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

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November 2016

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Photographs: All photos were taken by Jonathan Williams, Chelsea Williams, Dan Pondella, Matt Robart, Miranda Roethler, Jeremy Claisse, Dana Michels, or Ralph Appy

Acknowledgments:
We greatly appreciate Eileen Maher's oversight and management of this project, the assistance of Jessica Bredvik in granting of access to Naval Air Station North Island by the Unites States Navy, as well as the assistance of all of the field work volunteers listed above.

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EXECUTIVE SUMMARY

The Vantuna Research Group at Occidental College surveyed the estuarine fishes of San Diego Bay in April and July 2016 for the Port of San Diego. The survey followed the protocols established from July 1994 to April 1999 (Allen 1999, Allen et al. 2002, Pondella et al. 2006, Pondella and Williams 2009a, Williams and Pondella 2012, Williams et al. 2015). 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) Determine what, if any, impacts there were to ichthyofauna in San Diego Bay as a result of the 2015/2016 El Niño

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

- ✓ Fish species composition and abundance
  - Species diversity
  - Abundance by bay ecoregion
- ✓ Ecological importance of species
- ✓ Nursery area function
- ✓ Fish assemblage structure
- ✓ Water quality parameters
- ✓ 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
- ✓ Historical comparisons
  - Diversity, Richness, Biomass, Abundance
  - Community structure

Composition and Abundance

During this study, 21,127 (55 species) fishes weighing a total of 250 kg were collected during April and July 2016. The most numerous species comprising 41.8% of the catch was Slough Anchovy (*Anchoa delicatissima*), followed by Topsmelt (*Atherinops affinis*; 19.6%), Arrow Goby (*Clevelandia ios*; 8.3%), Northern Anchovy (*Engraulis mordax*; 5.7%), and Kelp Pipefish (*Syngnathus californiensis*; 5.2%). In terms of biomass, Round Stingrays (*Urobatis halleri*) dominated the catch comprising 44.3% of the biomass, followed by Northern Anchovy (11.6%), and Spotted Sand Bass (*Paralabrax maculatofasciatus*; 11.3%). These species are typically among the most dominant species in surveys of San Diego Bay.

Ecological Importance of Species

The principle fishes surveyed during these sampling periods as determined by the Ecological Index were the following species: Round Stingray, Slough Anchovy, Topsmelt, Spotted Sand Bass, and Arrow Goby. Round Stingray ranked first (E.I. 4,723), Slough Anchovy ranked second (E.I. 4,173), Topsmelt ranked third (E.I. 2,141), and Spotted Sand Bass ranked fourth (E.I. 1,243). All four species were found ubiquitously throughout the bay, though Slough Anchovy were not present in the North Ecoregion during the April sampling period. Round Stingray and Spotted Sand Bass were dominant in terms of biomass, and Slough Anchovy and Topsmelt were dominant in terms of numerical abundance. These species were followed by Arrow Goby (E.I. 836), which were nearly all captured in the South Ecoregion where it dominated the intertidal catch along with Topsmelt.

Best Estimates of Density and Standing Stock

The stock size estimate in 2016 was 30.1 million fishes, slightly below the 2015 estimate but still the second highest estimate of the last decade. With an estimated surface area of 4,858 ha this gives an overall fish density 0.62 individuals/m^2. The highest estimates were of Slough Anchovy (17.1 million), followed by Topsmelt (2.50 million), Northern Anchovy (2.35 million), Kelp Pipefish (2.05 million), and Giant Kelpfish (*Heterostichus rostratus*; 1.48 million). These five species also had the five highest stock estimates in 2015. As is typical, schooling and forage fishes dominated the stock estimate for the bay. The total best estimate of biomass standing stock was over 311 MT or approximately 6.41 g/m^2, far lower than the 2015 estimate but about average for all historical surveys. The highest biomass estimates were of Round Stingray (86.9 MT), followed by Northern Anchovy (56.5 MT), Spotted Sand Bass (41.4 MT), Slough Anchovy (27.7 MT), and Spotfin Croaker (*Roncador stearnsii*; 14.0 MT). Round Stingray, Northern Anchovy, and Spotted Sand Bass were all in the top five biomass estimates in 2015 as well, but Slough Anchovy was sixth and Spotfin Croaker was fifteenth.

Avian Forage and Fisheries Species

Forage species are primarily surface dwelling schooling fish that are accessible to diving avian predators, especially terns. Generally, forage fishes are small silvery-sided fishes that are found in large schools. These schooling fishes are not habitat-specific and move throughout the bay's ecosystem. Thirteen species of important forage fishes were captured during this study. The most abundant forage fishes were Slough Anchovy, Northern Anchovy, and Topsmelt. Northern Anchovies and Topsmelt were primarily found at small (juvenile) size classes (<50 mm SL) appropriate for nesting birds to feed their young in the area. The typical timing for the recruitment of fishes to San Diego Bay begins in the spring and continues through the summer, which is what was observed in 2016. The biomass standing stock estimate for forage fish was 112.7 MT. During this study, 15 important California recreational or commercial species were captured. The standing stock estimate of fisheries species totaled 150.9 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 Longtail Goby (*Ctenogobius sagittula*) – the first record of this species being captured during these surveys. This is a relatively low number considering the exceptionally warm water in the bay over the last two years due to the presence of a strong El Niño. These fishes were mostly found in the southern half of the bay, though at least one was found in each ecoregion. Of note, a large number of Cortez Bonefish (*Albula gilberti*) were caught throughout the bay, including adults, newly settled juveniles, and leptocephalus larvae.

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 (48%) of the fishes found there. 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 57.8% of the total catch in this survey.

Trends and Comparisons

Overall, 2016 Shannon-Wiener Diversity estimates in each ecoregion were relatively even but varied in rank among historical values. The North Ecoregion had the highest Shannon-Wiener Diversity values of any sampling period. Species richness for 2016 was among the highest of historical values for the North, North-Central, and South Ecoregions for any survey period, but the lowest for any survey in the South-Central Ecoregion. Community structure of fishes did not show a significant response to the 2015-2016 El Niño event, and the assemblage during that time was more similar to other recent sampling periods than the sampling events that occurred during 1997-1998 El Niño.

Field Surveys

To adequately assess the status of all components of the ichthyofauna of the San Diego Bay, four ecoregions of San Diego Bay including North, North-Central, South-Central, and South were sampled and inventoried (Figure 1, Table 1).

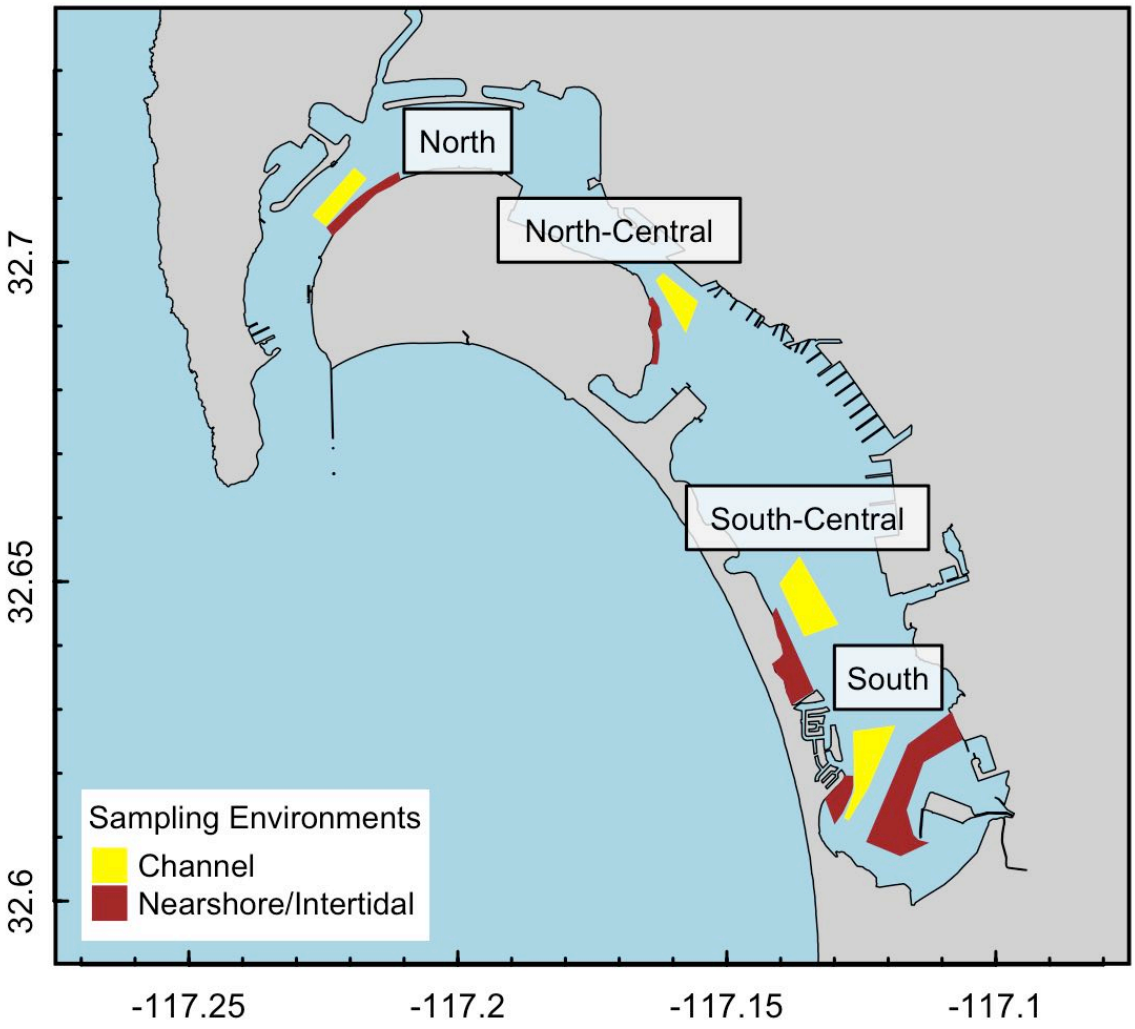


Figure 1. Sampling environment locations of the North, North-Central, South-Central, and South Ecoregions in San Diego Bay.

Table 1. Lambert Coordinates (LAT, LONG) for the San Diego Bay Fisheries Inventory and Utilization study, 2016.

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"

Sampling Procedures

Sampling occurred during the spring and summer quarters of 2016 (April 2-3, April 16-17 and July 12-15, 2016). One ecoregion was sampled per day. Collections were made off the 5-m *R/V Blennius* and the 6.5-m *R/V Neoclinus*. At each ecoregion, the following five subhabitats were sampled: deep channel, nearshore non-vegetated, nearshore vegetated, intertidal non-vegetated, and intertidal vegetated.

Fish were sampled at each ecoregion using the following gear:

1) A 15.2-m x 1.8-m large seine equipped with a 1.8-m X 1.8-m X 1.8-m bag (1.2-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 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-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) 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.

Downtown San Diego from Shelter Island. (photo: Ralph Appy)

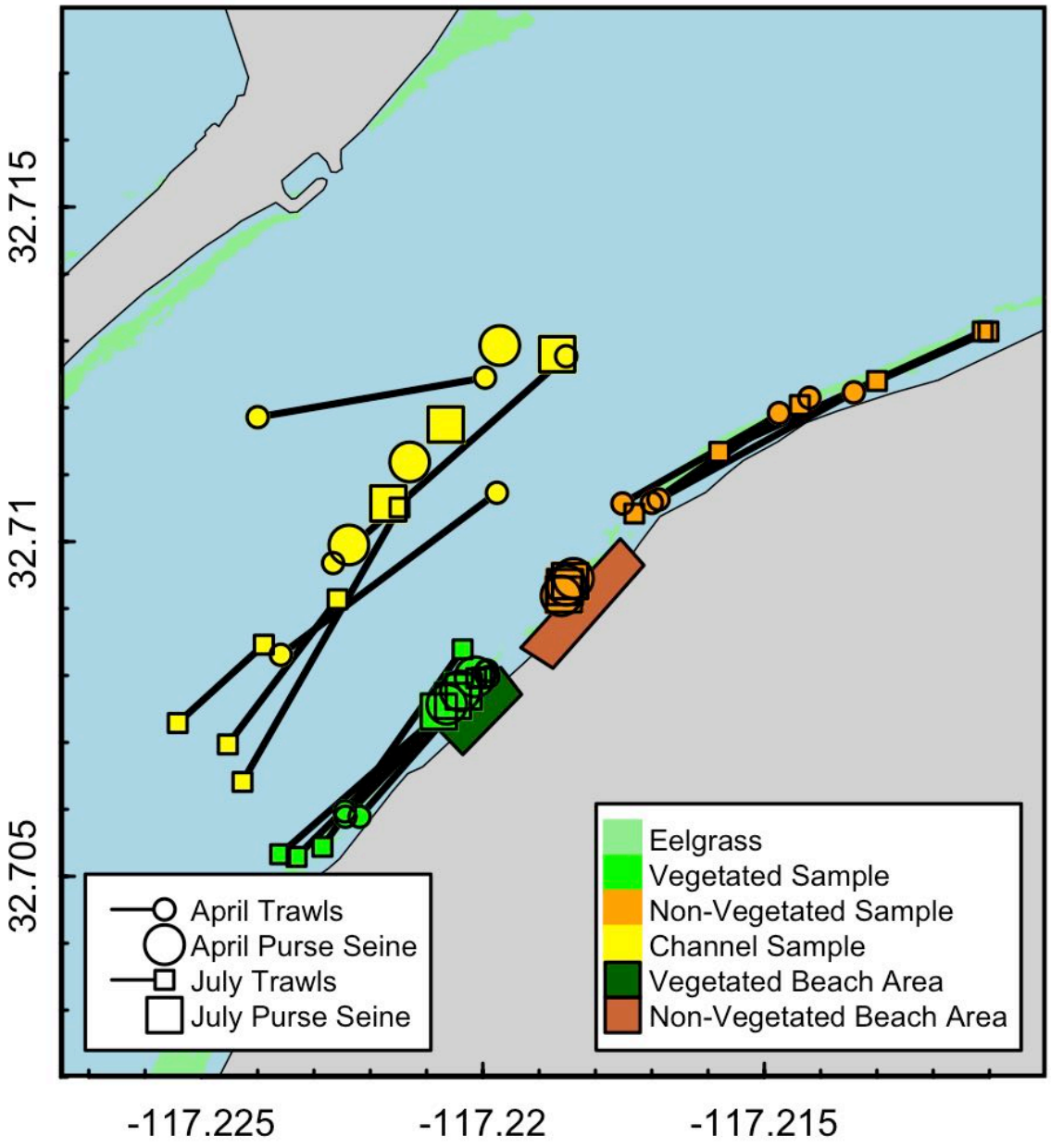


Figure 2. Sampling events for the North Ecoregion, 2016.

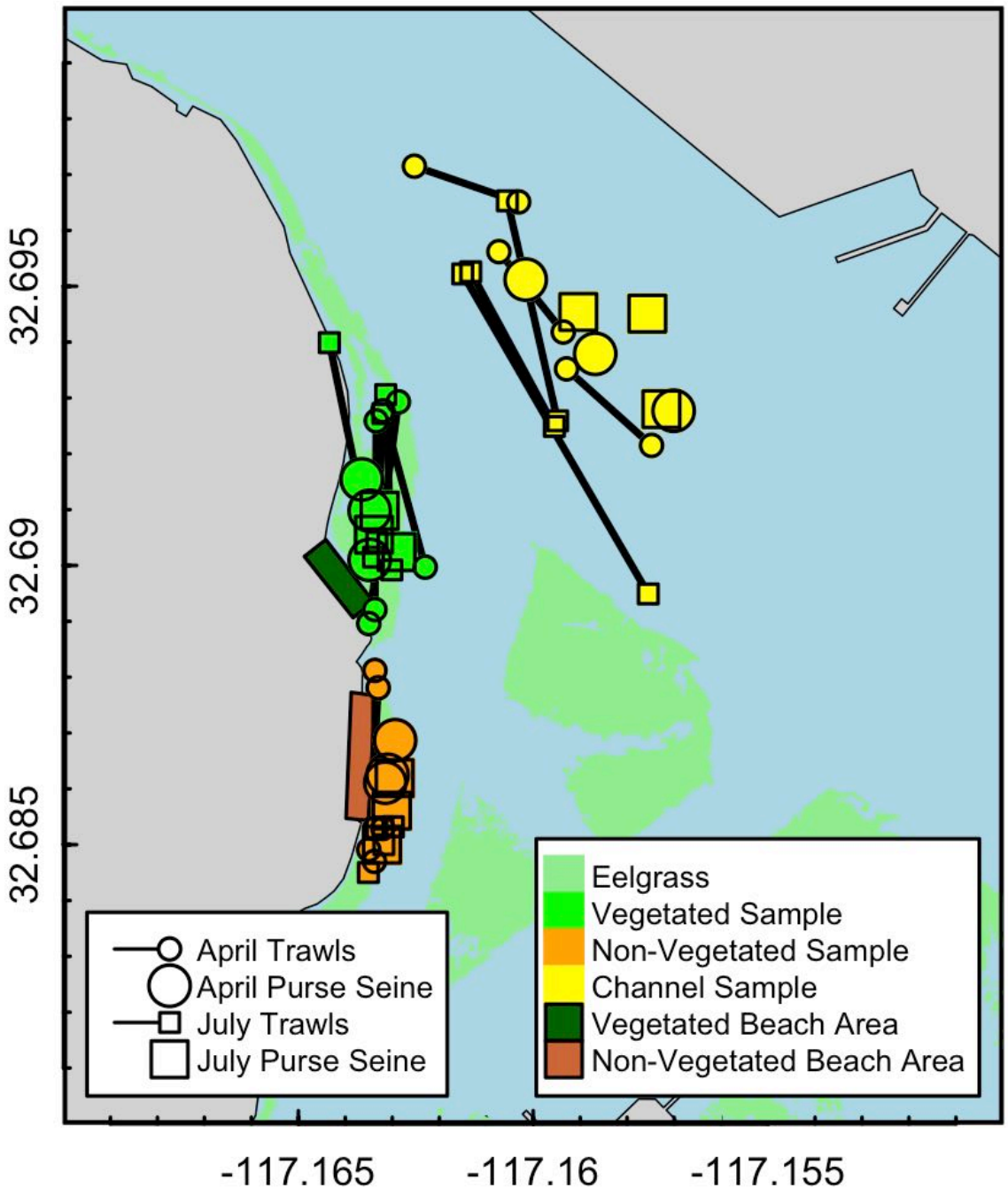


Figure 3. Sampling events for the North-Central Ecoregion, 2016.

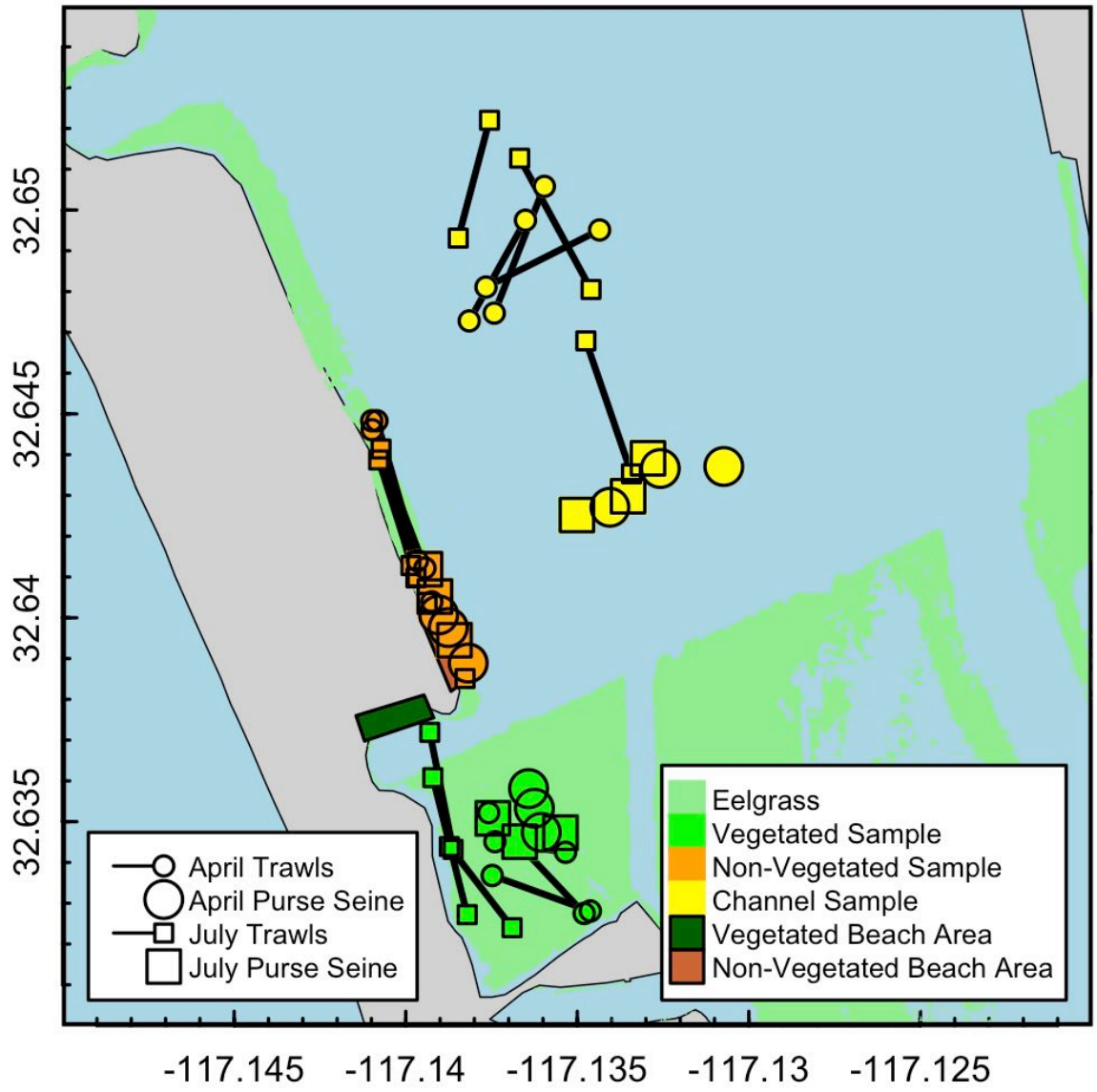


Figure 4. Sampling events for the South-Central Ecoregion, 2016.

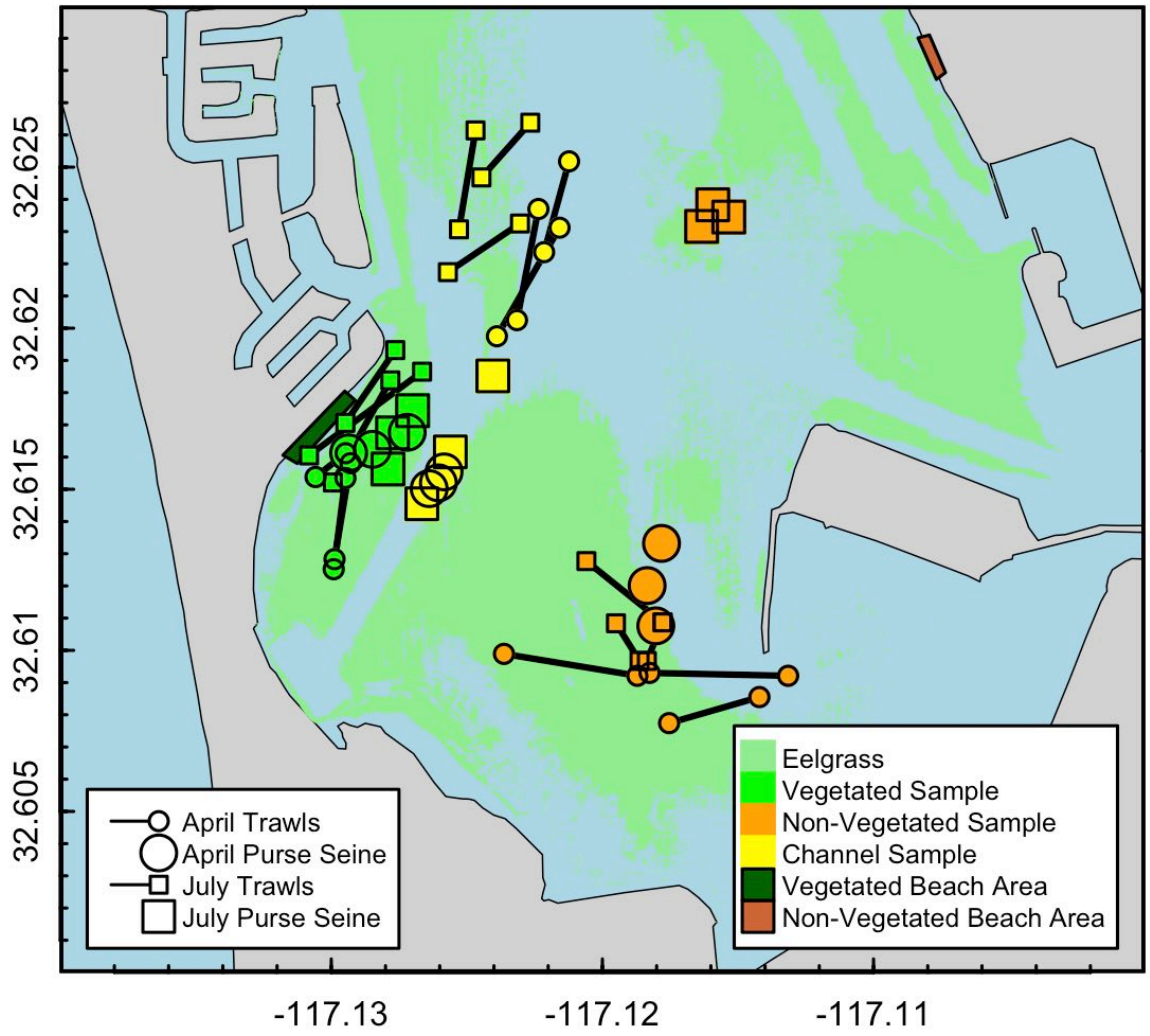


Figure 5. Sampling events for the South Ecoregion, 2016.

