saturnum	Black Croaker		7	7	2	16	0.08
Haemulon californiensis	Salema			15		15	0.08
Hyporhamphus rosae	California Halfbeak			5	8	13	0.07
Leptocottus armatus	Pacific Staghorn Sculpin			2	9	11	0.06
Halichoeres semicinctus	Rock Wrasse	9				9	0.05
Scomber japonicus	Pacific Chub Mackerel	8	1			9	0.05
Symphurus atricaudus	California Tonguefish	8	1			9	0.05
Ilypnus gilberti	Cheekspot Goby			7		7	0.04
Paralabrax clathratus	Kelp Bass	2	2		1	5	0.03
Sphyraena argentea	Pacific Barracuda		5			5	0.03
Paralabrax nebulifer	Barred Sand Bass	1	2		1	4	0.02
Cosmocampus arctus	Snubnose Pipefish	2	1			3	0.02
Gibbonsia elegans	Spotted Kelpfish		3			3	0.02
Paraclinus integripinnis	Reef Finspot		1	2		3	0.02
Acanthogobius flavimanus	Yellowfin Goby				2	2	0.01
Dasyatis dipterura	Diamond Stingray				2	2	0.01
Engraulis mordax	Northern Anchovy	2				2	0.01
Mugil cephalus	Striped Mullet			1	1	2	0.01
Strongylura exilis	California Needlefish		1		1	2	0.01
Umbrina roncador	Yellowfin Croaker	1	1			2	0.01
Xystreurys liolepis	Fantail Sole	2				2	0.01
Alloclinus holderi	Island Kelpfish	1				1	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	1				1	< 0.01
Ctenogobius sagittula	Longtail Goby				1	1	< 0.01
Heterodontus francisci	Horn Shark	1				1	< 0.01
Hippocampus ingens	Pacific Seahorse			1		1	< 0.01
Mustelus californicus	Gray Smoothhound				1	1	< 0.01
Pleuronichthys decurrens	Curlfin Sole		1			1	< 0.01
Rhinobatos productus	Shovelnose Guitarfish				1	1	< 0.01
Scorpaena guttata	California Scorpionfish		1			1	< 0.01
Synodus lucioceps	California Lizardfish	1				1	< 0.01
Trachurus symmetricus	Jack Mackerel	1				1	< 0.01
Zapteryx exasperata	Banded Guitarfish			1		1	< 0.01
# of Species:	**56**	**4,759**	**5,408**	**5,365**	**4,098**	**19,630**	

Table 4. Total biomass (grams [g]) of fishes collected in San Diego Bay during 2022 by ecoregion.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total (g)	%
Urobatis halleri	Round Stingray	47,209	15,020	41,578	28,539	132,346	35.47
Paralabrax maculatofasciatus	Spotted Sand Bass	17,382	12,400	16,637	13,554	59,973	16.07
Atherinops affinis	Topsmelt	37,418	8,124	1,736	2,885	50,163	13.45
Dasyatis dipterura	Diamond Stingray				39,700	39,700	10.64
Anchoa delicatissima	Slough Anchovy	2	4,405	5,876	3,066	13,349	3.58
Rhinobatos productus	Shovelnose Guitarfish				12,500	12,500	3.35
Zapteryx exasperata	Banded Guitarfish			6,700		6,700	1.80
Cynoscion parvipinnis	Shortfin Corvina		5,200	329	12	5,541	1.49
Albula gilberti	Cortez Bonefish			2,012	3,500	5,512	1.48
Heterostichus rostratus	Giant Kelpfish	1,913	3,133	167	22	5,235	1.40
Atherinopsis californiensis	Jacksmelt	1,440	3,535			4,975	1.33
Cymatogaster aggregata	Shiner Perch	1,421	1,020	1,319	889	4,649	1.25
Seriphus politus	Queenfish			4,500		4,500	1.21
Paralichthys californicus	California Halibut	376	250	2,795	244	3,665	0.98
Micrometrus minimus	Dwarf Perch	3,534				3,534	0.95
Mugil cephalus	Striped Mullet			1,700	1,200	2,900	0.78
Sphyraena argentea	Pacific Barracuda		2,200			2,200	0.59
Haemulon californiensis	Salema			1,696		1,696	0.45
Umbrina roncador	Yellowfin Croaker	600	900			1,500	0.40
Scomber japonicus	Pacific Chub Mackerel	915	210			1,125	0.30
Pleuronichthys guttulatus	Diamond Turbot		445	543	136	1,124	0.30
Mustelus californicus	Gray Smoothhound				1,100	1,100	0.29
Anchoa compressa	Deepbody Anchovy		4	985	58	1,047	0.28
Halichoeres semicinctus	Rock Wrasse	969				969	0.26
Syngnathus californiensis	Kelp Pipefish	247	66	306	259	878	0.24
Strongylura exilis	California Needlefish		1		800	801	0.21
Paralabrax clathratus	Kelp Bass	31	386		150	567	0.15
Porichthys myriaster	Specklefin Midshipman	536	1	1		538	0.14
Heterodontus francisci	Horn Shark	500				500	0.13
Cheilotrema saturnum	Black Croaker		51	119	310	480	0.13
Hypsoblennius gentilis	Bay Blenny	64	370		16	450	0.12
Embiotoca jacksoni	Black Perch	430				430	0.12
Fundulus parvipinnis	California Killifish			6	423	429	0.11
Pleuronichthys ritteri	Spotted Turbot	219	116	27		362	0.10
Clevelandia ios	Arrow Goby	77	7	109	152	345	0.09
Paralabrax nebulifer	Barred Sand Bass	51	101		160	312	0.08
Xystreurys liolepis	Fantail Sole	310				310	0.08
Leuresthes tenuis	California Grunion	106	49			155	0.04
Symphurus atricaudus	California Tonguefish	97	38			135	0.04
Synodus lucioceps	California Lizardfish	92				92	0.02
Leptocottus armatus	Pacific Staghorn Sculpin			14	68	82	0.02
Hippocampus ingens	Pacific Seahorse			45		45	0.01
Pleuronichthys decurrens	Curlfin Sole		30			30	< 0.01
Trachurus symmetricus	Jack Mackerel	30				30	< 0.01
Quietula y-cauda	Shadow Goby		2	6	17	25	< 0.01
Ctenogobius sagittula	Longtail Goby				23	23	< 0.01
Hyporhamphus rosae	California Halfbeak			9	10	19	< 0.01
Scorpaena guttata	California Scorpionfish		15			15	< 0.01
Gibbonsia elegans	Spotted Kelpfish		12			12	< 0.01
Acanthogobius flavimanus	Yellowfin Goby				11	11	< 0.01
Ilypnus gilberti	Cheekspot Goby			3		3	< 0.01
Paraclinus integripinnis	Reef Finspot		1	2		3	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	2				2	< 0.01
Cosmocampus arctus	Snubnose Pipefish	1	1			2	< 0.01
Engraulis mordax	Northern Anchovy	2				2	< 0.01
Alloclinus holderi	Island Kelpfish	1				1	< 0.01
# of Species:	**56**	**115,975**	**58,093**	**89,220**	**109,804**	**373,092**	

Table 5. Total number of individuals and biomass (g) of fish species captured in the North Ecoregion, 2022.

		Abundance		Biomass	
Scientific Name	Common Name	#	%	grams	%
Atherinops affinis	Topsmelt	2,482	52.15	37,418	32.26
Micrometrus minimus	Dwarf Perch	723	15.19	3,534	3.05
Heterostichus rostratus	Giant Kelpfish	521	10.95	1,913	1.65
Syngnathus californiensis	Kelp Pipefish	259	5.44	247	0.21
Cymatogaster aggregata	Shiner Perch	185	3.89	1,421	1.23
Urobatis halleri	Round Stingray	173	3.64	47,209	40.71
Porichthys myriaster	Specklefin Midshipman	96	2.02	536	0.46
Clevelandia ios	Arrow Goby	69	1.45	77	0.07
Atherinopsis californiensis	Jacksmelt	59	1.24	1,440	1.24
Paralabrax maculatofasciatus	Spotted Sand Bass	50	1.05	17,382	14.99
Leuresthes tenuis	California Grunion	47	0.99	106	0.09
Embiotoca jacksoni	Black Perch	20	0.42	430	0.37
Hypsoblennius gentilis	Bay Blenny	12	0.25	64	0.06
Paralichthys californicus	California Halibut	11	0.23	376	0.32
Pleuronichthys ritteri	Spotted Turbot	11	0.23	219	0.19
Halichoeres semicinctus	Rock Wrasse	9	0.19	969	0.84
Scomber japonicus	Pacific Chub Mackerel	8	0.17	915	0.79
Symphurus atricaudus	California Tonguefish	8	0.17	97	0.08
Cosmocampus arctus	Snubnose Pipefish	2	0.04	1	0.00
Engraulis mordax	Northern Anchovy	2	0.04	2	0.00
Paralabrax clathratus	Kelp Bass	2	0.04	31	0.03
Xystreurys liolepis	Fantail Sole	2	0.04	310	0.27
Alloclinus holderi	Island Kelpfish	1	0.02	1	0.00
Anchoa delicatissima	Slough Anchovy	1	0.02	2	0.00
Citharichthys stigmaeus	Speckled Sanddab	1	0.02	2	0.00
Heterodontus francisci	Horn Shark	1	0.02	500	0.43
Paralabrax nebulifer	Barred Sand Bass	1	0.02	51	0.04
Synodus lucioceps	California Lizardfish	1	0.02	92	0.08
Trachurus symmetricus	Jack Mackerel	1	0.02	30	0.03
Umbrina roncador	Yellowfin Croaker	1	0.02	600	0.52
# of Species:	**30**	**4,759**		**115,975**	

Lobster from an otter trawl in the North Ecoregion during the July 2022 survey.

Table 6. Total number of individuals and biomass (g) of fish species captured in the North-Central Ecoregion, 2022.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Atherinops affinis	Topsmelt	2,412	44.60	8,124	13.98
Anchoa delicatissima	Slough Anchovy	1,756	32.47	4,405	7.58
Heterostichus rostratus	Giant Kelpfish	720	13.31	3,133	5.39
Syngnathus californiensis	Kelp Pipefish	138	2.55	66	0.11
Cymatogaster aggregata	Shiner Perch	105	1.94	1,020	1.76
Urobatis halleri	Round Stingray	76	1.41	15,020	25.86
Clevelandia ios	Arrow Goby	52	0.96	7	0.01
Paralabrax maculatofasciatus	Spotted Sand Bass	52	0.96	12,400	21.35
Hypsoblennius gentilis	Bay Blenny	22	0.41	370	0.64
Cynoscion parvipinnis	Shortfin Corvina	13	0.24	5,200	8.95
Paralichthys californicus	California Halibut	10	0.18	250	0.43
Atherinopsis californiensis	Jacksmelt	8	0.15	3,535	6.09
Pleuronichthys ritteri	Spotted Turbot	8	0.15	116	0.20
Cheilotrema saturnum	Black Croaker	7	0.13	51	0.09
Sphyraena argentea	Pacific Barracuda	5	0.09	2,200	3.79
Gibbonsia elegans	Spotted Kelpfish	3	0.06	12	0.02
Pleuronichthys guttulatus	Diamond Turbot	3	0.06	445	0.77
Leuresthes tenuis	California Grunion	2	0.04	49	0.08
Paralabrax clathratus	Kelp Bass	2	0.04	386	0.66
Paralabrax nebulifer	Barred Sand Bass	2	0.04	101	0.17
Quietula y-cauda	Shadow Goby	2	0.04	2	0.00
Anchoa compressa	Deepbody Anchovy	1	0.02	4	0.01
Cosmocampus arctus	Snubnose Pipefish	1	0.02	1	0.00
Paraclinus integripinnis	Reef Finspot	1	0.02	1	0.00
Pleuronichthys decurrens	Curlfin Sole	1	0.02	30	0.05
Porichthys myriaster	Specklefin Midshipman	1	0.02	1	0.00
Scomber japonicus	Pacific Chub Mackerel	1	0.02	210	0.36
Scorpaena guttata	California Scorpionfish	1	0.02	15	0.03
Strongylura exilis	California Needlefish	1	0.02	1	0.00
Symphurus atricaudus	California Tonguefish	1	0.02	38	0.07
Umbrina roncador	Yellowfin Croaker	1	0.02	900	1.55
# of Species:	**31**	**5,408**		**58,093**	

Purse seine boat transporting crew at the South-Central Ecoregion during the July 2022 survey.

Table 7. Total number of individuals and biomass (g) of fish species captured in the South-Central Ecoregion, 2022.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Anchoa delicatissima	Slough Anchovy	3,074	57.30	5,876	6.59
Syngnathus californiensis	Kelp Pipefish	630	11.74	306	0.34
Clevelandia ios	Arrow Goby	594	11.07	109	0.12
Cymatogaster aggregata	Shiner Perch	352	6.56	1,319	1.48
Urobatis halleri	Round Stingray	232	4.32	41,578	46.60
Atherinops affinis	Topsmelt	129	2.40	1,736	1.95
Paralabrax maculatofasciatus	Spotted Sand Bass	76	1.42	16,637	18.65
Anchoa compressa	Deepbody Anchovy	57	1.06	985	1.10
Pleuronichthys guttulatus	Diamond Turbot	45	0.84	543	0.61
Seriphus politus	Queenfish	44	0.82	4,500	5.04
Heterostichus rostratus	Giant Kelpfish	33	0.62	167	0.19
Paralichthys californicus	California Halibut	32	0.60	2,795	3.13
Haemulon californiensis	Salema	15	0.28	1,696	1.90
Quietula y-cauda	Shadow Goby	9	0.17	6	0.01
Cynoscion parvipinnis	Shortfin Corvina	8	0.15	329	0.37
Cheilotrema saturnum	Black Croaker	7	0.13	119	0.13
Ilypnus gilberti	Cheekspot Goby	7	0.13	3	0.00
Albula gilberti	Cortez Bonefish	5	0.09	2,012	2.26
Hyporhamphus rosae	California Halfbeak	5	0.09	9	0.01
Leptocottus armatus	Pacific Staghorn Sculpin	2	0.04	14	0.02
Paraclinus integripinnis	Reef Finspot	2	0.04	2	0.00
Porichthys myriaster	Specklefin Midshipman	2	0.04	1	0.00
Fundulus parvipinnis	California Killifish	1	0.02	6	0.01
Hippocampus ingens	Pacific Seahorse	1	0.02	45.0	0.05
Mugil cephalus	Striped Mullet	1	0.02	1,700	1.91
Pleuronichthys ritteri	Spotted Turbot	1	0.02	27	0.03
Zapteryx exasperata	Banded Guitarfish	1	0.02	6,700	7.51
# of Species:	**27**	**5,365**		**89,220**	

Specklefin midshipman (dorsal and ventral view) caught in the otter trawl in the North Ecoregion during the July 2022 survey.

Table 8. Total number of individuals and biomass (g) of fish species captured in the South Ecoregion, 2022.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Anchoa delicatissima	Slough Anchovy	1,820	44.41	3,066	2.79
Syngnathus californiensis	Kelp Pipefish	610	14.89	259	0.24
Clevelandia ios	Arrow Goby	557	13.59	152	0.14
Cymatogaster aggregata	Shiner Perch	363	8.86	889	0.81
Atherinops affinis	Topsmelt	307	7.49	2,885	2.63
Urobatis halleri	Round Stingray	172	4.20	28,539	25.99
Fundulus parvipinnis	California Killifish	71	1.73	423	0.39
Paralabrax maculatofasciatus	Spotted Sand Bass	63	1.54	13,554	12.34
Quietula y-cauda	Shadow Goby	34	0.83	17	0.02
Pleuronichthys guttulatus	Diamond Turbot	28	0.68	136	0.12
Heterostichus rostratus	Giant Kelpfish	16	0.39	22	0.02
Albula gilberti	Cortez Bonefish	11	0.27	3,500	3.19
Leptocottus armatus	Pacific Staghorn Sculpin	9	0.22	68	0.06
Hyporhamphus rosae	California Halfbeak	8	0.20	10	0.01
Paralichthys californicus	California Halibut	6	0.15	244	0.22
Cynoscion parvipinnis	Shortfin Corvina	5	0.12	12	0.01
Anchoa compressa	Deepbody Anchovy	3	0.07	58	0.05
Acanthogobius flavimanus	Yellowfin Goby	2	0.05	11	0.01
Cheilotrema saturnum	Black Croaker	2	0.05	310	0.28
Dasyatis dipterura	Diamond Stingray	2	0.05	39,700	36.16
Hypsoblennius gentilis	Bay Blenny	2	0.05	16	0.01
Ctenogobius sagittula	Longtail Goby	1	0.02	23	0.02
Mugil cephalus	Striped Mullet	1	0.02	1,200	1.09
Mustelus californicus	Gray Smoothhound	1	0.02	1,100	1.00
Paralabrax clathratus	Kelp Bass	1	0.02	150	0.14
Paralabrax nebulifer	Barred Sand Bass	1	0.02	160	0.15
Rhinobatos productus	Shovelnose Guitarfish	1	0.02	12,500	11.38
Strongylura exilis	California Needlefish	1	0.02	800	0.73
# of Species:	**28**	**4,098**		**109,804**	

Black Surfperch (*Embiotoca jacksoni*) captured in the beam trawl net in the North Ecoregion during the April 2022 survey.

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. Both species richness (Range: 27-30) and diversity (Range: 1.43-1.78) were relatively consitent among ecoregions and sampling periods. Species richness was above average in 2022, and generally followed a typical spatial pattern with richness decreasing from north to south. Diversity, however, was lowest in the North-Central Ecoregion and highest in the South Ecoregion (Figure 10). Species richness decreased slightly while H' increased from April to July 2022 (Figure 11).

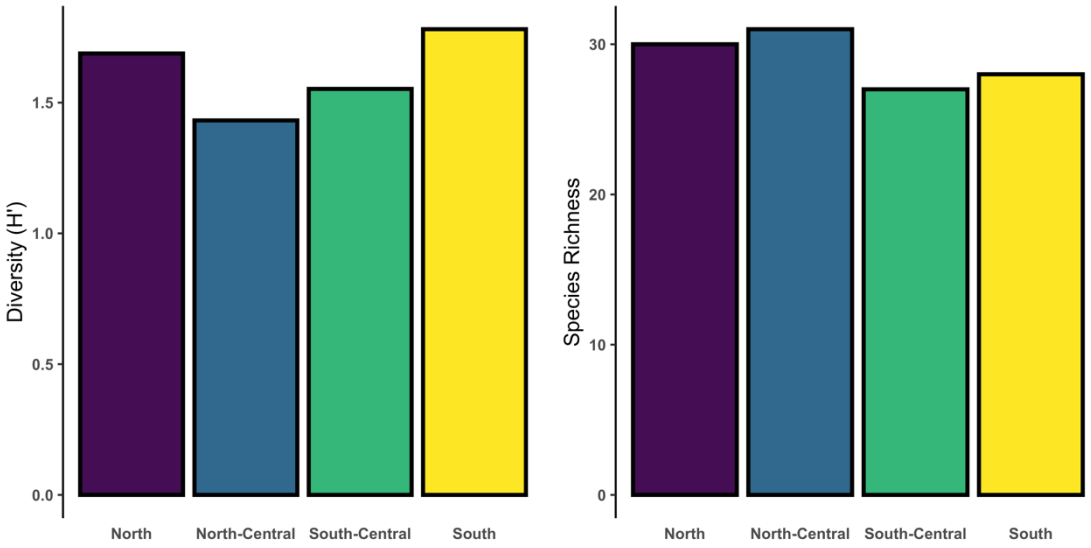


Figure 10. Shannon Diversity (H') and number of species (richness) of fishes taken in each San Diego Bay ecoregion, 2022.

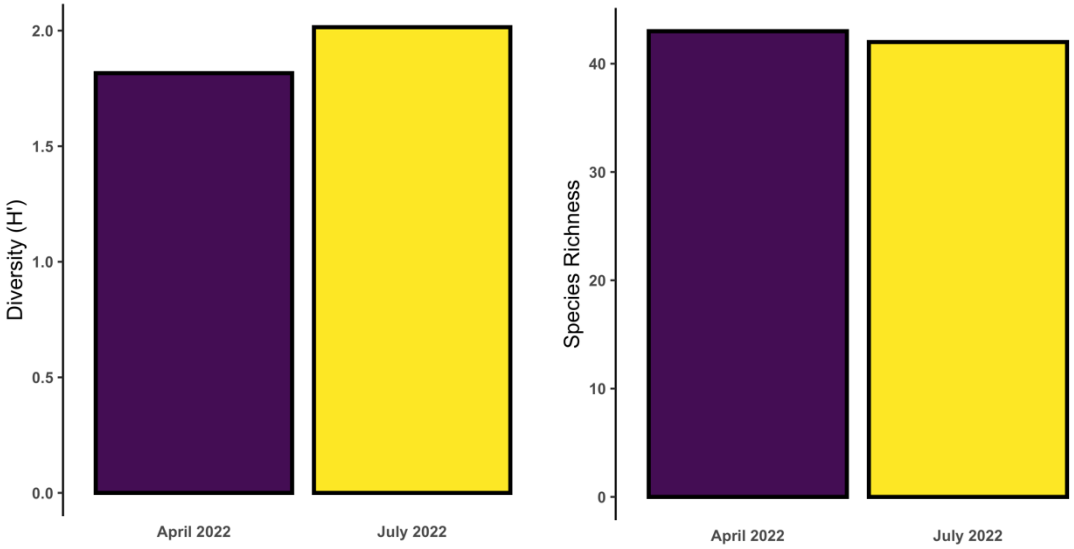


Figure 11. Shannon Diversity (H') and number of species (richness) of fishes taken in San Diego Bay by sampling month, 2022.

4.4 Catch by Sampling Ecoregion and Period

North Ecoregion – A total of 4,759 fishes belonging to 30 species and weighing 116 kg was collected in the North Ecoregion over two sampling periods in 2022 (Table 5). Topsmelt was by far the most frequently caught species (52.1%), followed by Dwarf Perch (15.9%), Giant Kelpfish (10.95%), Shiner Perch (*Cymatogaster aggregata*; 3.89%), and Round Stingray (3.64%). Round Stingray led in total biomass (40.7%), followed by Topsmelt (32.26%), Spotted Sand Bass (14.99%), Dwarf Perch (3.05%) and Giant Kelpfish (1.65%)

North-Central Ecoregion - A total of 5,408 fishes belonging to 31 species and weighing 58.1 kg was collected in the North-Central Ecoregion in April and July, 2022 (Table 6). Topsmelt was the most abundant species (44.6%), followed by Slough Anchovy (32.47%), Giant Kelpfish (13.31%), Kelp Pipefish (2.55%), and Shiner Perch (1.94%). Round Stingray led in total biomass (25.86%), followed by Spotted Sand Bass (21.35%), Topsmelt (13.98%), and Slough Anchovy (7.58%).

South-Central Ecoregion - A total of 5,365 fishes belonging to 27 species and weighing 89.2 kg was collected in the South-Central Ecoregion over the two sampling periods in 2022 (Table 7). Slough Anchovy was the most abundant species (57.3%), followed by Kelp Pipefish (11.74%), Arrow Goby (11.07%), Shiner Perch (6.56%), Round Stingray (4.32%) and Topsmelt (2.4%). Round Stingray led in total biomass (46.6%), followed by Spotted Sand Bass (18.65%), Banded Guitarfish (7.51%), Slough Anchovy (6.59%) and Queenfish (*Seriphus politus*; 5.04%).

South Ecoregion - A total of 4,098 fishes belonging to 28 species and weighing 109.8 kg was collected in the South Ecoregion in April and July 2022 (Table 8). Slough Anchovy was the most abundant species (44.1%), followed by Kelp Pipefish (14.89%), Arrow Goby (13.59%), Shiner Perch (8.86%), and Topsmelt (7.49%). Diamond Stingrays led in total biomass (36.16 %), followed by Round Stingrays (25.99%), Spotted Sand Bass (12.34%), and Shovelnose Guitarfish (11.38%).

Total biomass and abundance were generally consistent from April to July. In April 2022, 9,684 individuals comprised of 43 species of fishes were captured (Figure 12, Table 9). In July, the catch only increased slightly to 9,946 fish and species richness decreased slightly to 42. Total biomass was slightly greater in April (185.4 kg) than July (187.7 kg) (Figure 12, Table 10). Biomass was highest in the South Ecoregion in July due to catch of two large Diamond Stingrays totaling 39.7 kg in mass.

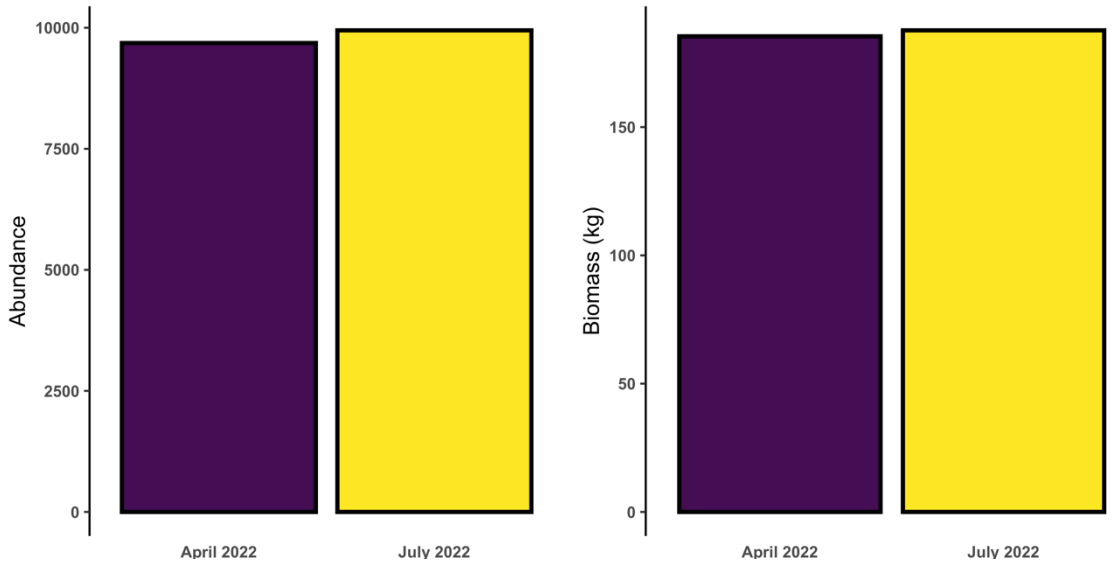


Figure 10. Total catch of fishes and biomass (kg) taken in San Diego Bay by sampling period, 2022.

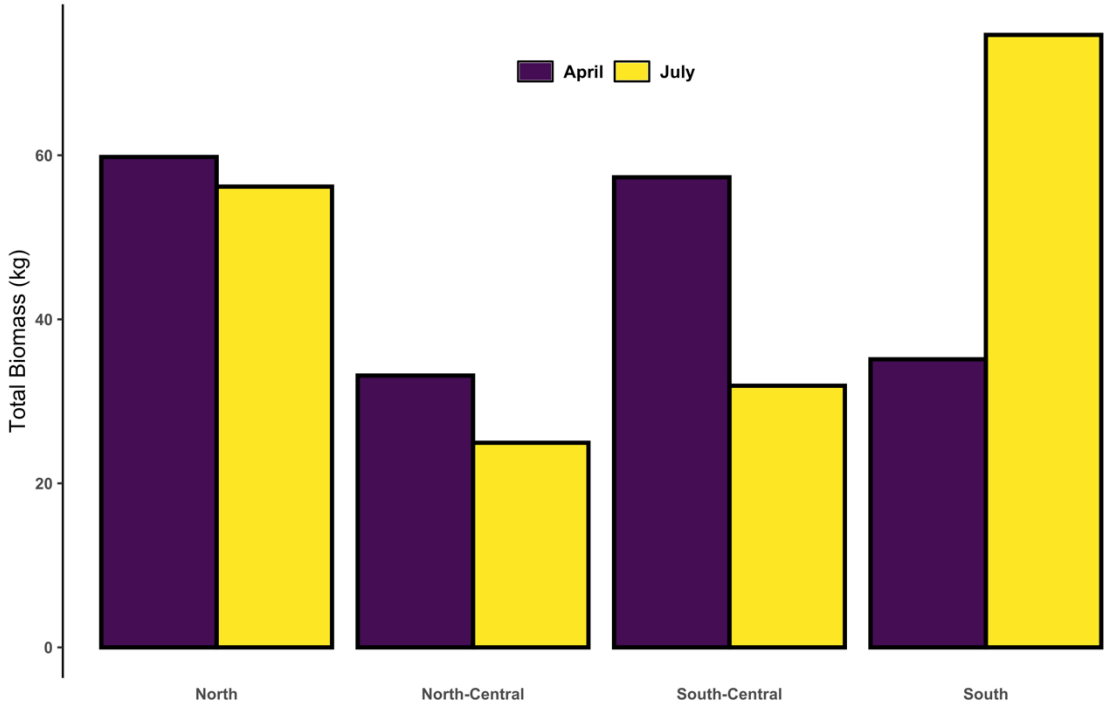


Figure 11. Biomass (kg) of San Diego Bay fishes taken by ecoregion, April and July 2022.

Table 9. Total abundance of fish species taken in San Diego Bay by sampling period, 2022.

		2022			
Scientific Name	**Common Name**	**April**	**July**	**Total**	**%**
Anchoa delicatissima	Slough Anchovy	3,421	3,230	6,651	33.88
Atherinops affinis	Topsmelt	3,187	2,143	5,330	27.15
Syngnathus californiensis	Kelp Pipefish	808	829	1,637	8.34
Heterostichus rostratus	Giant Kelpfish	320	970	1,290	6.57
Clevelandia ios	Arrow Goby	154	1,118	1,272	6.48
Cymatogaster aggregata	Shiner Perch	778	227	1,005	5.12
Micrometrus minimus	Dwarf Perch	92	631	723	3.68
Urobatis halleri	Round Stingray	331	322	653	3.33
Paralabrax maculatofasciatus	Spotted Sand Bass	131	110	241	1.23
Porichthys myriaster	Specklefin Midshipman		99	99	0.50
Pleuronichthys guttulatus	Diamond Turbot	70	6	76	0.39
Fundulus parvipinnis	California Killifish	25	47	72	0.37
Atherinopsis californiensis	Jacksmelt	67		67	0.34
Anchoa compressa	Deepbody Anchovy	51	10	61	0.31
Paralichthys californicus	California Halibut	30	29	59	0.30
Leuresthes tenuis	California Grunion	4	45	49	0.25
Quietula y-cauda	Shadow Goby	43	2	45	0.23
Seriphus politus	Queenfish	44		44	0.22
Hypsoblennius gentilis	Bay Blenny	10	26	36	0.18
Cynoscion parvipinnis	Shortfin Corvina	14	12	26	0.13
Embiotoca jacksoni	Black Perch	7	13	20	0.10
Pleuronichthys ritteri	Spotted Turbot	17	3	20	0.10
Albula gilberti	Cortez Bonefish	15	1	16	0.08
Cheilotrema saturnum	Black Croaker	1	15	16	0.08
Haemulon californiensis	Salema	15		15	0.08
Hyporhamphus rosae	California Halfbeak	4	9	13	0.07
Leptocottus armatus	Pacific Staghorn Sculpin	11		11	0.06
Halichoeres semicinctus	Rock Wrasse	6	3	9	0.05
Scomber japonicus	Pacific Chub Mackerel	1	8	9	0.05
Symphurus atricaudus	California Tonguefish	3	6	9	0.05
Ilypnus gilberti	Cheekspot Goby		7	7	0.04
Paralabrax clathratus	Kelp Bass	4	1	5	0.03
Sphyraena argentea	Pacific Barracuda	5		5	0.03
Paralabrax nebulifer	Barred Sand Bass	3	1	4	0.02
Cosmocampus arctus	Snubnose Pipefish		3	3	0.02
Gibbonsia elegans	Spotted Kelpfish		3	3	0.02
Paraclinus integripinnis	Reef Finspot		3	3	0.02
Acanthogobius flavimanus	Yellowfin Goby		2	2	0.01
Dasyatis dipterura	Diamond Stingray		2	2	0.01
Engraulis mordax	Northern Anchovy		2	2	0.01
Mugil cephalus	Striped Mullet	1	1	2	0.01
Strongylura exilis	California Needlefish	1	1	2	0.01
Umbrina roncador	Yellowfin Croaker		2	2	0.01
Xystreurys liolepis	Fantail Sole	2		2	0.01
Alloclinus holderi	Island Kelpfish		1	1	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	1		1	< 0.01
Ctenogobius sagittula	Longtail Goby	1		1	< 0.01
Heterodontus francisci	Horn Shark		1	1	< 0.01
Hippocampus ingens	Pacific Seahorse	1		1	< 0.01
Mustelus californicus	Gray Smoothhound	1		1	< 0.01
Pleuronichthys decurrens	Curlfin Sole	1		1	< 0.01
Rhinobatos productus	Shovelnose Guitarfish		1	1	< 0.01
Scorpaena guttata	California Scorpionfish		1	1	< 0.01
Synodus lucioceps	California Lizardfish	1		1	< 0.01
Trachurus symmetricus	Jack Mackerel	1		1	< 0.01
Zapteryx exasperata	Banded Guitarfish	1		1	< 0.01
	Total:	**9,684**	**9,946**	**19,630**	
	# of Species:	43	42		

Table 10. Total biomass (g) of fish species taken in San Diego Bay by sampling period, 2022.

		2022			
Scientific Name	**Common Name**	**April**	**July**	**Total**	**%**
Urobatis halleri	Round Stingray	63,223	69,123	132,346	35.47
Paralabrax maculatofasciatus	Spotted Sand Bass	31,299	28,674	59,973	16.07
Atherinops affinis	Topsmelt	37,964	12,199	50,163	13.45
Dasyatis dipterura	Diamond Stingray		39,700	39,700	10.64
Anchoa delicatissima	Slough Anchovy	6,545	6,804	13,349	3.58
Rhinobatos productus	Shovelnose Guitarfish		12,500	12,500	3.35
Zapteryx exasperata	Banded Guitarfish	6,700		6,700	1.80
Cynoscion parvipinnis	Shortfin Corvina	5,520	21	5,541	1.49
Albula gilberti	Cortez Bonefish	5,500	12	5,512	1.48
Heterostichus rostratus	Giant Kelpfish	796	4,439	5,235	1.40
Atherinopsis californiensis	Jacksmelt	4,975		4,975	1.33
Cymatogaster aggregata	Shiner Perch	2,835	1,814	4,649	1.25
Seriphus politus	Queenfish	4,500		4,500	1.21
Paralichthys californicus	California Halibut	2,748	917	3,665	0.98
Micrometrus minimus	Dwarf Perch	830	2,704	3,534	0.95
Mugil cephalus	Striped Mullet	1,200	1,700	2,900	0.78
Sphyraena argentea	Pacific Barracuda	2,200		2,200	0.59
Haemulon californiensis	Salema	1,696		1,696	0.45
Umbrina roncador	Yellowfin Croaker		1,500	1,500	0.40
Scomber japonicus	Pacific Chub Mackerel	210	915	1,125	0.30
Pleuronichthys guttulatus	Diamond Turbot	839	285	1,124	0.30
Mustelus californicus	Gray Smoothhound	1,100		1,100	0.29
Anchoa compressa	Deepbody Anchovy	914	133	1,047	0.28
Halichoeres semicinctus	Rock Wrasse	155	814	969	0.26
Syngnathus californiensis	Kelp Pipefish	396	482	878	0.24
Strongylura exilis	California Needlefish	800	1	801	0.21
Paralabrax clathratus	Kelp Bass	539	28	567	0.15
Porichthys myriaster	Specklefin Midshipman		538	538	0.14
Heterodontus francisci	Horn Shark		500	500	0.13
Cheilotrema saturnum	Black Croaker	300	180	480	0.13
Hypsoblennius gentilis	Bay Blenny	25	425	450	0.12
Embiotoca jacksoni	Black Perch	41	389	430	0.12
Fundulus parvipinnis	California Killifish	121	308	429	0.11
Pleuronichthys ritteri	Spotted Turbot	246	116	362	0.10
Clevelandia ios	Arrow Goby	106	239	345	0.09
Paralabrax nebulifer	Barred Sand Bass	232	80	312	0.08
Xystreurys liolepis	Fantail Sole	310		310	0.08
Leuresthes tenuis	California Grunion	91	64	155	0.04
Symphurus atricaudus	California Tonguefish	85	50	135	0.04
Synodus lucioceps	California Lizardfish	92		92	0.02
Leptocottus armatus	Pacific Staghorn Sculpin	82		82	0.02
Hippocampus ingens	Pacific Seahorse	45		45	0.01
Pleuronichthys decurrens	Curlfin Sole	30		30	< 0.01
Trachurus symmetricus	Jack Mackerel	30		30	< 0.01
Quietula y-cauda	Shadow Goby	23	2	25	< 0.01
Ctenogobius sagittula	Longtail Goby	23		23	< 0.01
Hyporhamphus rosae	California Halfbeak	14	5	19	< 0.01
Scorpaena guttata	California Scorpionfish		15	15	< 0.01
Gibbonsia elegans	Spotted Kelpfish		12	12	< 0.01
Acanthogobius flavimanus	Yellowfin Goby		11	11	< 0.01
Ilypnus gilberti	Cheekspot Goby		3	3	< 0.01
Paraclinus integripinnis	Reef Finspot		3	3	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	2		2	< 0.01
Cosmocampus arctus	Snubnose Pipefish		2	2	< 0.01
Engraulis mordax	Northern Anchovy		2	2	< 0.01
Alloclinus holderi	Island Kelpfish		1	1	< 0.01
	Total:	**185,382**	**187,710**	**373,092**	
	# of Species:	43	42		

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 nearshore strata (12,183 individuals from 42 species; Table 11). 5,463 fishes from 25 species were captured in the intertidal, and 1,984 fishes from 29 species were captured in the channel. A total of 11,453 fishes was taken in vegetated areas of the nearshore and intertidal (Table 12) comprised of 38 of the 56 species captured during the 2022 surveys. 6,193 fishes from 36 species were caught in the nearshore and intertidal non-vegetated areas, and 1,984 fishes from 29 species were caught in the channel.

Beach crew recording data at the North Ecoregion during the April 2022 survey.

Striped Mullet (*Mugil cephalus*) captured by purse seine in the South-Central Ecoregion during the July 2022 survey.

Table 11. Total abundance of fish species taken from San Diego Bay by depth strata, 2022.

		Depth Strata				
Scientific Name	**Common Name**	**Channel**	**Intertidal**	**Nearshore**	**Total**	**%**
Anchoa delicatissima	Slough Anchovy	1,260	123	5,268	6,651	33.88
Atherinops affinis	Topsmelt	238	2,981	2,111	5,330	27.15
Syngnathus californiensis	Kelp Pipefish	7	271	1,359	1,637	8.34
Heterostichus rostratus	Giant Kelpfish	1	117	1,172	1,290	6.57
Clevelandia ios	Arrow Goby	2	1,204	66	1,272	6.48
Cymatogaster aggregata	Shiner Perch	10	67	928	1,005	5.12
Micrometrus minimus	Dwarf Perch		395	328	723	3.68
Urobatis halleri	Round Stingray	330	43	280	653	3.33
Paralabrax maculatofasciatus	Spotted Sand Bass	35	4	202	241	1.23
Porichthys myriaster	Specklefin Midshipman	3		96	99	0.50
Pleuronichthys guttulatus	Diamond Turbot	2	73	1	76	0.39
Fundulus parvipinnis	California Killifish		72		72	0.37
Atherinopsis californiensis	Jacksmelt			67	67	0.34
Anchoa compressa	Deepbody Anchovy	9		52	61	0.31
Paralichthys californicus	California Halibut	36	15	8	59	0.30
Leuresthes tenuis	California Grunion	1		48	49	0.25
Quietula y-cauda	Shadow Goby		43	2	45	0.23
Seriphus politus	Queenfish			44	44	0.22
Hypsoblennius gentilis	Bay Blenny		7	29	36	0.18
Cynoscion parvipinnis	Shortfin Corvina		9	17	26	0.13
Embiotoca jacksoni	Black Perch		1	19	20	0.10
Pleuronichthys ritteri	Spotted Turbot	19		1	20	0.10
Albula gilberti	Cortez Bonefish	11	1	4	16	0.08
Cheilotrema saturnum	Black Croaker	2		14	16	0.08
Haemulon californiensis	Salema			15	15	0.08
Hyporhamphus rosae	California Halfbeak		13		13	0.07
Leptocottus armatus	Pacific Staghorn Sculpin		11		11	0.06
Halichoeres semicinctus	Rock Wrasse			9	9	0.05
Scomber japonicus	Pacific Chub Mackerel	2		7	9	0.05
Symphurus atricaudus	California Tonguefish	3		6	9	0.05
Ilypnus gilberti	Cheekspot Goby		7		7	0.04
Paralabrax clathratus	Kelp Bass		1	4	5	0.03
Sphyraena argentea	Pacific Barracuda			5	5	0.03
Paralabrax nebulifer	Barred Sand Bass	1		3	4	0.02
Cosmocampus arctus	Snubnose Pipefish			3	3	0.02
Gibbonsia elegans	Spotted Kelpfish		1	2	3	0.02
Paraclinus integripinnis	Reef Finspot	1		2	3	0.02
Acanthogobius flavimanus	Yellowfin Goby		2		2	0.01
Dasyatis dipterura	Diamond Stingray	2			2	0.01
Engraulis mordax	Northern Anchovy			2	2	0.01
Mugil cephalus	Striped Mullet	1		1	2	0.01
Strongylura exilis	California Needlefish	1	1		2	0.01
Umbrina roncador	Yellowfin Croaker			2	2	0.01
Xystreurys liolepis	Fantail Sole	2			2	0.01
Alloclinus holderi	Island Kelpfish			1	1	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	1			1	< 0.01
Ctenogobius sagittula	Longtail Goby		1		1	< 0.01
Heterodontus francisci	Horn Shark			1	1	< 0.01
Hippocampus ingens	Pacific Seahorse			1	1	< 0.01
Mustelus californicus	Gray Smoothhound			1	1	< 0.01
Pleuronichthys decurrens	Curlfin Sole	1			1	< 0.01
Rhinobatos productus	Shovelnose Guitarfish	1			1	< 0.01
Scorpaena guttata	California Scorpionfish			1	1	< 0.01
Synodus lucioceps	California Lizardfish	1			1	< 0.01
Trachurus symmetricus	Jack Mackerel			1	1	< 0.01
Zapteryx exasperata	Banded Guitarfish	1			1	< 0.01
	Total:	**1,984**	**5,463**	**12,183**	**19,630**	
	# of Species:	29	25	42		

Table 12. Total abundance of fish species taken from San Diego Bay by subhabitat, 2022.