Water Quality Parameters

Water temperature (°C), salinity (ppt), dissolved oxygen (mg O_2/1), and pH were measured at each ecoregion (Figure 6). Temperature increased from north to south in the bay during both sampling periods, though the temperature was about 5 ºC warmer at each ecoregion during the July sampling period. Dissolved oxygen generally decreased from north to south. Salinity and pH increased slightly from north to south during the April sampling period, and sharply during the July sampling period. These physical-chemical results are fairly typical of the bay, and are not surprising given the warm water but low rainfall El Niño conditions that occurred during 2016.

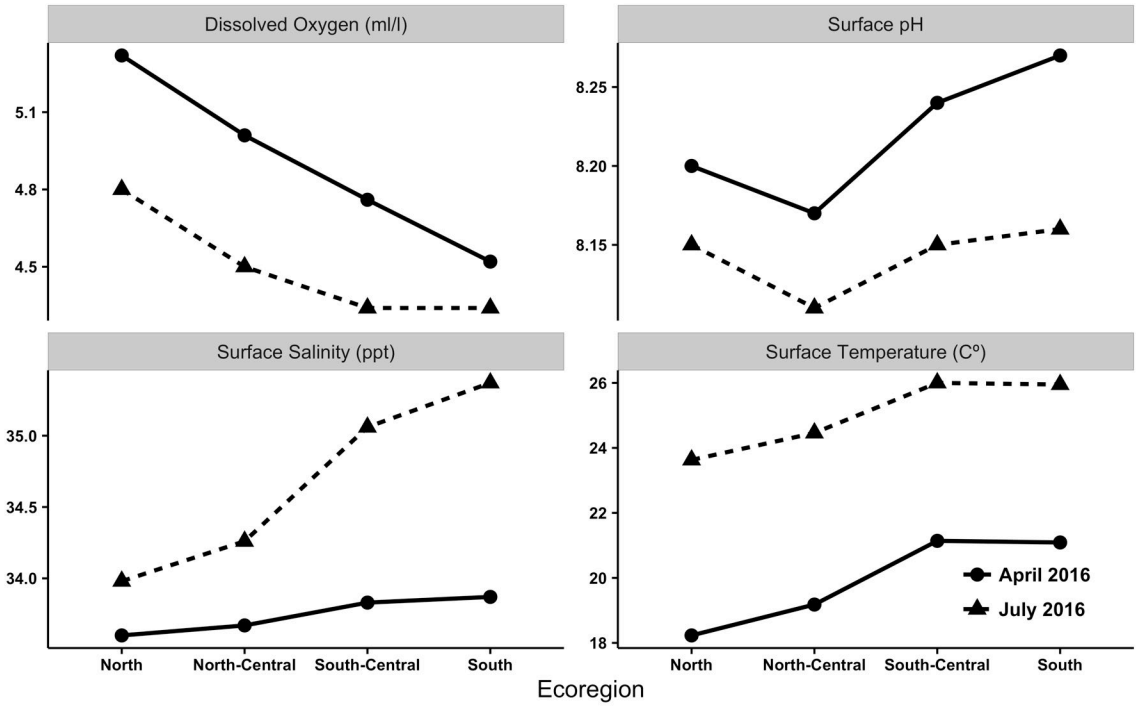


Figure 6. Summary of mean physical-chemical measurements by ecoregion in April and July, 2016.

Numerical Catch and Biomass

During this study, 21,127 (55 species) fishes weighing a total of 250 kg were collected during April and July 2016. The most numerous species comprising 41.8% of the catch was Slough Anchovy (*Anchoa delicatissima*), followed by Topsmelt (*Atherinops affinis*; 19.6%), Arrow Goby (*Clevelandia ios*; 8.3%), Northern Anchovy (*Engraulis mordax*; 5.7%), and Kelp Pipefish (*Syngnathus californiensis* – considered synonymous with *Syngnathus leptorhynchus* in this document; Garcia and Rouse, in prep; 5.2%). In terms of biomass, Round Stingrays (*Urobatis halleri*) dominated the catch comprising 44.3% of the biomass, followed by Northern Anchovy (11.6%), and Spotted Sand Bass (*Paralabrax maculatofasciatus*; 11.3%). These species are typically among the most dominant species in surveys of San Diego Bay.

Total catch varied moderately by ecoregion (Figure 7) with differences in total fish abundance reflecting the differences in Slough Anchovy abundance. Abundance was greatest at the North-Central Ecoregion (7,932; Table 5), followed by the North Ecoregion (5,158; Table 4), South Ecoregion (5,036; Table 7), and South Ecoregion (3,001; Table 6). Slough Anchovy dominated catches in the North-Central (2,918), South-Central (3,136), and South (1,409) Ecoregions. Slough Anchovy (1,107) was also dominant in the North Ecoregion along with Topsmelt (1,577) and Northern Anchovy (1,197). Many Topsmelt (1,697) were taken in the North-Central Ecoregion and a nearly number of Arrow Goby (1,670) were taken in the South Ecoregion.

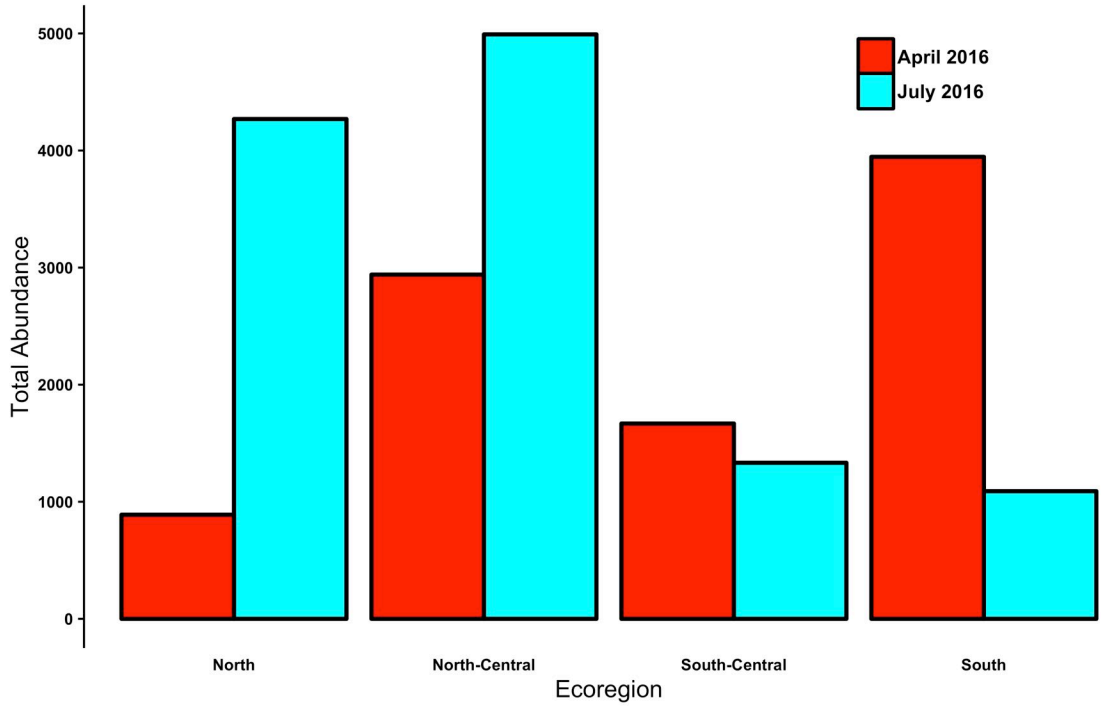


Figure 7. Catch of San Diego Bay fishes by ecoregion, April and July 2016.

The catch of the five numerically dominant fishes had mixed patterns over the four ecoregions (Figure 8), though Slough Anchovies were ubiquitous and numerous throughout the bay. Topsmelt and Kelp Pipefish were also ubiquitous, but in smaller numbers than Slough Anchovy. Arrow Gobies were infrequent in the South-Central Ecoregion, but dominant in the South Ecoregion. Northern Anchovies were limited to the North Ecoregion and were a numerically dominant species there.

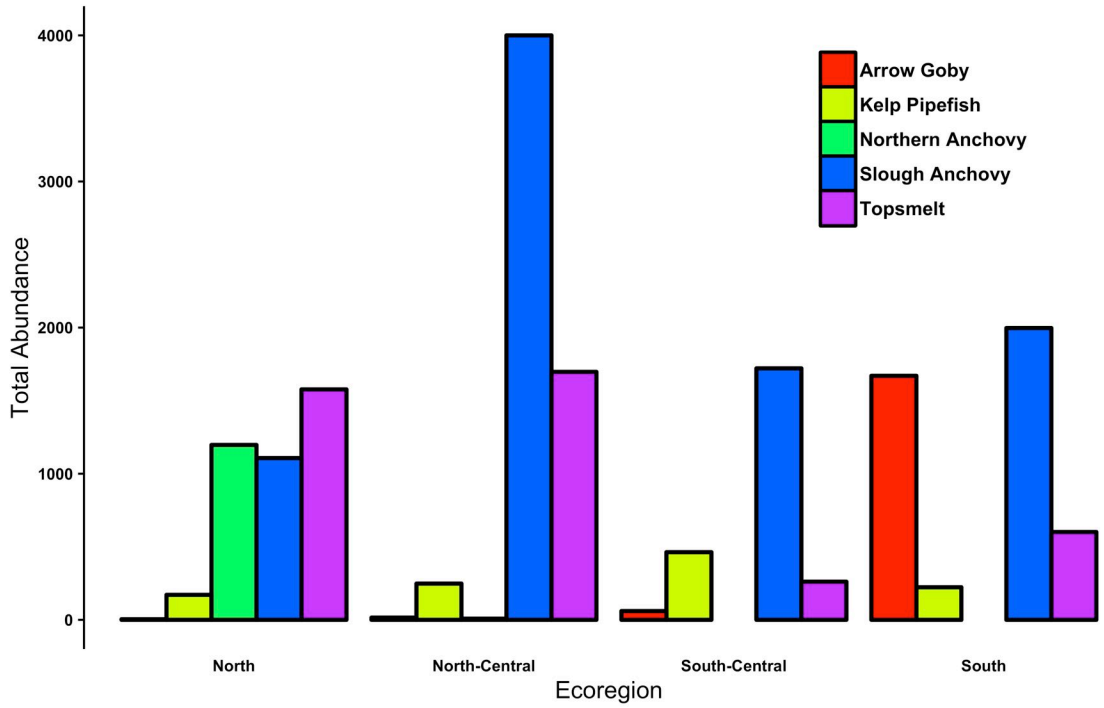


Figure 8. Total catch of the five numerically dominant species by ecoregion, 2016.

Round Stingray had the highest catch in terms of biomass at three ecoregions (North-Central, 23.6 kg; South-Central, 34.8 kg; South, 25.6 kg) and was second in biomass (26.8 kg) to Northern Anchovy (29.0 kg) in the North Ecoregion. Spotted Sand Bass (North to South: 5.78 kg, 9.86 kg, 4.91 kg, 7.69 kg) and Slough Anchovy (North to South: 2.76 kg, 5.91 kg, 2.66 kg, 3.48 kg) were also dominant species in terms of biomass in each ecoregion, while California Halibut (*Paralichthys californicus*; 5.60 kg) and Spotfin Croaker (*Roncador stearnsii*; 7.20 kg) were among the dominant species in the North and North-Central Ecoregions, respectively.

Table 2. Total abundance of fishes collected in San Diego Bay during 2016 by ecoregion.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total	%
Anchoa delicatissima	Slough Anchovy	1,107	4,000	1,721	1,997	8,825	41.77
Atherinops affinis	Topsmelt	1,577	1,697	261	601	4,136	19.58
Clevelandia ios	Arrow Goby	4	15	60	1,670	1,749	8.28
Engraulis mordax	Northern Anchovy	1,197	8			1,205	5.70
Syngnathus californiensis	Kelp Pipefish	171	248	463	223	1,105	5.23
Leuresthes tenuis	California Grunion	77	888			965	4.57
Heterostichus rostratus	Giant Kelpfish	415	335	28	1	779	3.69
Urobatis halleri	Round Stingray	117	119	185	183	604	2.86
Paralabrax nebulifer	Barred Sand Bass	12	147	109	22	290	1.37
Paralabrax maculatofasciatus	Spotted Sand Bass	32	117	34	56	239	1.13
Hypsoblennius gentilis	Bay Blenny	22	172	21	3	218	1.03
Micrometrus minimus	Dwarf Perch	212				212	1.00
Cymatogaster aggregata	Shiner Perch	51	36	62	50	199	0.94
Haemulon californiensis	Salema		24		55	79	0.37
Albula gilberti	Cortez Bonefish	3	43	7	24	77	0.36
Paralichthys californicus	California Halibut	33	7	14	14	68	0.32
Sphyraena argentea	Pacific Barracuda	10	8		41	59	0.28
Atherinopsis californiensis	Jacksmelt	7			36	43	0.20
Halichoeres semicinctus	Rock Wrasse	34				34	0.16
Anchoa compressa	Deepbody Anchovy		2	1	27	30	0.14
Paralabrax clathratus	Kelp Bass	18	10			28	0.13
Fundulus parvipinnis	California Killifish			20	3	23	0.11
Porichthys myriaster	Specklefin Midshipman	7	3	6	1	17	0.08
Gibbonsia elegans	Spotted Kelpfish	8	8			16	0.08
Cynoscion parvipinnis	Shortfin Corvina	2	7	1	3	13	0.06
Pleuronichthys ritteri	Spotted Turbot	1	7	3		11	0.05
Embiotoca jacksoni	Black Perch	10				10	0.05
Pleuronichthys guttulatus	Diamond Turbot	2		2	6	10	0.05
Quietula y-cauda	Shadow Goby		8		1	9	0.04
Sardinops sagax	Pacific Sardine	8				8	0.04
Roncador stearnsii	Spotfin Croaker		7			7	0.03
Symphurus atricaudus	California Tonguefish	6				6	0.03
Cosmocampus arctus	Snubnose Pipefish	1	4			5	0.02
Myliobatis californica	Bat Ray		1		4	5	0.02
Seriphus politus	Queenfish	1	3		1	5	0.02
Ctenogobius sagittula	Longtail Goby				4	4	0.02
Ilypnus gilberti	Cheekspot Goby		2		2	4	0.02
Citharichthys stigmaeus	Speckled Sanddab	1	2			3	0.01
Umbrina roncador	Yellowfin Croaker			1	2	3	0.01
Xystreurys liolepis	Fantail Sole	3				3	0.01
Acanthogobius flavimanus	Yellowfin Goby				2	2	0.01
Anisotremus davidsonii	Sargo		1		1	2	0.01
Gymnura marmorata	California Butterfly Ray			1	1	2	0.01
Hippocampus ingens	Pacific Seahorse	1		1		2	0.01
Scorpaena guttata	California Scorpionfish	1	1			2	0.01
Strongylura exilis	California Needlefish	1	1			2	0.01
Alloclinus holderi	Island Kelpfish	1				1	< 0.01
Atractoscion nobilis	White Seabass		1			1	< 0.01
Heterodontus francisci	Horn Shark	1				1	< 0.01
Hyporhamphus rosae	California Halfbeak				1	1	< 0.01
Porichthys notatus	Plainfin Midshipman				1	1	< 0.01
Rimicola muscarum	Kelp Clingfish	1				1	< 0.01
Sebastes serranoides	Olive Rockfish	1				1	< 0.01
Synodus lucioceps	California Lizardfish	1				1	< 0.01
Zapteryx exasperata	Banded Guitarfish	1				1	< 0.01
# of Species:	**55**	**5,158**	**7,932**	**3,001**	**5,036**	**21,127**	

Table 3. Total biomass (g) of fishes collected in San Diego Bay during 2016 by ecoregion.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total (g)	%
Urobatis halleri	Round Stingray	26,760	23,618	34,835	25,640	110,853	44.37
Engraulis mordax	Northern Anchovy	28,961	8.0			28,969	11.59
Paralabrax maculatofasciatus	Spotted Sand Bass	5,782	9,855	4,914	7,690	28,241	11.30
Anchoa delicatissima	Slough Anchovy	2,759	5,908	2,657	3,476	14,800	5.92
Paralichthys californicus	California Halibut	5,599	2,671	1,346	419	10,035	4.02
Paralabrax nebulifer	Barred Sand Bass	382	4,639	1,992	534	7,547	3.02
Roncador stearnsii	Spotfin Croaker		7,200			7,200	2.88
Cynoscion parvipinnis	Shortfin Corvina	1,125	3,000	600	420	5,145	2.06
Myliobatis californica	Bat Ray		1,400		3,200	4,600	1.84
Atherinops affinis	Topsmelt	2,394	1,410	298	478	4,580	1.83
Sphyraena argentea	Pacific Barracuda	12	700		2,900	3,612	1.45
Atherinopsis californiensis	Jacksmelt	1,000			2,330	3,330	1.33
Heterostichus rostratus	Giant Kelpfish	1,453	1,074	147	7.0	2,681	1.07
Gymnura marmorata	California Butterfly Ray			1,100	1,250	2,350	0.94
Hypsoblennius gentilis	Bay Blenny	141	1,546	170	75	1,932	0.77
Micrometrus minimus	Dwarf Perch	1,818				1,818	0.73
Leuresthes tenuis	California Grunion	1,450	141			1,591	0.64
Albula gilberti	Cortez Bonefish	1.3	109	22	1,390	1,522	0.61
Haemulon californiensis	Salema		354		738	1,092	0.44
Cymatogaster aggregata	Shiner Perch	180	447	152	147	926	0.37
Porichthys myriaster	Specklefin Midshipman	202	280	247	47	776	0.31
Embiotoca jacksoni	Black Perch	688				688	0.28
Scorpaena guttata	California Scorpionfish	590	50			640	0.26
Halichoeres semicinctus	Rock Wrasse	571				571	0.23
Umbrina roncador	Yellowfin Croaker			40	519	559	0.22
Syngnathus californiensis	Kelp Pipefish	152	112	183	99	547	0.22
Anchoa compressa	Deepbody Anchovy		25	16	395	436	0.17
Pleuronichthys ritteri	Spotted Turbot	60	289	73		422	0.17
Pleuronichthys guttulatus	Diamond Turbot	198		178	37	413	0.17
Paralabrax clathratus	Kelp Bass	235	155			390	0.16
Gibbonsia elegans	Spotted Kelpfish	53	219			272	0.11
Fundulus parvipinnis	California Killifish			181	31	212	0.08
Clevelandia ios	Arrow Goby	0.3	1.8	3.3	187	193	0.08
Xystreurys liolepis	Fantail Sole	172				172	0.07
Symphurus atricaudus	California Tonguefish	157				157	0.06
Synodus lucioceps	California Lizardfish	90				90	0.04
Sardinops sagax	Pacific Sardine	81				81	0.03
Ctenogobius sagittula	Longtail Goby				70	70	0.03
Zapteryx exasperata	Banded Guitarfish	65				65	0.03
Hippocampus ingens	Pacific Seahorse	15		43		58	0.02
Seriphus politus	Queenfish	20	20		12	52	0.02
Heterodontus francisci	Horn Shark	42				42	0.02
Acanthogobius flavimanus	Yellowfin Goby				40	40	0.02
Anisotremus davidsonii	Sargo		16		21	37	0.01
Citharichthys stigmaeus	Speckled Sanddab	14	18			32	0.01
Quietula y-cauda	Shadow Goby		3.0		0.5	3.5	< 0.01
Sebastes serranoides	Olive Rockfish	3.0				3.0	< 0.01
Ilypnus gilberti	Cheekspot Goby		0.8		0.8	1.6	< 0.01
Cosmocampus arctus	Snubnose Pipefish	0.1	1.3			1.4	< 0.01
Hyporhamphus rosae	California Halfbeak				1.0	1.0	< 0.01
Porichthys notatus	Plainfin Midshipman				1.0	1.0	< 0.01
Alloclinus holderi	Island Kelpfish	0.6				0.6	< 0.01
Strongylura exilis	California Needlefish	0.2	0.3			0.4	< 0.01
Atractoscion nobilis	White Seabass		0.4			0.4	< 0.01
Rimicola muscarum	Kelp Clingfish	0.2				0.2	< 0.01
# of Species:	**55**	**83,225**	**65,272**	**49,198**	**52,156**	**249,851**	

Table 4. Total number of individuals and biomass (g) of fish species captured in the North Ecoregion, 2016.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Atherinops affinis	Topsmelt	1,577	30.57	2,394	2.88
Engraulis mordax	Northern Anchovy	1,197	23.21	28,961	34.80
Anchoa delicatissima	Slough Anchovy	1,107	21.46	2,759	3.32
Heterostichus rostratus	Giant Kelpfish	415	8.05	1,453	1.75
Micrometrus minimus	Dwarf Perch	212	4.11	1,818	2.18
Syngnathus californiensis	Kelp Pipefish	171	3.32	152	0.18
Urobatis halleri	Round Stingray	117	2.27	26,760	32.15
Leuresthes tenuis	California Grunion	77	1.49	1,450	1.74
Cymatogaster aggregata	Shiner Perch	51	0.99	180	0.22
Halichoeres semicinctus	Rock Wrasse	34	0.66	571	0.69
Paralichthys californicus	California Halibut	33	0.64	5,599	6.73
Paralabrax maculatofasciatus	Spotted Sand Bass	32	0.62	5,782	6.95
Hypsoblennius gentilis	Bay Blenny	22	0.43	141	0.17
Paralabrax clathratus	Kelp Bass	18	0.35	235	0.28
Paralabrax nebulifer	Barred Sand Bass	12	0.23	382	0.46
Embiotoca jacksoni	Black Perch	10	0.19	688	0.83
Sphyraena argentea	Pacific Barracuda	10	0.19	12	0.01
Gibbonsia elegans	Spotted Kelpfish	8	0.16	53	0.06
Sardinops sagax	Pacific Sardine	8	0.16	81	0.10
Atherinopsis californiensis	Jacksmelt	7	0.14	1,000	1.20
Porichthys myriaster	Specklefin Midshipman	7	0.14	202	0.24
Symphurus atricaudus	California Tonguefish	6	0.12	157	0.19
Clevelandia ios	Arrow Goby	4	0.08	0.3	< 0.01
Albula gilberti	Cortez Bonefish	3	0.06	1.3	< 0.01
Xystreurys liolepis	Fantail Sole	3	0.06	172	0.21
Cynoscion parvipinnis	Shortfin Corvina	2	0.04	1,125	1.35
Pleuronichthys guttulatus	Diamond Turbot	2	0.04	198	0.24
Alloclinus holderi	Island Kelpfish	1	0.02	0.6	< 0.01
Citharichthys stigmaeus	Speckled Sanddab	1	0.02	14	0.02
Cosmocampus arctus	Snubnose Pipefish	1	0.02	0.1	< 0.01
Heterodontus francisci	Horn Shark	1	0.02	42	0.05
Hippocampus ingens	Pacific Seahorse	1	0.02	15	0.02
Pleuronichthys ritteri	Spotted Turbot	1	0.02	60	0.07
Rimicola muscarum	Kelp Clingfish	1	0.02	0.2	< 0.01
Scorpaena guttata	California Scorpionfish	1	0.02	590	0.71
Sebastes serranoides	Olive Rockfish	1	0.02	3.0	< 0.01
Seriphus politus	Queenfish	1	0.02	20	0.02
Strongylura exilis	California Needlefish	1	0.02	0.2	< 0.01
Synodus lucioceps	California Lizardfish	1	0.02	90	0.11
Zapteryx exasperata	Banded Guitarfish	1	0.02	65	0.08
# of Species:	**40**	**5,158**		**83,225**	

Table 5. Total number of individuals and biomass (g) of fish species captured in the North-Central Ecoregion, 2016.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Anchoa delicatissima	Slough Anchovy	4,000	50.43	5,908	9.05
Atherinops affinis	Topsmelt	1,697	21.39	1,410	2.16
Leuresthes tenuis	California Grunion	888	11.20	141	0.22
Heterostichus rostratus	Giant Kelpfish	335	4.22	1,074	1.65
Syngnathus californiensis	Kelp Pipefish	248	3.13	112	0.17
Hypsoblennius gentilis	Bay Blenny	172	2.17	1,546	2.37
Paralabrax nebulifer	Barred Sand Bass	147	1.85	4,639	7.11
Urobatis halleri	Round Stingray	119	1.50	23,618	36.18
Paralabrax maculatofasciatus	Spotted Sand Bass	117	1.48	9,855	15.10
Albula gilberti	Cortez Bonefish	43	0.54	109	0.17
Cymatogaster aggregata	Shiner Perch	36	0.45	447	0.68
Haemulon californiensis	Salema	24	0.30	354	0.54
Clevelandia ios	Arrow Goby	15	0.19	1.8	0.00
Paralabrax clathratus	Kelp Bass	10	0.13	155	0.24
Engraulis mordax	Northern Anchovy	8	0.10	8.0	0.01
Gibbonsia elegans	Spotted Kelpfish	8	0.10	219	0.34
Quietula y-cauda	Shadow Goby	8	0.10	3.0	< 0.01
Sphyraena argentea	Pacific Barracuda	8	0.10	700	1.07
Cynoscion parvipinnis	Shortfin Corvina	7	0.09	3,000	4.60
Paralichthys californicus	California Halibut	7	0.09	2,671	4.09
Pleuronichthys ritteri	Spotted Turbot	7	0.09	289	0.44
Roncador stearnsii	Spotfin Croaker	7	0.09	7,200	11.03
Cosmocampus arctus	Snubnose Pipefish	4	0.05	1.3	< 0.01
Porichthys myriaster	Specklefin Midshipman	3	0.04	280	0.43
Seriphus politus	Queenfish	3	0.04	20	0.03
Anchoa compressa	Deepbody Anchovy	2	0.03	25	0.04
Citharichthys stigmaeus	Speckled Sanddab	2	0.03	18	0.03
Ilypnus gilberti	Cheekspot Goby	2	0.03	0.8	< 0.01
Anisotremus davidsonii	Sargo	1	0.01	16	0.02
Atractoscion nobilis	White Seabass	1	0.01	0.4	< 0.01
Myliobatis californica	Bat Ray	1	0.01	1,400	2.14
Scorpaena guttata	California Scorpionfish	1	0.01	50	0.08
Strongylura exilis	California Needlefish	1	0.01	0.3	< 0.01
# of Species:	**33**	**7,932**		**65,272**	

Table 6. Total number of individuals and biomass (g) of fish species captured in the South-Central Ecoregion, 2016.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Anchoa delicatissima	Slough Anchovy	1,721	57.35	2,657	5.40
Syngnathus californiensis	Kelp Pipefish	463	15.43	183	0.37
Atherinops affinis	Topsmelt	261	8.70	298	0.61
Urobatis halleri	Round Stingray	185	6.16	34,835	70.81
Paralabrax nebulifer	Barred Sand Bass	109	3.63	1,992	4.05
Cymatogaster aggregata	Shiner Perch	62	2.07	152	0.31
Clevelandia ios	Arrow Goby	60	2.00	3.3	0.01
Paralabrax maculatofasciatus	Spotted Sand Bass	34	1.13	4,914	9.99
Heterostichus rostratus	Giant Kelpfish	28	0.93	147	0.30
Hypsoblennius gentilis	Bay Blenny	21	0.70	170	0.35
Fundulus parvipinnis	California Killifish	20	0.67	181	0.37
Paralichthys californicus	California Halibut	14	0.47	1,346	2.74
Albula gilberti	Cortez Bonefish	7	0.23	22	0.05
Porichthys myriaster	Specklefin Midshipman	6	0.20	247	0.50
Pleuronichthys ritteri	Spotted Turbot	3	0.10	73	0.15
Pleuronichthys guttulatus	Diamond Turbot	2	0.07	178	0.36
Anchoa compressa	Deepbody Anchovy	1	0.03	16	0.03
Cynoscion parvipinnis	Shortfin Corvina	1	0.03	600	1.22
Gymnura marmorata	California Butterfly Ray	1	0.03	1,100	2.24
Hippocampus ingens	Pacific Seahorse	1	0.03	43	0.09
Umbrina roncador	Yellowfin Croaker	1	0.03	40	0.08
# of Species:	**21**	**3,001**		**49,198**	

Table 7. Total number of individuals and biomass (g) of fish species captured in the South Ecoregion, 2016.

		Abundance		Biomass	
Scientific Name	**Common Name**	**#**	**%**	**grams**	**%**
Anchoa delicatissima	Slough Anchovy	1,997	39.65	3,476	6.66
Clevelandia ios	Arrow Goby	1,670	33.16	187	0.36
Atherinops affinis	Topsmelt	601	11.93	478	0.92
Syngnathus californiensis	Kelp Pipefish	223	4.43	99	0.19
Urobatis halleri	Round Stingray	183	3.63	25,640	49.16
Paralabrax maculatofasciatus	Spotted Sand Bass	56	1.11	7,690	14.74
Haemulon californiensis	Salema	55	1.09	738	1.41
Cymatogaster aggregata	Shiner Perch	50	0.99	147	0.28
Sphyraena argentea	Pacific Barracuda	41	0.81	2,900	5.56
Atherinopsis californiensis	Jacksmelt	36	0.71	2,330	4.47
Anchoa compressa	Deepbody Anchovy	27	0.54	395	0.76
Albula gilberti	Cortez Bonefish	24	0.48	1,390	2.67
Paralabrax nebulifer	Barred Sand Bass	22	0.44	534	1.02
Paralichthys californicus	California Halibut	14	0.28	419	0.80
Pleuronichthys guttulatus	Diamond Turbot	6	0.12	37	0.07
Ctenogobius sagittula	Longtail Goby	4	0.08	70	0.13
Myliobatis californica	Bat Ray	4	0.08	3,200	6.14
Cynoscion parvipinnis	Shortfin Corvina	3	0.06	420	0.81
Fundulus parvipinnis	California Killifish	3	0.06	31	0.06
Hypsoblennius gentilis	Bay Blenny	3	0.06	75	0.14
Acanthogobius flavimanus	Yellowfin Goby	2	0.04	40	0.08
Ilypnus gilberti	Cheekspot Goby	2	0.04	0.8	0.00
Umbrina roncador	Yellowfin Croaker	2	0.04	519	1.00
Anisotremus davidsonii	Sargo	1	0.02	21	0.04
Gymnura marmorata	California Butterfly Ray	1	0.02	1,250	2.40
Heterostichus rostratus	Giant Kelpfish	1	0.02	7.0	0.01
Hyporhamphus rosae	California Halfbeak	1	0.02	1.0	0.00
Porichthys myriaster	Specklefin Midshipman	1	0.02	47	0.09
Porichthys notatus	Plainfin Midshipman	1	0.02	1.0	0.00
Quietula y-cauda	Shadow Goby	1	0.02	0.5	0.00
Seriphus politus	Queenfish	1	0.02	12	0.02
# of Species:	**31**	**5,036**		**52,156**	

Shannon-Wiener Diversity and Species Richness

The Shannon-Wiener Diversity index was used to estimate diversity in San Diego Bay and provide a basis for comparison among ecoregions within the bay. The Shannon-Wiener Diversity index, (H'): $H' = -\Sigma\, p_i\, (\ln p_i)$ where p_i = proportion of species *i*, was calculated for total catches by ecoregion and by sampling month. As is typical of these diversity metrics in the bay, Species Richness and H' were highest in the North Ecoregion and lowest in the South-Central Ecoregion (Figure 9), and Species Richness and H' both declined from April to July 2016 (Figure 10). Both temporally and spatially, reduced H' values were due to dominance of Slough Anchovies.

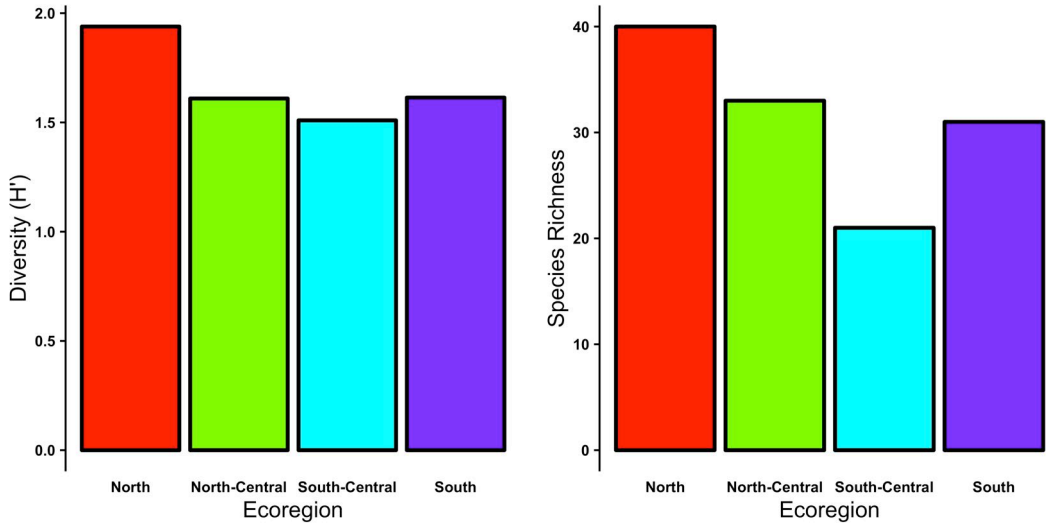


Figure 9. Shannon-Wiener Diversity (H') and number of species (richness) in each San Diego Bay ecoregion, 2016.

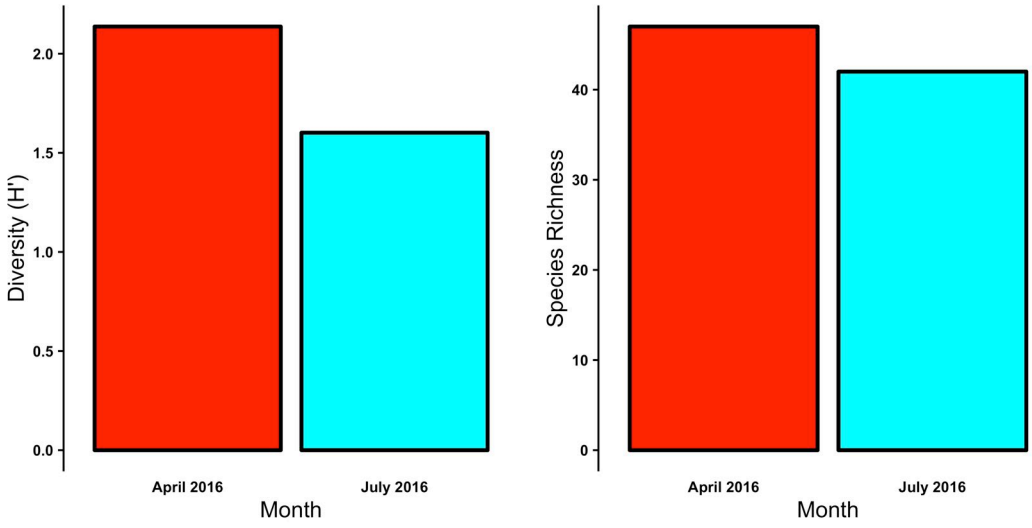


Figure 10. Shannon-Wiener Diversity (H') and number of species (richness) of fishes in San Diego Bay by sampling month, 2016.

Catch by Sampling Ecoregion and Period

North Ecoregion – A total of 5,158 fishes belonging to 40 species and weighing 83.2 kg was collected in the North Ecoregion over two sampling periods in 2016 (Table 4). Topsmelt was the most frequently caught species (30.6%), followed by Northern Anchovy (23.2%), Slough Anchovy (21.5%), Giant Kelpfish (*Heterostichus rostratus*; 8.1%), and Dwarf Perch (*Micrometrus minimus*; 4.1 %). Northern Anchovy led in total biomass (34.8%), followed by Round Stingray (32.2%), Spotted Sand Bass (7.0%), California Halibut (6.7%) and Slough Anchovy (3.3%).

North-Central Ecoregion - A total of 7,932 fishes belonging to 33 species and weighing 65.3 kg was collected in the North-Central Ecoregion in April and July, 2016 (Table 5). Slough Anchovy was the most abundant species (50.4%), followed by Topsmelt (21.4%), California Grunion (*Leuresthes tenuis*; 11.2%), Giant Kelpfish (4.2%), and Kelp Pipefish (3.1%). Round Stingray led in total biomass (36.1%), followed by Spotted Sand Bass (15.1%), Spotfin Croaker (11.0%), and Slough Anchovy (9.1%).

South-Central Ecoregion - A total of 3,001 fishes belonging to 21 species and weighing 49.2 kg was collected in the South-Central Ecoregion over the two sampling periods in 2016 (Table 6). Slough Anchovy was by far the most abundant species (57.4%), followed by Kelp Pipefish (15.4%), Topsmelt (8.7%), Round Stingray (6.2%), and Round Stingray led in total biomass (70.8%), followed by Spotted Sand Bass (10.0%), Slough Anchovy (5.4%) and Barred Sand Bass (*Paralabrax nebulifer*; 4.1%).

South Ecoregion - A total of 5,036 fishes belonging to 31 species and weighing 52.2 kg was collected in the South Ecoregion in April and July, 2016 (Table 7). Slough Anchovy was the most abundant species (39.7%), followed Arrow Goby (33.2%), Topsmelt (11.9%), Kelp Pipefish (4.4%), and Round Stingray (3.6%). Round Stingray led in total biomass (49.2%), followed by Spotted Sand Bass (14.7%), Slough Anchovy (6.7%), Bat Ray (*Myliobatis californica*; 6.1%), and Pacific Barracuda (*Sphyraena argentea*; 5.6%).

In April 2016, 9,443 individuals comprised of 47 species of fishes were captured (Figure 11, Table 8). In July, the catch increased to 11,684 fish, though species richness decreased to 42. Total biomass was greater in July (133.6 kg) than April (116.2 kg) (Figure 11, Table 9). From April to July there was a substantial decrease in total biomass in the South Ecoregion and an equally substantial increase in the North Ecoregion. This phenomenon is presumably due to Slough Anchovies and Topsmelt moving from the warm, protected waters in the South Ecoregion towards the open ocean (the North Ecoregion) over this period, plus an influx of Northern Anchovies into the North Ecoregion (Figure 12).

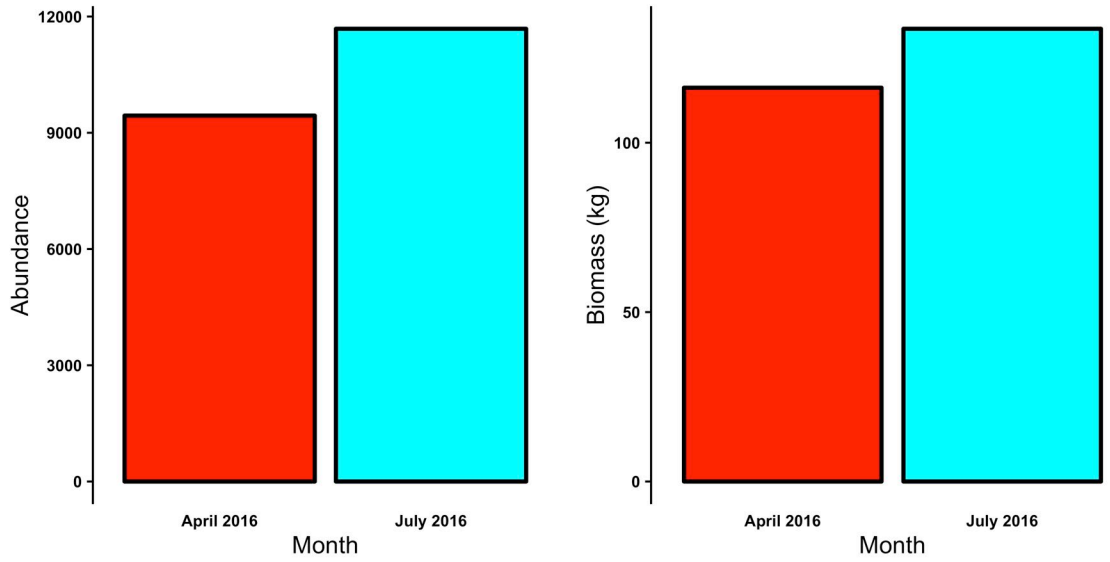


Figure 11. Total catch of fishes and biomass (kg) in San Diego Bay by sampling period, 2016.

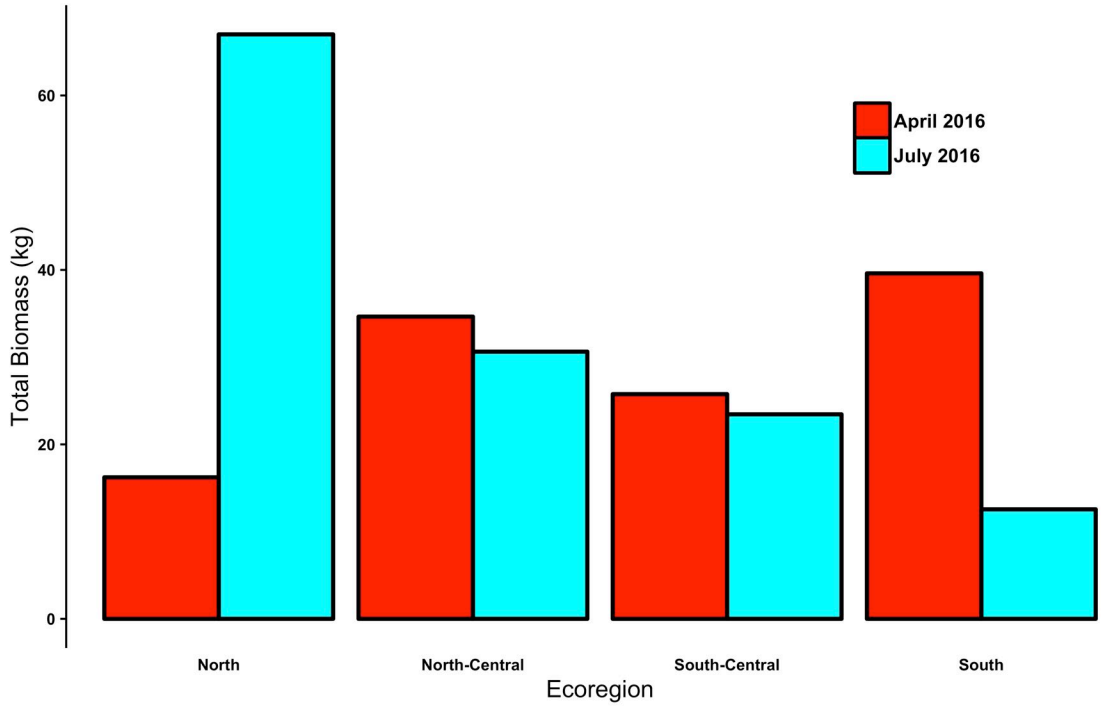


Figure 12. Biomass (kg) of San Diego Bay fishes by ecoregion, April and July 2016.

Table 8. Total abundance of fish species taken in San Diego Bay by sampling period, 2016.

		2016			
Scientific Name	**Common Name**	**April**	**July**	**Total**	**%**
Anchoa delicatissima	Slough Anchovy	2,313	6,512	8,825	41.77
Atherinops affinis	Topsmelt	2,162	1,974	4,136	19.58
Clevelandia ios	Arrow Goby	1,524	225	1,749	8.28
Engraulis mordax	Northern Anchovy		1,205	1,205	5.70
Syngnathus californiensis	Kelp Pipefish	805	300	1,105	5.23
Leuresthes tenuis	California Grunion	965		965	4.57
Heterostichus rostratus	Giant Kelpfish	564	215	779	3.69
Urobatis halleri	Round Stingray	316	288	604	2.86
Paralabrax nebulifer	Barred Sand Bass	67	223	290	1.37
Paralabrax maculatofasciatus	Spotted Sand Bass	127	112	239	1.13
Hypsoblennius gentilis	Bay Blenny	87	131	218	1.03
Micrometrus minimus	Dwarf Perch	20	192	212	1.00
Cymatogaster aggregata	Shiner Perch	137	62	199	0.94
Haemulon californiensis	Salema	54	25	79	0.37
Albula gilberti	Cortez Bonefish	47	30	77	0.36
Paralichthys californicus	California Halibut	39	29	68	0.32
Sphyraena argentea	Pacific Barracuda	49	10	59	0.28
Atherinopsis californiensis	Jacksmelt	43		43	0.20
Halichoeres semicinctus	Rock Wrasse	31	3	34	0.16
Anchoa compressa	Deepbody Anchovy	6	24	30	0.14
Paralabrax clathratus	Kelp Bass	7	21	28	0.13
Fundulus parvipinnis	California Killifish	1	22	23	0.11
Porichthys myriaster	Specklefin Midshipman	6	11	17	0.08
Gibbonsia elegans	Spotted Kelpfish	2	14	16	0.08
Cynoscion parvipinnis	Shortfin Corvina	10	3	13	0.06
Pleuronichthys ritteri	Spotted Turbot	10	1	11	0.05
Embiotoca jacksoni	Black Perch		10	10	0.05
Pleuronichthys guttulatus	Diamond Turbot	5	5	10	0.05
Quietula y-cauda	Shadow Goby	4	5	9	0.04
Sardinops sagax	Pacific Sardine		8	8	0.04
Roncador stearnsii	Spotfin Croaker	7		7	0.03
Symphurus atricaudus	California Tonguefish	1	5	6	0.03
Cosmocampus arctus	Snubnose Pipefish	5		5	0.02
Myliobatis californica	Bat Ray	4	1	5	0.02
Seriphus politus	Queenfish	4	1	5	0.02
Ctenogobius sagittula	Longtail Goby		4	4	0.02
Ilypnus gilberti	Cheekspot Goby	2	2	4	0.02
Citharichthys stigmaeus	Speckled Sanddab	3		3	0.01
Umbrina roncador	Yellowfin Croaker	2	1	3	0.01
Xystreurys liolepis	Fantail Sole	2	1	3	0.01
Acanthogobius flavimanus	Yellowfin Goby	1	1	2	0.01
Anisotremus davidsonii	Sargo	1	1	2	0.01
Gymnura marmorata	California Butterfly Ray	2		2	0.01
Hippocampus ingens	Pacific Seahorse		2	2	0.01
Scorpaena guttata	California Scorpionfish	1	1	2	0.01
Strongylura exilis	California Needlefish		2	2	0.01
Alloclinus holderi	Island Kelpfish	1		1	< 0.01
Atractoscion nobilis	White Seabass	1		1	< 0.01
Heterodontus francisci	Horn Shark	1		1	< 0.01
Hyporhamphus rosae	California Halfbeak		1	1	< 0.01
Porichthys notatus	Plainfin Midshipman		1	1	< 0.01
Rimicola muscarum	Kelp Clingfish	1		1	< 0.01
Sebastes serranoides	Olive Rockfish	1		1	< 0.01
Synodus lucioceps	California Lizardfish	1		1	< 0.01
Zapteryx exasperata	Banded Guitarfish	1		1	< 0.01
	Total:	**9,443**	**11,684**	**21,127**	
	# of Species:	47	42		

Table 9. Total biomass (g) of fish species taken in San Diego Bay by sampling period, 2016.