		Subhabitat				
Scientific Name	Common Name	Channel	Non-Vegetated	Vegetated	Total	%
Anchoa delicatissima	Slough Anchovy	1,260	1,995	3,396	6,651	33.88
Atherinops affinis	Topsmelt	238	1,695	3,397	5,330	27.15
Syngnathus californiensis	Kelp Pipefish	7	660	970	1,637	8.34
Heterostichus rostratus	Giant Kelpfish	1	524	765	1,290	6.57
Clevelandia ios	Arrow Goby	2	139	1,131	1,272	6.48
Cymatogaster aggregata	Shiner Perch	10	289	706	1,005	5.12
Micrometrus minimus	Dwarf Perch		417	306	723	3.68
Urobatis halleri	Round Stingray	330	116	207	653	3.33
Paralabrax maculatofasciatus	Spotted Sand Bass	35	90	116	241	1.23
Porichthys myriaster	Specklefin Midshipman	3	96		99	0.50
Pleuronichthys guttulatus	Diamond Turbot	2	16	58	76	0.39
Fundulus parvipinnis	California Killifish			72	72	0.37
Atherinopsis californiensis	Jacksmelt		1	66	67	0.34
Anchoa compressa	Deepbody Anchovy	9	7	45	61	0.31
Paralichthys californicus	California Halibut	36	17	6	59	0.30
Leuresthes tenuis	California Grunion	1	1	47	49	0.25
Quietula y-cauda	Shadow Goby		11	34	45	0.23
Seriphus politus	Queenfish		44		44	0.22
Hypsoblennius gentilis	Bay Blenny		16	20	36	0.18
Cynoscion parvipinnis	Shortfin Corvina		3	23	26	0.13
Embiotoca jacksoni	Black Perch		5	15	20	0.10
Pleuronichthys ritteri	Spotted Turbot	19	1		20	0.10
Albula gilberti	Cortez Bonefish	11	4	1	16	0.08
Cheilotrema saturnum	Black Croaker	2	8	6	16	0.08
Haemulon californiensis	Salema		1	14	15	0.08
Hyporhamphus rosae	California Halfbeak		7	6	13	0.07
Leptocottus armatus	Pacific Staghorn Sculpin			11	11	0.06
Halichoeres semicinctus	Rock Wrasse			9	9	0.05
Scomber japonicus	Pacific Chub Mackerel	2	7		9	0.05
Symphurus atricaudus	California Tonguefish	3	6		9	0.05
Ilypnus gilberti	Cheekspot Goby			7	7	0.04
Paralabrax clathratus	Kelp Bass			5	5	0.03
Sphyraena argentea	Pacific Barracuda		5		5	0.03
Paralabrax nebulifer	Barred Sand Bass	1	1	2	4	0.02
Cosmocampus arctus	Snubnose Pipefish		3		3	0.02
Gibbonsia elegans	Spotted Kelpfish			3	3	0.02
Paraclinus integripinnis	Reef Finspot	1	2		3	0.02
Acanthogobius flavimanus	Yellowfin Goby		1	1	2	0.01
Dasyatis dipterura	Diamond Stingray	2			2	0.01
Engraulis mordax	Northern Anchovy		2		2	0.01
Mugil cephalus	Striped Mullet	1		1	2	0.01
Strongylura exilis	California Needlefish	1		1	2	0.01
Umbrina roncador	Yellowfin Croaker		1	1	2	0.01
Xystreurys liolepis	Fantail Sole	2			2	0.01
Alloclinus holderi	Island Kelpfish		1		1	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	1			1	< 0.01
Ctenogobius sagittula	Longtail Goby			1	1	< 0.01
Heterodontus francisci	Horn Shark			1	1	< 0.01
Hippocampus ingens	Pacific Seahorse			1	1	< 0.01
Mustelus californicus	Gray Smoothhound		1		1	< 0.01
Pleuronichthys decurrens	Curlfin Sole	1			1	< 0.01
Rhinobatos productus	Shovelnose Guitarfish	1			1	< 0.01
Scorpaena guttata	California Scorpionfish			1	1	< 0.01
Synodus lucioceps	California Lizardfish	1			1	< 0.01
Trachurus symmetricus	Jack Mackerel			1	1	< 0.01
Zapteryx exasperata	Banded Guitarfish	1			1	< 0.01
	Total:	**1,984**	**6,193**	**11,453**	**19,630**	
	# of Species:	29	36	38		

4.6 Nursery Area Function

San Diego Bay continues to be a nursery area for nearly half of the fishes found there. Approximately 46% of all fishes sampled in San Diego Bay were juveniles (Table 13). The most abundant juveniles (Topsmelt, Giant Kelpfish, Arrow Goby) 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, 2022.

Scientific Name	Common Name	Juveniles	Total Abundance	% Juvenile
Porichthys myriaster	Specklefin Midshipman	97	99	97.98
Pleuronichthys guttulatus	Diamond Turbot	71	76	93.42
Leuresthes tenuis	California Grunion	45	49	91.84
Heterostichus rostratus	Giant Kelpfish	1,116	1,290	86.51
Hypsoblennius gentilis	Bay Blenny	31	36	86.11
Atherinops affinis	Topsmelt	4,399	5,330	82.53
Clevelandia ios	Arrow Goby	997	1,272	78.38
Cymatogaster aggregata	Shiner Perch	646	1,005	64.28
Syngnathus californiensis	Kelp Pipefish	851	1,637	51.99
Micrometrus minimus	Dwarf Perch	343	723	47.44
Quietula y-cauda	Shadow Goby	21	45	46.67
Cynoscion parvipinnis	Shortfin Corvina	12	26	46.15
Fundulus parvipinnis	California Killifish	19	72	26.39
Paralichthys californicus	California Halibut	13	59	22.03
Urobatis halleri	Round Stingray	31	653	4.75
Anchoa delicatissima	Slough Anchovy	216	6,651	3.25
Paralabrax maculatofasciatus	Spotted Sand Bass	6	241	2.49
Atherinopsis californiensis	Jacksmelt	0	67	0
Anchoa compressa	Deepbody Anchovy	0	61	0
Seriphus politus	Queenfish	0	44	0
		8,914	**19,436**	**45.86**

Juvenile California Scorpionfish (left) and Black Croaker (right) caught in the beam trawl in the North-Central Ecoregion during the July 2022 survey.

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. 4,060), Round Stingray ranked second (E.I. 3,880), Slough Anchovy ranked third (E.I. 3,278) and Spotted Sandbass ranked fourth (E.I. 1,730). Topsmelt, Round Stingray, and Spotted Sandbass were all found ubiquitously throughout the bay during both sampling periods, while only two Slough Anchovy were found in the North Ecoregion in July. Round Stingrays and Spotted Sandbass were dominant in terms of biomass, and Topsmelt and Slough Anchovies were dominant in terms of numerical abundance.

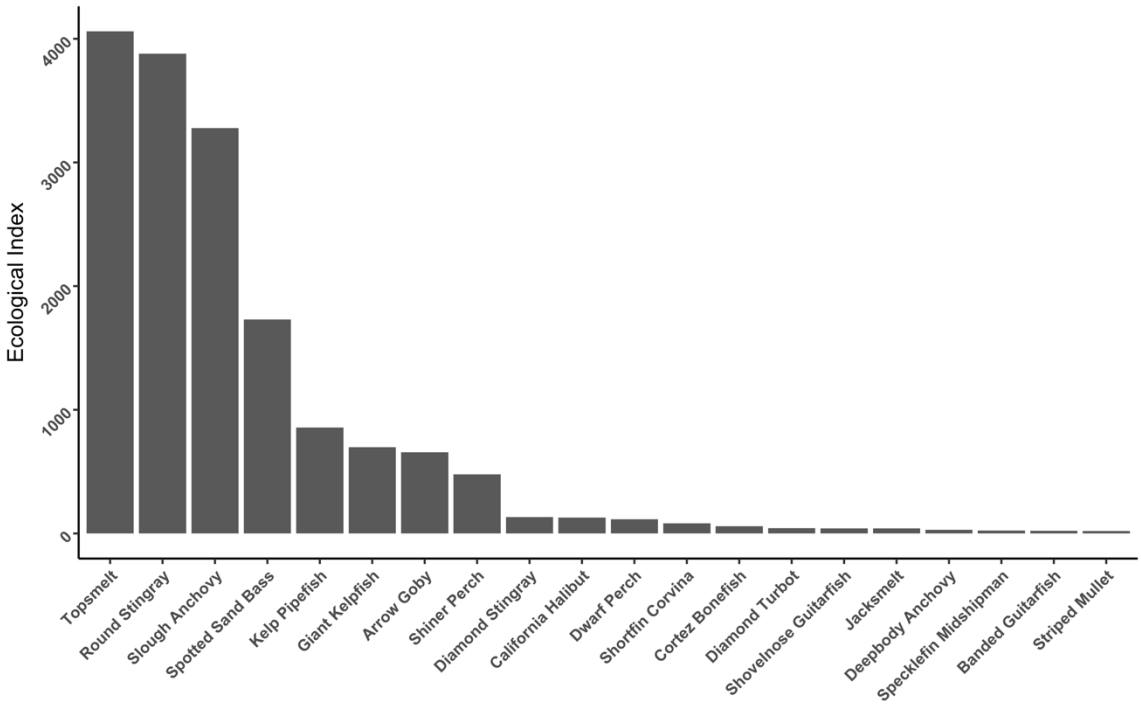


Figure 12. Top 20 species of San Diego Bay fishes ranked by Ecological Index, 2022.

Table 14. Relative abundance, relative biomass, frequency of occurrence, and Ecological Index (E.I.) of San Diego Bay fishes, 2022.

Scientific Name	Common Name	Abundance %	Biomass %	Frequency of Occurance	Ecological Index
Atherinops affinis	Topsmelt	27.15	13.45	100.0	4059.75
Urobatis halleri	Round Stingray	3.33	35.47	100.0	3879.93
Anchoa delicatissima	Slough Anchovy	33.88	3.58	87.5	3277.73
Paralabrax maculatofasciatus	Spotted Sand Bass	1.23	16.07	100.0	1730.23
Syngnathus californiensis	Kelp Pipefish	8.34	0.24	100.0	857.45
Heterostichus rostratus	Giant Kelpfish	6.57	1.40	87.5	697.79
Clevelandia ios	Arrow Goby	6.48	0.09	100.0	657.23
Cymatogaster aggregata	Shiner Perch	5.12	1.25	75.0	477.43
Dasyatis dipterura	Diamond Stingray	0.01	10.64	12.5	133.14
Paralichthys californicus	California Halibut	0.30	0.98	100.0	128.29
Micrometrus minimus	Dwarf Perch	3.68	0.95	25.0	115.76
Cynoscion parvipinnis	Shortfin Corvina	0.13	1.49	50.0	80.88
Albula gilberti	Cortez Bonefish	0.08	1.48	37.5	58.46
Pleuronichthys guttulatus	Diamond Turbot	0.39	0.30	62.5	43.03
Rhinobatos productus	Shovelnose Guitarfish	0.01	3.35	12.5	41.94
Atherinopsis californiensis	Jacksmelt	0.34	1.33	25.0	41.87
Anchoa compressa	Deepbody Anchovy	0.31	0.28	50.0	29.57
Porichthys myriaster	Specklefin Midshipman	0.50	0.14	37.5	24.32
Zapteryx exasperata	Banded Guitarfish	0.01	1.80	12.5	22.51
Mugil cephalus	Striped Mullet	0.01	0.78	25.0	19.69
Fundulus parvipinnis	California Killifish	0.37	0.11	37.5	18.07
Seriphus politus	Queenfish	0.22	1.21	12.5	17.88
Hypsoblennius gentilis	Bay Blenny	0.18	0.12	50.0	15.20
Leuresthes tenuis	California Grunion	0.25	0.04	37.5	10.92
Cheilotrema saturnum	Black Croaker	0.08	0.13	50.0	10.51
Umbrina roncador	Yellowfin Croaker	0.01	0.40	25.0	10.31
Pleuronichthys ritteri	Spotted Turbot	0.10	0.10	50.0	9.95
Paralabrax clathratus	Kelp Bass	0.03	0.15	50.0	8.87
Quietula y-cauda	Shadow Goby	0.23	0.01	37.5	8.85
Scomber japonicus	Pacific Chub Mackerel	0.05	0.30	25.0	8.68
Sphyraena argentea	Pacific Barracuda	0.03	0.59	12.5	7.69
Halichoeres semicinctus	Rock Wrasse	0.05	0.26	25.0	7.64
Haemulon californiensis	Salema	0.08	0.45	12.5	6.64
Strongylura exilis	California Needlefish	0.01	0.21	25.0	5.62
Embiotoca jacksoni	Black Perch	0.10	0.12	25.0	5.43
Paralabrax nebulifer	Barred Sand Bass	0.02	0.08	50.0	5.20
Mustelus californicus	Gray Smoothhound	0.01	0.29	12.5	3.75
Hyporhamphus rosae	California Halfbeak	0.07	0.01	50.0	3.57
Symphurus atricaudus	California Tonguefish	0.05	0.04	37.5	3.08
Leptocottus armatus	Pacific Staghorn Sculpin	0.06	0.02	25.0	1.95
Heterodontus francisci	Horn Shark	0.01	0.13	12.5	1.74
Xystreurys liolepis	Fantail Sole	0.01	0.08	12.5	1.17
Ilypnus gilberti	Cheekspot Goby	0.04	0.00	12.5	0.46
Paraclinus integripinnis	Reef Finspot	0.02	0.00	25.0	0.40
Cosmocampus arctus	Snubnose Pipefish	0.02	0.00	25.0	0.40
Synodus lucioceps	California Lizardfish	0.01	0.02	12.5	0.37
Gibbonsia elegans	Spotted Kelpfish	0.02	0.00	12.5	0.23
Hippocampus ingens	Pacific Seahorse	0.01	0.01	12.5	0.21
Acanthogobius flavimanus	Yellowfin Goby	0.01	< 0.01	12.5	0.16
Pleuronichthys decurrens	Curlfin Sole	0.01	< 0.01	12.5	0.16
Trachurus symmetricus	Jack Mackerel	< 0.01	< 0.01	12.5	0.16
Ctenogobius sagittula	Longtail Goby	< 0.01	< 0.01	12.5	0.14
Engraulis mordax	Northern Anchovy	0.01	< 0.01	12.5	0.13
Scorpaena guttata	California Scorpionfish	< 0.01	< 0.01	12.5	0.11
Citharichthys stigmaeus	Speckled Sanddab	< 0.01	< 0.01	12.5	0.07
Alloclinus holderi	Island Kelpfish	< 0.01	< 0.01	12.5	0.07

4.8 Principal Species

Topsmelt (*Atherinops affinis*)

Topsmelt 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 (82.5%) were two times as abundant in the vegetated (3,397) versus non-vegetated (1,695) subhabitats. They were the second most abundant fish in the survey comprising 27.15% of the catch, but only 13.45% of the biomass due to their relatively small size. Their size frequency distribution (Figure 15) was bimodal in both April and July and individuals greater than 19 cm were only found in April. This pattern is unusual for topsmelt as the catch in both April and July is usually numerically dominated by individuals less than 5 cm in lenth.

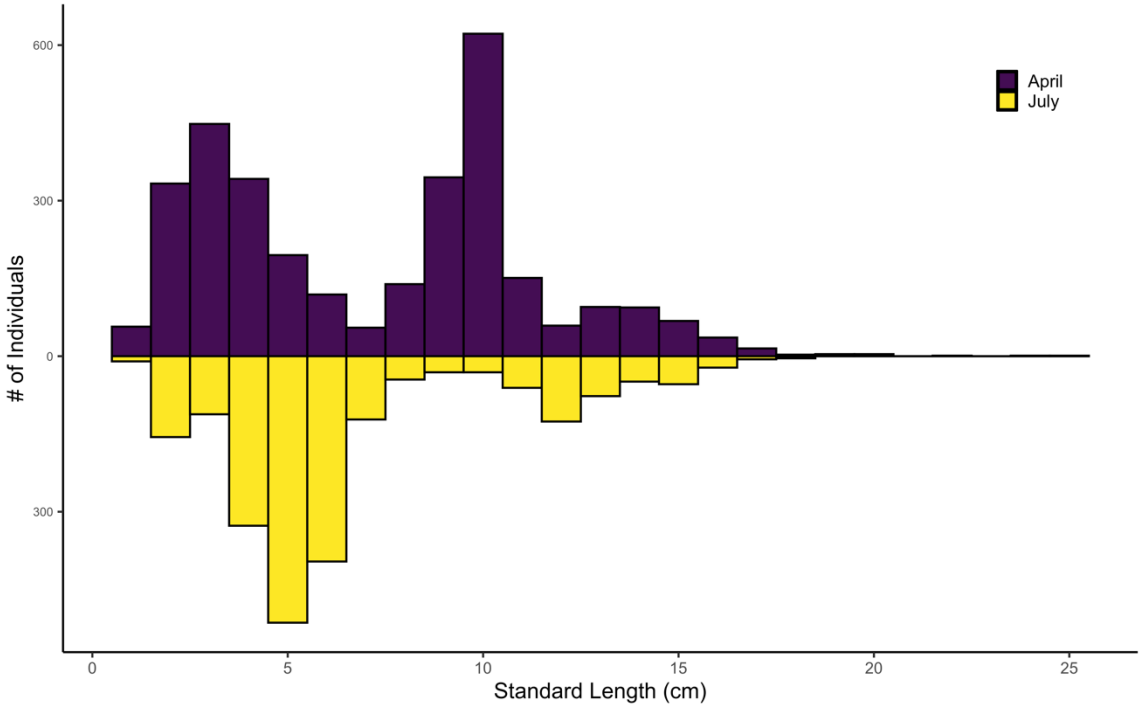


Figure 13. Total number of Topsmelt individuals by standard length (cm) from San Diego Bay, April and July 2022.

Round Stingray (*Urobatis halleri*)

The second highest ranked species in terms of ecological importance in 2022 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 3.33% of the total individuals captured in the 2022 surveys, those individuals accounted for 35.5% 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). As has been common in previous surveys, 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-Central Ecoregion.

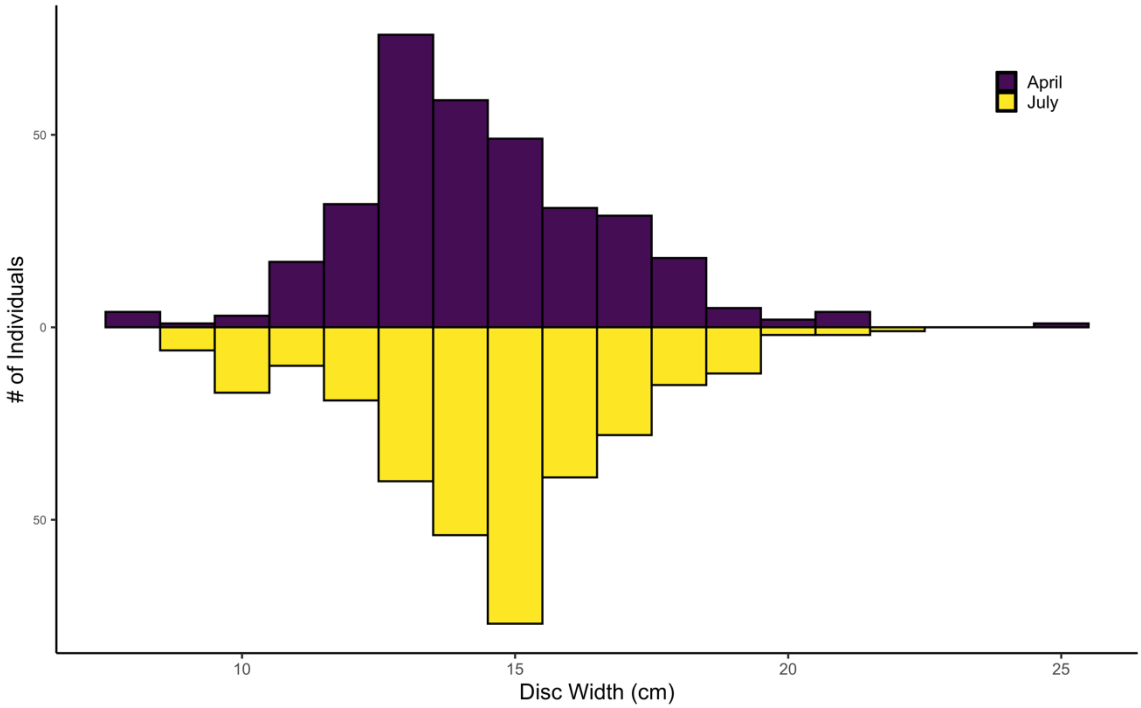


Figure 14. Total number of Round Stingray individuals by disc width (cm) from San Diego Bay, April and July 2022.

Slough Anchovy (*Anchoa delicatissima*)

Slough Anchovy ranked as the third most ecologically important fish species in San Diego Bay. This species was ubiquitous throughout the bay except for the North Ecoregion where only one individual was captured during the July survey. They were found in all depth strata and subhabitats. They had the fourth highest biomass of all fishes captured in 2022 and were the most abundant species captured during the surveys. Juvenile individuals made up only 3.25% of the total and were only captured during the July surveys indicating that juveniles likely settled in late spring to early summer (Figure 17). The bay is a well-known nursery area for this critical forage species and there is no doubt that 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 in this study.