		2016			
Scientific Name	**Common Name**	**April**	**July**	**Total**	**%**
Urobatis halleri	Round Stingray	54,440	56,413	110,853	44.37
Engraulis mordax	Northern Anchovy		28,969	28,969	11.59
Paralabrax maculatofasciatus	Spotted Sand Bass	15,869	12,372	28,241	11.30
Anchoa delicatissima	Slough Anchovy	4,234	10,566	14,800	5.92
Paralichthys californicus	California Halibut	8,058	1,977	10,035	4.02
Paralabrax nebulifer	Barred Sand Bass	682	6,865	7,547	3.02
Roncador stearnsii	Spotfin Croaker	7,200		7,200	2.88
Cynoscion parvipinnis	Shortfin Corvina	3,420	1,725	5,145	2.06
Myliobatis californica	Bat Ray	3,200	1,400	4,600	1.84
Atherinops affinis	Topsmelt	1,647	2,933	4,580	1.83
Sphyraena argentea	Pacific Barracuda	3,600	12	3,612	1.45
Atherinopsis californiensis	Jacksmelt	3,330		3,330	1.33
Heterostichus rostratus	Giant Kelpfish	790	1,891	2,681	1.07
Gymnura marmorata	California Butterfly Ray	2,350		2,350	0.94
Hypsoblennius gentilis	Bay Blenny	343	1,589	1,932	0.77
Micrometrus minimus	Dwarf Perch	402	1,416	1,818	0.73
Leuresthes tenuis	California Grunion	1,591		1,591	0.64
Albula gilberti	Cortez Bonefish	574	948	1,522	0.61
Haemulon californiensis	Salema	702	390	1,092	0.44
Cymatogaster aggregata	Shiner Perch	420	506	926	0.37
Porichthys myriaster	Specklefin Midshipman	440	336	776	0.31
Embiotoca jacksoni	Black Perch		688	688	0.28
Scorpaena guttata	California Scorpionfish	590	50	640	0.26
Halichoeres semicinctus	Rock Wrasse	278	293	571	0.23
Umbrina roncador	Yellowfin Croaker	519	40	559	0.22
Syngnathus californiensis	Kelp Pipefish	265	282	547	0.22
Anchoa compressa	Deepbody Anchovy	81	355	436	0.17
Pleuronichthys ritteri	Spotted Turbot	362	60	422	0.17
Pleuronichthys guttulatus	Diamond Turbot	173	240	413	0.17
Paralabrax clathratus	Kelp Bass	40	350	390	0.16
Gibbonsia elegans	Spotted Kelpfish	6	266	272	0.11
Fundulus parvipinnis	California Killifish	1	211	212	0.08
Clevelandia ios	Arrow Goby	165	27	193	0.08
Xystreurys liolepis	Fantail Sole	95	77	172	0.07
Symphurus atricaudus	California Tonguefish	17	140	157	0.06
Synodus lucioceps	California Lizardfish	90		90	0.04
Sardinops sagax	Pacific Sardine		81	81	0.03
Ctenogobius sagittula	Longtail Goby		70	70	0.03
Zapteryx exasperata	Banded Guitarfish	65		65	0.03
Hippocampus ingens	Pacific Seahorse		58	58	0.02
Seriphus politus	Queenfish	50	2	52	0.02
Heterodontus francisci	Horn Shark	42		42	0.02
Acanthogobius flavimanus	Yellowfin Goby	33	7	40	0.02
Anisotremus davidsonii	Sargo	21	16	37	0.01
Citharichthys stigmaeus	Speckled Sanddab	32		32	0.01
Quietula y-cauda	Shadow Goby	2	2	4	< 0.01
Sebastes serranoides	Olive Rockfish	3		3	< 0.01
Ilypnus gilberti	Cheekspot Goby	1	1	2	< 0.01
Cosmocampus arctus	Snubnose Pipefish	1		1	< 0.01
Hyporhamphus rosae	California Halfbeak		1	1	< 0.01
Porichthys notatus	Plainfin Midshipman		1	1	< 0.01
Alloclinus holderi	Island Kelpfish	1		1	< 0.01
Strongylura exilis	California Needlefish		0.4	0.4	< 0.01
Atractoscion nobilis	White Seabass	0.4		0.4	< 0.01
Rimicola muscarum	Kelp Clingfish	0.2		0.2	< 0.01
	Total:	**116,226**	**133,625**	**249,851**	
	# of Species:	47	42		

Catch in Bay Depth Strata and Subhabitats

Of the three bay depth strata (intertidal, nearshore, and channel) the greatest catch of fishes was in the nearshore strata (11,322 individuals from 36 species; Table 10). 7,452 fishes from 30 species were captured in the intertidal, and 2,353 fishes from 26 species were captured in the channel. A total of 10,883 fishes was taken in non-vegetated areas of the nearshore and intertidal (Table 11) comprised of 39 of the 55 species captured during the 2016 surveys. 7,891 fishes, also from 39 species, were caught in the nearshore and intertidal vegetated areas.

Purse seine being retrieved from the channel in the South-Central Ecoregion in July. (photo: Matt Robart)

Table 10. Total abundance of fish species taken from San Diego Bay by depth strata, 2016.

		Depth Strata				
Scientific Name	**Common Name**	**Channel**	**Intertidal**	**Nearshore**	**Total**	**%**
Anchoa delicatissima	Slough Anchovy	1,620	639	6,566	8,825	41.77
Atherinops affinis	Topsmelt	79	3,813	244	4,136	19.58
Clevelandia ios	Arrow Goby		1,665	84	1,749	8.28
Engraulis mordax	Northern Anchovy			1,205	1,205	5.70
Syngnathus californiensis	Kelp Pipefish		102	1,003	1,105	5.23
Leuresthes tenuis	California Grunion	77	888		965	4.57
Heterostichus rostratus	Giant Kelpfish		17	762	779	3.69
Urobatis halleri	Round Stingray	359	15	230	604	2.86
Paralabrax nebulifer	Barred Sand Bass	31	75	184	290	1.37
Paralabrax maculatofasciatus	Spotted Sand Bass	15	40	184	239	1.13
Hypsoblennius gentilis	Bay Blenny	2	28	188	218	1.03
Micrometrus minimus	Dwarf Perch		1	211	212	1.00
Cymatogaster aggregata	Shiner Perch	1	18	180	199	0.94
Haemulon californiensis	Salema			79	79	0.37
Albula gilberti	Cortez Bonefish	1	71	5	77	0.36
Paralichthys californicus	California Halibut	55	6	7	68	0.32
Sphyraena argentea	Pacific Barracuda		10	49	59	0.28
Atherinopsis californiensis	Jacksmelt	36		7	43	0.20
Halichoeres semicinctus	Rock Wrasse			34	34	0.16
Anchoa compressa	Deepbody Anchovy	27	3		30	0.14
Paralabrax clathratus	Kelp Bass		1	27	28	0.13
Fundulus parvipinnis	California Killifish		23		23	0.11
Porichthys myriaster	Specklefin Midshipman	17			17	0.08
Gibbonsia elegans	Spotted Kelpfish		3	13	16	0.08
Cynoscion parvipinnis	Shortfin Corvina	1		12	13	0.06
Pleuronichthys ritteri	Spotted Turbot	10		1	11	0.05
Embiotoca jacksoni	Black Perch			10	10	0.05
Pleuronichthys guttulatus	Diamond Turbot	4	6		10	0.05
Quietula y-cauda	Shadow Goby		9		9	0.04
Sardinops sagax	Pacific Sardine			8	8	0.04
Roncador stearnsii	Spotfin Croaker			7	7	0.03
Symphurus atricaudus	California Tonguefish	6			6	0.03
Cosmocampus arctus	Snubnose Pipefish		1	4	5	0.02
Myliobatis californica	Bat Ray			5	5	0.02
Seriphus politus	Queenfish		2	3	5	0.02
Ctenogobius sagittula	Longtail Goby		4		4	0.02
Ilypnus gilberti	Cheekspot Goby		4		4	0.02
Citharichthys stigmaeus	Speckled Sanddab	1	2		3	0.01
Umbrina roncador	Yellowfin Croaker	1		2	3	0.01
Xystreurys liolepis	Fantail Sole	3			3	0.01
Acanthogobius flavimanus	Yellowfin Goby		2		2	0.01
Anisotremus davidsonii	Sargo			2	2	0.01
Gymnura marmorata	California Butterfly Ray	2			2	0.01
Hippocampus ingens	Pacific Seahorse	1		1	2	0.01
Scorpaena guttata	California Scorpionfish	1		1	2	0.01
Strongylura exilis	California Needlefish		2		2	0.01
Alloclinus holderi	Island Kelpfish			1	1	< 0.01
Atractoscion nobilis	White Seabass		1		1	< 0.01
Heterodontus francisci	Horn Shark	1			1	< 0.01
Hyporhamphus rosae	California Halfbeak		1		1	< 0.01
Porichthys notatus	Plainfin Midshipman	1			1	< 0.01
Rimicola muscarum	Kelp Clingfish			1	1	< 0.01
Sebastes serranoides	Olive Rockfish			1	1	< 0.01
Synodus lucioceps	California Lizardfish			1	1	< 0.01
Zapteryx exasperata	Banded Guitarfish	1			1	< 0.01
	Total:	**2,353**	**7,452**	**11,322**	**21,127**	
	# of Species:	26	30	36		

Table 11. Total abundance of fish species taken from San Diego Bay by subhabitat, 2016.

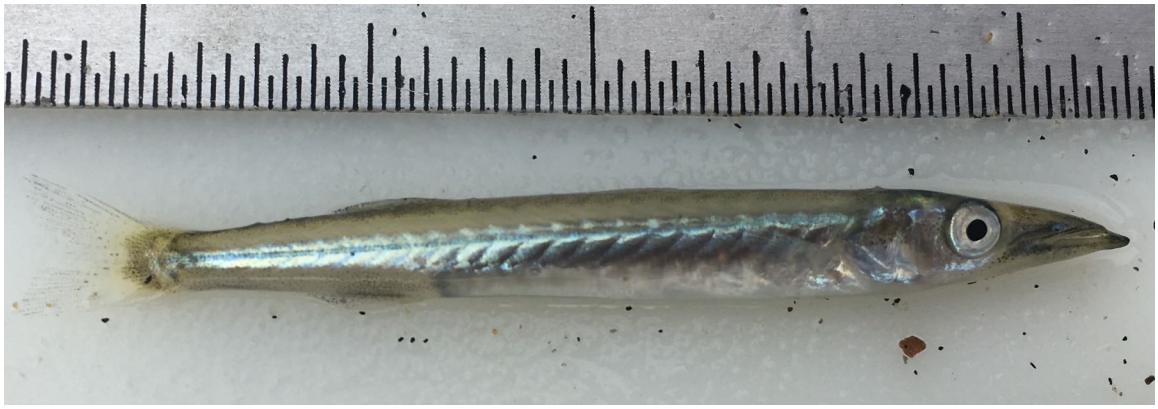
		Subhabitat				
Scientific Name	Common Name	Channel	Non-Vegetated	Vegetated	Total	%
Anchoa delicatissima	Slough Anchovy	1,620	5,564	1,641	8,825	41.77
Atherinops affinis	Topsmelt	79	1,152	2,905	4,136	19.58
Clevelandia ios	Arrow Goby		13	1,736	1,749	8.28
Engraulis mordax	Northern Anchovy		1,187	18	1,205	5.70
Syngnathus californiensis	Kelp Pipefish		651	454	1,105	5.23
Leuresthes tenuis	California Grunion	77	888		965	4.57
Heterostichus rostratus	Giant Kelpfish		513	266	779	3.69
Urobatis halleri	Round Stingray	359	78	167	604	2.86
Paralabrax nebulifer	Barred Sand Bass	31	159	100	290	1.37
Paralabrax maculatofasciatus	Spotted Sand Bass	15	114	110	239	1.13
Hypsoblennius gentilis	Bay Blenny	2	132	84	218	1.03
Micrometrus minimus	Dwarf Perch		90	122	212	1.00
Cymatogaster aggregata	Shiner Perch	1	115	83	199	0.94
Haemulon californiensis	Salema		50	29	79	0.37
Albula gilberti	Cortez Bonefish	1	42	34	77	0.36
Paralichthys californicus	California Halibut	55	4	9	68	0.32
Sphyraena argentea	Pacific Barracuda		59		59	0.28
Atherinopsis californiensis	Jacksmelt	36		7	43	0.20
Halichoeres semicinctus	Rock Wrasse		1	33	34	0.16
Anchoa compressa	Deepbody Anchovy	27		3	30	0.14
Paralabrax clathratus	Kelp Bass		11	17	28	0.13
Fundulus parvipinnis	California Killifish		1	22	23	0.11
Porichthys myriaster	Specklefin Midshipman	17			17	0.08
Gibbonsia elegans	Spotted Kelpfish		8	8	16	0.08
Cynoscion parvipinnis	Shortfin Corvina	1	5	7	13	0.06
Pleuronichthys ritteri	Spotted Turbot	10		1	11	0.05
Embiotoca jacksoni	Black Perch		7	3	10	0.05
Pleuronichthys guttulatus	Diamond Turbot	4	3	3	10	0.05
Quietula y-cauda	Shadow Goby		8	1	9	0.04
Sardinops sagax	Pacific Sardine		8		8	0.04
Roncador stearnsii	Spotfin Croaker			7	7	0.03
Symphurus atricaudus	California Tonguefish	6			6	0.03
Cosmocampus arctus	Snubnose Pipefish		4	1	5	0.02
Myliobatis californica	Bat Ray		3	2	5	0.02
Seriphus politus	Queenfish		2	3	5	0.02
Ctenogobius sagittula	Longtail Goby			4	4	0.02
Ilypnus gilberti	Cheekspot Goby		2	2	4	0.02
Citharichthys stigmaeus	Speckled Sanddab	1	1	1	3	0.01
Umbrina roncador	Yellowfin Croaker	1	1	1	3	0.01
Xystreurys liolepis	Fantail Sole	3			3	0.01
Acanthogobius flavimanus	Yellowfin Goby			2	2	0.01
Anisotremus davidsonii	Sargo			2	2	0.01
Gymnura marmorata	California Butterfly Ray	2			2	0.01
Hippocampus ingens	Pacific Seahorse	1	1		2	0.01
Scorpaena guttata	California Scorpionfish	1	1		2	0.01
Strongylura exilis	California Needlefish		1	1	2	0.01
Alloclinus holderi	Island Kelpfish		1		1	< 0.01
Atractoscion nobilis	White Seabass		1		1	< 0.01
Heterodontus francisci	Horn Shark	1			1	< 0.01
Hyporhamphus rosae	California Halfbeak		1		1	< 0.01
Porichthys notatus	Plainfin Midshipman	1			1	< 0.01
Rimicola muscarum	Kelp Clingfish		1		1	< 0.01
Sebastes serranoides	Olive Rockfish			1	1	< 0.01
Synodus lucioceps	California Lizardfish			1	1	< 0.01
Zapteryx exasperata	Banded Guitarfish	1			1	< 0.01
	Total:	**2,353**	**10,883**	**7,891**	**21,127**	
	# of Species:	26	39	39		

Nursery Area Function

San Diego Bay continues to be a nursery area for nearly half of the fishes found there. Approximately 48% of all fishes sampled in San Diego Bay were juveniles (Table 12). In terms of percent juveniles captured, the top three species (Northern Anchovy, Topsmelt, 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 12. Percent of juveniles taken of the top 20 species of fish from San Diego Bay, 2016.

Scientific Name	Common Name	Juveniles	Total Abundance	% Juvenile
Engraulis mordax	Northern Anchovy	1,205	1,205	100.00
Atherinops affinis	Topsmelt	4,018	4,136	97.15
Clevelandia ios	Arrow Goby	1,674	1,749	95.71
Haemulon californiensis	Salema	75	79	94.94
Albula gilberti	Cortez Bonefish	73	77	94.81
Hypsoblennius gentilis	Bay Blenny	203	218	93.12
Leuresthes tenuis	California Grunion	890	965	92.23
Halichoeres semicinctus	Rock Wrasse	30	34	88.24
Heterostichus rostratus	Giant Kelpfish	657	779	84.34
Paralabrax nebulifer	Barred Sand Bass	213	290	73.45
Cymatogaster aggregata	Shiner Perch	114	199	57.29
Syngnathus californiensis	Kelp Pipefish	622	1,105	56.29
Micrometrus minimus	Dwarf Perch	117	212	55.19
Paralabrax maculatofasciatus	Spotted Sand Bass	69	239	28.87
Sphyraena argentea	Pacific Barracuda	10	59	16.95
Paralichthys californicus	California Halibut	11	68	16.18
Atherinopsis californiensis	Jacksmelt	6	43	13.95
Urobatis halleri	Round Stingray	36	604	5.96
Anchoa compressa	Deepbody Anchovy	0	30	0.00
Anchoa delicatissima	Slough Anchovy	0	8,825	0.00
		10,023	**20,916**	**47.92**



Juvenile Pacific Barracuda captured by large seine from the North Ecoregion in July 2016. (photo: Dana Michels)

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. = (%N + % Wt) * % F.O; Table 13; Figure 13). This index is indicative of the importance of each species to the energy flow within the San Diego Bay ecosystem. Round Stingray ranked first (E.I. 4,723), Slough Anchovy ranked second (E.I. 4,173), Topsmelt ranked third (E.I. 2,141), and Spotted Sand Bass ranked fourth (E.I. 1,243). All four species were found ubiquitously throughout the bay, though Slough Anchovy were not present in the North Ecoregion during the April sampling period. Round Stingray and Spotted Sand Bass were dominant in terms of biomass, and Slough Anchovy and Topsmelt were dominant in terms of numerical abundance. These species were followed by Arrow Goby (E.I. 836), which were nearly all captured in the South Ecoregion where it dominated the intertidal catch along with Topsmelt.

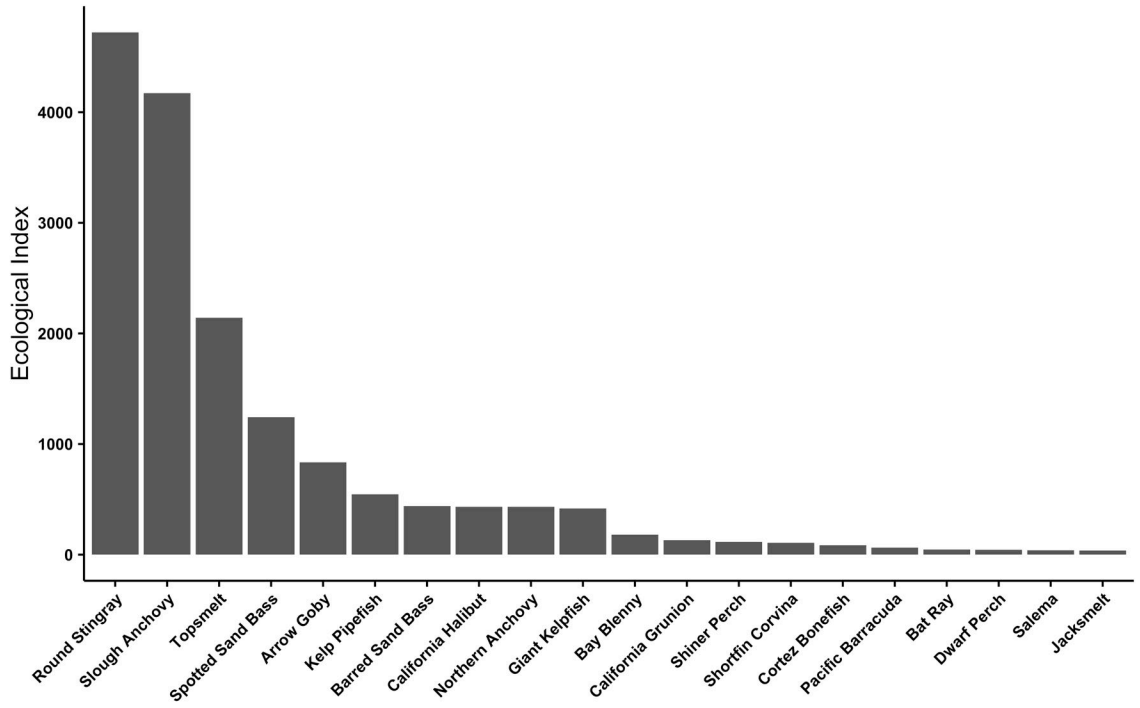


Figure 13. Top 20 species of San Diego Bay fishes ranked by Ecological Index, 2016.

Table 13. Relative abundance, relative biomass, frequency of occurrence, and Ecological Index (E.I.) of San Diego Bay fishes, 2016.

Scientific Name	Common Name	Abundance %	Biomass %	Frequency of Occurance	Ecological Index
Urobatis halleri	Round Stingray	2.86	44.37	100.0	4722.66
Anchoa delicatissima	Slough Anchovy	41.77	5.92	87.5	4173.30
Atherinops affinis	Topsmelt	19.58	1.83	100.0	2140.99
Paralabrax maculatofasciatus	Spotted Sand Bass	1.13	11.30	100.0	1243.44
Clevelandia ios	Arrow Goby	8.28	0.08	100.0	835.56
Syngnathus californiensis	Kelp Pipefish	5.23	0.22	100.0	544.92
Paralabrax nebulifer	Barred Sand Bass	1.37	3.02	100.0	439.34
Paralichthys californicus	California Halibut	0.32	4.02	100.0	433.83
Engraulis mordax	Northern Anchovy	5.70	11.59	25.0	432.45
Heterostichus rostratus	Giant Kelpfish	3.69	1.07	87.5	416.52
Hypsoblennius gentilis	Bay Blenny	1.03	0.77	100.0	180.51
Leuresthes tenuis	California Grunion	4.57	0.64	25.0	130.11
Cymatogaster aggregata	Shiner Perch	0.94	0.37	87.5	114.83
Cynoscion parvipinnis	Shortfin Corvina	0.06	2.06	50.0	106.04
Albula gilberti	Cortez Bonefish	0.36	0.61	87.5	85.21
Sphyraena argentea	Pacific Barracuda	0.28	1.45	37.5	64.69
Myliobatis californica	Bat Ray	0.02	1.84	25.0	46.62
Micrometrus minimus	Dwarf Perch	1.00	0.73	25.0	43.28
Haemulon californiensis	Salema	0.37	0.44	50.0	40.55
Atherinopsis californiensis	Jacksmelt	0.20	1.33	25.0	38.41
Roncador stearnsii	Spotfin Croaker	0.03	2.88	12.5	36.44
Porichthys myriaster	Specklefin Midshipman	0.08	0.31	75.0	29.33
Gymnura marmorata	California Butterfly Ray	0.01	0.94	25.0	23.75
Anchoa compressa	Deepbody Anchovy	0.14	0.17	50.0	15.83
Paralabrax clathratus	Kelp Bass	0.13	0.16	50.0	14.43
Pleuronichthys guttulatus	Diamond Turbot	0.05	0.17	62.5	13.29
Halichoeres semicinctus	Rock Wrasse	0.16	0.23	25.0	9.74
Pleuronichthys ritteri	Spotted Turbot	0.05	0.17	37.5	8.29
Fundulus parvipinnis	California Killifish	0.11	0.08	37.5	7.26
Gibbonsia elegans	Spotted Kelpfish	0.08	0.11	37.5	6.92
Scorpaena guttata	California Scorpionfish	0.01	0.26	25.0	6.64
Umbrina roncador	Yellowfin Croaker	0.01	0.22	25.0	5.95
Embiotoca jacksoni	Black Perch	0.05	0.28	12.5	4.03
Symphurus atricaudus	California Tonguefish	0.03	0.06	25.0	2.28
Seriphus politus	Queenfish	0.02	0.02	50.0	2.22
Xystreurys liolepis	Fantail Sole	0.01	0.07	25.0	2.08
Quietula y-cauda	Shadow Goby	0.04	< 0.01	37.5	1.65
Sardinops sagax	Pacific Sardine	0.04	0.03	12.5	0.88
Hippocampus ingens	Pacific Seahorse	0.01	0.02	25.0	0.82
Citharichthys stigmaeus	Speckled Sanddab	0.01	0.01	25.0	0.68
Acanthogobius flavimanus	Yellowfin Goby	0.01	0.02	25.0	0.64
Anisotremus davidsonii	Sargo	0.01	0.01	25.0	0.61
Cosmocampus arctus	Snubnose Pipefish	0.02	< 0.01	25.0	0.61
Ctenogobius sagittula	Longtail Goby	0.02	0.03	12.5	0.59
Synodus lucioceps	California Lizardfish	< 0.01	0.04	12.5	0.51
Ilypnus gilberti	Cheekspot Goby	0.02	< 0.01	25.0	0.49
Zapteryx exasperata	Banded Guitarfish	< 0.01	0.03	12.5	0.38
Heterodontus francisci	Horn Shark	< 0.01	0.02	12.5	0.27
Strongylura exilis	California Needlefish	0.01	< 0.01	25.0	0.24
Sebastes serranoides	Olive Rockfish	< 0.01	< 0.01	12.5	0.07
Hyporhamphus rosae	California Halfbeak	< 0.01	< 0.01	12.5	0.06
Porichthys notatus	Plainfin Midshipman	< 0.01	< 0.01	12.5	0.06
Alloclinus holderi	Island Kelpfish	< 0.01	< 0.01	12.5	0.06
Atractoscion nobilis	White Seabass	< 0.01	< 0.01	12.5	0.06
Rimicola muscarum	Kelp Clingfish	< 0.01	< 0.01	12.5	0.06

Principle species

Round Stingray (*Urobatis halleri*)

The highest ranked species in terms of ecological importance in 2016 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 2.9% of the total individuals captured in the 2016 surveys, those individuals accounted for 44.4% of the biomass. The sizes of captured Round Stingrays were widely stratified and representative of its entire size range, and showed growth of juveniles and sub-adults between the April to July sampling periods (Figure 14). 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 and South Ecoregions.