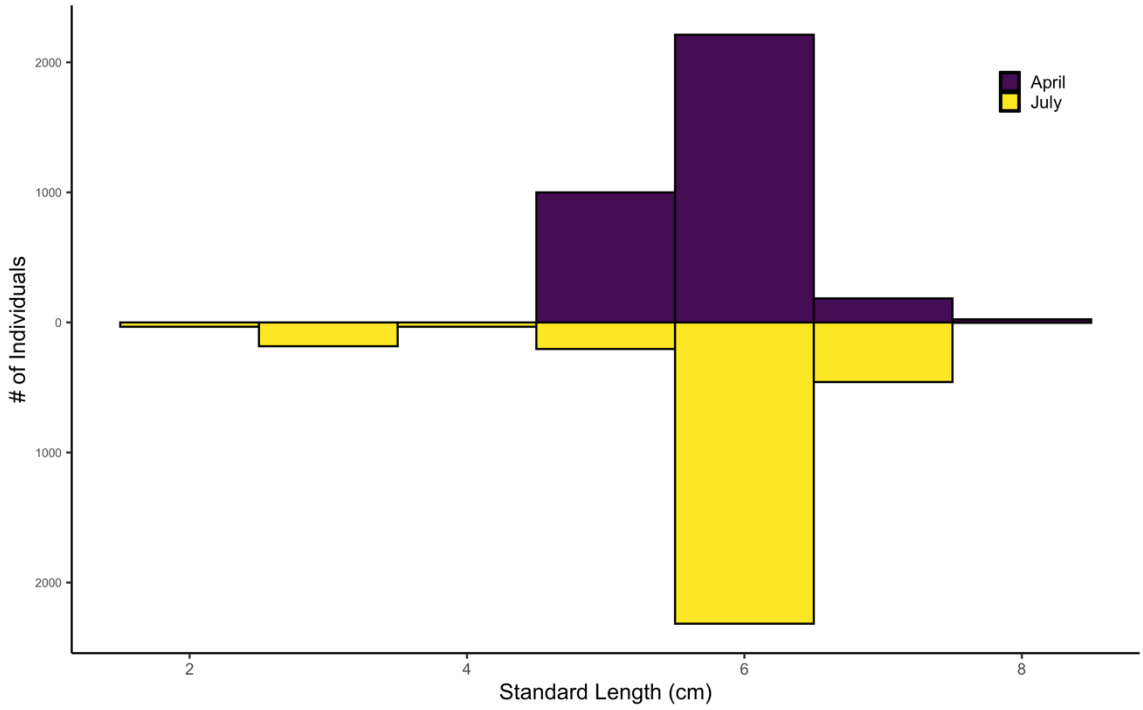


Figure 15. Total number of Slough Anchovy individuals by standard length (cm) from San Diego Bay, April and July 2022.

Spotted Sand Bass (*Paralabrax maculatofasciatus*)

Spotted Sand Bass are the ubiquitous mesocarnivore in San Diego Bay. In 2022, they ranked fourth 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. Similar to 2019, but unlike prior years, there was no bimodal size distribution (Figure 18) 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 weak recruitment year for Spotted Sand Bass.

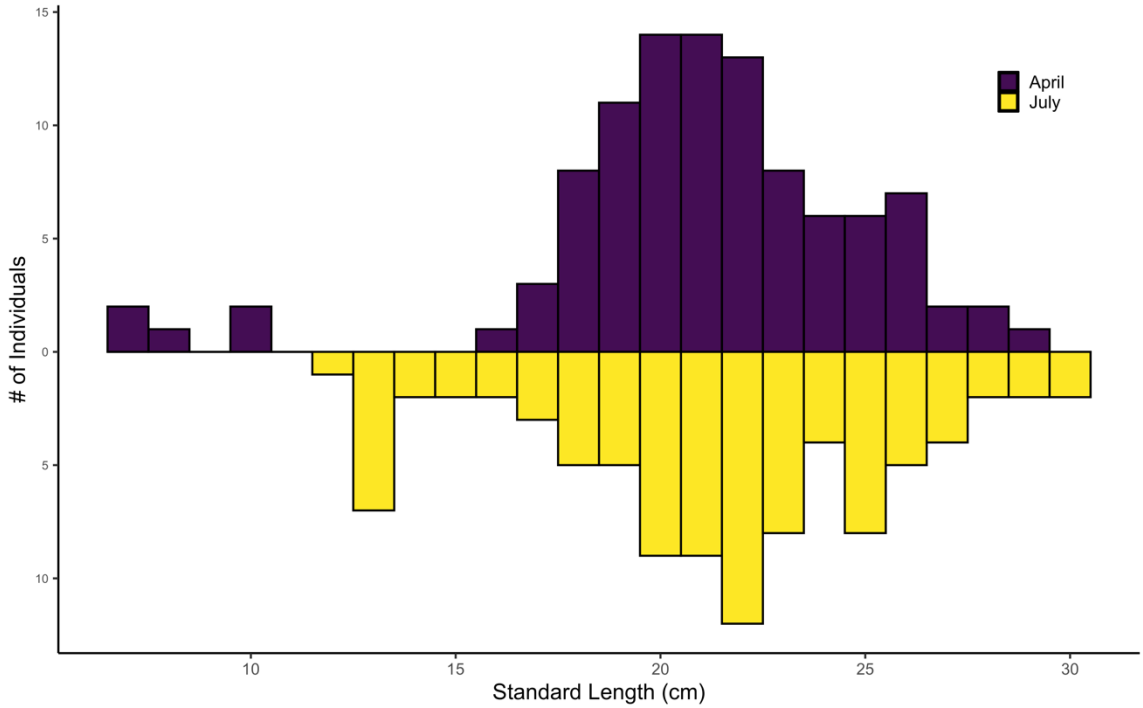


Figure 16. Total number of Spotted Sand Bass individuals by standard length (cm) from San Diego Bay, April and July 2022.

Kelp Pipefish (*Syngnathus californiensis*)

Though these long, narrow fishes only accounted for 0.24% of the biomass captured in 2022, Kelp Pipefish ranked fifth in Ecological Index by accounting for 8.34% of the total abundance and being caught in all ecoregions during both survey periods. They were caught in all depth strata and habitats, although they were significantly less common in the channel. More than 83% of the individuals were captured in the nearshore subhabitat and showed a preference for vegetated versus non-vegetated habitat. A uniform size distribution belied the fact that just over half (52%) of the individuals captured were juveniles (Figure 22), but the sharp increase in mean size from April to July indicates that this species grows quickly.

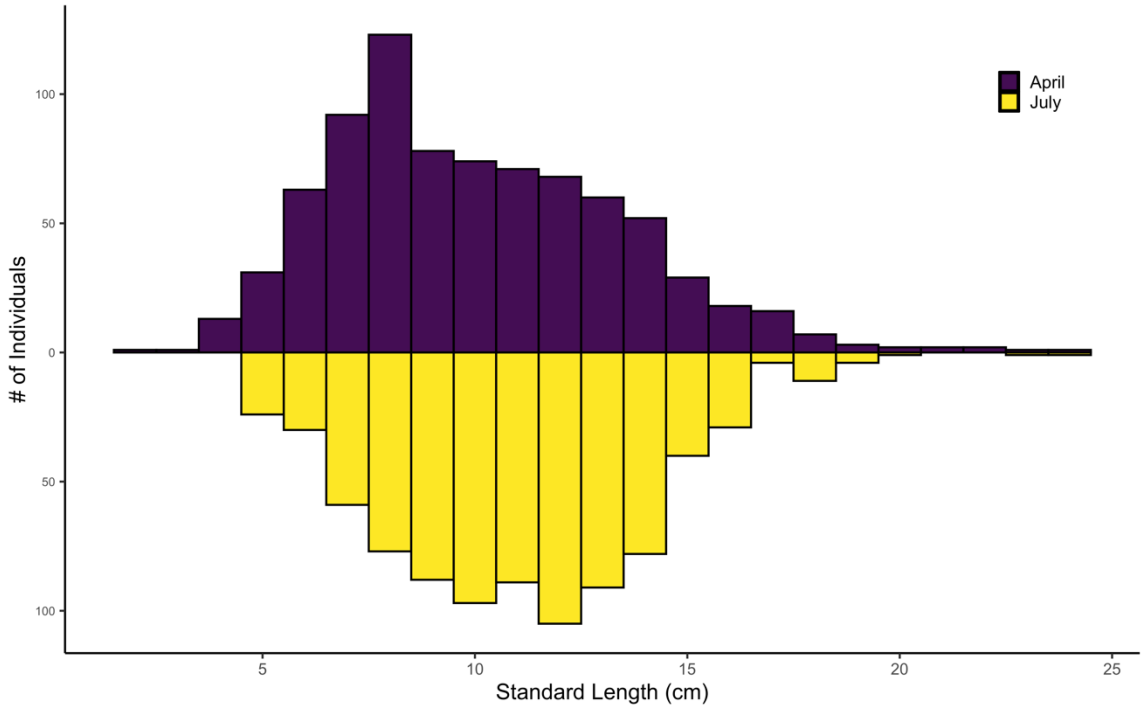


Figure 17. Total number of Kelp Pipefish individuals by standard length (cm) from San Diego Bay, April and July 2022.

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, 10 times the number of individuals were taken in the nearshore strata (1,172) than the intertidal (117). 86.5% of the Giant Kelpfish captured were juveniles, and nearly all individuals were less than 19 cm SL. One 28 cm SL individual was captured in July. The shift in the distribution of size classes (Figure 20) from April to July suggesting a strong winter recruitment event, relatively 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).

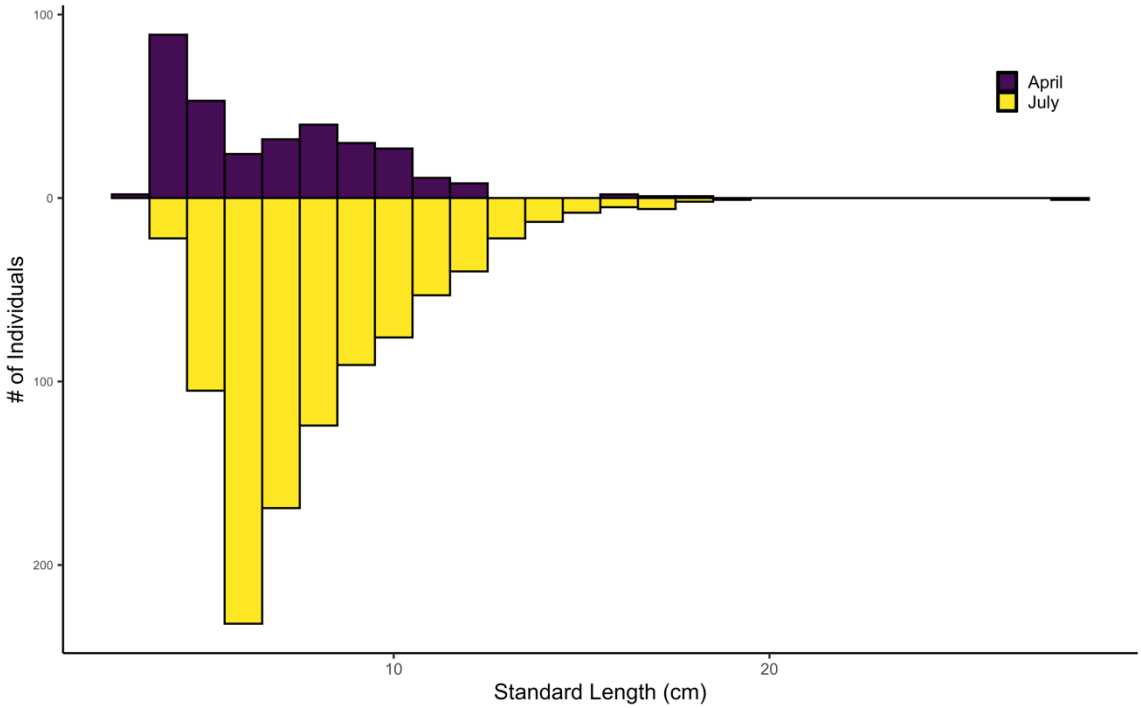


Figure 18. Total number of Giant Kelpfish individuals by standard length (cm) from San Diego Bay, April and July 2022.

Arrow Goby (*Clevelandia ios*)

Arrow Goby ranked seventh by the Ecological Index and were ubiquitous throughout the bay during these surveys, and were found in all sampling periods, ecoregions, depth strata and subhabitats. Arrow Goby were more common in the South-Central and South Ecoregions and were caught almost exclusively in the vegetated intertidal subhabitat. These mostly juvenile fish (78%) were the fifth most abundant fish in the survey comprising 6.48% of total abundance but only 0.09% of the biomass due to their small size. There were significantly more individuals captured in April (154) than July (1,118). The size frequency distribution (Figure 21) suggests that there was a recruitment event and slight growth between the April and July sampling events.

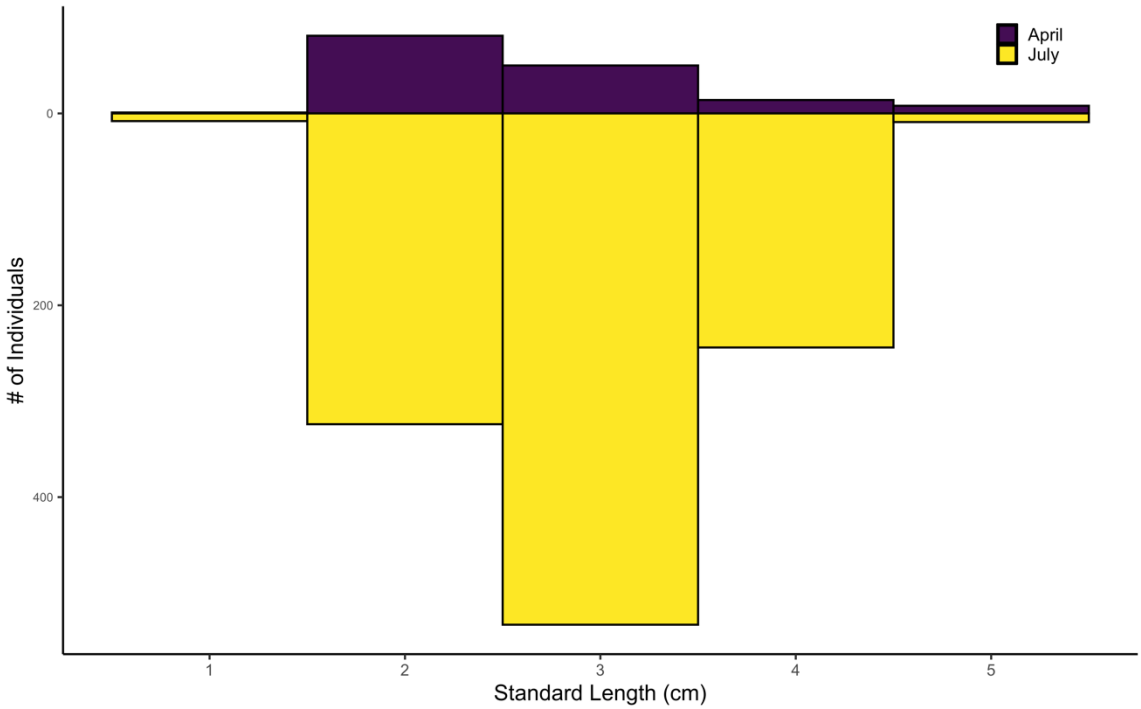


Figure 19. Total number of Arrow Goby individuals by standard length (cm) from San Diego Bay, April and July 2022.

Shiner Perch (*Cymatogaster aggregata*)

Shiner Perch ranked eighth 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, primarily in the vegetated subhabitat. These mostly juvenile fish (64.3%) were the sixth most abundant fish in the survey comprising 5.12% of the catch, but only 1.25% 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 growth between April and July. This distribution pattern is similar to that of other survey years.

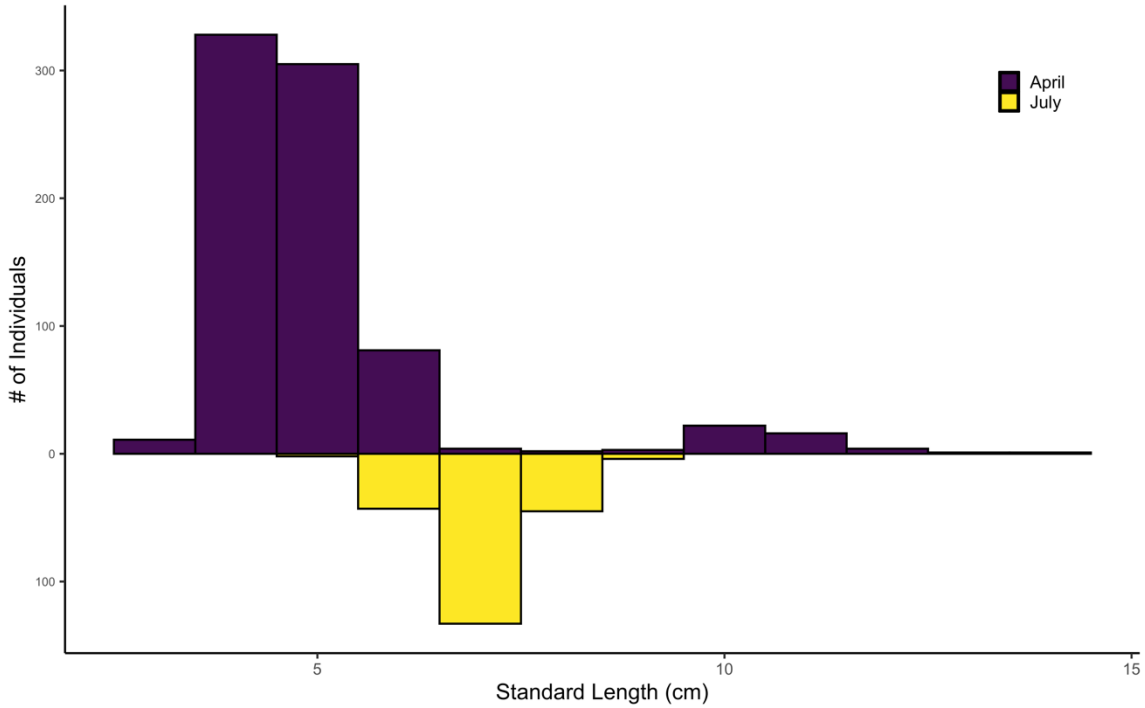


Figure 20. Total number of Shiner Perch individuals by standard length (cm) from San Diego Bay, April and July 2022.

Diamond Stingray (*Dasyatis dupterura*)

Diamond Stingrays (*Dasyatis dipterura*) ranked ninth in Ecological Index. Although they accounted for 0.01% of the abundance, they had the fourth highest biomass due to two very large (78, 80 cm DW; 39.7 kg total weight) females caught in the channel at the South Ecoregion, one of which was actively pupping. Diamond stingrays had a limited distribution over time and space, as both individuals were caught during a single purse seine replicate in the channel at the South Ecoregion in July. While these individuals certainly skew the results of the ecological importance metric, it is likely that there are a significant number of individuals utilizing the large, flat, shallow, muddy substrate and elevated temperatures in the southern half of the bay.

Two large female Diamond Stingrays caught in the purse seine in the channel at the South Ecoregion during the July 2022 survey.

California Halibut (*Paralichthys californicus*)

While not a frequently caught species (0.3% of the total catch), Calfornia Halibut ranked tenth in Ecological Index as a product of being caught at all ecoregions, all depth strata, and all subhabitats, and ranking fourteenth in biomass (0.98%). About 23% of the individuals were juveniles, and the largest fish caught was just under legal size for recreational fishing purposes (Figure 23).

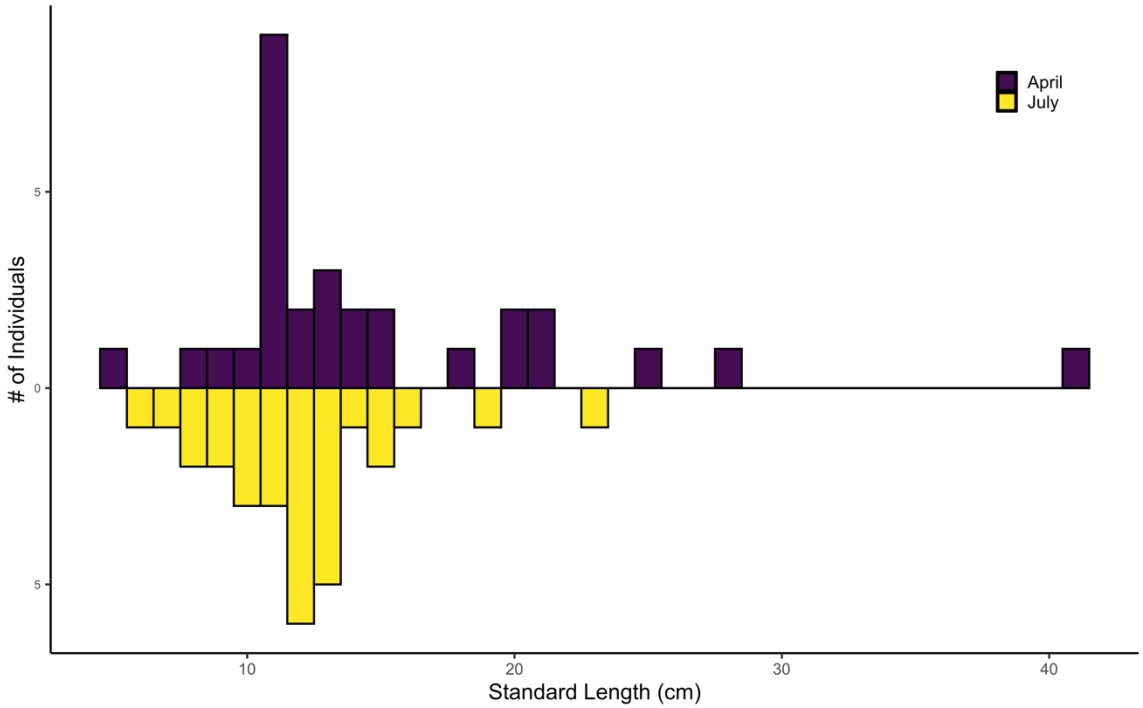


Figure 21. Total number of California Halibut individuals by standard length (cm) from San Diego Bay, April and July 2022.