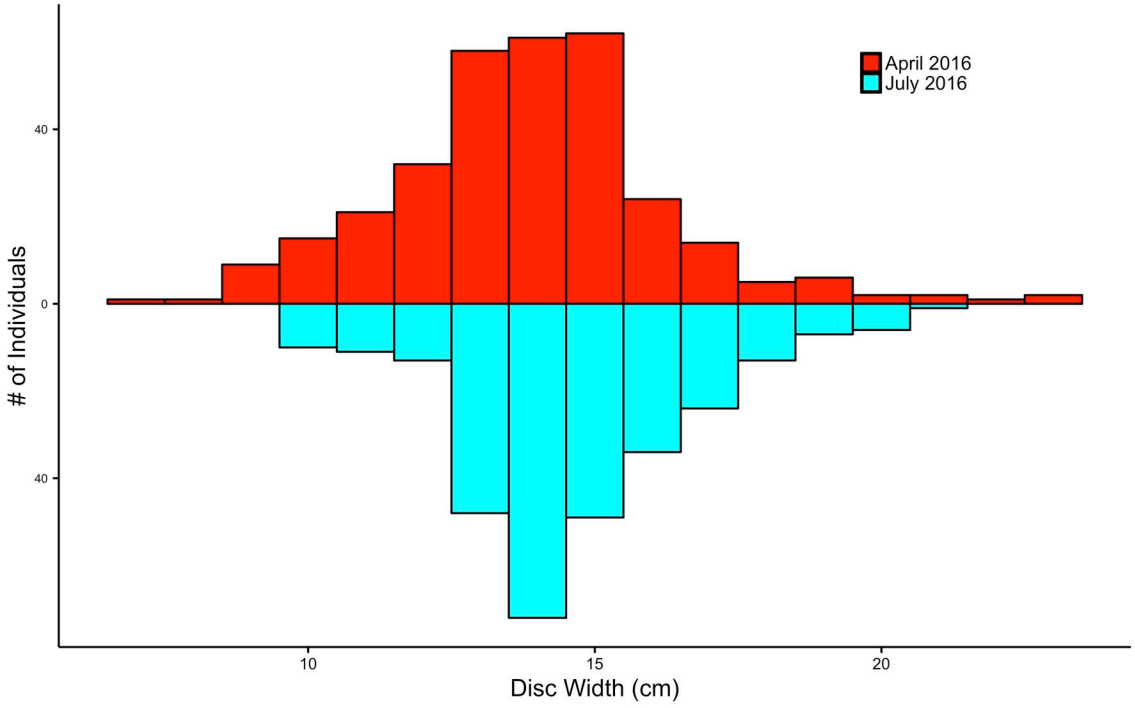


Figure 14. Total number of Round Stingray individuals by disc width (cm) from San Diego Bay, April and July 2016.

Slough Anchovy (*Anchoa delicatissima*)

Slough Anchovy was ranked as the second most ecologically important in San Diego Bay. This species was ubiquitous throughout the bay during the July survey and was found in all Ecoregions except the North Ecoregion during the April survey. They were found in all depth strata and subhabitats. Despite only having the fourth highest biomass of all fishes captured in 2016, they accounted for 41.8% of the total abundance captured during the surveys, and all individuals were considered to be adults, though their size distribution showed clear growth between the April and July sampling periods (Figure 15). The bay is a well-known nursery area for this critical species and there are no doubt a significant number of juveniles of this species utilizing the bay, however juvenile Slough Anchovy are exceptionally narrow species that are unlikely to be captured through most sampling methods employed.

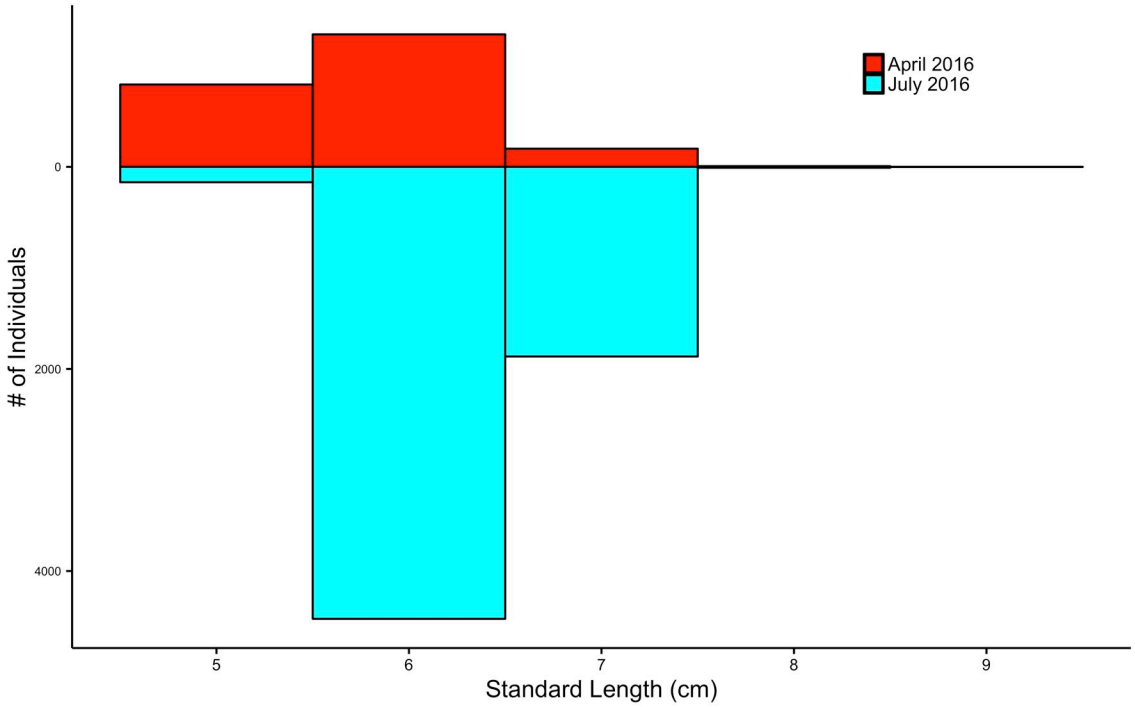


Figure 15. Total number of Slough Anchovy individuals by standard length (cm) from San Diego Bay, April and July 2016.

Topsmelt (*Atherinops affinis*)

Topsmelt was ranked third 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 (97.2%) were nearly thrice as abundant in the vegetated (2,905) versus non-vegetated (1,152) subhabitats. They were the second most abundant fish in the survey comprising 19.8% of the catch, but only 1.8% of the biomass due to their small size. Their size frequency distributions (Figure 16) suggested a recruitment event occurred between the April and July sampling events, but also indicated that while the vast majority of individuals were young-of-the-year fishes, some adults were present in the bay during July sampling.

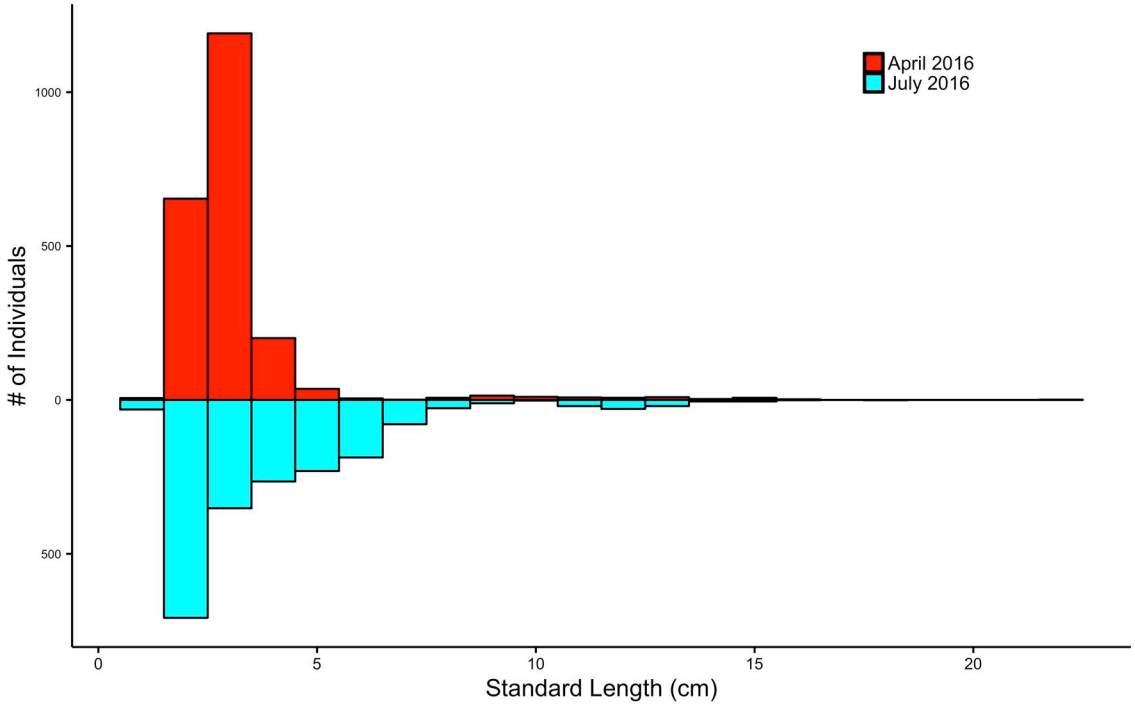


Figure 16. Total number of Topsmelt individuals by standard length (cm) from San Diego Bay, April and July 2016.

Spotted Sand Bass (*Paralabrax maculatofasciatus*)

Spotted Sand Bass are the ubiquitous mesocarnivore in San Diego Bay. In 2016, they ranked fourth in Ecological Index – a product of having the third highest biomass despite only having the tenth 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. There was extremely fast growth of juvenile and sub-adult Spotted Sand Bass between sampling periods, and a bimodal size distribution (Figure 17) during each sampling period indicated the presence of both juveniles and adults.

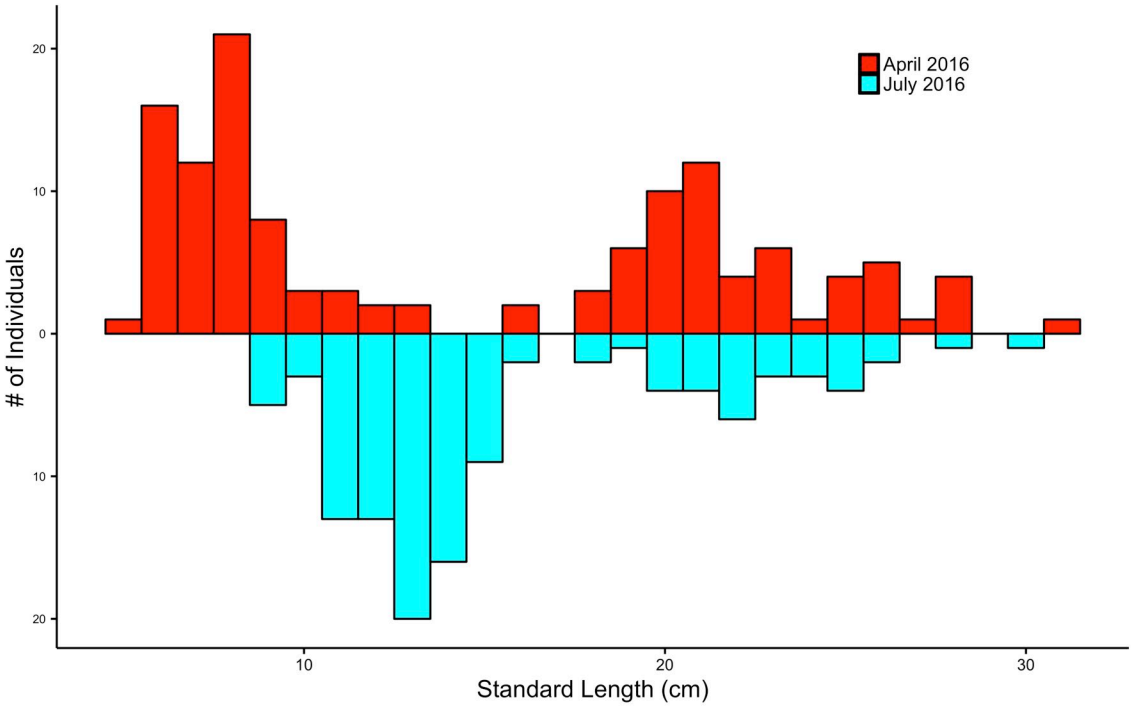


Figure 17. Total number of Spotted Sand Bass individuals by standard length (cm) from San Diego Bay, April and July 2016.

Arrow Goby (*Clevelandia ios*)

Arrow Goby was ranked fifth by the Ecological Index and were found during both sampling periods and at all ecoregions, though were caught almost exclusively in the vegetated intertidal subhabitat. These mostly juvenile fish (95.7%) were the third most abundant fish in the survey comprising 8.3% of the catch, but less than 0.1% of the biomass due to their small size. Their size frequency distributions (Figure 18) suggested a recruitment event prior to the April sampling event, and heavy natural mortality with slight growth between the April and July sampling events.

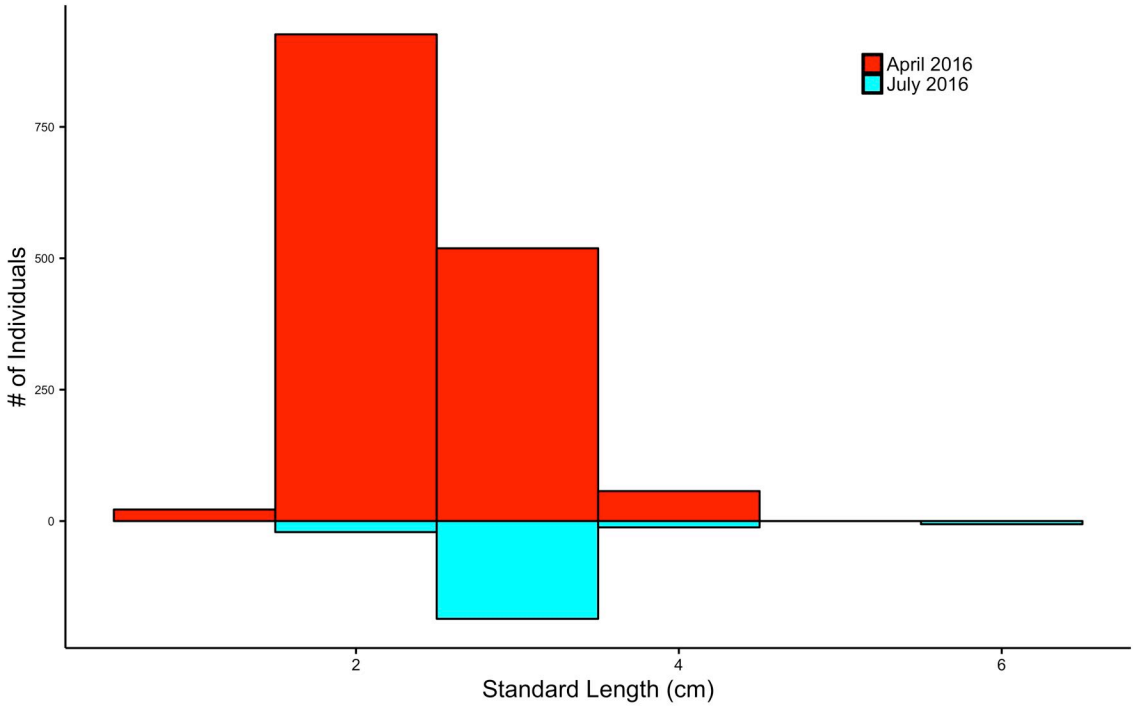


Figure 18. Total number of Arrow Goby individuals by standard length (cm) from San Diego Bay, April and July 2016.

Kelp Pipefish (*Syngnathus californiensis*)

Though these long, narrow fishes only accounted for 0.2% of the biomass captured in 2016, Kelp Pipefish ranked sixth in Ecological Index by accounting for 5.2% of the total abundance and being caught in the all ecoregions during both survey periods. They were caught in all depth strata and habitats except for the channel subhabitat. More than 90% of the individuals were captured in the nearshore subhabitat and showed no apparent preference for vegetated versus non-vegetated habitat. A uniform size distribution belied the fact that more than half (56.3%) of the individuals captured were juveniles (Figure 19), but the sharp increase in size from April to July supported the idea that this species grows quickly.

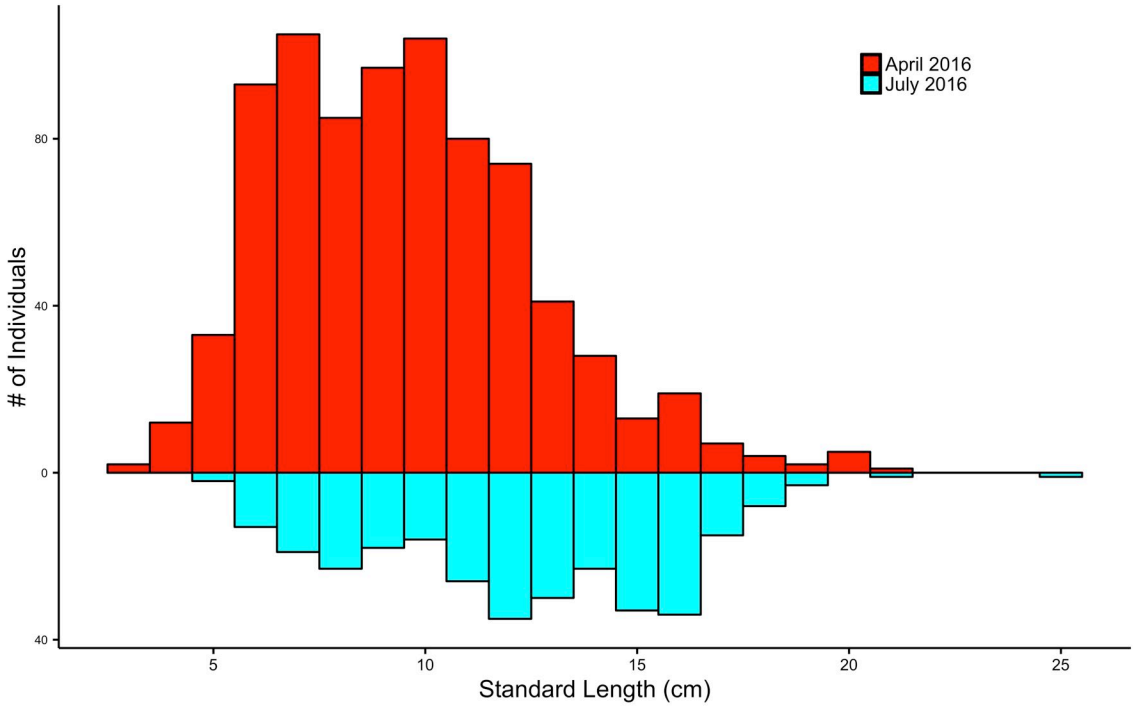


Figure 19. Total number of Kelp Pipefish individuals by standard length (cm) from San Diego Bay, April and July 2016.

Barred Sand Bass (*Paralabrax nebulifer*)

This species was ranked seventh in terms of Ecological Index, because it was the ninth most frequent catch (1.4%) with the sixth highest biomass (3.0%) during the 2016 surveys. Like its congener (*P. maculatofasciatus*), they are a ubiquitous mesocarnivore having been caught in all ecoregions, survey periods, subhabitats, and depth strata. They were present mostly in the nearshore in the North-Central and South-Central Ecoregions in July, but were also present in the same areas in smaller numbers during April. About three-quarters of the Barred Sand Bass captured during the surveys were juveniles, including nearly every individual during the April sampling period (Figure 20) suggesting that these young-of-the-year grew quickly between the two sampling periods.

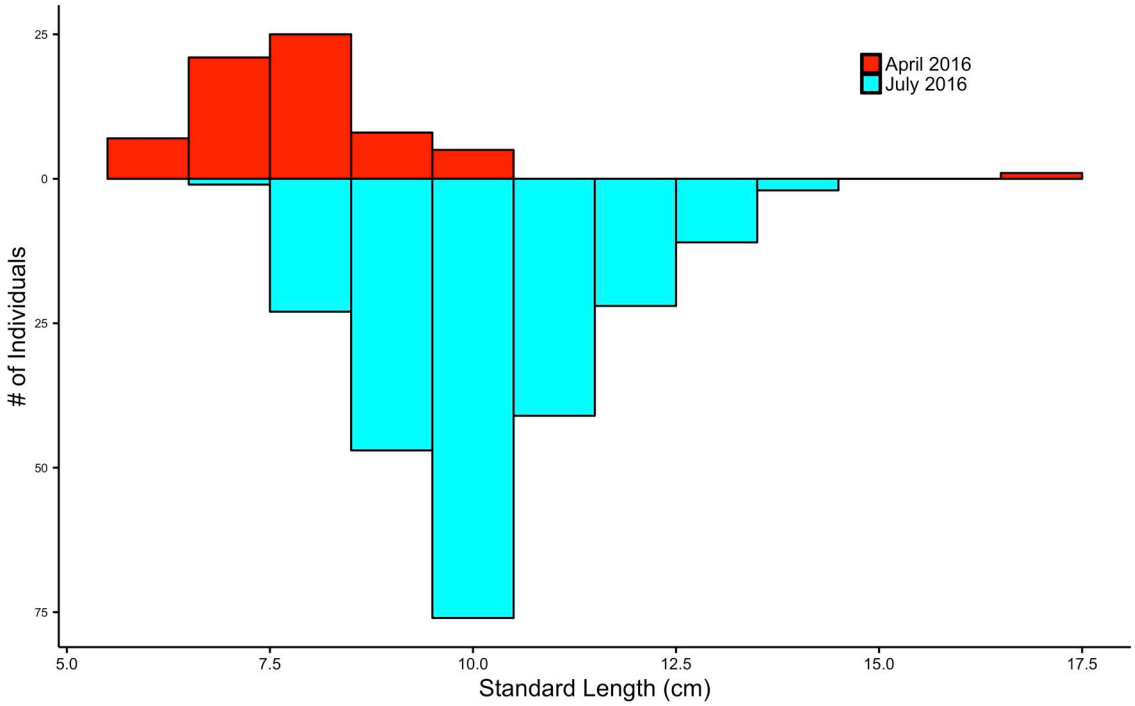


Figure 20. Total number of Barred Sand Bass individuals by standard length (cm) from San Diego Bay, April and July 2016.

California Halibut (*Paralichthys californicus*)

While not a frequently caught species (0.3% of the total catch), Calfornia Halibut are ranked eighth in in Ecological Index as a product of being caught at all Ecoregions, all depth strata, and all subhabitats, and ranking fifth in biomass (4.0%). Only about 16% of the individuals were juveniles, but very few were mature adults and only one fish would have been considered legal for recreation fishing purposes (Figure 21).

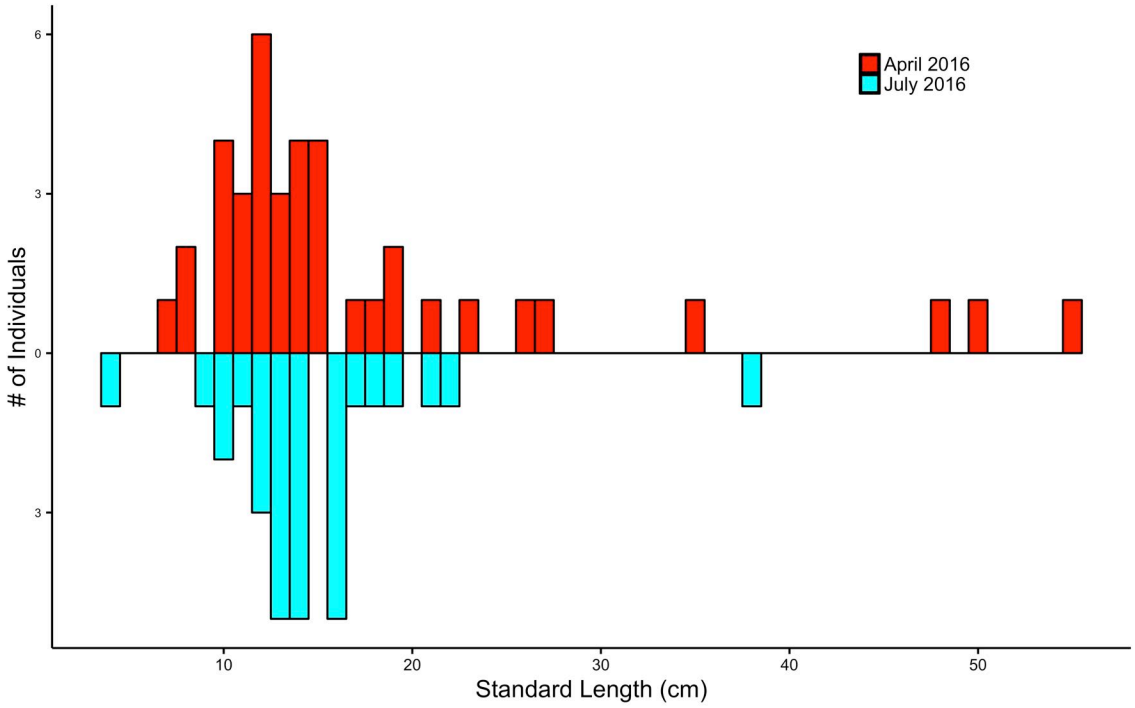


Figure 21. Total number of California Halibut individuals by standard length (cm) from San Diego Bay, April and July 2016.

Northern Anchovy (*Engraulis mordax*)

Northern Anchovy ranked ninth in Ecological Index. Despite being a dominant species in the North Ecoregion and accounting for 5.7% of the individuals and 11.6% of the biomass throughout the bay, their distribution was extremely limited over time and space. Over 99% of individuals were caught in the North Ecoregion, only during the July sampling period, and almost exclusively in the nearshore non-vegetated subhabitat. In fact, 97% of the individuals caught were from one purse seine replicate, and every one was a juvenile (Figure 22). Although adult Northern Anchovies typically live outside of bays and harbors, young-of-the-year utilize the calm, warm water and vegetation in the bay for shelter.

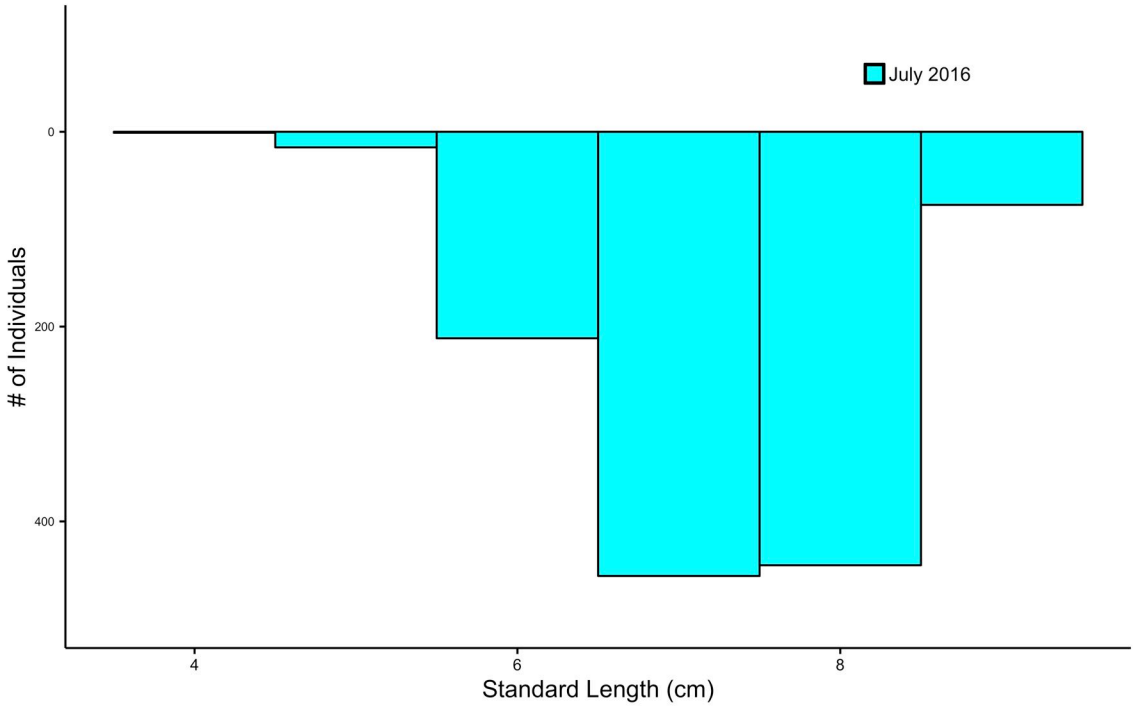


Figure 22. Total number of Northern Anchovy individuals by standard length (cm) from San Diego Bay, July 2016. No Northern Anchovy were caught in April 2016.

Giant Kelpfish (*Heterostichus rostratus*)

Giant Kelpfish ranked tenth in the Ecological Index and were present during each sampling period in all ecoregions, except for the South Ecoregion during July. They were found in both vegetated and non-vegetated habitats in the nearshore and intertidal depth strata, however, 45 times the number of individuals were taken in the nearshore strata (762) than the intertidal (17). 84.3% of the Giant Kelpfish captured were juveniles, and all individuals were less than 22 cm SL. There was a stark shift in distribution of size classes (Figure 23) from April to July suggesting a strong winter recruitment event and rapid growth between sampling events. This observed growth fits within parameters for juvenile growth rates as estimated by a recent otolith ageing study (Winston et al., *in review*).

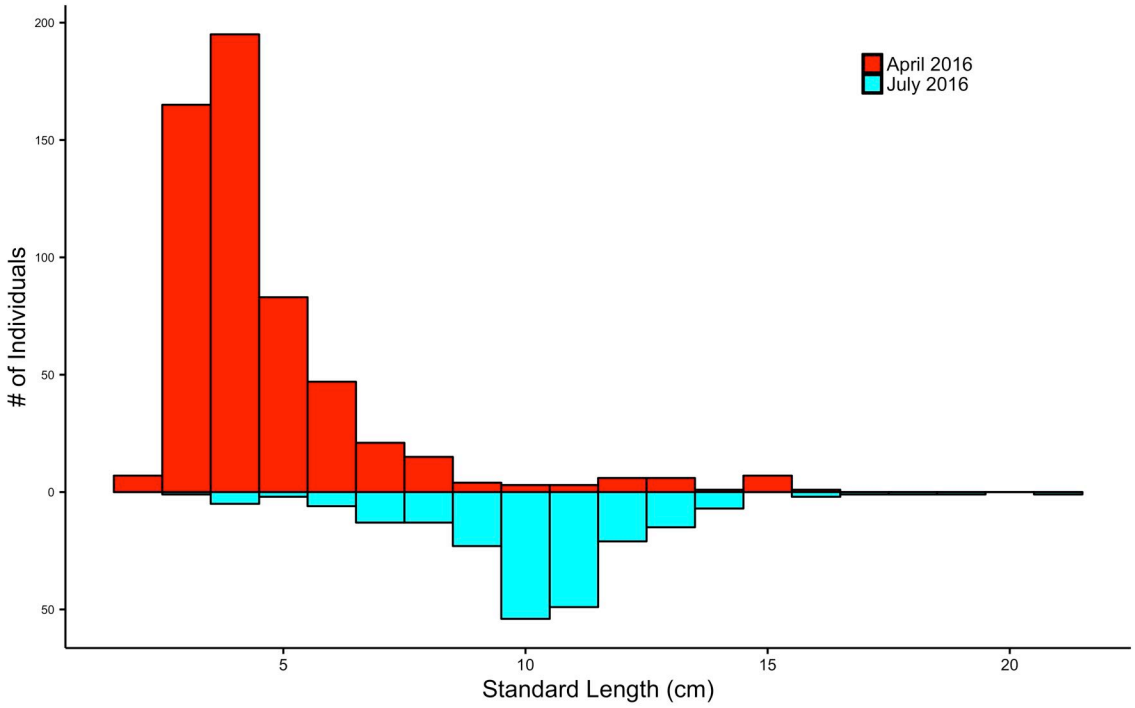


Figure 23. Total number of Giant Kelpfish individuals by standard length (cm) from San Diego Bay, April and July 2016.

Catch by Sampling Method

The greatest number of species were collected in the purse seines (33 species), followed by beam trawl and large seine (26 each), small seine (19), otter trawl (18), and square enclosure (1; Tables 14 and 15). The purse seine captured the greatest number of fish, catching a total of 10,543, a number greatly influenced by large schools of anchovies. There was an unusually large catch in the small seine (5,574), most of which were Arrow Gobies and newly settled Topsmelt, and there were moderate catches in the beam trawl (2,635) and large seine (1,871), a relatively low catch in the otter trawl (497), and only 7 fish in the square enclosure (all Arrow Gobies; Table 14). The greatest amount of biomass was also captured in the purse seine (135.5 kg), with high biomass also captured in the otter trawl (74.7 kg) and beam trawl (30.5 kg). The large seine (8.1 kg) and small seine (1.2 kg) captured lower amounts of biomass, and the square enclosure captured only 7 g of fishes (Table 15).

The purse seine was most effective sampling the schooling fishes (Slough Anchovy, Northern Anchovy, Topsmelt). The beam trawl was most effective for catching benthic nearshore and eelgrass fishes [Kelp Pipefish, Giant Kelpfish, Bay Blenny (*Hypsoblennius gentilis*), Barred Sand Bass, Dwarf Perch]. The square enclosure was largely ineffective in 2016, just as it had been in 2015. The beach seines were most effective at catching juvenile Topsmelt, and the small beach seine was particularly effective at catching Arrow Gobies. The top species caught in the otter trawls was Round Stingray. The highest density of fishes was captured in the small seine (1.873 individuals/m^2) followed by the purse seine (0.495 individuals/m^2; Table 16). The purse seines and beam trawls produced the highest biomass density values (6.356 g/m^2 and 2.188 g/m^2, respectively). The square enclosures captured the smallest amount of biomass (0.019 g/m^2).

Pulling the large seine in towards shore in the South-Central Ecoregion during April. (photo: Miranda Roethler)

Table 14. Total catch (# of individuals) of fish species taken in San Diego Bay in 2016 by sampling method.

PURSE SEINE			
Scientific Name	Common Name	Abundance	%
Anchoa delicatissima	Slough Anchovy	8,133	77.14
Engraulis mordax	Northern Anchovy	1,205	11.43
Atherinops affinis	Topsmelt	321	3.04
Urobatis halleri	Round Stingray	164	1.56
Paralabrax maculatofasciatus	Spotted Sand Bass	135	1.28
Cymatogaster aggregata	Shiner Perch	111	1.05
Haemulon californiensis	Salema	77	0.73
Leuresthes tenuis	California Grunion	77	0.73
Micrometrus minimus	Dwarf Perch	65	0.62
Sphyraena argentea	Pacific Barracuda	49	0.46
Atherinopsis californiensis	Jacksmelt	43	0.41
Anchoa compressa	Deepbody Anchovy	27	0.26
Heterostichus rostratus	Giant Kelpfish	20	0.19
Paralabrax nebulifer	Barred Sand Bass	19	0.18
Halichoeres semicinctus	Rock Wrasse	18	0.17
Cynoscion parvipinnis	Shortfin Corvina	13	0.12
Paralabrax clathratus	Kelp Bass	13	0.12
Hypsoblennius gentilis	Bay Blenny	9	0.09
Sardinops sagax	Pacific Sardine	8	0.08
Roncador stearnsii	Spotfin Croaker	7	0.07
Myliobatis californica	Bat Ray	4	0.04
Paralichthys californicus	California Halibut	4	0.04
Syngnathus californiensis	Kelp Pipefish	4	0.04
Albula gilberti	Cortez Bonefish	3	0.03
Embiotoca jacksoni	Black Perch	3	0.03
Seriphus politus	Queenfish	3	0.03
Umbrina roncador	Yellowfin Croaker	2	0.02
Anisotremus davidsonii	Sargo	1	0.01
Cosmocampus arctus	Snubnose Pipefish	1	0.01
Hippocampus ingens	Pacific Seahorse	1	0.01
Pleuronichthys guttulatus	Diamond Turbot	1	0.01
Sebastes serranoides	Olive Rockfish	1	0.01
Synodus lucioceps	California Lizardfish	1	0.01
# of Species: 33		**10,543**	

BEAM TRAWL			
Scientific Name	Common Name	Abundance	%
Syngnathus californiensis	Kelp Pipefish	999	37.91
Heterostichus rostratus	Giant Kelpfish	742	28.16
Hypsoblennius gentilis	Bay Blenny	181	6.87
Paralabrax nebulifer	Barred Sand Bass	165	6.26
Micrometrus minimus	Dwarf Perch	146	5.54
Clevelandia ios	Arrow Goby	84	3.19
Urobatis halleri	Round Stingray	76	2.88
Cymatogaster aggregata	Shiner Perch	69	2.62
Paralabrax maculatofasciatus	Spotted Sand Bass	53	2.01
Anchoa delicatissima	Slough Anchovy	50	1.90
Halichoeres semicinctus	Rock Wrasse	16	0.61
Paralabrax clathratus	Kelp Bass	14	0.53
Gibbonsia elegans	Spotted Kelpfish	13	0.49
Embiotoca jacksoni	Black Perch	7	0.27
Albula gilberti	Cortez Bonefish	3	0.11
Cosmocampus arctus	Snubnose Pipefish	3	0.11
Paralichthys californicus	California Halibut	3	0.11
Atherinops affinis	Topsmelt	2	0.08
Haemulon californiensis	Salema	2	0.08
Alloclinus holderi	Island Kelpfish	1	0.04
Anisotremus davidsonii	Sargo	1	0.04
Myliobatis californica	Bat Ray	1	0.04
Pleuronichthys ritteri	Spotted Turbot	1	0.04
Rimicola muscarum	Kelp Clingfish	1	0.04
Scorpaena guttata	California Scorpionfish	1	0.04
Umbrina roncador	Yellowfin Croaker	1	0.04
# of Species: 26		**2,635**	

Table 14 (continued).

LARGE SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Atherinops affinis	Topsmelt	1,023	54.68
Anchoa delicatissima	Slough Anchovy	566	30.25
Paralabrax nebulifer	Barred Sand Bass	74	3.96
Paralabrax maculatofasciatus	Spotted Sand Bass	38	2.03
Albula gilberti	Cortez Bonefish	29	1.55
Hypsoblennius gentilis	Bay Blenny	22	1.18
Fundulus parvipinnis	California Killifish	21	1.12
Cymatogaster aggregata	Shiner Perch	18	0.96
Urobatis halleri	Round Stingray	15	0.80
Heterostichus rostratus	Giant Kelpfish	13	0.69
Clevelandia ios	Arrow Goby	12	0.64
Paralichthys californicus	California Halibut	6	0.32
Syngnathus californiensis	Kelp Pipefish	6	0.32
Ctenogobius sagittula	Longtail Goby	4	0.21
Pleuronichthys guttulatus	Diamond Turbot	4	0.21
Quietula y-cauda	Shadow Goby	4	0.21
Anchoa compressa	Deepbody Anchovy	3	0.16
Acanthogobius flavimanus	Yellowfin Goby	2	0.11
Citharichthys stigmaeus	Speckled Sanddab	2	0.11
Ilypnus gilberti	Cheekspot Goby	2	0.11
Strongylura exilis	California Needlefish	2	0.11
Gibbonsia elegans	Spotted Kelpfish	1	0.05
Hyporhamphus rosae	California Halfbeak	1	0.05
Micrometrus minimus	Dwarf Perch	1	0.05
Paralabrax clathratus	Kelp Bass	1	0.05
Seriphus politus	Queenfish	1	0.05
# of Species:	**26**	**1,871**	

SMALL SEINE			
Scientific Name	**Common Name**	**Abundance**	**%**
Atherinops affinis	Topsmelt	2,790	50.05
Clevelandia ios	Arrow Goby	1,646	29.53
Leuresthes tenuis	California Grunion	888	15.93
Syngnathus californiensis	Kelp Pipefish	96	1.72
Anchoa delicatissima	Slough Anchovy	73	1.31
Albula gilberti	Cortez Bonefish	42	0.75
Sphyraena argentea	Pacific Barracuda	10	0.18
Hypsoblennius gentilis	Bay Blenny	6	0.11
Quietula y-cauda	Shadow Goby	5	0.09
Heterostichus rostratus	Giant Kelpfish	4	0.07
Fundulus parvipinnis	California Killifish	2	0.04
Gibbonsia elegans	Spotted Kelpfish	2	0.04
Ilypnus gilberti	Cheekspot Goby	2	0.04
Paralabrax maculatofasciatus	Spotted Sand Bass	2	0.04
Pleuronichthys guttulatus	Diamond Turbot	2	0.04
Atractoscion nobilis	White Seabass	1	0.02
Cosmocampus arctus	Snubnose Pipefish	1	0.02
Paralabrax nebulifer	Barred Sand Bass	1	0.02
Seriphus politus	Queenfish	1	0.02
# of Species:	**19**	**5,574**	

Table 14 (continued).

OTTER TRAWL			
Scientific Name	Common Name	Abundance	%
Urobatis halleri	Round Stingray	349	70.22
Paralichthys californicus	California Halibut	55	11.07
Paralabrax nebulifer	Barred Sand Bass	31	6.24
Porichthys myriaster	Specklefin Midshipman	17	3.42
Paralabrax maculatofasciatus	Spotted Sand Bass	11	2.21
Pleuronichthys ritteri	Spotted Turbot	10	2.01
Symphurus atricaudus	California Tonguefish	6	1.21
Anchoa delicatissima	Slough Anchovy	3	0.60
Pleuronichthys guttulatus	Diamond Turbot	3	0.60
Xystreurys liolepis	Fantail Sole	3	0.60
Gymnura marmorata	California Butterfly Ray	2	0.40
Citharichthys stigmaeus	Speckled Sanddab	1	0.20
Cymatogaster aggregata	Shiner Perch	1	0.20
Heterodontus francisci	Horn Shark	1	0.20
Hippocampus ingens	Pacific Seahorse	1	0.20
Porichthys notatus	Plainfin Midshipman	1	0.20
Scorpaena guttata	California Scorpionfish	1	0.20
Zapteryx exasperata	Banded Guitarfish	1	0.20
# of Species: 18		**497**	

SQUARE ENCLOSURE			
Scientific Name	Common Name	Abundance	%
Clevelandia ios	Arrow Goby	7	100.0
# of Species: 1		**7**	

Table 15. Total biomass (g) of fish species taken from San Diego Bay in 2016 by sampling method.

PURSE SEINE			
Scientific Name	Common Name	Biomass (g)	%
Urobatis halleri	Round Stingray	36,118	26.66
Engraulis mordax	Northern Anchovy	28,969	21.39
Paralabrax maculatofasciatus	Spotted Sand Bass	20,946	15.46
Anchoa delicatissima	Slough Anchovy	13,282	9.81
Roncador stearnsii	Spotfin Croaker	7,200	5.32
Cynoscion parvipinnis	Shortfin Corvina	5,145	3.80
Myliobatis californica	Bat Ray	3,850	2.84
Sphyraena argentea	Pacific Barracuda	3,600	2.66
Atherinopsis californiensis	Jacksmelt	3,330	2.46
Atherinops affinis	Topsmelt	2,998	2.21
Paralichthys californicus	California Halibut	1,925	1.42
Leuresthes tenuis	California Grunion	1,450	1.07
Albula gilberti	Cortez Bonefish	1,178	0.87
Haemulon californiensis	Salema	1,085	0.80
Micrometrus minimus	Dwarf Perch	959	0.71
Umbrina roncador	Yellowfin Croaker	540	0.40
Embiotoca jacksoni	Black Perch	505	0.37
Halichoeres semicinctus	Rock Wrasse	479	0.35
Cymatogaster aggregata	Shiner Perch	461	0.34
Anchoa compressa	Deepbody Anchovy	391	0.29
Paralabrax nebulifer	Barred Sand Bass	375	0.28
Paralabrax clathratus	Kelp Bass	191	0.14
Heterostichus rostratus	Giant Kelpfish	105	0.08
Synodus lucioceps	California Lizardfish	90	0.07
Sardinops sagax	Pacific Sardine	81	0.06
Hypsoblennius gentilis	Bay Blenny	69	0.05
Hippocampus ingens	Pacific Seahorse	43	0.03
Pleuronichthys guttulatus	Diamond Turbot	38	0.03
Seriphus politus	Queenfish	30	0.02
Anisotremus davidsonii	Sargo	21	0.02
Syngnathus californiensis	Kelp Pipefish	7	0.01
Sebastes serranoides	Olive Rockfish	3	< 0.01
Cosmocampus arctus	Snubnose Pipefish	0.1	< 0.01
# of Species: 33		**135,462**	

BEAM TRAWL			
Scientific Name	Common Name	Biomass (g)	%
Urobatis halleri	Round Stingray	11,280	37.03
Paralabrax maculatofasciatus	Spotted Sand Bass	5,169	16.97
Paralabrax nebulifer	Barred Sand Bass	4,881	16.03
Heterostichus rostratus	Giant Kelpfish	2,459	8.07
Paralichthys californicus	California Halibut	1,699	5.58
Hypsoblennius gentilis	Bay Blenny	1,694	5.56
Micrometrus minimus	Dwarf Perch	854	2.80
Myliobatis californica	Bat Ray	750	2.46
Syngnathus californiensis	Kelp Pipefish	486	1.60
Gibbonsia elegans	Spotted Kelpfish	247	0.81
Paralabrax clathratus	Kelp Bass	194	0.64
Cymatogaster aggregata	Shiner Perch	193	0.63
Embiotoca jacksoni	Black Perch	183	0.60
Anchoa delicatissima	Slough Anchovy	142	0.47
Halichoeres semicinctus	Rock Wrasse	92	0.30
Scorpaena guttata	California Scorpionfish	50	0.16
Pleuronichthys ritteri	Spotted Turbot	24	0.08
Umbrina roncador	Yellowfin Croaker	19	0.06
Anisotremus davidsonii	Sargo	16	0.05
Atherinops affinis	Topsmelt	12	0.04
Haemulon californiensis	Salema	7	0.02
Clevelandia ios	Arrow Goby	4	0.01
Albula gilberti	Cortez Bonefish	2	< 0.01
Cosmocampus arctus	Snubnose Pipefish	1	< 0.01
Alloclinus holderi	Island Kelpfish	1	< 0.01
Rimicola muscarum	Kelp Clingfish	0.2	< 0.01
# of Species: 26		**30,459**	

Table 15 (continued).

LARGE SEINE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	2,850	35.33
Anchoa delicatissima	Slough Anchovy	1,208	14.98
Paralabrax nebulifer	Barred Sand Bass	1,180	14.63
Atherinops affinis	Topsmelt	1,060	13.15
Albula gilberti	Cortez Bonefish	327	4.05
Paralabrax maculatofasciatus	Spotted Sand Bass	295	3.66
Cymatogaster aggregata	Shiner Perch	263	3.26
Fundulus parvipinnis	California Killifish	210	2.60
Paralichthys californicus	California Halibut	178	2.21
Hypsoblennius gentilis	Bay Blenny	145	1.80
Heterostichus rostratus	Giant Kelpfish	90	1.12
Ctenogobius sagittula	Longtail Goby	70	0.87
Anchoa compressa	Deepbody Anchovy	45	0.56
Acanthogobius flavimanus	Yellowfin Goby	40	0.50
Pleuronichthys guttulatus	Diamond Turbot	33	0.41
Seriphus politus	Queenfish	20	0.25
Citharichthys stigmaeus	Speckled Sanddab	18	0.22
Gibbonsia elegans	Spotted Kelpfish	10	0.12
Syngnathus californiensis	Kelp Pipefish	9	0.11
Micrometrus minimus	Dwarf Perch	5	0.06
Paralabrax clathratus	Kelp Bass	5	0.06
Clevelandia ios	Arrow Goby	1	0.01
Hyporhamphus rosae	California Halfbeak	1	0.01
Quietula y-cauda	Shadow Goby	1	0.01
Ilypnus gilberti	Cheekspot Goby	1	0.01
Strongylura exilis	California Needlefish	0.4	0.01
# of Species:	**26**	**8,066**	

SMALL SEINE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Atherinops affinis	Topsmelt	510	43.90
Clevelandia ios	Arrow Goby	187	16.07
Anchoa delicatissima	Slough Anchovy	164	14.12
Leuresthes tenuis	California Grunion	141	12.14
Syngnathus californiensis	Kelp Pipefish	45	3.84
Heterostichus rostratus	Giant Kelpfish	27	2.35
Hypsoblennius gentilis	Bay Blenny	24	2.08
Albula gilberti	Cortez Bonefish	16	1.37
Gibbonsia elegans	Spotted Kelpfish	15	1.29
Sphyraena argentea	Pacific Barracuda	12	1.04
Paralabrax nebulifer	Barred Sand Bass	5	0.43
Paralabrax maculatofasciatus	Spotted Sand Bass	4	0.34
Pleuronichthys guttulatus	Diamond Turbot	4	0.34
Quietula y-cauda	Shadow Goby	3	0.22
Fundulus parvipinnis	California Killifish	2	0.17
Seriphus politus	Queenfish	2	0.17
Ilypnus gilberti	Cheekspot Goby	1	0.07
Atractoscion nobilis	White Seabass	0.4	0.03
Cosmocampus arctus	Snubnose Pipefish	0.1	0.01
# of Species:	**19**	**1,161**	

Table 15 (continued).