4.9 Catch by Sampling Method

The greatest number of species were collected in the purse seines (35 species), followed by large seine (25) and beam trawl (25), otter trawl (19), small seine (13), and square enclosure (5; Tables 15 and 16). The purse seine captured the greatest number of fish, catching a total of 10,103, a number greatly influenced by large schools of Slough Anchovies and Topsmelt. There was an unusually large catch in the beam trawl (3,487), most of which were newly settled Kelp Pipefish and Arrow Gobies, and there were moderate catches in the large seine (2,921) and small seine (2,505), a relatively low catch in the otter trawl (577), and only 37 fish in the square enclosure (Table 15). The greatest amount of biomass was also captured in the purse seine (243.4 kg), with high biomass also captured in the otter trawl (67.0 kg) and beam trawl (40.0 kg). The large seine (20.9 kg) and small seine (1.7 kg) captured lower amounts of biomass, and the square enclosure captured only 21 g of fishes (Table 16).

The purse seine was most effective at sampling the schooling fishes (Slough Anchovy, Topsmelt). The beam trawl was most effective for catching benthic nearshore and eelgrass fishes (Kelp Pipefish, Giant Kelpfish, Shiner Perch, Dwarf Perch). The 2022 square enclosure was the most effective out of any square enclosure surveys conducted in the last two decades. The beach seines were most effective at catching juvenile Topsmelt, Dwarf Perch and Arrow Gobies. The top species caught in the otter trawls was Round Stingray. The highest density of fishes was captured in the small seine (0.842 individuals/m^2) followed by the square enclosure (0.771 individuals/m^2; Table 17). The purse seines and beam trawls produced the highest biomass density values (11.421 g/m^2 and 2.876 g/m^2, respectively). The square enclosures captured the smallest amount of biomass (0.438 g/m^2).

Purse seine crew measuring Round Stingrays during the July 2022 survey.

Table 15. Total catch (number of individuals) of fish species taken in San Diego Bay in 2022 by sampling method.

PURSE SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Anchoa delicatissima	Slough Anchovy	6,299	62.35
Atherinops affinis	Topsmelt	2,349	23.25
Cymatogaster aggregata	Shiner Perch	603	5.97
Urobatis halleri	Round Stingray	215	2.13
Paralabrax maculatofasciatus	Spotted Sand Bass	178	1.76
Micrometrus minimus	Dwarf Perch	75	0.74
Atherinopsis californiensis	Jacksmelt	67	0.66
Anchoa compressa	Deepbody Anchovy	61	0.60
Leuresthes tenuis	California Grunion	49	0.49
Seriphus politus	Queenfish	44	0.44
Syngnathus californiensis	Kelp Pipefish	33	0.33
Heterostichus rostratus	Giant Kelpfish	27	0.27
Albula gilberti	Cortez Bonefish	15	0.15
Cynoscion parvipinnis	Shortfin Corvina	15	0.15
Haemulon californiensis	Salema	15	0.15
Embiotoca jacksoni	Black Perch	11	0.11
Scomber japonicus	Pacific Chub Mackerel	9	0.09
Paralichthys californicus	California Halibut	6	0.06
Halichoeres semicinctus	Rock Wrasse	5	0.05
Sphyraena argentea	Pacific Barracuda	5	0.05
Paralabrax nebulifer	Barred Sand Bass	3	0.03
Clevelandia ios	Arrow Goby	2	0.02
Dasyatis dipterura	Diamond Stingray	2	0.02
Engraulis mordax	Northern Anchovy	2	0.02
Mugil cephalus	Striped Mullet	2	0.02
Umbrina roncador	Yellowfin Croaker	2	0.02
Cheilotrema saturnum	Black Croaker	1	< 0.01
Heterodontus francisci	Horn Shark	1	< 0.01
Mustelus californicus	Gray Smoothhound	1	< 0.01
Paralabrax clathratus	Kelp Bass	1	< 0.01
Pleuronichthys guttulatus	Diamond Turbot	1	< 0.01
Quietula y-cauda	Shadow Goby	1	< 0.01
Rhinobatos productus	Shovelnose Guitarfish	1	< 0.01
Strongylura exilis	California Needlefish	1	< 0.01
Trachurus symmetricus	Jack Mackerel	1	< 0.01
# of Species:	**35**	**10,103**	

BEAM TRAWL			
Scientific Name	**Common Name**	**Abundance**	**%**
Syngnathus californiensis	Kelp Pipefish	1,328	38.08
Heterostichus rostratus	Giant Kelpfish	1,146	32.86
Cymatogaster aggregata	Shiner Perch	325	9.32
Micrometrus minimus	Dwarf Perch	253	7.26
Urobatis halleri	Round Stingray	105	3.01
Porichthys myriaster	Specklefin Midshipman	96	2.75
Clevelandia ios	Arrow Goby	64	1.84
Anchoa delicatissima	Slough Anchovy	57	1.63
Paralabrax maculatofasciatus	Spotted Sand Bass	32	0.92
Hypsoblennius gentilis	Bay Blenny	29	0.83
Cheilotrema saturnum	Black Croaker	13	0.37
Embiotoca jacksoni	Black Perch	8	0.23
Symphurus atricaudus	California Tonguefish	6	0.17
Halichoeres semicinctus	Rock Wrasse	4	0.11
Paralichthys californicus	California Halibut	4	0.11
Cosmocampus arctus	Snubnose Pipefish	3	0.09
Paralabrax clathratus	Kelp Bass	3	0.09
Cynoscion parvipinnis	Shortfin Corvina	2	0.06
Gibbonsia elegans	Spotted Kelpfish	2	0.06
Paraclinus integripinnis	Reef Finspot	2	0.06
Alloclinus holderi	Island Kelpfish	1	0.03
Hippocampus ingens	Pacific Seahorse	1	0.03
Pleuronichthys ritteri	Spotted Turbot	1	0.03
Quietula y-cauda	Shadow Goby	1	0.03
Scorpaena guttata	California Scorpionfish	1	0.03
# of Species:	**25**	**3,487**	

Table 15 (continued).

LARGE SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Atherinops affinis	Topsmelt	1,852	63.40
Micrometrus minimus	Dwarf Perch	350	11.98
Clevelandia ios	Arrow Goby	149	5.10
Anchoa delicatissima	Slough Anchovy	115	3.94
Heterostichus rostratus	Giant Kelpfish	82	2.81
Pleuronichthys guttulatus	Diamond Turbot	71	2.43
Fundulus parvipinnis	California Killifish	68	2.33
Cymatogaster aggregata	Shiner Perch	67	2.29
Syngnathus californiensis	Kelp Pipefish	42	1.44
Urobatis halleri	Round Stingray	36	1.23
Quietula y-cauda	Shadow Goby	28	0.96
Paralichthys californicus	California Halibut	15	0.51
Leptocottus armatus	Pacific Staghorn Sculpin	11	0.38
Hyporhamphus rosae	California Halfbeak	10	0.34
Cynoscion parvipinnis	Shortfin Corvina	6	0.21
Hypsoblennius gentilis	Bay Blenny	6	0.21
Paralabrax maculatofasciatus	Spotted Sand Bass	4	0.14
Acanthogobius flavimanus	Yellowfin Goby	2	0.07
Albula gilberti	Cortez Bonefish	1	0.03
Ctenogobius sagittula	Longtail Goby	1	0.03
Embiotoca jacksoni	Black Perch	1	0.03
Gibbonsia elegans	Spotted Kelpfish	1	0.03
Ilypnus gilberti	Cheekspot Goby	1	0.03
Paralabrax clathratus	Kelp Bass	1	0.03
Strongylura exilis	California Needlefish	1	0.03
# of Species:	**25**	**2,921**	

SMALL SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Atherinops affinis	Topsmelt	1,129	45.07
Clevelandia ios	Arrow Goby	1,032	41.20
Syngnathus californiensis	Kelp Pipefish	226	9.02
Micrometrus minimus	Dwarf Perch	45	1.80
Heterostichus rostratus	Giant Kelpfish	31	1.24
Quietula y-cauda	Shadow Goby	14	0.56
Anchoa delicatissima	Slough Anchovy	8	0.32
Urobatis halleri	Round Stingray	7	0.28
Fundulus parvipinnis	California Killifish	4	0.16
Cynoscion parvipinnis	Shortfin Corvina	3	0.12
Hyporhamphus rosae	California Halfbeak	3	0.12
Pleuronichthys guttulatus	Diamond Turbot	2	0.08
Hypsoblennius gentilis	Bay Blenny	1	0.04
# of Species:	**13**	**2,505**	

Table 15 (continued).

OTTER TRAWL			
Scientific Name	**Common Name**	**Abundance**	**%**
Urobatis halleri	Round Stingray	290	50.26
Anchoa delicatissima	Slough Anchovy	172	29.81
Paralichthys californicus	California Halibut	34	5.89
Paralabrax maculatofasciatus	Spotted Sand Bass	27	4.68
Pleuronichthys ritteri	Spotted Turbot	19	3.29
Cymatogaster aggregata	Shiner Perch	10	1.73
Syngnathus californiensis	Kelp Pipefish	5	0.87
Porichthys myriaster	Specklefin Midshipman	3	0.52
Symphurus atricaudus	California Tonguefish	3	0.52
Cheilotrema saturnum	Black Croaker	2	0.35
Clevelandia ios	Arrow Goby	2	0.35
Pleuronichthys guttulatus	Diamond Turbot	2	0.35
Xystreurys liolepis	Fantail Sole	2	0.35
Citharichthys stigmaeus	Speckled Sanddab	1	0.17
Paraclinus integripinnis	Reef Finspot	1	0.17
Paralabrax nebulifer	Barred Sand Bass	1	0.17
Pleuronichthys decurrens	Curlfin Sole	1	0.17
Synodus lucioceps	California Lizardfish	1	0.17
Zapteryx exasperata	Banded Guitarfish	1	0.17
# of Species:	**19**	**577**	

SQUARE ENCLOSURE			
Scientific Name	**Common Name**	**Abundance**	**%**
Clevelandia ios	Arrow Goby	23	62.2
Ilypnus gilberti	Cheekspot Goby	6	16.2
Heterostichus rostratus	Giant Kelpfish	4	10.8
Syngnathus californiensis	Kelp Pipefish	3	8.1
Quietula y-cauda	Shadow Goby	1	2.7
# of Species:	**5**	**37**	

Table 16. Total biomass (g) of fish species taken from San Diego Bay in 2022 by sampling method.

PURSE SEINE			
Scientific Name	Common Name	Biomass (g)	%
Urobatis halleri	Round Stingray	49,450	20.32
Paralabrax maculatofasciatus	Spotted Sand Bass	45,751	18.80
Atherinops affinis	Topsmelt	42,827	17.60
Dasyatis dipterura	Diamond Stingray	39,700	16.31
Anchoa delicatissima	Slough Anchovy	13,150	5.40
Rhinobatos productus	Shovelnose Guitarfish	12,500	5.14
Cynoscion parvipinnis	Shortfin Corvina	5,521	2.27
Albula gilberti	Cortez Bonefish	5,500	2.26
Atherinopsis californiensis	Jacksmelt	4,975	2.04
Seriphus politus	Queenfish	4,500	1.85
Cymatogaster aggregata	Shiner Perch	3,529	1.45
Mugil cephalus	Striped Mullet	2,900	1.19
Sphyraena argentea	Pacific Barracuda	2,200	0.90
Haemulon californiensis	Salema	1,696	0.70
Umbrina roncador	Yellowfin Croaker	1,500	0.62
Scomber japonicus	Pacific Chub Mackerel	1,125	0.46
Mustelus californicus	Gray Smoothhound	1,100	0.45
Anchoa compressa	Deepbody Anchovy	1,047	0.43
Halichoeres semicinctus	Rock Wrasse	964	0.40
Strongylura exilis	California Needlefish	800	0.33
Paralichthys californicus	California Halibut	562	0.23
Heterodontus francisci	Horn Shark	500	0.21
Micrometrus minimus	Dwarf Perch	399	0.16
Embiotoca jacksoni	Black Perch	274	0.11
Paralabrax nebulifer	Barred Sand Bass	261	0.11
Pleuronichthys guttulatus	Diamond Turbot	250	0.10
Leuresthes tenuis	California Grunion	155	0.06
Heterostichus rostratus	Giant Kelpfish	151	0.06
Syngnathus californiensis	Kelp Pipefish	31	0.01
Trachurus symmetricus	Jack Mackerel	30	0.01
Paralabrax clathratus	Kelp Bass	28	0.01
Cheilotrema saturnum	Black Croaker	21	< 0.01
Clevelandia ios	Arrow Goby	2	< 0.01
Engraulis mordax	Northern Anchovy	2	< 0.01
Quietula y-cauda	Shadow Goby	1	< 0.01
# of Species:	**35**	**243,402**	

BEAM TRAWL			
Scientific Name	Common Name	Biomass (g)	%
Urobatis halleri	Round Stingray	22,610	56.47
Paralabrax maculatofasciatus	Spotted Sand Bass	8,150	20.36
Heterostichus rostratus	Giant Kelpfish	4,408	11.01
Micrometrus minimus	Dwarf Perch	1,809	4.52
Cymatogaster aggregata	Shiner Perch	755	1.89
Syngnathus californiensis	Kelp Pipefish	699	1.74
Hypsoblennius gentilis	Bay Blenny	389	0.97
Paralabrax clathratus	Kelp Bass	389	0.97
Porichthys myriaster	Specklefin Midshipman	267	0.67
Cheilotrema saturnum	Black Croaker	149	0.37
Embiotoca jacksoni	Black Perch	122	0.30
Clevelandia ios	Arrow Goby	74	0.18
Symphurus atricaudus	California Tonguefish	50	0.12
Hippocampus ingens	Pacific Seahorse	45	0.11
Paralichthys californicus	California Halibut	34	0.08
Pleuronichthys ritteri	Spotted Turbot	27	0.07
Anchoa delicatissima	Slough Anchovy	21	0.05
Scorpaena guttata	California Scorpionfish	15	0.04
Gibbonsia elegans	Spotted Kelpfish	11	0.03
Halichoeres semicinctus	Rock Wrasse	5	0.01
Cosmocampus arctus	Snubnose Pipefish	2	< 0.01
Cynoscion parvipinnis	Shortfin Corvina	2.0	< 0.01
Paraclinus integripinnis	Reef Finspot	2.0	< 0.01
Alloclinus holderi	Island Kelpfish	1.0	< 0.01
Quietula y-cauda	Shadow Goby	1.0	< 0.01
# of Species:	**25**	**40,037**	

Table 16 (continued).

LARGE SEINE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	9,088	43.47
Atherinops affinis	Topsmelt	7,100	33.96
Micrometrus minimus	Dwarf Perch	1,154	5.52
Paralabrax maculatofasciatus	Spotted Sand Bass	782	3.74
Heterostichus rostratus	Giant Kelpfish	622	2.98
Pleuronichthys guttulatus	Diamond Turbot	500	2.39
Fundulus parvipinnis	California Killifish	405	1.94
Paralichthys californicus	California Halibut	400	1.91
Cymatogaster aggregata	Shiner Perch	218	1.04
Paralabrax clathratus	Kelp Bass	150	0.72
Anchoa delicatissima	Slough Anchovy	128	0.61
Leptocottus armatus	Pacific Staghorn Sculpin	82	0.39
Hypsoblennius gentilis	Bay Blenny	60	0.29
Clevelandia ios	Arrow Goby	51	0.24
Embiotoca jacksoni	Black Perch	34	0.16
Syngnathus californiensis	Kelp Pipefish	33	0.16
Ctenogobius sagittula	Longtail Goby	23	0.11
Hyporhamphus rosae	California Halfbeak	17	0.08
Quietula y-cauda	Shadow Goby	17	0.08
Cynoscion parvipinnis	Shortfin Corvina	16	0.08
Albula gilberti	Cortez Bonefish	12	0.06
Acanthogobius flavimanus	Yellowfin Goby	11	0.05
Gibbonsia elegans	Spotted Kelpfish	1	< 0.01
Ilypnus gilberti	Cheekspot Goby	1	< 0.01
Strongylura exilis	California Needlefish	1	< 0.01
# of Species:	**25**	**20,906**	

SMALL SEINE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	944	53.30
Atherinops affinis	Topsmelt	236	13.33
Clevelandia ios	Arrow Goby	207	11.69
Micrometrus minimus	Dwarf Perch	172	9.71
Syngnathus californiensis	Kelp Pipefish	108	6.10
Heterostichus rostratus	Giant Kelpfish	48	2.71
Fundulus parvipinnis	California Killifish	24	1.36
Pleuronichthys guttulatus	Diamond Turbot	20	1.13
Quietula y-cauda	Shadow Goby	5	0.28
Anchoa delicatissima	Slough Anchovy	2	0.11
Cynoscion parvipinnis	Shortfin Corvina	2	0.11
Hyporhamphus rosae	California Halfbeak	2	0.11
Hypsoblennius gentilis	Bay Blenny	1	0.06
# of Species:	**13**	**1,771**	

Table 16 (continued).

OTTER TRAWL			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	50,254	75.06
Zapteryx exasperata	Banded Guitarfish	6,700	10.01
Paralabrax maculatofasciatus	Spotted Sand Bass	5,290	7.90
Paralichthys californicus	California Halibut	2,669	3.99
Pleuronichthys guttulatus	Diamond Turbot	354	0.53
Pleuronichthys ritteri	Spotted Turbot	335	0.50
Cheilotrema saturnum	Black Croaker	310	0.46
Xystreurys liolepis	Fantail Sole	310	0.46
Porichthys myriaster	Specklefin Midshipman	271	0.40
Cymatogaster aggregata	Shiner Perch	147	0.22
Synodus lucioceps	California Lizardfish	92	0.14
Symphurus atricaudus	California Tonguefish	85	0.13
Paralabrax nebulifer	Barred Sand Bass	51	0.08
Anchoa delicatissima	Slough Anchovy	48	0.07
Pleuronichthys decurrens	Curlfin Sole	30	0.04
Syngnathus californiensis	Kelp Pipefish	4	0.01
Citharichthys stigmaeus	Speckled Sanddab	2	< 0.01
Clevelandia ios	Arrow Goby	2	< 0.01
Paraclinus integripinnis	Reef Finspot	1	< 0.01
# of Species:	**19**	**66,955**	

SQUARE ENCLOSURE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Clevelandia ios	Arrow Goby	9	42.9
Heterostichus rostratus	Giant Kelpfish	6	28.6
Syngnathus californiensis	Kelp Pipefish	3	14.3
Ilypnus gilberti	Cheekspot Goby	2.0	9.5
Quietula y-cauda	Shadow Goby	1.0	4.8
# of Species:	**5**	**21.0**	

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
	2022	0.251	0.010	0.474	0.277	0.842	0.771

	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
	2022	2.876	1.154	11.421	1.980	0.595	0.438

4.10 Best Estimates of Density and Standing Stock

The best estimate for the total stock size was 28,727,027 fishes (Table 18). With an estimated surface area of 4,858 ha (Table 2) this gives an overall fish density 0.59 individuals/m^2 (Table 18). The highest estimates were of Slough Anchovy (13.08 million) and Topsmelt (5.49 million), followed by Kelp Pipefish (2.79 million), Giant Kelpfish (2.44 million), and Shiner Perch (1.19 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 552 metric tons (MT) (Table 19). This gives an overall estimate of 11.36 g/m^2, about 24% higher than the 2019 estimate and above average for all historical surveys (Williams et al. 2019). The highest biomass estimates were of Diamond Stingray (105.9 MT), followed by Round Stingray (103.8 MT), Spotted Sand Bass (91 MT), Topsmelt (88.2 MT), and Shovelnose Guitarfish (33.3 MT). Round Stingray, Spotted Sand Bass and Topsmelt are typically in the top five biomass estimates from past surveys, but Diamond Stingray is a historically atypical top biomass species, and this standing stock estimate is solely based upon the catch of just two individuals.

Table 18. Best estimate of densities (#/m^2) and stock estimates, April and July 2022.

		Best Estimate of Density (#/m^2) Depth Strata				
Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate (#)
Anchoa delicatissima	Slough Anchovy	0.15315	0.01089	0.36677	0.26922	13,078,781
Atherinops affinis	Topsmelt	0.03350	0.37937	0.14858	0.11293	5,486,150
Syngnathus californiensis	Kelp Pipefish	0.00028	0.07594	0.09540	0.05753	2,794,649
Heterostichus rostratus	Giant Kelpfish	0.00014	0.08333	0.08233	0.05031	2,444,301
Cymatogaster aggregata	Shiner Perch	0.00017	0.00634	0.04244	0.02451	1,190,809
Clevelandia ios	Arrow Goby	0.00003	0.47917	0.00460	0.02180	1,059,083
Micrometrus minimus	Dwarf Perch		0.03314	0.01818	0.01169	567,690
Urobatis halleri	Round Stingray	0.00563	0.00341	0.01232	0.00935	454,369
Paralabrax maculatofasciatus	Spotted Sand Bass	0.00113	0.00038	0.01197	0.00727	353,392
Ilypnus gilberti	Cheekspot Goby		0.12500		0.00500	242,900
Porichthys myriaster	Specklefin Midshipman	0.00005		0.00690	0.00395	191,949
Atherinopsis californiensis	Jacksmelt			0.00472	0.00269	130,579
Anchoa compressa	Deepbody Anchovy	0.00127		0.00366	0.00258	125,348
Leuresthes tenuis	California Grunion	0.00014		0.00338	0.00198	96,216
Seriphus politus	Queenfish			0.00310	0.00177	85,754
Hypsoblennius gentilis	Bay Blenny		0.00057	0.00208	0.00121	58,793
Quietula y-cauda	Shadow Goby		0.02083	0.00007	0.00087	42,473
Albula gilberti	Cortez Bonefish	0.00155	0.00009	0.00028	0.00077	37,317
Cynoscion parvipinnis	Shortfin Corvina		0.00101	0.00106	0.00064	31,193
Haemulon californiensis	Salema			0.00106	0.00060	29,234
Cheilotrema saturnum	Black Croaker	0.00003		0.00093	0.00055	26,514
Paralichthys californicus	California Halibut	0.00059	0.00142	0.00029	0.00045	21,822
Embiotoca jacksoni	Black Perch		0.00009	0.00077	0.00045	21,622
Scomber japonicus	Pacific Chub Mackerel	0.00028		0.00049	0.00039	18,977
Pleuronichthys guttulatus	Diamond Turbot	0.00003	0.00672	0.00007	0.00032	15,667
Symphurus atricaudus	California Tonguefish	0.00005		0.00043	0.00027	12,915
Fundulus parvipinnis	California Killifish		0.00644		0.00026	12,513
Halichoeres semicinctus	Rock Wrasse			0.00035	0.00020	9,745
Sphyraena argentea	Pacific Barracuda			0.00035	0.00020	9,745
Pleuronichthys ritteri	Spotted Turbot	0.00033		0.00007	0.00017	8,195
Paralabrax nebulifer	Barred Sand Bass	0.00002		0.00021	0.00013	6,173
Paralabrax clathratus	Kelp Bass		0.00009	0.00022	0.00013	6,152
Cosmocampus arctus	Snubnose Pipefish			0.00022	0.00012	5,968
Dasyatis dipterura	Diamond Stingray	0.00028			0.00011	5,334
Mugil cephalus	Striped Mullet	0.00014		0.00007	0.00010	4,616
Paraclinus integripinnis	Reef Finspot	0.00002		0.00014	0.00009	4,305
Gibbonsia elegans	Spotted Kelpfish		0.00009	0.00014	0.00009	4,163
Engraulis mordax	Northern Anchovy			0.00014	0.00008	3,898
Umbrina roncador	Yellowfin Croaker			0.00014	0.00008	3,898
Strongylura exilis	California Needlefish	0.00014	0.00009		0.00006	2,851
Rhinobatos productus	Shovelnose Guitarfish	0.00014			0.00005	2,667
Leptocottus armatus	Pacific Staghorn Sculpin		0.00104		0.00004	2,024
Alloclinus holderi	Island Kelpfish			0.00007	0.00004	1,989
Hippocampus ingens	Pacific Seahorse			0.00007	0.00004	1,989
Scorpaena guttata	California Scorpionfish			0.00007	0.00004	1,989
Hyporhamphus rosae	California Halfbeak		0.00101		0.00004	1,959
Heterodontus francisci	Horn Shark			0.00007	0.00004	1,949
Mustelus californicus	Gray Smoothhound			0.00007	0.00004	1,949
Trachurus symmetricus	Jack Mackerel			0.00007	0.00004	1,949
Xystreurys liolepis	Fantail Sole	0.00003			0.00001	653
Acanthogobius flavimanus	Yellowfin Goby		0.00019		0.00001	368
Citharichthys stigmaeus	Speckled Sanddab	0.00002			0.00001	327
Pleuronichthys decurrens	Curlfin Sole	0.00002			0.00001	327
Synodus lucioceps	California Lizardfish	0.00002			0.00001	327
Zapteryx exasperata	Banded Guitarfish	0.00002			0.00001	327
Ctenogobius sagittula	Longtail Goby		0.00009		< 0.00001	184
	Grand Totals:	**0.19921**	**1.23678**	**0.81434**	**0.59133**	**28,727,027**

Table 19. Best estimate of biomass densities (g/m^2) and standing stock, April and July 2022.

		Best Estimate of Density (g/m^2) Depth Strata					
Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
Dasyatis dipterura	Diamond Stingray	5.58840			2.17948	105,879	105.9
Urobatis halleri	Round Stingray	1.12331	0.86061	2.91878	2.13622	103,778	103.8
Paralabrax maculatofasciatus	Spotted Sand Bass	0.33784	0.07405	3.05117	1.87388	91,033	91.0
Atherinops affinis	Topsmelt	0.67680	0.67235	2.67589	1.81610	88,226	88.2
Rhinobatos productus	Shovelnose Guitarfish	1.75957			0.68623	33,337	33.3
Anchoa delicatissima	Slough Anchovy	0.33319	0.01212	0.75894	0.56302	27,352	27.4
Albula gilberti	Cortez Bonefish	0.49268	0.00114	0.14077	0.27243	13,235	13.2
Cynoscion parvipinnis	Shortfin Corvina		0.00152	0.38858	0.22155	10,763	10.7
Atherinopsis californiensis	Jacksmelt			0.35015	0.19959	9,696	9.70
Heterostichus rostratus	Giant Kelpfish	0.00056	0.12500	0.31667	0.18572	9,022	9.02
Seriphus politus	Queenfish			0.31672	0.18053	8,770	8.77
Cymatogaster aggregata	Shiner Perch	0.00253	0.02064	0.24838	0.14339	6,966	6.97
Mugil cephalus	Striped Mullet	0.16892		0.11965	0.13408	6,514	6.51
Sphyraena argentea	Pacific Barracuda			0.15484	0.08826	4,288	4.29
Micrometrus minimus	Dwarf Perch		0.10928	0.12996	0.07845	3,811	3.81
Haemulon californiensis	Salema			0.11937	0.06804	3,305	3.31
Umbrina roncador	Yellowfin Croaker			0.10557	0.06018	2,923	2.92
Scomber japonicus	Pacific Chub Mackerel	0.03026		0.06405	0.04831	2,347	2.35
Zapteryx exasperata	Banded Guitarfish	0.11550			0.04505	2,188	2.19
Mustelus californicus	Gray Smoothhound			0.07742	0.04413	2,144	2.14
Anchoa compressa	Deepbody Anchovy	0.01830		0.06454	0.04393	2,134	2.13
Strongylura exilis	California Needlefish	0.11261	0.00009		0.04392	2,134	2.13
Halichoeres semicinctus	Rock Wrasse			0.06785	0.03867	1,879	1.88
Syngnathus californiensis	Kelp Pipefish	0.00014	0.06250	0.05018	0.03116	1,514	1.51
Paralichthys californicus	California Halibut	0.04716	0.03788	0.01598	0.02901	1,409	1.41
Heterodontus francisci	Horn Shark			0.03519	0.02006	974	0.97
Paralabrax clathratus	Kelp Bass		0.01420	0.02795	0.01650	801	0.80
Hypsoblennius gentilis	Bay Blenny		0.00568	0.02795	0.01616	785	0.78
Pleuronichthys guttulatus	Diamond Turbot	0.00610	0.04735	0.01760	0.01430	695	0.69
Porichthys myriaster	Specklefin Midshipman	0.00467		0.01918	0.01276	620	0.62
Embiotoca jacksoni	Black Perch		0.00322	0.01928	0.01112	540	0.54
Paralabrax nebulifer	Barred Sand Bass	0.00088		0.01837	0.01081	525	0.53
Clevelandia ios	Arrow Goby	0.00003	0.18750	0.00532	0.01054	512	0.51
Cheilotrema saturnum	Black Croaker	0.00534		0.01070	0.00819	398	0.40
Leuresthes tenuis	California Grunion	0.00225		0.00978	0.00645	314	0.31
Pleuronichthys ritteri	Spotted Turbot	0.00578		0.00194	0.00336	163	0.16
Symphurus atricaudus	California Tonguefish	0.00147		0.00359	0.00262	127	0.13
Xystreurys liolepis	Fantail Sole	0.00534			0.00208	101	0.10
Hippocampus ingens	Pacific Seahorse			0.00323	0.00184	90	0.09
Ilypnus gilberti	Cheekspot Goby		0.04167		0.00167	81	0.08
Fundulus parvipinnis	California Killifish		0.03835		0.00153	75	0.07
Trachurus symmetricus	Jack Mackerel			0.00211	0.00120	58	0.06
Quietula y-cauda	Shadow Goby		0.02083	0.00007	0.00087	42	0.04
Synodus lucioceps	California Lizardfish	0.00159			0.00062	30	0.03
Scorpaena guttata	California Scorpionfish			0.00108	0.00061	30	0.03
Gibbonsia elegans	Spotted Kelpfish		0.00009	0.00079	0.00045	22	0.02
Leptocottus armatus	Pacific Staghorn Sculpin		0.00777		0.00031	15	0.02
Pleuronichthys decurrens	Curlfin Sole	0.00052			0.00020	10	0.01
Paraclinus integripinnis	Reef Finspot	0.00002		0.00014	0.00009	4	< 0.01
Ctenogobius sagittula	Longtail Goby		0.00218		0.00009	4	< 0.01
Cosmocampus arctus	Snubnose Pipefish			0.00014	0.00008	4	< 0.01
Engraulis mordax	Northern Anchovy			0.00014	0.00008	4	< 0.01
Hyporhamphus rosae	California Halfbeak		0.00161		0.00006	3	< 0.01
Acanthogobius flavimanus	Yellowfin Goby		0.00104		0.00004	2	< 0.01
Alloclinus holderi	Island Kelpfish			0.00007	0.00004	2	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	0.00003			0.00001	1	< 0.01
	Grand Totals:	**10.84181**	**2.34867**	**12.34009**	**11.35610**	**551,680**	**551.7**

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 and Slough Anchovy that were primarily found at small (juvenile) size classes (< 50 mm SL) appropriate for nesting birds in the area to feed their young. The typical timing for the recruitment of fishes to San Diego Bay begins in the spring and continues through the summer which appears to be consistent in 2022. The biomass standing stock estimate for forage fish was 106.6 MT. When estimating by ecoregion, values were highest at the North Ecoregion (47.8 MT) which was driven by Topsmelt. This was followed by the South-Central Ecoregion (31.6 MT), the North-Central Ecoregion (17.5 MT), and the South Ecoregion (9.7 MT; Table 20).

Shiner Perch captured with the purse seine net at the North Ecoregion during the July 2022 survey.

Topsmelt (top) and Grunion (bottom) collected by the purse seine in the North-Central Ecoregion during the April 2022 survey.

Table 20. Best estimate of biomass standing stock for forage fish species by ecoregion, 2022.

Ecoregion	Scientific Name	Common Name	Depth Strata			Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
			Channel	Intertidal	Nearshore			
North	*Atherinops affinis*	Topsmelt	1.97072	1.29924	8.57798	4.11083	40,368	40.4
	Micrometrus minimus	Dwarf Perch		0.43712	0.51983	0.19777	1,942	1.94
	Scomber japonicus	Pacific Chub Mackerel	0.12106		0.19707	0.13888	1,364	1.36
	Heterostichus rostratus	Giant Kelpfish		0.16894	0.37960	0.13540	1,330	1.33
	Atherinopsis californiensis	Jacksmelt			0.40541	0.13378	1,314	1.31
	Cymatogaster aggregata	Shiner Perch		0.03598	0.36008	0.12099	1,188	1.19
	Leuresthes tenuis	California Grunion	0.00901		0.02534	0.01386	136	0.14
	Clevelandia ios	Arrow Goby		0.08333	0.02011	0.01164	114	0.11
	Anchoa delicatissima	Slough Anchovy			0.00056	0.00019	2	0.00
	Engraulis mordax	Northern Anchovy			0.00056	0.00019	2	0.00
		Grand Total:	**2.10079**	**2.02462**	**10.48654**	**4.86352**	**47,760**	**47.8**
North-Central	*Atherinops affinis*	Topsmelt	0.31813	0.45189	1.73255	0.86230	6,967	6.97
	Anchoa delicatissima	Slough Anchovy		0.04811	1.20439	0.46007	3,717	3.72
	Atherinopsis californiensis	Jacksmelt			0.99521	0.37818	3,056	3.06
	Heterostichus rostratus	Giant Kelpfish		0.50000	0.84253	0.34516	2,789	2.79
	Cymatogaster aggregata	Shiner Perch			0.25619	0.09735	787	0.79
	Scomber japonicus	Pacific Chub Mackerel			0.05912	0.02247	182	0.18
	Leuresthes tenuis	California Grunion			0.01380	0.00524	42	0.04
	Anchoa compressa	Deepbody Anchovy			0.00113	0.00043	3	0.00
	Clevelandia ios	Arrow Goby		0.00403	0.00057	0.00042	3	0.00
		Grand Total:	**0.31813**	**1.00403**	**5.10549**	**2.17162**	**17,547**	**17.5**
South-Central	*Anchoa delicatissima*	Slough Anchovy	0.56025	0.00269	1.36346	1.03348	20,721	20.72
	Atherinops affinis	Topsmelt	0.30574	0.31402	0.10220	0.18183	3,646	3.65
	Anchoa compressa	Deepbody Anchovy	0.04786		0.25338	0.17179	3,444	3.44
	Cymatogaster aggregata	Shiner Perch		0.03750	0.24775	0.15225	3,053	3.05
	Heterostichus rostratus	Giant Kelpfish	0.00225	0.01098	0.03851	0.02463	494	0.49
	Clevelandia ios	Arrow Goby	0.00007	0.33333	0.00057	0.01038	208	0.21
	Hyporhamphus rosae	California Halfbeak		0.00269		0.00008	2	0.00
	Fundulus parvipinnis	California Killifish		0.00227		0.00007	1	0.00
		Grand Total:	**0.91617**	**0.70348**	**2.00586**	**1.57450**	**31,569**	**31.6**
South	*Anchoa delicatissima*	Slough Anchovy	0.77252		0.46734	0.48832	5,196	5.20
	Atherinops affinis	Topsmelt	0.11261	0.62424	0.29082	0.28099	2,990	2.99
	Cymatogaster aggregata	Shiner Perch	0.01014	0.00909	0.12950	0.10917	1,162	1.16
	Clevelandia ios	Arrow Goby	0.00007	0.33333	0.00056	0.01381	147	0.15
	Anchoa compressa	Deepbody Anchovy	0.02534		0.00366	0.00633	67	0.07
	Fundulus parvipinnis	California Killifish		0.15114		0.00605	64	0.06
	Heterostichus rostratus	Giant Kelpfish			0.00603	0.00501	53	0.05
	Hyporhamphus rosae	California Halfbeak		0.00379		0.00015	2	0.00
		Grand Total:	**0.92068**	**1.12159**	**0.89793**	**0.90983**	**9,681**	**9.7**

4.12 Fisheries Species

During this study, 14 species were captured that have importance in either the recreational or commercial fisheries in California. The most abundant fisheries species were Spotted Sand Bass, California Halibut and Queenfish. Including all ecoregions, standing stock estimates of fisheries species totaled 123 MT. When estimating by ecoregion values were greatest at the South-Central Ecoregion (67.3 MT), this time driven by Spotted Sand Bass, Queenfish and Cortez Bonefish. Stock estimates were next highest in the South Ecoregion (23.8 MT) and the North Ecoregion (16.3 MT), both driven almost exclusively by Spotted Sand Bass. The North-Central Ecoregion had the smallest stock estimate at 15.6 MT (Table 21).

Table 21. Best estimate of biomass standing stock for recreational/commercial fishery species by ecoregion, 2022.

			Depth Strata					
Ecoregion	Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
North	*Paralabrax maculatofasciatus*	Spotted Sand Bass			4.26295	1.40677	13,815	13.8
	Scomber japonicus	Pacific Chub Mackerel	0.12106		0.19707	0.13888	1,364	1.36
	Umbrina roncador	Yellowfin Croaker			0.16892	0.05574	547	0.55
	Embiotoca jacksoni	Black Perch		0.01288	0.07714	0.02623	258	0.26
	Paralichthys californicus	California Halibut	0.00862	0.02045	0.05349	0.02414	237	0.24
	Paralabrax clathratus	Kelp Bass			0.00788	0.00260	26	0.03
	Paralabrax nebulifer	Barred Sand Bass	0.00352			0.00215	21	0.02
	Engraulis mordax	Northern Anchovy			0.00056	0.00019	2	< 0.01
		Grand Total:	**0.13319**	**0.03333**	**4.76802**	**1.65669**	**16,269**	**16.3**
North-Central	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.02689	0.06250	2.46199	0.95401	7,708	7.71
	Cynoscion parvipinnis	Shortfin Corvina			1.46396	0.55631	4,495	4.49
	Sphyraena argentea	Pacific Barracuda			0.61937	0.23536	1,902	1.90
	Umbrina roncador	Yellowfin Croaker			0.25338	0.09628	778	0.78
	Paralabrax clathratus	Kelp Bass			0.11092	0.04215	341	0.34
	Scomber japonicus	Pacific Chub Mackerel			0.05912	0.02247	182	0.18
	Paralabrax nebulifer	Barred Sand Bass			0.02843	0.01081	87	0.09
	Paralichthys californicus	California Halibut	0.01117	0.01250	0.00788	0.00999	81	0.08
	Cheilotrema saturnum	Black Croaker			0.01466	0.00557	45	0.04
	Scorpaena guttata	California Scorpionfish			0.00431	0.00164	13	0.01
		Grand Total:	**0.03806**	**0.07500**	**5.02403**	**1.93458**	**15,631**	**15.6**
South-Central	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.15963	0.00644	3.36289	2.10903	42,286	42.29
	Seriphus politus	Queenfish			1.26689	0.77280	15,495	15.49
	Albula gilberti	Cortez Bonefish		0.00455	0.56306	0.34360	6,889	6.89
	Paralichthys californicus	California Halibut	0.15736	0.11856		0.06021	1,207	1.21
	Cynoscion parvipinnis	Shortfin Corvina		0.00269	0.09037	0.05521	1,107	1.11
	Cheilotrema saturnum	Black Croaker			0.02816	0.01718	344	0.34
		Grand Total:	**0.31699**	**0.13223**	**5.31138**	**3.35803**	**67,328**	**67.3**
South	*Paralabrax maculatofasciatus*	Spotted Sand Bass	1.23874	0.22727	2.11684	1.92710	20,504	20.50
	Albula gilberti	Cortez Bonefish	1.97072			0.25619	2,726	2.73
	Paralabrax nebulifer	Barred Sand Bass			0.04505	0.03739	398	0.40
	Paralichthys californicus	California Halibut	0.07601		0.00253	0.01198	128	0.13
	Cheilotrema saturnum	Black Croaker	0.02138			0.00278	30	0.03
	Paralabrax clathratus	Kelp Bass		0.05682		0.00227	24	0.02
	Cynoscion parvipinnis	Shortfin Corvina		0.00455		0.00018	2	< 0.01
		Grand Total:	**3.30685**	**0.28864**	**2.16441**	**2.23790**	**23,811**	**23.8**

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, eight species [Cortez Bonefish, Longtail Goby (*Ctenogobius* sagittula), Shortfin Corvina (*Cynoscion* parvipinnis), Diamond Stingray, Pacific Seahorse (*Hippocampus ingens*), California Halfbeak (*Hyporhamphus rosae*), California Needlefish (*Strongylura exilis*), and the largest Banded Guitarfish (*Zapteryx exasperata*; 96 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)

Juvenile Cortez Bonefish caught by Large Seine in the South-Central Ecoregion in July 2022.

Table 23. Abundance of Panamic species collected in San Diego Bay by ecoregion, April and July 2022.

		Ecoregions							
		North		North-Central		South-Central		South	
Scientific Name	Common Name	*April*	*July*	*April*	*July*	*April*	*July*	*April*	*July*
Albula gilberti	Cortez Bonefish					4	1	11	
Ctenogobius sagittula	Longtail Goby							1	
Cynoscion parvipinnis	Shortfin Corvina			13		1	7		5
Dasyatis dipterura	Diamond Stingray								2
Hippocampus ingens	Pacific Seahorse					1			
Hyporhamphus rosae	California Halfbeak					1	4	3	5
Strongylura exilis	California Needlefish				1			1	
Zapteryx exasperata	Banded Guitarfish					1			

Pacific Seahorse captured in the beam trawl in the South-Central Ecoregion during the April 2022 survey.

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 just under half (45.8%) 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 51.1% of the total catch in this survey (Table 24).

Table 24. Indigenous bay/estuarine species taken in San Diego Bay by ecoregion in 2022.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total	%
Anchoa delicatissima	Slough Anchovy	1,756	3,074	1,820	1	6,651	33.19
Syngnathus californiensis	Kelp Pipefish	138	630	610	259	1,637	8.17
Clevelandia ios	Arrow Goby	52	594	557	69	1,272	6.35
Paralabrax maculatofasciatus	Spotted Sand Bass	52	76	63	50	241	1.20
Fundulus parvipinnis	California Killifish		1	71		72	0.36
Anchoa compressa	Deepbody Anchovy	1	57	3		61	0.30
Quietula y-cauda	Shadow Goby	2	9	34		45	0.22
Hypsoblennius gentilis	Bay Blenny	22		2	12	36	0.18
Ilypnus gilberti	Cheekspot Goby		7			7	0.03
Mugil cephalus	Striped Mullet		1	3		4	0.01
	Total % of catch:	**42.5%**	**82.3%**	**59.0%**	**9.5%**		**51.1%**

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 reduce 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, 2019, or 2022 (Williams et al. 2015, Williams et al. 2016, Williams et al. 2019). 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, one was captured in 2019 in the North Ecoregion, and two were caught in the South Ecoregion in 2022. 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. Both species thrive in fresh to brackish water environments. The winter of 2021-2022 did not produce heavy rainfall, and the prolonged drought period in southern California from 2012-2016 and subsequent years of minimal winter rainfall could also explain the infrequent capture of either species over the last decade.

Invasive Yellowfin Goby captured by large seine at the South Ecoregion in July 2022.