OTTER TRAWL			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Urobatis halleri	Round Stingray	60,605	81.13
Paralichthys californicus	California Halibut	6,233	8.34
Gymnura marmorata	California Butterfly Ray	2,350	3.15
Paralabrax maculatofasciatus	Spotted Sand Bass	1,827	2.45
Paralabrax nebulifer	Barred Sand Bass	1,106	1.48
Porichthys myriaster	Specklefin Midshipman	776	1.04
Scorpaena guttata	California Scorpionfish	590	0.79
Pleuronichthys ritteri	Spotted Turbot	398	0.53
Pleuronichthys guttulatus	Diamond Turbot	338	0.45
Xystreurys liolepis	Fantail Sole	172	0.23
Symphurus atricaudus	California Tonguefish	157	0.21
Zapteryx exasperata	Banded Guitarfish	65	0.09
Heterodontus francisci	Horn Shark	42	0.06
Hippocampus ingens	Pacific Seahorse	15	0.02
Citharichthys stigmaeus	Speckled Sanddab	14	0.02
Cymatogaster aggregata	Shiner Perch	9	0.01
Anchoa delicatissima	Slough Anchovy	4	0.01
Porichthys notatus	Plainfin Midshipman	1	< 0.01
# of Species:	**18**	**74,702**	

SQUARE ENCLOSURE			
Scientific Name	**Common Name**	**Biomass (g)**	**%**
Clevelandia ios	Arrow Goby	7.0	100.0
# of Species:	**1**	**7.0**	

Table 16. Comparison of mean densities and biomass densities by gear type for San Diego Bay 1994-1999 and April and July 2005, April and July 2008, June 2009, April and July 2012, April and July 2015, and April and July 2016.

	Gear	1994-1999	April/July 2005	April/July 2008	June 2009	April/July 2012	April/July 2015	April/July 2016
Density (#/m^2)	BT	0.080	1.164	0.223	-	0.386	0.183	0.189
	OT	0.009	0.032	0.004	-	0.005	0.028	0.009
	PS	1.770	0.569	0.390	0.485	0.122	0.697	0.495
	LS	0.369	0.676	0.171	-	0.366	0.188	0.177
	SS	2.338	0.440	0.702	-	1.659	0.820	1.873
	SE	3.583	1.042	0.542	1.542	0.708	0.146	0.146
Biomass Density (g/m^2)	BT	2.232	5.137	3.496	-	7.199	2.573	2.188
	OT	1.678	1.425	0.416	-	0.684	1.582	1.288
	PS	6.306	5.579	3.910	5.355	7.949	11.000	6.356
	LS	1.051	1.684	1.114	-	1.502	1.311	0.764
	SS	0.272	0.216	0.256	-	1.044	0.453	0.390
	SE	0.636	0.176	12.313	0.542	2.063	0.010	0.019

Table 17. 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		

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 estimate was 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. 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.

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 17). The best estimate for the total stock size was 30,173,603 fishes (Table 18). With an estimated surface area of 4858 ha (Table 17) this gives an overall fish density 0.62 individuals/m^2 (Table 18). The highest estimates were of Slough Anchovy (17.1 million), followed by Topsmelt (2.50 million), Northern Anchovy (2.35 million), Kelp Pipefish (2.05 million), and Giant Kelpfish (1.48 million). These five species also had the five highest stock estimates in 2015. As is typical, schooling and forage fishes dominated the stock estimate for the bay.

The total best estimate of biomass standing stock was over 311 MT (Table 19). This gives an overall estimate of 6.41 g/m^2, far lower than the 2015 estimate but about average for all historical surveys (Table 20). The highest biomass estimates were of Round Stingray (86.9 MT), followed by Northern Anchovy (56.5 MT), Spotted Sand Bass (41.4 MT), Slough Anchovy (27.7 MT), and Spotfin Croaker (14.0 MT). Round Stingray, Northern Anchovy, and Spotted Sand Bass were all in the top five biomass estimates in 2015 as well, but Slough Anchovy were sixth and Spotfin Croaker was fifteenth.

Table 18. Best estimate of densities and stock estimates, April and July 2016.

		Depth Strata				
Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate
Anchoa delicatissima	Slough Anchovy	0.22762	0.05360	0.45861	0.35233	17,115,974
Atherinops affinis	Topsmelt	0.01112	0.93750	0.01703	0.05155	2,504,086
Engraulis mordax	Northern Anchovy			0.08481	0.04834	2,348,478
Syngnathus californiensis	Kelp Pipefish		0.03226	0.07177	0.04220	2,049,962
Heterostichus rostratus	Giant Kelpfish		0.00134	0.05330	0.03044	1,478,648
Clevelandia ios	Arrow Goby		0.55309	0.00603	0.02556	1,241,866
Leuresthes tenuis	California Grunion	0.01084	0.29839		0.01616	785,183
Urobatis halleri	Round Stingray	0.00602	0.00142	0.01084	0.00858	416,886
Hypsoblennius gentilis	Bay Blenny	0.00028	0.00208	0.01300	0.00760	369,440
Paralabrax nebulifer	Barred Sand Bass	0.00053	0.00701	0.01185	0.00725	351,971
Micrometrus minimus	Dwarf Perch		0.00009	0.01049	0.00598	290,617
Paralabrax maculatofasciatus	Spotted Sand Bass	0.00056	0.00360	0.00922	0.00562	272,972
Cymatogaster aggregata	Shiner Perch	0.00002	0.00170	0.00781	0.00453	219,972
Haemulon californiensis	Salema			0.00542	0.00309	150,069
Atherinopsis californiensis	Jacksmelt	0.00507		0.00049	0.00226	109,654
Sphyraena argentea	Pacific Barracuda		0.00336	0.00345	0.00210	102,028
Anchoa compressa	Deepbody Anchovy	0.00380	0.00028		0.00149	72,560
Albula gilberti	Cortez Bonefish	0.00014	0.01411	0.00022	0.00074	36,059
Halichoeres semicinctus	Rock Wrasse			0.00127	0.00072	35,081
Paralabrax clathratus	Kelp Bass		0.00009	0.00101	0.00058	28,034
Gibbonsia elegans	Spotted Kelpfish		0.00067	0.00093	0.00056	27,166
Paralichthys californicus	California Halibut	0.00095	0.00057	0.00028	0.00055	26,864
Cynoscion parvipinnis	Shortfin Corvina	0.00014		0.00084	0.00054	26,054
Sardinops sagax	Pacific Sardine			0.00056	0.00032	15,592
Embiotoca jacksoni	Black Perch			0.00050	0.00029	13,925
Roncador stearnsii	Spotfin Croaker			0.00049	0.00028	13,643
Myliobatis californica	Bat Ray			0.00028	0.00016	7,796
Cosmocampus arctus	Snubnose Pipefish		0.00034	0.00022	0.00014	6,621
Seriphus politus	Queenfish		0.00034	0.00021	0.00013	6,500
Porichthys myriaster	Specklefin Midshipman	0.00029			0.00011	5,552
Pleuronichthys ritteri	Spotted Turbot	0.00017		0.00007	0.00011	5,255
Umbrina roncador	Yellowfin Croaker	0.00014		0.00007	0.00010	4,656
Pleuronichthys guttulatus	Diamond Turbot	0.00014	0.00067		0.00008	3,973
Fundulus parvipinnis	California Killifish		0.00199		0.00008	3,864
Quietula y-cauda	Shadow Goby		0.00168		0.00007	3,265
Scorpaena guttata	California Scorpionfish	0.00002		0.00007	0.00005	2,316
Hippocampus ingens	Pacific Seahorse	0.00002		0.00007	0.00005	2,276
Alloclinus holderi	Island Kelpfish			0.00007	0.00004	1,989
Anisotremus davidsonii	Sargo			0.00007	0.00004	1,989
Rimicola muscarum	Kelp Clingfish			0.00007	0.00004	1,989
Symphurus atricaudus	California Tonguefish	0.00010			0.00004	1,960
Sebastes serranoides	Olive Rockfish			0.00007	0.00004	1,949
Synodus lucioceps	California Lizardfish			0.00007	0.00004	1,949
Ilypnus gilberti	Cheekspot Goby		0.00067		0.00003	1,306
Xystreurys liolepis	Fantail Sole	0.00005			0.00002	980
Ctenogobius sagittula	Longtail Goby		0.00038		0.00002	736
Citharichthys stigmaeus	Speckled Sanddab	0.00002	0.00019		0.00001	695
Gymnura marmorata	California Butterfly Ray	0.00003			0.00001	653
Atractoscion nobilis	White Seabass		0.00034		0.00001	653
Acanthogobius flavimanus	Yellowfin Goby		0.00019		0.00001	368
Strongylura exilis	California Needlefish		0.00019		0.00001	368
Heterodontus francisci	Horn Shark	0.00002			0.00001	327
Porichthys notatus	Plainfin Midshipman	0.00002			0.00001	327
Zapteryx exasperata	Banded Guitarfish	0.00002			0.00001	327
Hyporhamphus rosae	California Halfbeak		0.00009		0.00000	184
	Grand Totals:	**0.26813**	**1.91824**	**0.77160**	**0.62111**	**30,173,603**

Table 19. Best estimate of biomass densities and standing stock, April and July 2016.

		Depth Strata					
Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
Urobatis halleri	Round Stingray	1.04477	0.26989	2.40414	1.78861	86,891	86.9
Engraulis mordax	Northern Anchovy			2.03889	1.16217	56,458	56.5
Paralabrax maculatofasciatus	Spotted Sand Bass	0.11135	0.02794	1.41856	0.85312	41,445	41.4
Anchoa delicatissima	Slough Anchovy	0.31954	0.11439	0.77507	0.57099	27,738	27.7
Roncador stearnsii	Spotfin Croaker			0.50676	0.28885	14,032	14.0
Paralabrax nebulifer	Barred Sand Bass	0.01907	0.11174	0.35065	0.21177	10,288	10.3
Cynoscion parvipinnis	Shortfin Corvina	0.02675		0.34875	0.20922	10,164	10.2
Atherinopsis californiensis	Jacksmelt	0.32798		0.07038	0.16803	8,163	8.16
Myliobatis californica	Bat Ray			0.27097	0.15446	7,503	7.50
Atherinops affinis	Topsmelt	0.22382	0.17134	0.09907	0.15061	7,317	7.32
Sphyraena argentea	Pacific Barracuda		0.00407	0.25338	0.14459	7,024	7.02
Paralichthys californicus	California Halibut	0.10745	0.01686	0.13549	0.11981	5,820	5.82
Heterostichus rostratus	Giant Kelpfish		0.00917	0.17665	0.10106	4,909	4.91
Leuresthes tenuis	California Grunion	0.20411	0.04738		0.08150	3,959	3.96
Hypsoblennius gentilis	Bay Blenny	0.00084	0.01373	0.12170	0.07025	3,413	3.41
Albula gilberti	Cortez Bonefish	0.07742	0.03097	0.04420	0.05663	2,751	2.75
Haemulon californiensis	Salema			0.07637	0.04353	2,115	2.11
Micrometrus minimus	Dwarf Perch		0.00047	0.06750	0.03849	1,870	1.87
Umbrina roncador	Yellowfin Croaker	0.00563		0.03519	0.02226	1,081	1.08
Anchoa compressa	Deepbody Anchovy	0.05504	0.00426		0.02164	1,051	1.05
Syngnathus californiensis	Kelp Pipefish		0.01499	0.03492	0.02050	996	1.00
Embiotoca jacksoni	Black Perch			0.03554	0.02026	984	0.98
Cymatogaster aggregata	Shiner Perch	0.00016	0.02489	0.03243	0.01954	949	0.95
Halichoeres semicinctus	Rock Wrasse			0.03371	0.01922	934	0.93
Gymnura marmorata	California Butterfly Ray	0.04051			0.01580	768	0.77
Gibbonsia elegans	Spotted Kelpfish		0.00504	0.01774	0.01032	501	0.50
Paralabrax clathratus	Kelp Bass		0.00047	0.01394	0.00796	387	0.39
Scorpaena guttata	California Scorpionfish	0.01017		0.00359	0.00601	292	0.29
Porichthys myriaster	Specklefin Midshipman	0.01338			0.00522	253	0.25
Pleuronichthys ritteri	Spotted Turbot	0.00686		0.00172	0.00366	178	0.18
Synodus lucioceps	California Lizardfish			0.00633	0.00361	175	0.18
Sardinops sagax	Pacific Sardine			0.00567	0.00323	157	0.16
Clevelandia ios	Arrow Goby		0.06270	0.00027	0.00266	129	0.13
Pleuronichthys guttulatus	Diamond Turbot	0.00583	0.00313		0.00240	116	0.12
Hippocampus ingens	Pacific Seahorse	0.00026		0.00303	0.00183	89	0.09
Seriphus politus	Queenfish		0.00189	0.00211	0.00128	62	0.06
Xystreurys liolepis	Fantail Sole	0.00297			0.00116	56	0.06
Symphurus atricaudus	California Tonguefish	0.00271			0.00106	51	0.05
Anisotremus davidsonii	Sargo			0.00148	0.00084	41	0.04
Fundulus parvipinnis	California Killifish		0.01989		0.00080	39	0.04
Zapteryx exasperata	Banded Guitarfish	0.00112			0.00044	21	0.02
Heterodontus francisci	Horn Shark	0.00072			0.00028	14	0.01
Ctenogobius sagittula	Longtail Goby		0.00663		0.00027	13	0.01
Citharichthys stigmaeus	Speckled Sanddab	0.00024	0.00170		0.00016	8	0.01
Acanthogobius flavimanus	Yellowfin Goby		0.00381		0.00015	7	0.01
Sebastes serranoides	Olive Rockfish			0.00021	0.00012	6	0.01
Cosmocampus arctus	Snubnose Pipefish		0.00003	0.00009	0.00005	2	< 0.01
Quietula y-cauda	Shadow Goby		0.00084		0.00003	1.6	< 0.01
Alloclinus holderi	Island Kelpfish			0.00004	0.00002	1.2	< 0.01
Ilypnus gilberti	Cheekspot Goby		0.00027		0.00001	0.5	< 0.01
Rimicola muscarum	Kelp Clingfish			0.00001	0.00001	0.4	< 0.01
Porichthys notatus	Plainfin Midshipman	0.00002			0.00001	0.3	< 0.01
Atractoscion nobilis	White Seabass		0.00013		0.00001	0.3	< 0.01
Hyporhamphus rosae	California Halfbeak		0.00009		< 0.00001	0.2	< 0.01
Strongylura exilis	California Needlefish		0.00004		< 0.00001	0.1	< 0.01
	Grand Totals:	**2.60870**	**0.96875**	**9.38656**	**6.40648**	**311,227**	**311.2**

Table 20. Stock estimates and biomass standing stock; 1994-1999, April and July 2005, April and July 2008, April and July 2012, April and July 2015, and April and July 2016.

Survey	Stock Estimate (#)	Standing Stock (kg)
1994-1999 (Allen et al. 2002)	84,776,769	342,427
April/July 2005 (Pondella et al. 2006)	56,320,404	339,268
April/July 2008 (Pondella and Williams 2009a)	24,776,133	246,492
April/July 2012 (Williams and Pondella 2012)	14,249,941	459,754
April/July 2015 (Williams et al. 2015)	35,117,726	518,177
April/July 2016 (Present Study)	30,173,603	311,227

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 Slough Anchovy, Northern Anchovy, and Topsmelt. These species were primarily found at small (juvenile) size classes (<50 mm SL) appropriate for nesting birds to feed their young in the area. The typical timing for the recruitment of fishes to San Diego Bay begins in the spring and continues through the summer and this is what was observed in 2016. The biomass standing stock estimate for forage fish was 112.7 MT. When estimating by ecoregion, values were highest at the North Ecoregion (311.4 MT) which was driven almost entirely by Northen Anchovy, and decreased in the North-Central (49.4 MT) to South-Central (26.9 MT) Ecoregions, then increased again in the South Ecoregion (63.5 MT; Table 21).

Great Blue Heron (*Ardea herodias*) wading near Sweetwater Marsh. (photo: Matt Robart)

Table 21. Best estimate of biomass standing stock for forage fish species by ecoregion, 2016.

			Depth Strata					
Ecoregion	Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
North	*Engraulis mordax*	Northern Anchovy			8.15332	4.64739	225,770	225.8
	Anchoa delicatissima	Slough Anchovy			0.77680	0.44278	21,510	21.51
	Atherinops affinis	Topsmelt	0.89527	0.25444	0.11028	0.42219	20,510	20.51
	Leuresthes tenuis	California Grunion	0.81644			0.31841	15,468	15.47
	Heterostichus rostratus	Giant Kelpfish			0.39368	0.22440	10,901	10.90
	Atherinopsis californiensis	Jacksmelt			0.28153	0.16047	7,796	7.80
	Micrometrus minimus	Dwarf Perch		0.00189	0.26999	0.15397	7,480	7.48
	Cymatogaster aggregata	Shiner Perch			0.04668	0.02661	1,293	1.29
	Sardinops sagax	Pacific Sardine			0.02266	0.01292	628	0.63
	Clevelandia ios	Arrow Goby		0.00013	0.00006	0.00004	2	< 0.01
		Grand Total:		**0.25646**	**10.05500**	**6.40917**	**311,358**	**311.4**
North-Central	*Anchoa delicatissima*	Slough Anchovy		0.43598	1.25985	0.73556	35,733	35.73
	Heterostichus rostratus	Giant Kelpfish		0.03669	0.28103	0.16166	7,853	7.85
	Atherinops affinis	Topsmelt		0.32930	0.12751	0.08585	4,171	4.17
	Cymatogaster aggregata	Shiner Perch		0.09955	0.03660	0.02484	1,207	1.21
	Leuresthes tenuis	California Grunion		0.18952		0.00758	368	0.37
	Engraulis mordax	Northern Anchovy			0.00225	0.00128	62	0.06
	Anchoa compressa	Deepbody Anchovy		0.00947		0.00038	18	0.02
	Clevelandia ios	Arrow Goby		0.00013	0.00043	0.00025	12	0.01
		Grand Total:	**0.00000**	**1.10065**	**1.70768**	**1.01740**	**49,425**	**49.4**
South-Central	*Anchoa delicatissima*	Slough Anchovy	0.67230	0.02083	0.39048	0.48561	23,591	23.59
	Atherinops affinis	Topsmelt		0.04780	0.04392	0.02695	1,309	1.31
	Heterostichus rostratus	Giant Kelpfish		0.01136	0.03190	0.01864	905	0.91
	Cymatogaster aggregata	Shiner Perch	0.00062		0.02787	0.01613	784	0.78
	Anchoa compressa	Deepbody Anchovy	0.00901			0.00351	171	0.17
	Fundulus parvipinnis	California Killifish		0.06818		0.00273	132	0.13
	Clevelandia ios	Arrow Goby		0.00833	0.00040	0.00056	27	0.03
		Grand Total:	**0.68193**	**0.15652**	**0.49457**	**0.55412**	**26,919**	**26.9**
South	*Anchoa delicatissima*	Slough Anchovy	0.60586	0.00403	0.67314	0.62014	30,126	30.13
	Atherinopsis californiensis	Jacksmelt	1.31194			0.51166	24,856	24.86
	Anchoa compressa	Deepbody Anchovy	0.21115	0.00758		0.08265	4,015	4.02
	Atherinops affinis	Topsmelt		0.07984	0.11458	0.06851	3,328	3.33
	Cymatogaster aggregata	Shiner Perch			0.02328	0.01327	645	0.64
	Clevelandia ios	Arrow Goby		0.24812	0.00020	0.01004	488	0.49
	Fundulus parvipinnis	California Killifish		0.01136		0.00045	22	0.02
	Heterostichus rostratus	Giant Kelpfish		0.00265		0.00011	5	0.01
	Hyporhamphus rosae	California Halfbeak		0.00038		0.00002	1	< 0.01
		Grand Total:	**2.12894**	**0.35396**	**0.81120**	**1.30683**	**63,486**	**63.5**

Fisheries Species

During this study, 15 species were captured which have importance in either the recreational or commercial fisheries in California. The most abundant fisheries species were the Northern Anchovy, Barred Sand Bass, and Spotted Sand Bass. Including all Ecoregions, standing stock estimates of fisheries species totaled 150.9 MT. Like the forage fishes, when estimating by ecoregion values were greatest at the North Ecoregion (302.8 MT) which was again driven almost entirely by Northern Anchovy, and declined to the south (172.0 MT and 45.2 MT for North-Central and South-Central, respectively) before rising again in the South Ecoregion (86.9 MT; Table 22).

Table 22. Best estimate of biomass standing stock for recreational/commercial fishery species by ecoregion, 2016.

			Depth Strata					
Ecoregion	Scientific Name	Common Name	Channel	Intertidal	Nearshore	Weighted Mean	Stock Estimate (kg)	Stock Estimate (MT)
North	*Engraulis mordax*	Northern Anchovy			8.15332	4.64739	225,770	225.8
	Paralabrax maculatofasciatus	Spotted Sand Bass	0.01724		1.54248	0.88594	43,039	43.04
	Paralichthys californicus	California Halibut	0.14253	0.01326	0.53378	0.36037	17,507	17.51
	Cynoscion parvipinnis	Shortfin Corvina			0.31672	0.18053	8,770	8.77
	Embiotoca jacksoni	Black Perch			0.14217	0.08104	3,937	3.94
	Paralabrax clathratus	Kelp Bass		0.00189	0.04499	0.02572	1,249	1.25
	Paralabrax nebulifer	Barred Sand Bass	0.01710		0.02852	0.02293	1,114	1.11
	Scorpaena guttata	California Scorpionfish	0.04068			0.01587	771	0.77
	Sardinops sagax	Pacific Sardine			0.02266	0.01292	628	0.63
	Sphyraena argentea	Pacific Barracuda		0.01626		0.00065	32	0.03
	Seriphus politus	Queenfish		0.00758		0.00030	15	0.01
	Albula gilberti	Cortez Bonefish		0.00108	0.00014	0.00012	6	0.01
		Grand Total:	**0.21756**	**0.04007**	**10.78480**	**6.23379**	**302,837**	**302.8**
North-Central	*Roncador stearnsii*	Spotfin Croaker			2.02703	1.15541	56,130	56.13
	Paralabrax maculatofasciatus	Spotted Sand Bass	0.04103	0.11174	1.77843	1.03418	50,240	50.24
	Paralabrax nebulifer	Barred Sand Bass	0.00138	0.24053	1.11695	0.64682	31,423	31.42
	Cynoscion parvipinnis	Shortfin Corvina			0.84459	0.48142	23,387	23.39
	Sphyraena argentea	Pacific Barracuda			0.19707	0.11233	5,457	5.46
	Paralichthys californicus	California Halibut	0.17942	0.01515	0.00816	0.07523	3,655	3.65
	Paralabrax clathratus	Kelp Bass			0.03563	0.02031	987	0.99
	Scorpaena guttata	California Scorpionfish			0.01437	0.00819	398	0.40
	Seriphus politus	Queenfish		0.00269	0.00507	0.00300	146	0.15
	Albula gilberti	Cortez Bonefish		0.03598		0.00144	70	0.07
	Engraulis mordax	Northern Anchovy			0.00225	0.00128	62	0.06
	Atractoscion nobilis	White Seabass		0.00054		0.00002	1	< 0.01
		Grand Total:	**0.22183**	**0.40663**	**6.02957**	**3.53963**	**171,955**	**172.0**
South-Central	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.20270		0.96171	0.62723	30,471	30.47
	Paralabrax nebulifer	Barred Sand Bass	0.03600	0.16477	0.24799	0.16198	7,869	7.87
	Cynoscion parvipinnis	Shortfin Corvina			0.16892	0.09628	4,677	4.68
	Paralichthys californicus	California Halibut	0.09281			0.03620	1,758	1.76
	Umbrina roncador	Yellowfin Croaker	0.02252			0.00878	427	0.43
	Albula gilberti	Cortez Bonefish		0.00758	0.00029	0.00047	23	0.02
		Grand Total:	**0.35404**	**0.17235**	**1.37891**	**0.93094**	**45,225**	**45.2**
South	*Paralabrax maculatofasciatus*	Spotted Sand Bass	0.24268		1.39161	0.88786	43,132	43.13
	Sphyraena argentea	Pacific Barracuda			0.81644	0.46537	22,608	22.61
	Albula gilberti	Cortez Bonefish	0.30968	0.08030	0.17680	0.22477	10,919	10.92
	Umbrina roncador	Yellowfin Croaker			0.14077	0.08024	3,898	3.90
	Cynoscion parvipinnis	Shortfin Corvina	0.10698		0.06475	0.07863	3,820	3.82
	Paralabrax nebulifer	Barred Sand Bass	0.02179	0.04167	0.02816	0.02622	1,274	1.27
	Paralichthys californicus	California Halibut	0.01503	0.03902	0.02816	0.02347	1,140	1.14
	Seriphus politus	Queenfish			0.00338	0.00193	94	0.09
		Grand Total:	**0.69617**	**0.16098**	**2.65007**	**1.78849**	**86,885**	**86.9**

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 23). During this study, eight species [Cortez Bonefish (*Albula gilberti*), California Butterfly Ray (*Gymnura marmorata*), Banded Guitarfish (*Zapteryx exasperata*), Shortfin Corvina (*Cynoscion parvipinnis*), Pacific Seahorse (*Hippocampus ingens*), California Halfbeak (*Hyporhamphus rosae*), California Needlefish (*Strongylura exilis*), and Longtail Goby (*Ctenogobius sagittula* – the first record of this species being captured during these surveys)] with primarily southern distributions were taken (Table 24). This is a relatively low number considering the exceptionally warm water in the bay over the last two years due to the presence of a strong El Niño. These fishes were mostly found in the southern half of the bay, though at least one was found in each ecoregion. Of note, a large number of Cortez Bonefish were caught throughout the bay, including adults, newly settled juveniles, and leptocephalus larvae.