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 2022 sampling periods were also compared to values from 1995-1998, 2005, 2008, 2012, 2015, 2016, and 2019. The 2022 surveys represent an average catch compared to surveys conducted within last two decades and the biomass captured was slightly above average for all historical surveys (Tables 25-28; Figures 25-28). Total abundance was heavily influenced by large schools of forage fishes, as is common in historical surveys. Estimates of biomass were about average among all surveys in every ecoregion except the South Ecoregion, which reported the highest biomass catch at that ecoregion out of any sampling year at 109.8 kg. However, 52.2 kg of this total can be attributed to the catch of two large Diamond Stingrays and a large Shovelnose Guitarfish. The 2022 stock estimate was less than 35% of the mean number of individuals while the biomass standing stock estimate was 30% above average (Table 29), a product of capturing fewer, but larger, fish throughout the survey.

Spotted Sandbass (29 cm SL) caught by beam trawl during the April 2022 survey at the South Ecoregion.

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**	**2022**
North	59,178	91,176	8,978	14,486	4,237	7,233	4,244	10,240	5,158	6,238	4,759
North-Central	19,523	112,964	8,718	11,603	12,539	3,354	5,645	5,874	7,932	4,005	5,408
South-Central	22,403	3,623	10,659	8,267	2,346	2,666	3,422	4,789	3,001	2,233	4,098
South	5,063	3,153	4,735	14,738	5,337	2,438	3,952	3,240	5,036	1,548	5,365
Total:	**106,167**	**210,916**	**33,090**	**49,094**	**24,459**	**15,691**	**17,263**	**24,143**	**21,127**	**14,024**	**19,630**

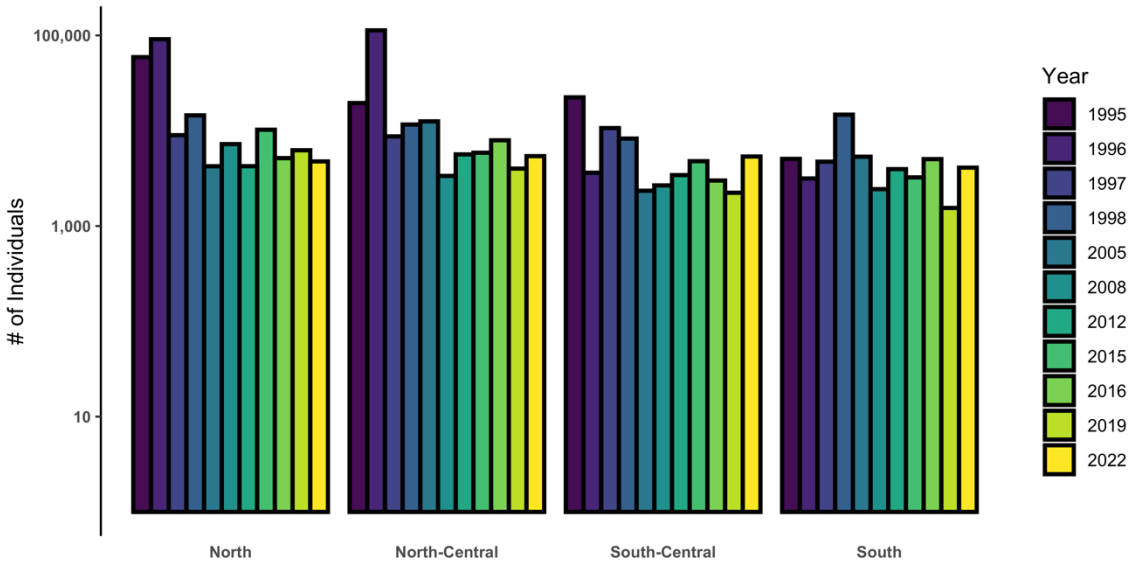


Figure 22. Total abundance by ecoregion and sampling year. Results were calculated for years that were sampled in April and July and only includes data from those sampling months.

Kelp Pipefish (above) and Snubnose Pipefish (*Cosmocampus arctus*) (below) from the beam trawl at the North Ecoregion in July 2022.

Table 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.

	Sampling Years										
Common Name	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**	**2019**	**2022**
Northern Anchovy	52,389	147,173	3	8,373	1,397	10	0	6,666	1,205	0	2
Topsmelt	25,272	33,915	12,917	9,232	7,448	3,393	6,529	2,024	4,136	8,044	5,330
Slough Anchovy	16,821	16,616	11,029	27,790	11,219	5,538	1,566	7,957	8,825	1,266	6,651
Shiner Perch	3,998	3,222	2,794	336	1,180	1,700	2,174	915	199	536	1,005
Arrow Goby	401	339	104	73	62	927	2,438	629	1,749	52	1,272
California Grunion	0	739	3,136	1,123	186	0	0	1,608	965	32	49
Kelp Pipefish	28	1	0	0	371	673	488	1,065	1,105	431	1,637
Deepbody Anchovy	69	221	29	5	2	72	17	80	30	1,033	61
Other	7,217	8,691	3,078	2,162	2,965	4,051	4,539	4,264	4,018	3,061	3,623

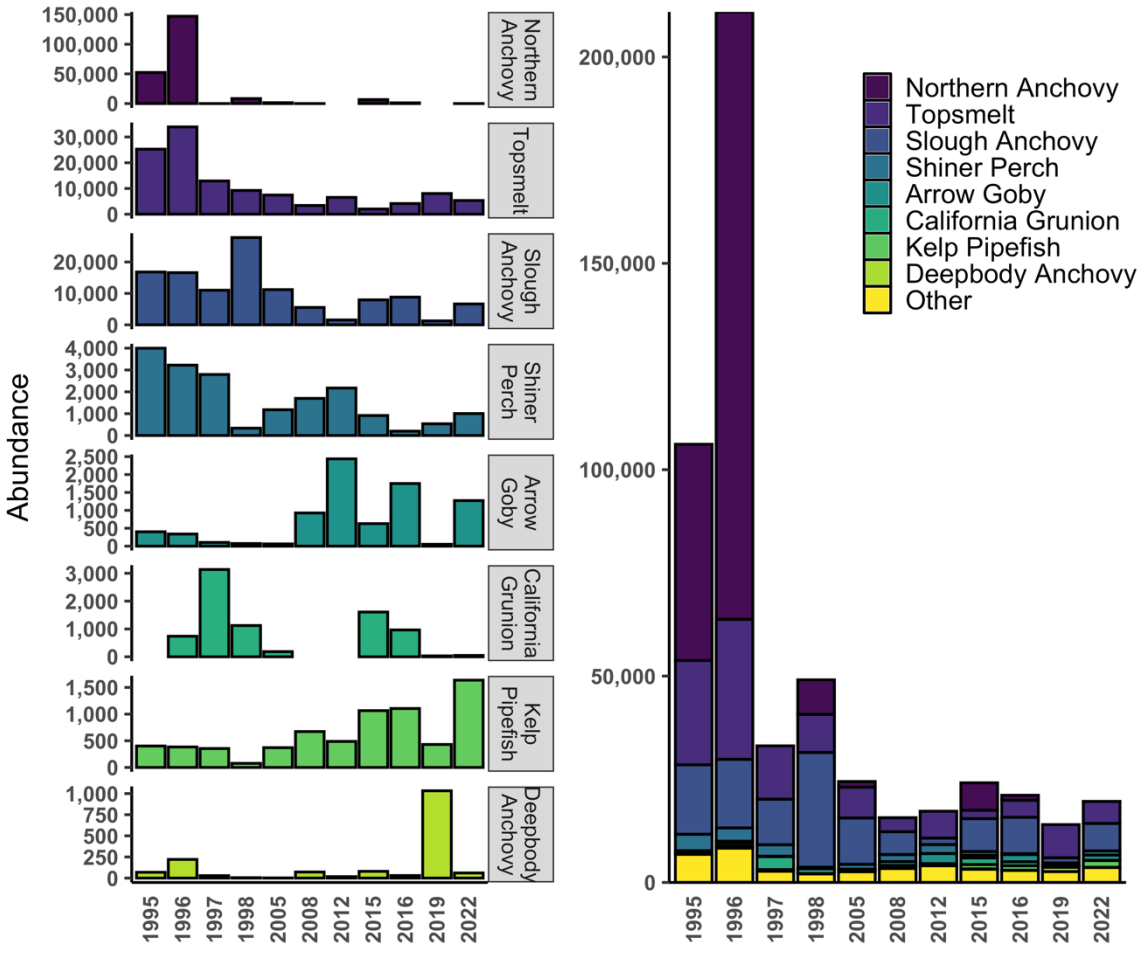


Figure 23. Total abundance of the most frequently caught species by sampling year. Results were calculated for years that were sampled in April and July and only includes data from those sampling months.

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**	**2022**
North	111.9	195.4	70.1	58.7	58.9	36.5	119.7	112.8	83.2	69.0	116.0
North-Central	97.2	192.3	88.4	74.4	121.0	55.3	83.0	120.9	65.3	55.1	58.1
South-Central	111.8	46.6	65.4	33.2	34.2	43.7	70.7	69.2	49.2	59.7	89.2
South	89.2	75.8	48.2	52.3	77.4	49.0	74.8	75.3	52.2	87.7	109.8
Total:	**410.0**	**510.1**	**272.1**	**218.6**	**291.6**	**184.5**	**348.2**	**378.2**	**249.9**	**271.5**	**373.1**

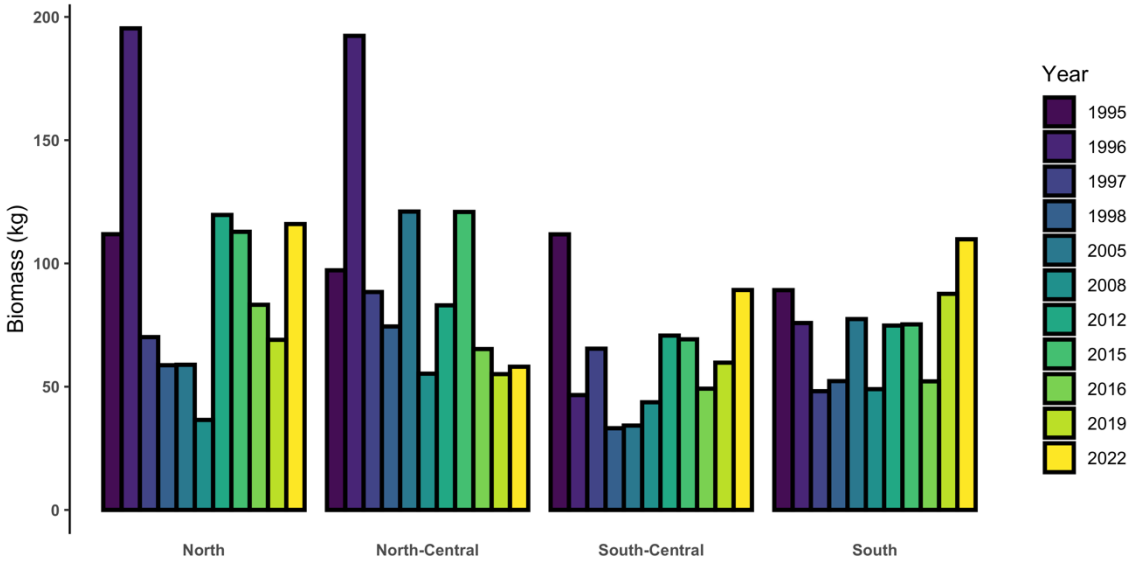


Figure 24. Total biomass (kg) of fishes captured during April and July surveys by ecoregion.

Adult halibut (41 cm SL; 13.5 kg) from an otter trawl in the South-Central Ecoregion during the April 2022 survey.

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**	**2019**	**2022**
Round Stingray	79.1	63.5	77.2	25.9	109.8	60.9	134.2	129.9	110.9	115.5	132.3
Spotted Sand Bass	59.9	29.7	33.5	42.2	36.3	47.3	62.3	50.8	28.2	65.7	60.0
Northern Anchovy	49.7	178.9	0	9.5	3.0	0	0	50.9	29.0	0	< 0.01
Slough Anchovy	45.7	30.1	19.3	66.0	17.4	10.2	2.4	14.7	14.8	1.7	13.3
Topsmelt	22.9	20.5	44.4	20.5	12.1	10.3	11.4	4.7	4.6	22.7	50.2
Bat Ray	26.3	37.2	0	0.5	36.5	0	31.3	26.2	4.6	8.7	0
Barred Sand Bass	38.3	40.2	10.6	4.7	4.7	2.7	2.2	5.6	7.5	0.6	0.3
California Butterfly Ray	0	0	0	8.6	2.1	5.1	15.5	51.2	2.4	2.1	0
Other	88.2	109.9	87.1	40.7	69.7	48.0	88.9	44.1	47.9	54.6	116.9

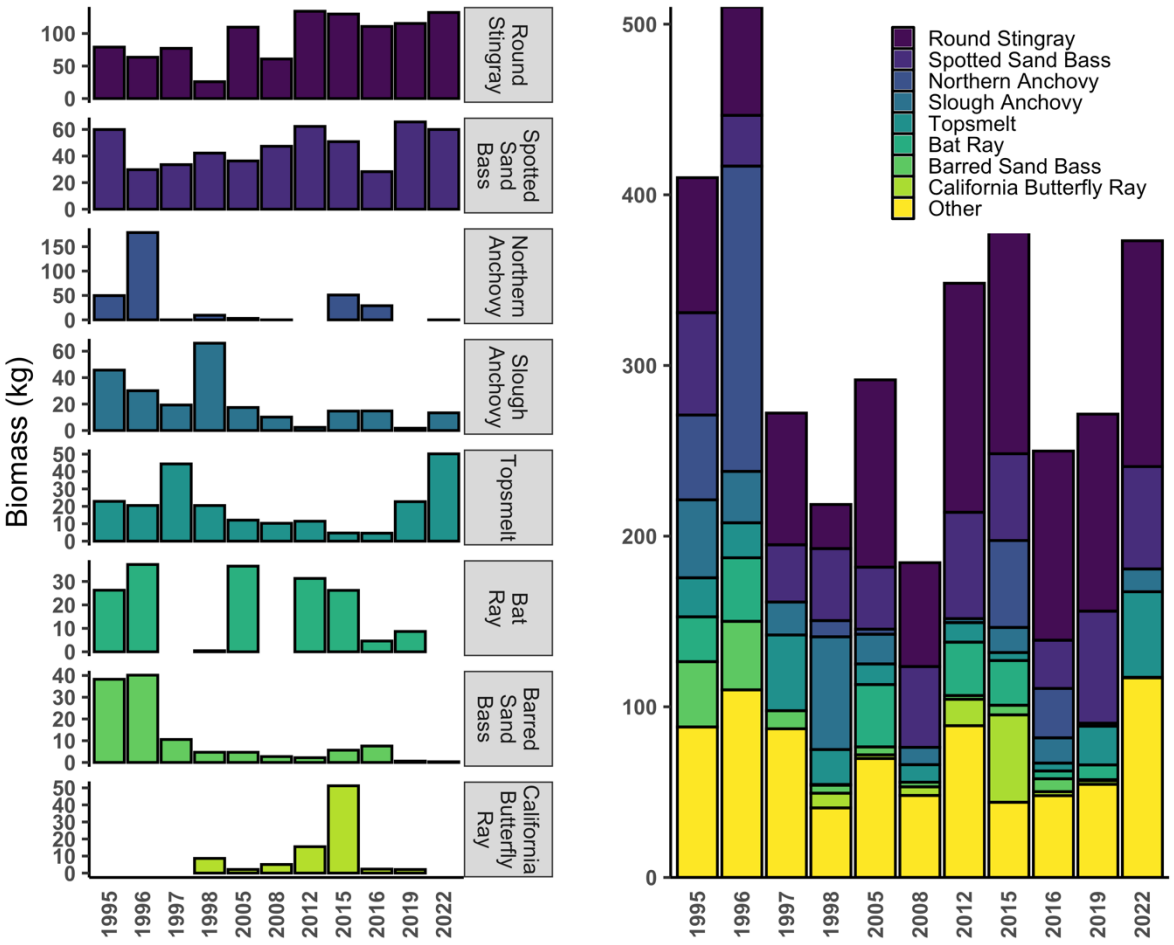


Figure 25. Total biomass (kg) of the highest biomass fishes captured during April and July surveys, shown by species over time (left) and as a proportion of the annual catch (right).

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 (Williams et al. 2019)	18,321,764	419,630
2022 (Present Study)	28,727,027	551,680

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, Williams et al. 2019) 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, 2022 H' estimates were variable among ecoregions and rank among historical values. The North and South-Central Ecoregions had above average diversity values, and the North-Central and South Ecoregions had slightly below average diversity values (Table 30, Figure 28). Species richness for 2022 was average for the North-Central and South Ecoregions. The South-Central Ecoregion ranked third highest for any previous survey year and the North ranked the third lowest for any previous survey year (Table 31; Figure 29).

Salema (*Haemulon californiensis*) captured by purse seine in the South-Central Ecoregion during the April 2022 survey.

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**	**2022**
North	0.74	0.90	1.34	1.42	1.77	1.72	1.56	1.43	1.94	0.93	1.69
North-Central	1.75	0.93	1.50	1.25	1.36	1.62	1.63	1.81	1.61	1.18	1.43
South-Central	1.32	1.72	1.13	0.37	1.77	1.88	1.92	1.41	1.51	1.77	1.78
South	1.93	1.84	1.35	0.59	1.06	2.03	1.84	1.71	1.61	1.82	1.55
Total:	**1.46**	**1.04**	**1.65**	**1.31**	**1.65**	**2.05**	**2.02**	**2.05**	**2.00**	**1.69**	**1.99**

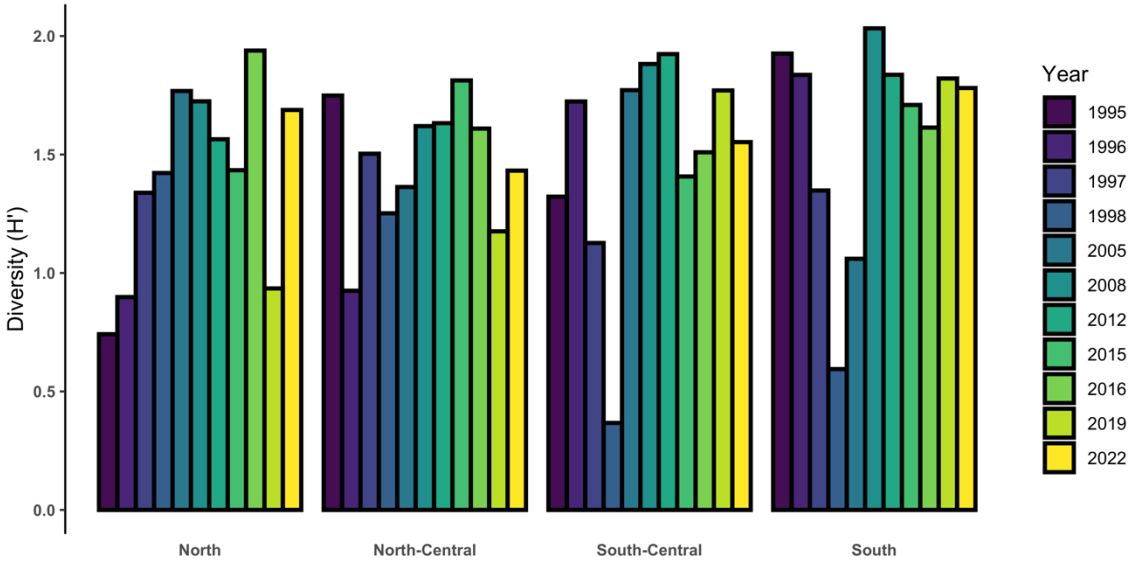


Figure 26. Shannon diversity (H') values by ecoregion and sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

Retrieving the purse seine net in the South Ecoregion during the July 2022 surveys.

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**	**2022**
North	35	42	29	34	38	33	30	35	40	28	30
North-Central	32	33	31	26	38	27	37	35	33	23	31
South-Central	31	23	27	22	25	23	32	27	21	22	28
South	34	24	26	30	23	25	29	23	31	24	27
Total:	**53**	**54**	**42**	**51**	**57**	**48**	**52**	**52**	**55**	**45**	**56**

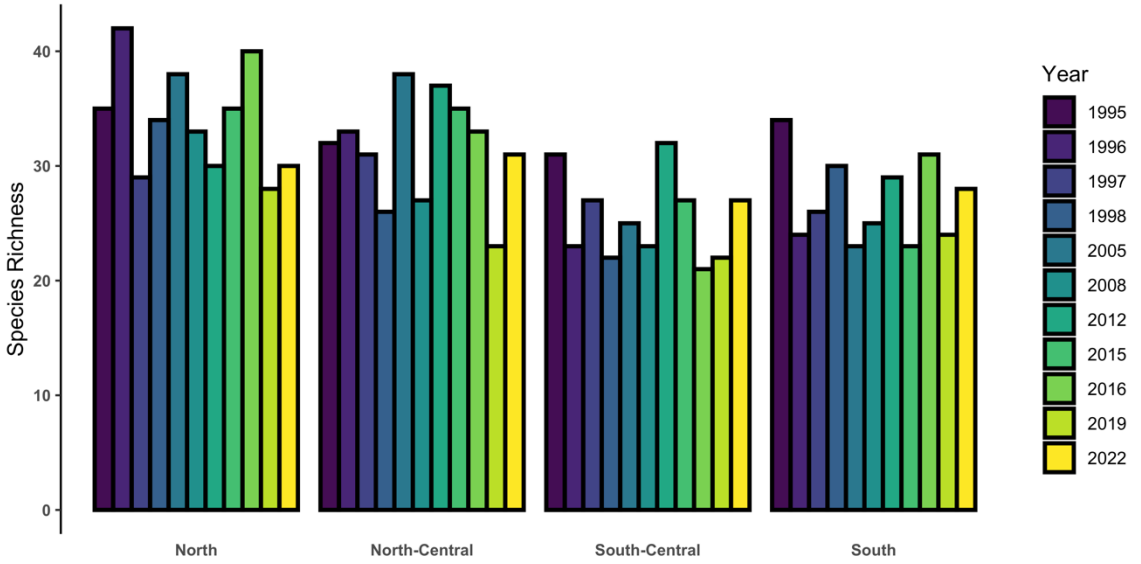


Figure 27. Species richness values by ecoregion and sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

Black Croaker captured in the beam trawl in the North-Central Ecoregion during the July 2022 survey showing juvenile and sub-adult color patterns.

4.16.3 Historical Nursery Area Function

Percent of juveniles from the April and July 2022 sampling periods were also compared to values from April and July 1995-1998, 2005, 2008, 2012, 2015, 2016, and 2019. Approximately 46% of fish were juveniles in 2022, which is the lowest percentage among historical values, and roughly 14% below the average for all sampling years (Table 32). The general trend is that the proportion of juveniles is decreasing over time (Figure 28) aside from some high-proportion catches in 2012 and 2019. These can be attributed to large catches of juvenile Topsmelt, Arrow Goby, Giant Kelpfish and Shiner Perch, which are all critical commercial and/or forage fish species. San Diego Bay continues to function as a nursery area for nearly half of the fishes found there. 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 32. Percent of juveniles collected from San Diego Bay by sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months.

Sampling Year	% Juvenile
1995	67.3
1996	69.3
1997	63.2
1998	57.1
2005	55.2
2008	53.3
2012	78.3
2015	56.0
2016	47.9
2019	65.0
2022	45.8
Average:	**59.9**

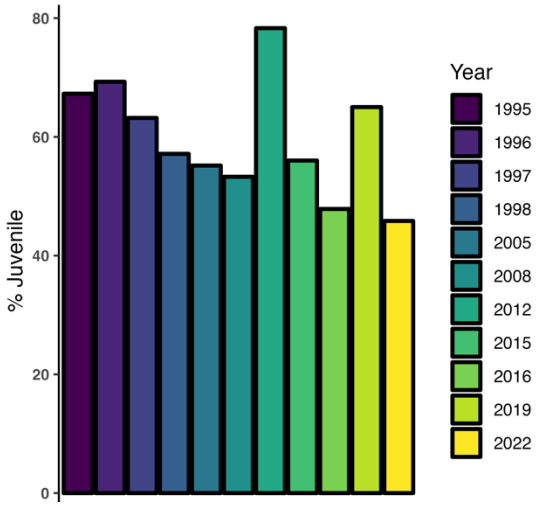


Figure 28. Percent of juveniles collected from San Diego Bay by sampling year. Estimates were calculated for years that were sampled in April and July and only includes data from those sampling months

4.16.4 Community Structure

Six significantly different groups (a-f) were determined by cluster analysis of fish communities for each survey period (Figure 29). The driving species behind each community group can be visualized in Figure 31, 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.

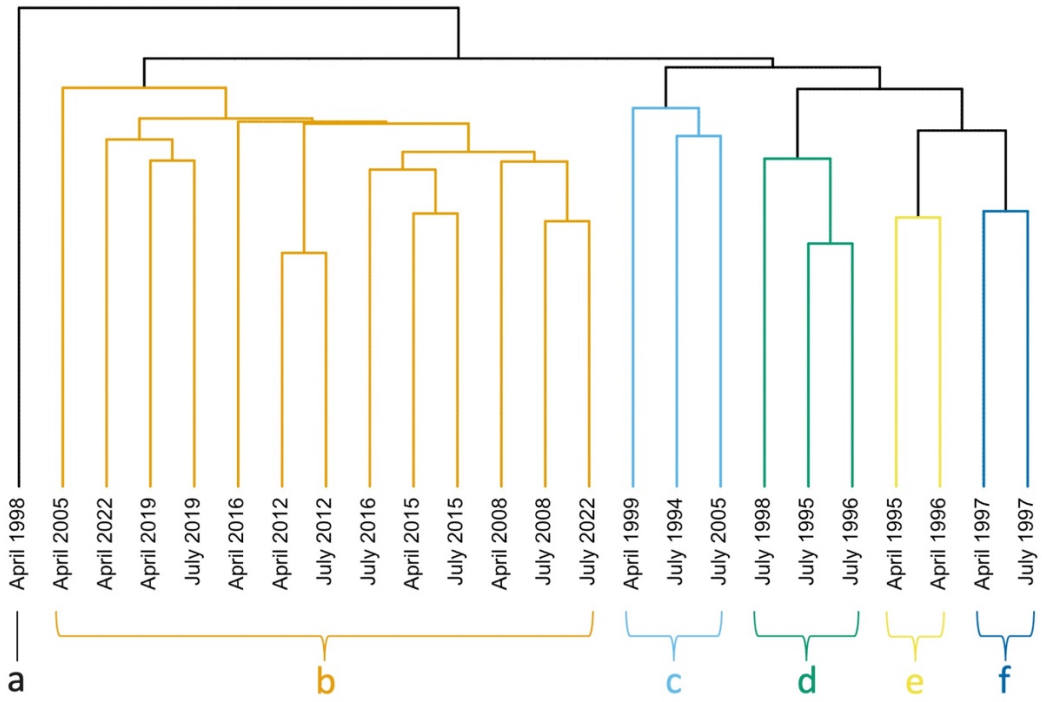


Figure 29. Fish communities for the twenty-two April and July surveys were clustered in this tree. Branch distances shown in this diagram represent the relative similarity of stations to each other using Bray-Curtis distances and group-average linkage. Significantly different (SIMPROF, $\alpha = 0.05$) 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 2022. Community structure of fishes in April 2022 was most similar to that of the 2019 surveys and July was most similar to that of the 2008 surveys but both were not statistically different than any other survey performed in the 21st Century.

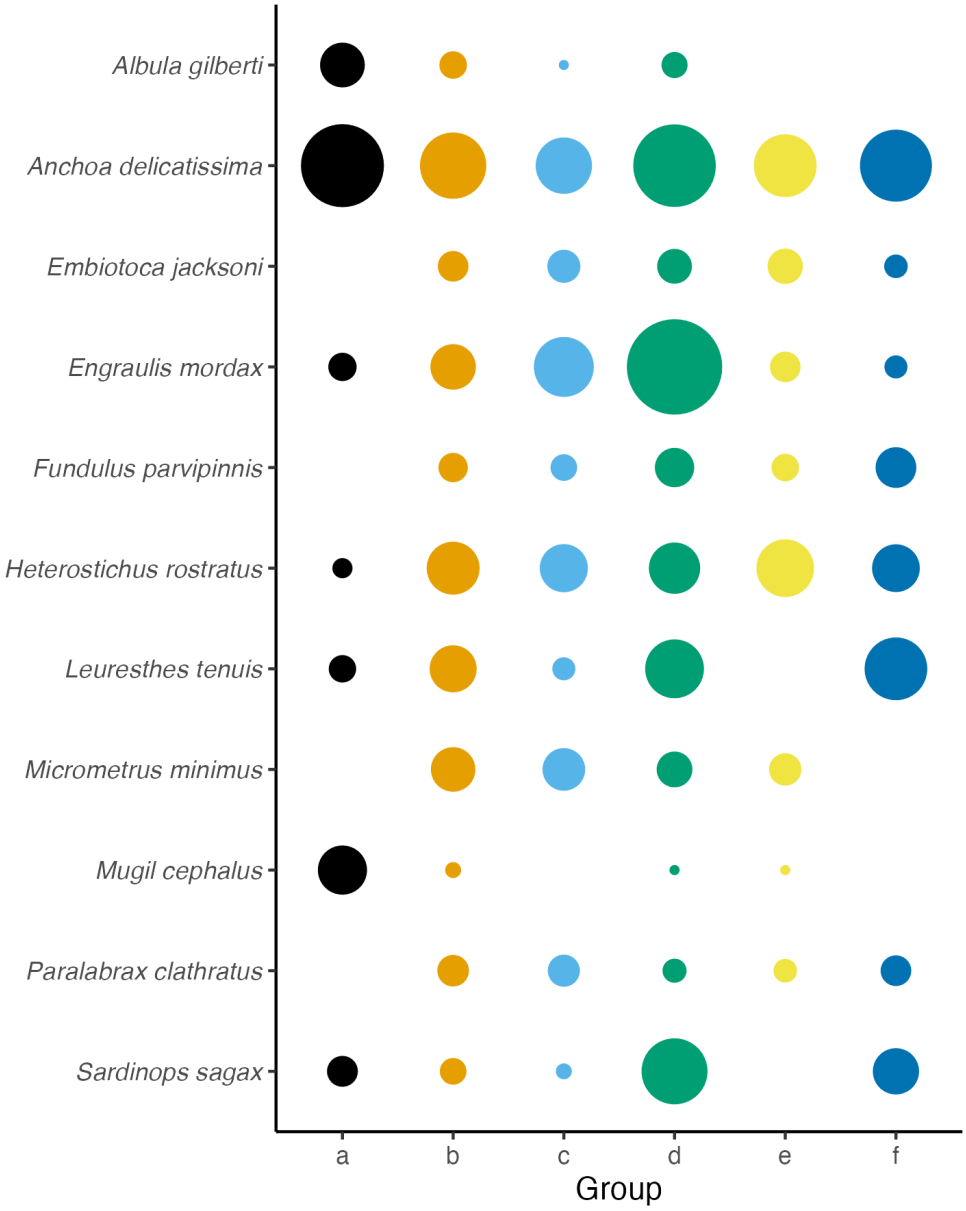


Figure 30. Relative mean abundance (circles scaled to value) per sampling period for select fish taxa in San Diego Bay by community group (as identified in Figure 29).

4.17 Recommendations to Improve Future Surveys

Currently, fisheries utilization surveys are performed for the Port of San Diego every three years. This survey frequency is adequate for long-term studies (Allen et al. 2022), but often fails to capture fish population responses to marine heat waves (Gentemann et al. 2017) and other major oceanographic events (e.g., El Niño/Southern Oscillation). With the forecasted increase in frequency and intensity of severe weather events, increasing sampling frequency while maintaining historical methodology is advised. In addition, we recommend that the sampling effort within years remain consistent to allow for comparisons with the historical dataset.

Ideally, monitoring of San Diego Bay would occur annually, but with practicality in mind, we suggest surveys be performed on either a bi-annual basis or as two consecutive years of sampling with one year off. This will allow adequate temporal resolution for capturing variation in fish populations, particularly in the event of anomalous oceanographic or climatic conditions, without dramatically increasing the cost of monitoring. By sampling consecutive years, we would be more likely to identify recruitment failures or shifts in reproductive seasons, like we note with Topsmelt and Spotted Sand Bass in this report. Increasing sampling frequency will also provide more information that may identify causes for high chick mortality of sensitive foraging species in the region, as has happened with the California least tern (Frost 2013). Annual sampling would accomplish both goals but at triple the cost and effort as is currently being employed.

Mortality due to sampling is very low in species other than forage fish (e.g., Topsmelt, Slough Anchovy) and small gobies (e.g., Arrow Goby), all of which are very abundant within the bay. We estimate that 95% of all non-forage fish are returned to the bay alive, making mortality around 60-65% numerically for all species collected, but only about 15% by biomass. This means that each year, if we assume that all forage fish and small gobies do not survive after release, mortality from our sampling is about 11,000 or 0.04% of individuals and 50 kg or 0.01% of biomass for the entire bay. Therefore, the sampling methods used in this study have a negligible effect on the standing stock of San Diego Bay. Additionally, the forage fish species experiencing high mortality rates in this survey do not have a significant commercial fishery and from a conservation standpoint, have an IUCN listing as being of least concern. Deceased forage fish are returned back into the bay where they can be consumed by birds and other marine animals.

5.0 Literature Cited

Allen, L. G. 1980. Seasonal abundance, composition, and productivity of the littoral fish assemblage in upper Newport Bay, California. U.S. Fish Bull., 80(4): 769-790.

Allen, L. G., A. M. Findlay, and C. M. Phalen. 2002. Structure and standing stock of the fish assemblages of San Diego Bay, California from 1994-1999. Bull. So. Calif. Acad. Sci. 101(2), 49.85.

Allen, L. G. 1999. Fisheries inventory and utilization of San Diego Bay, San Diego, California. Final report for contract to the U.S. Navy Naval Engineering Naval Command Southwest Division and the San Diego Unified Port District, 138 pp.

Allen, L. G. J. P. Williams, J. Bredvik-Curran, D. J. Pondella II, S. Graham, N. Martinez-Takeshita. 2022 A quarter century of monitoring the fish assemblages of San Diego Bay, California from 1995 to 2019. Bulletin of the Southern California Academy of Sciences, 121(3): in press

Clarke K. R., P. J. Somerfield, R. N. Gorley. 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. J. Exp. Mar. Biol. Ecol. 366: 56-69.

Cooper, J.G. 1864. On new genera and species of California fishes. No. III. Proc. Cal. Acad. Sci. Ser. 1, v. 3 (sigs. 7-8): 108-114.

Duffy, J. M. 1987. A review of the San Diego Bay striped mullet, *Mugil cephalus*, fishery. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 56, 10 pp.

Duffy, J. M. and H. J. Bernard. 1985. Milkfish, *Chanos chanos* (Forsskal, 1775), taken in southern California adds new family (Channidae) to the California marine fauna. Calif. Fish Game, 71(2): 122-125.

Frost, N. 2013. California least tern breeding survey, 2012 season. California Department of Fish and Wildlife, Wildlife Branch, Nongame Wildlife Program Report, 2013-01. Sacramento, CA. 19 pp. + app.

Gentemann, C. L., M. R. Fewing, and M. Garcia-Reyes. 2017. Satellite sea surface temperatures along the West Coast of the United States during the 2014-2016 northeast Pacific marine heat wave. Geophys. Res. Lett., 44: 312-319.

Girard, C. F. 1858. Fishes. In: U.S. War Department, Reports of explorations and surveys, to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, v. 10, part 4 (Washington, D.C.)

Jordan, D. S. and C. H. Gilbert. 1880. Notes on a collection of fishes from San Diego, California. Proc. U. S. Nat. Mus., 3:23-34

Jordan, D. S., B. W. Evermann and H. W. Clark. 1930. Check list of the fishes and fish-like vertebrates of North and Middle America north of the northern boundary of Venezuela and Columbia. Appendix X to the Report of the United States Commission of Fish and Fisheries for 1928. Washington, DC: Government Printing Office. 670 pp.

Lea, R. N., C. C. Swift, and R. J. Lavenberg. 1988. Records of *Mugil curema* Valenciennes, the white mullet, from southern California. Bull. So. Calif. Acad. Sci., 87(1): 31-34.

Lea, R. N. and R. H. Rosenblatt. 1992. The Cortez grunt (*Haemulon flaviguttatum*) recorded from two embayments in southern California. Calif. Fish Game, 78(4): 163-165.
Lea, R. N. and H. J. Walker, Jr. 1995. Record of the bigeye trevally, *Caranx sexfasciatus*, and Mexican lookdown, *Selene brevoorti*, with notes on other carangids from California. Calif. Fish Game, 81(3): 89-95.
Lea, R. N. and R. H. Rosenblatt. 2000. Observations on fishes associated with the El Niño off California. CalCOFI Rep. 41: 117-129.
Meng, L., P. B. Moyle, and B. Herbold. 1994. Changes in abundance and distribution of native and introduced fishes of Suisun Marsh. Trans. Am. Fish. Soc., 123(4):498-507
Molnar, J. L., R. L. Gamboa, C. Revenga, and M. D. Spalding. 2008. Assessing the global threat of invasive species to marine biodiversity. Front. Ecol. Environ. 6(9): 485-492
Oksanen J., G. L. Simpson, F. G. Blanchet, R. Kindt, P. Legendre, P. R. Minchin, R. B. O'Hara, P. Solymos, M. H. H. Stevens, E. Szoecs, H. Wagner, M. Barbour, M. Bedward, B. Bolker, D. Borcard, G. Cavalho, M. Chirico, M. De Caceres, S. Durand, H. B.A. Evangelista, et al. 2022. vegan: Community Ecology Package. R package version 2.6-4. http://CRAN.R-project.org/package=vegan
Peeling, T. J. 1975. A proximate biological survey of San Diego Bay, California. No. NUC-TP-389-REV-1. Naval Undersea Center, San Diego, CA, Report No. TP389.
Pondella, D. J., II, J. Froeschke and B. Young. 2006. Fisheries Inventory and Utilization of San Diego Bay, San Diego California for surveys conducted in April and July 2005. February 2006. 103 p.
Pondella, D. J., II and J. P. Williams. 2009a. Fisheries Inventory and Utilization of San Diego Bay, San Diego California for surveys conducted in April and July 2008. February 2009. 68 p.
Pondella, D. J., II and J. P. Williams. 2009b. Fisheries Inventory and Utilization of San Diego Bay, San Diego California for surveys conducted in June 2009. June 2009. 24 p.
Pondella, D. J., II and J. P. Williams. 2011. Summary and analysis of past fish collection data, with comparison to past California Least Tern productivity, San Diego: oceanographic indices, forage fish and tern breeding success. March 2011. 249 p.
R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/
San Diego County MS4 Co-permittees. 2008. San Diego Bay Watershed Urban Runoff Management Program Document. Final, March 2008. Submitted to the San Diego Regional Water Quality Control Board by the San Diego Bay Copermittees.
Shannon, C. E. 1948. A mathematical theory of communication. Bell System Technical Journal, 27, 379-423.
Starks, E. C. 1918. The herrings and herring-like fishes of California. Calif. Fish and Game 4(2): 58-65.

Wang, P. F., R.T, Cheng, K. Richter, E. S. Gross, D. Sutton, J.W. Gartner. 1998. Modeling tidal hydrodynamics of San Diego Bay, California. Journal of the American Water Resources Association, 34(5): 1123-1140.

Whitaker D., Christman M. 2014. clustsig: Significant Cluster Analysis. R package version 1.1. http://CRAN.R-project.org/package=clustsig

Williams, G. D., J. S. Desmond, and J. B. Zedler. 1998. Extension of two nonindigenous fishes, *Acanthogobius flavimanus* and *Poecilia latipinna*, into San Diego Bay marsh habitats. Calif. Fish Game 84(1): 1-17.

Williams, J. P., D. J. Pondella II, B. M. Haggin, and L. G. Allen. 2011. New record of Pacific sierra (*Scomberomorus sierra*) with notes on previous California records. Calif. Fish Game 97(1): 43-46.

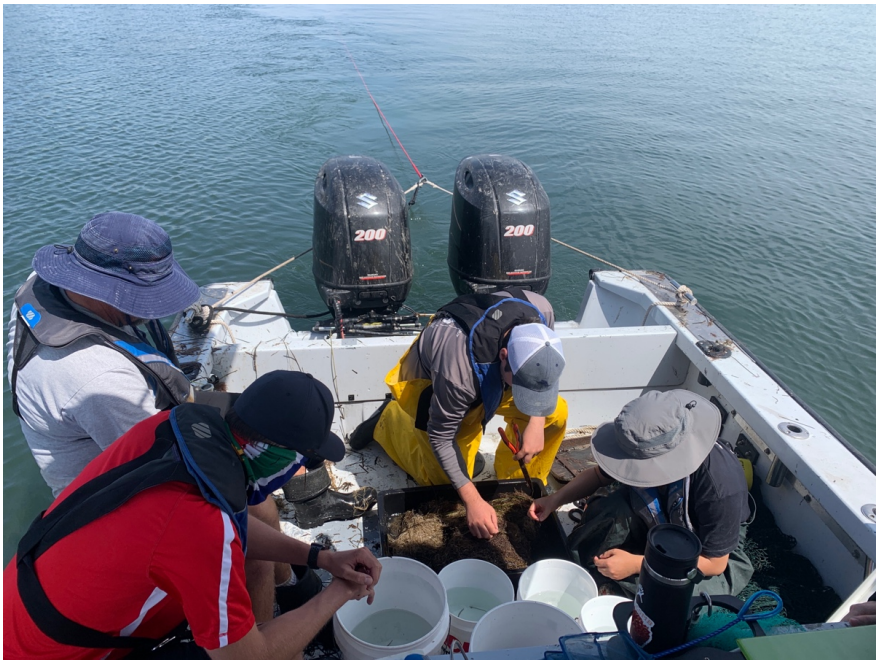
Williams, J. P. and D. J. Pondella II. 2012. Fisheries Inventory and Utilization of San Diego Bay, San Diego California for surveys conducted in April and July 2012. September 2012. 66 p.

Williams, J. P., D. J. Pondella II, C. M. Williams, S. Schwab. 2015. Fisheries Inventory and Utilization of San Diego Bay, San Diego California for surveys conducted in April and July 2015. September 2015. 64 p.

Williams, J. P., D. J. Pondella II, C. M. Williams, M. J. Robart. 2016. Fisheries Inventory and Utilization Study to Determine Impacts from El Niño in San Diego Bay, San Diego California for surveys conducted in April and July 2016. November 2015. 68 p.

Williams, J. P., C. M. Williams, Z. Scholz, M. J. Robart, and D.J. Pondella, II. 2019. Fisheries Inventory and Utilization of San Diego Bay, San Diego, California for surveys conducted in April and July 2019. September 2019. 72 p.

Winston, M., J. T. Claisse, C. M. Williams, J. P. Williams, D. J. Pondella, II. 2018. Age and growth of the Giant Kelpfish, *Heterostichus rostratus* Girard 1854, in southern California, USA. Journal of Applied Ichthyology 34(1): 91-96.



Sorting through a beam trawl catch in the South Ecoregion during the July 2022 survey.