Table 23. 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)

Longtail Goby captured by large seine from the South Ecoregion in July. (photo: Jonathan Williams)

Table 24. Abundance of Panamic species collected in San Diego Bay by ecoregion, April and July 2016.

		Ecoregions							
		North		North-Central		South-Central		South	
Scientific Name	Common Name	April	July	April	July	April	July	April	July
Albula gilberti	Cortez Bonefish	3		33	10	4	3	7	17
Ctenogobius sagittula	Longtail Goby								4
Cynoscion parvipinnis	Shortfin Corvina		2	7			1	3	
Gymnura marmorata	California Butterfly Ray					1		1	
Hippocampus ingens	Pacific Seahorse		1				1		
Hyporhamphus rosae	California Halfbeak								1
Strongylura exilis	California Needlefish		1		1				
Zapteryx exasperata	Banded Guitarfish	1							

Indigenous Bay and Estuary Fishes

As the largest estuary in Southern California, San Diego Bay provides critical habitat for bay and estuary 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. San Diego Bay serves as critical habitat for many fishes that, in turn support surrounding nearshore ecosystems. Juvenile fishes migrate out of the bay to surrounding habitats. Furthermore, these fishes provide a critical forage base for important and endangered avian species. Southern California indigenous bay and estuary fishes represented 57.8% of the total catch throughout the bay in this survey, increasing in proportion with increased distance from the mouth of the bay (Table 25).

Table 25. Indigenous bay/estuarine species taken in San Diego Bay by ecoregion in 2016.

		Ecoregions					
Scientific Name	Common Name	North	North-Central	South-Central	South	Total	%
Anchoa delicatissima	Slough Anchovy	1,107	4,000	1,721	1,997	8,825	41.77
Clevelandia ios	Arrow Goby	4	15	60	1,670	1,749	8.28
Syngnathus californiensis	Kelp Pipefish	171	248	463	223	1,105	5.23
Paralabrax maculatofasciatus	Spotted Sand Bass	32	117	34	56	239	1.13
Hypsoblennius gentilis	Bay Blenny	22	172	21	3	218	1.03
Anchoa compressa	Deepbody Anchovy		2	1	27	30	0.14
Fundulus parvipinnis	California Killifish			20	3	23	0.11
Quietula y-cauda	Shadow Goby		8		1	9	0.04
Ilypnus gilberti	Cheekspot Goby		2		2	4	0.02
	Total % of catch:	**25.9%**	**57.5%**	**77.3%**	**79.1%**		**57.8%**

Bay Blenny captured by large seine from the South-Central Ecoregion in July. (photo: Dana Michels)

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. 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 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).

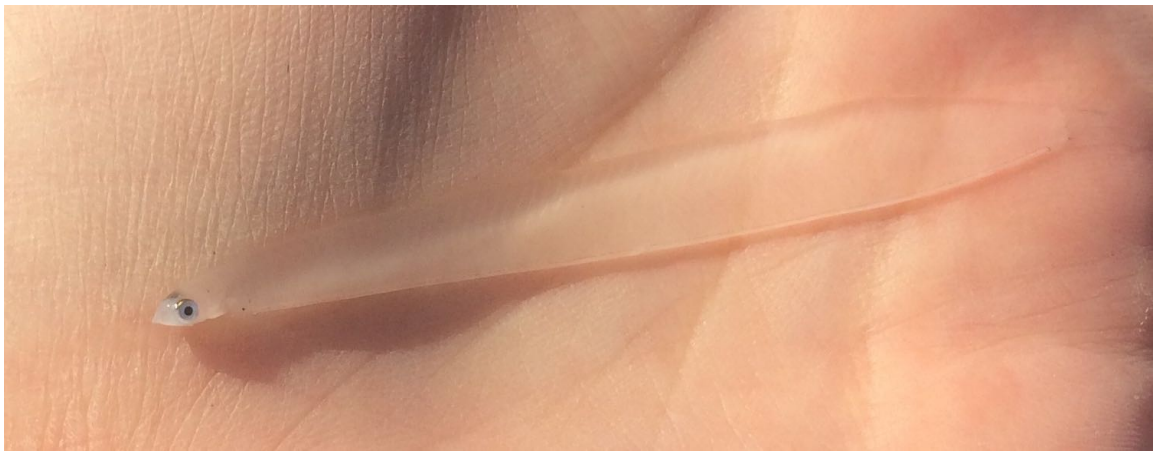
During the 2012 survey, sampling yielded both of those species: three Yellowfin Gobies and 18 Chameleon Gobies. Given the widespread nature of Chameleon Goby throughout the bay during those surveys (captured in the channel, nearshore vegetated, and nearshore non-vegetated areas, in all ecoregions but 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, and the only Yellowfin Goby encountered was a single partially digested individual that was regurgitated by a Spotted Sand Bass in the South Ecoregion (Williams et al. 2015). In this survey, only two Yellowfin Gobies were caught, both in the interdal depth strata in the South Ecoregion, and no Chameleon Gobies were found. 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. The 2015-2016 El Niño event is likely not a factor in the decline of these gobies as the temperatures in the bay were well within their thermal tolerance limits and they survived and thrived in the warm waters caused by the 1997-1998 event. However, this recent event did not produce heavy winter rainfall typically associated with El Niño events, and both species thrive in fresh to brackish water environments.

Comparison of the Current and Historical April and July Surveys

Community Metrics

Shannon-Wiener 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) 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 the Allen et al. (2002) where both April and July were sampled. Overall, 2016 H' estimates in each ecoregion were relatively even but varied in rank among historical values. H' in the North Ecoregion was the highest on record (1.94) despite the dominance of Northern Anchovy, and near the historical mean for each of the other ecoregions (Table 26, Figure 24). Species richness for 2016 was among the highest of historical values for the North, North-Central, and South Ecoregions for any survey period, but the lowest on record for the South-Central Ecoregion (Table 27; Figure 25).

Total catch and biomass from the April and July 2016 sampling periods were also compared to values from 1995-1998, 2005, 2008, 2012, and 2015. Overall, catch in 2016 at all ecoregions was about average compared to recent sampling years, but far below the 1995 and 1996 sampling periods where Northern Anchovies and Pacific Sardines (*Sardinops sagax*) numbered in the tens of thousands (Tables 28, 29; Figures 26, 27). Total abundance was heavily influenced by large schools of forage fishes, just as they were during the 1995-1998 sampling periods, but not to the same extent. Estimates of total biomass were also about average among all surveys in every ecoregion (Tables 30, 31; Figures 28, 29), though clearly decreased from the 2015 survey. Overall, the 2016 community metrics were comparable to previous surveys, with no apparent impacts from the strong El Niño conditions of 2015-2016.



A leptocephalus larva of a Cortez Bonefish from the North Ecoregion in April. (photo: Chelsea Williams)

Table 26. Shannon-Wiener diversity (H') values for April and July surveys by ecoregion and sampling year.

	Sampling Years								
Ecoregion	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**
North	0.74	0.90	1.34	1.42	1.77	1.72	1.59	1.43	1.94
North-Central	1.75	0.93	1.50	1.25	1.36	1.62	1.64	1.81	1.61
South-Central	1.32	1.72	1.13	0.37	1.77	1.88	1.92	1.41	1.51
South	1.93	1.84	1.35	0.59	1.06	2.03	1.83	1.71	1.61
Total:	**1.46**	**1.04**	**1.65**	**1.31**	**1.65**	**2.05**	**2.03**	**2.05**	**2.00**

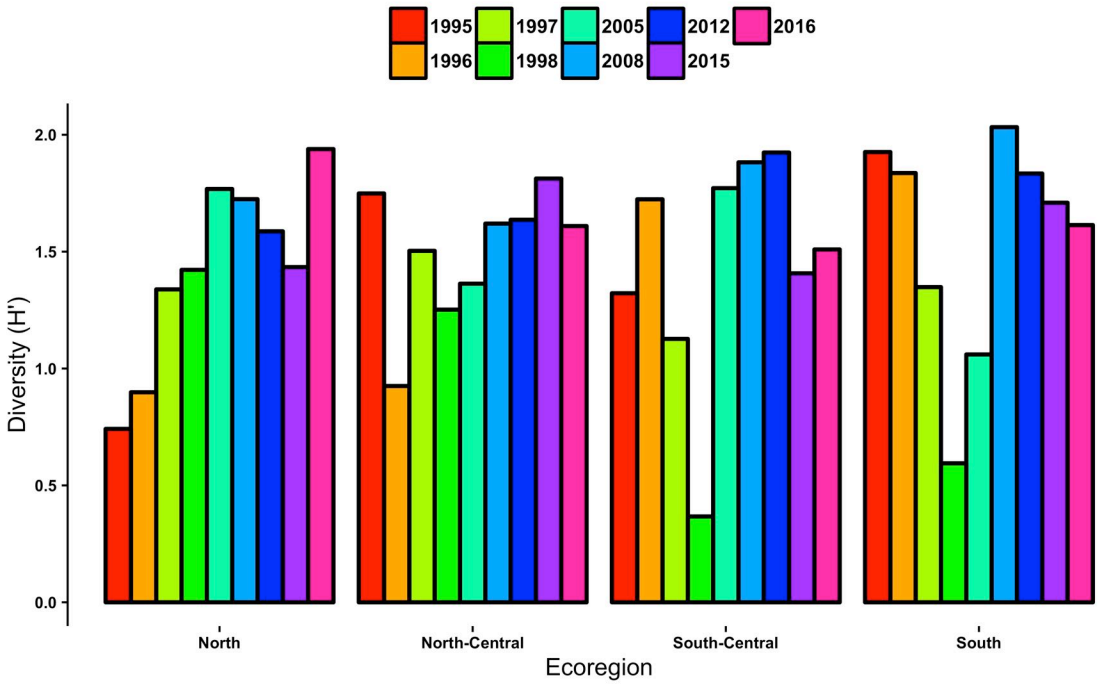


Figure 24. Shannon-Wiener diversity (H') values for April and July surveys by ecoregion and sampling year.

Table 27. Species richness values for April and July surveys by ecoregion and sampling year.

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

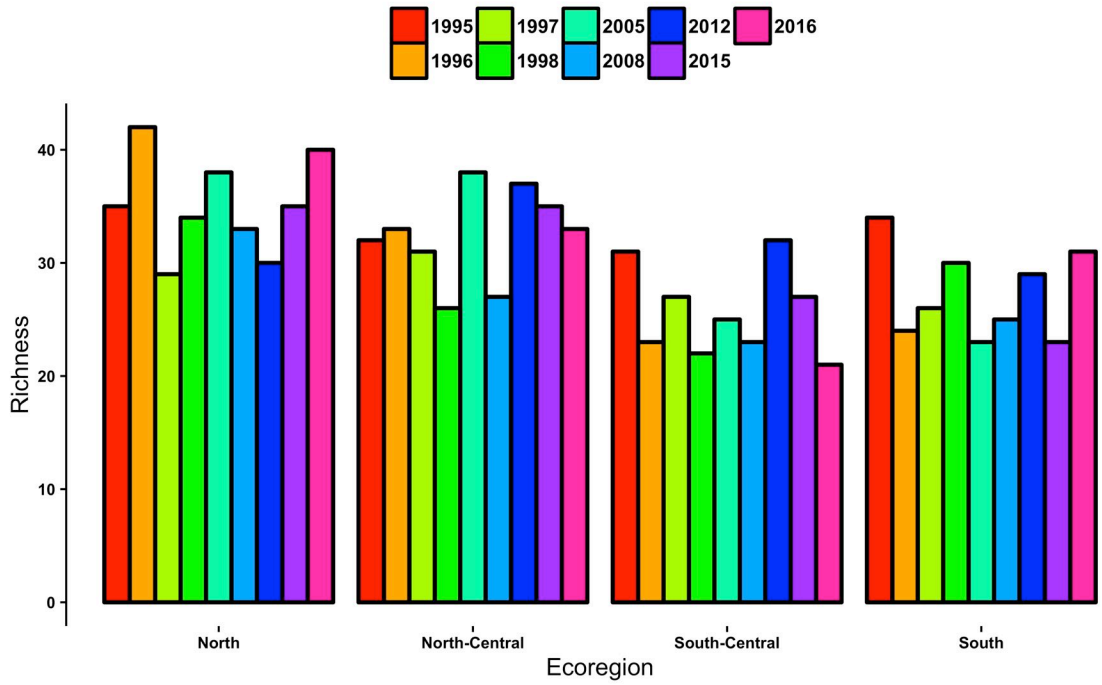


Figure 25. Species richness values for April and July surveys by ecoregion and sampling year.

Table 28. Total abundance for April and July surveys by ecoregion and sampling year.

	Sampling Years								
Ecoregion	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**
North	59,178	91,176	8,978	14,486	4,237	7,233	4,383	10,240	5,158
North-Central	19,523	112,964	8,718	11,603	12,539	3,354	5,675	5,874	7,932
South-Central	22,403	3,623	10,659	8,267	2,346	2,666	3,422	4,789	3,001
South	5,063	3,153	4,735	14,738	5,337	2,438	4,167	3,240	5,036
Total:	**106,167**	**210,916**	**33,090**	**49,094**	**24,459**	**15,691**	**17,647**	**24,143**	**21,127**

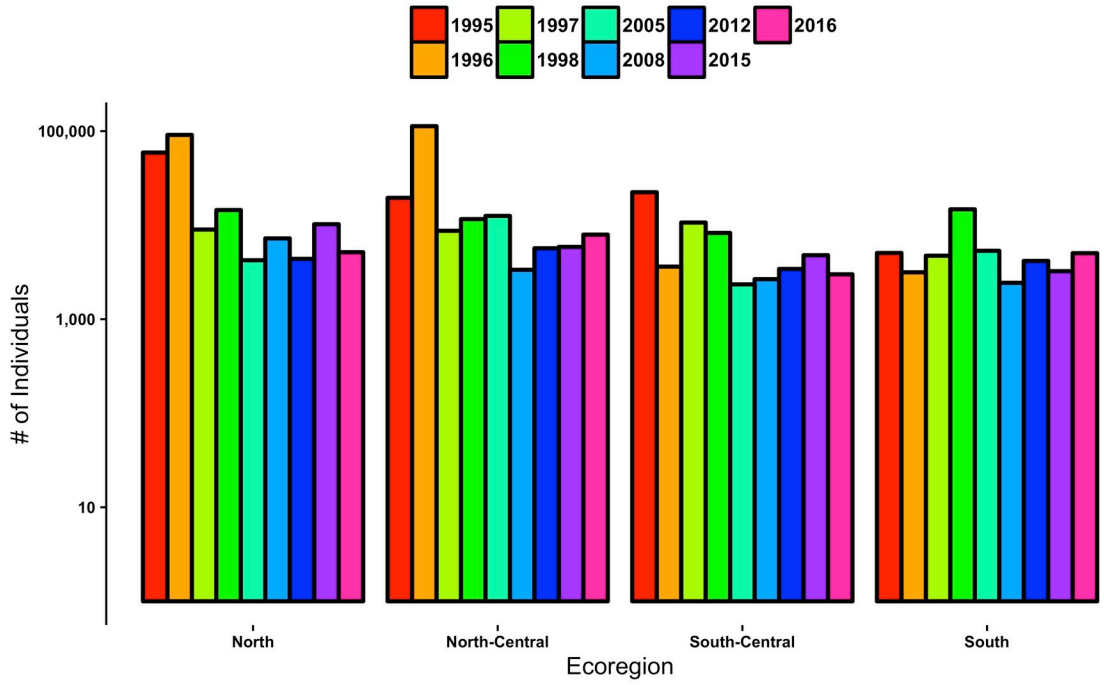


Figure 26. Total abundance for April and July surveys by ecoregion and sampling year.

Table 29. Total abundance for April and July surveys by most frequently caught species and sampling year.

	Sampling Years								
Common Name	**1995**	**1996**	**1997**	**1998**	**2005**	**2008**	**2012**	**2015**	**2016**
Northern Anchovy	52,389	147,173	3	8,373	1,397	10	0	6,666	1,205
Slough Anchovy	16,821	16,616	11,029	27,790	11,219	5,538	1,566	7,957	8,825
Topsmelt	25,272	33,915	12,917	9,232	7,448	3,393	6,529	2,024	4,136
Shiner Perch	3,998	3,222	2,794	336	1,180	1,700	2,419	915	199
California Grunion	0	739	3,136	1,123	186	0	0	1,608	965
Arrow Goby	401	339	104	73	62	927	2,438	629	1,749
Other	7,286	8,912	3,107	2,167	2,967	4,123	4,695	4,344	4,048

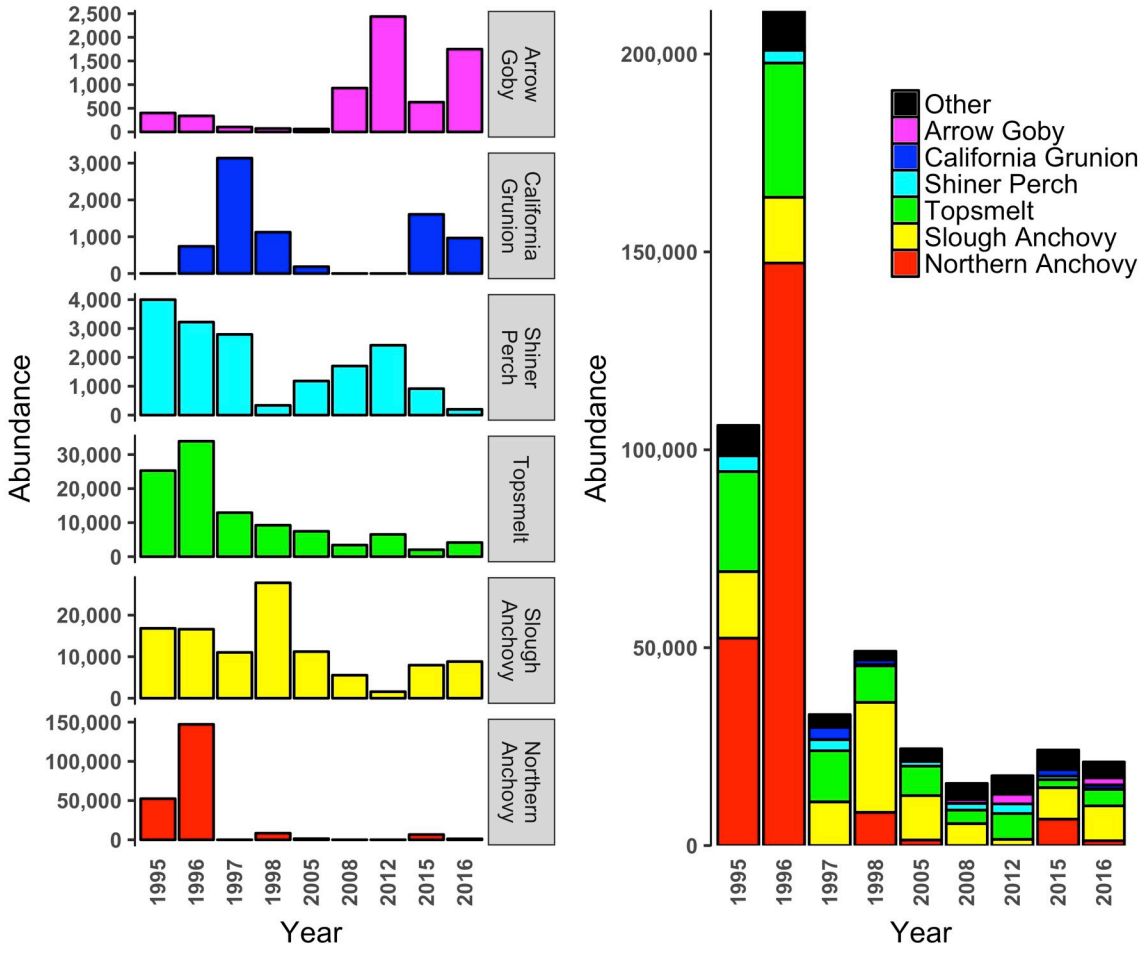


Figure 27. Total abundance of the most frequently caught species for April and July surveys, shown by species over time (left) and as a proportion of the annual catch (right).

Table 30. 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**
North	111.9	195.4	70.1	58.7	58.9	36.5	119.7	112.8	83.2
North-Central	97.2	192.3	88.4	74.4	121.0	55.3	83.0	120.9	65.3
South-Central	111.8	46.6	65.4	33.2	34.2	43.7	70.7	69.2	49.2
South	89.2	75.8	48.2	52.3	77.4	49.0	74.8	75.3	52.2
Total:	**410.0**	**510.1**	**272.1**	**218.6**	**291.6**	**184.5**	**348.2**	**378.2**	**249.9**

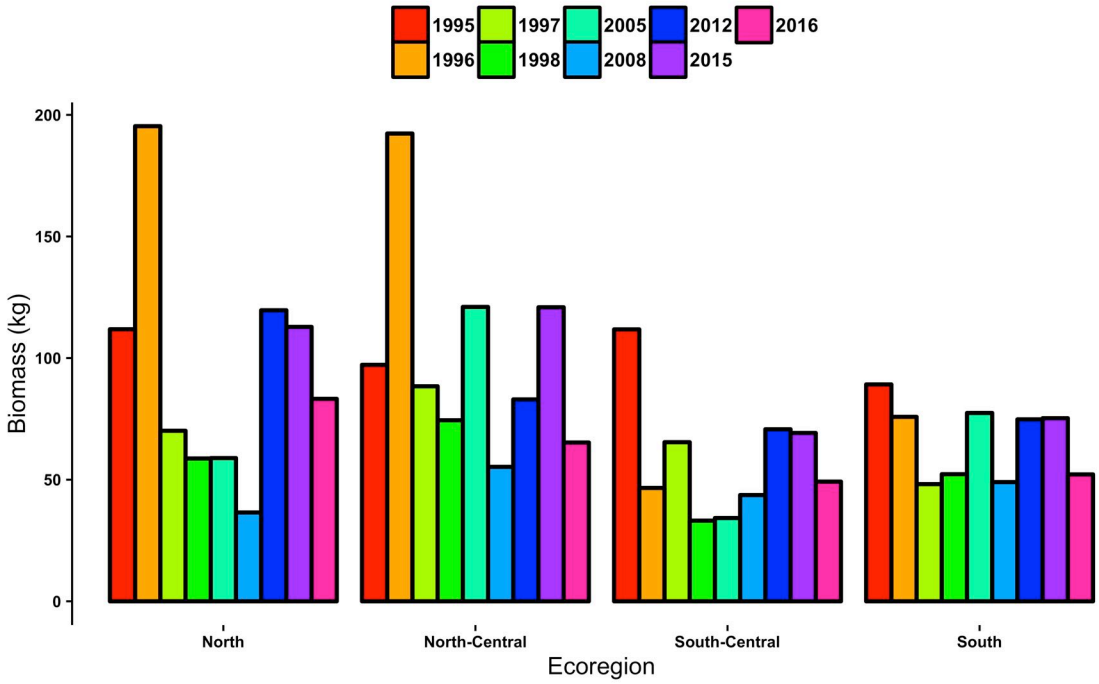


Figure 28. Total biomass (kg) of fishes captured during April and July surveys by ecoregion.

Table 31. 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**
Round Stingray	79.1	63.5	77.2	25.9	109.8	60.9	134.2	129.9	110.9
Spotted Sand Bass	59.9	29.7	33.5	42.2	36.3	47.3	62.3	50.8	28.2
Northern Anchovy	49.7	178.9	0.0	9.5	3.0	0.0	0.0	50.9	29.0
Slough Anchovy	45.7	30.1	19.3	66.0	17.4	10.2	2.4	14.7	14.8
Bat Ray	26.3	37.2	0.0	0.5	36.5	0.0	31.3	26.2	4.6
Topsmelt	22.9	20.5	44.4	20.5	12.1	10.3	11.4	4.7	4.6
Barred Sand Bass	38.3	40.2	10.6	4.7	4.7	2.7	2.2	5.6	7.5
California Butterfly Ray	0.0	0.0	0.0	8.6	2.1	5.1	15.5	51.2	2.4
Other	88.2	109.9	87.1	40.7	69.7	48.0	88.9	44.1	47.9

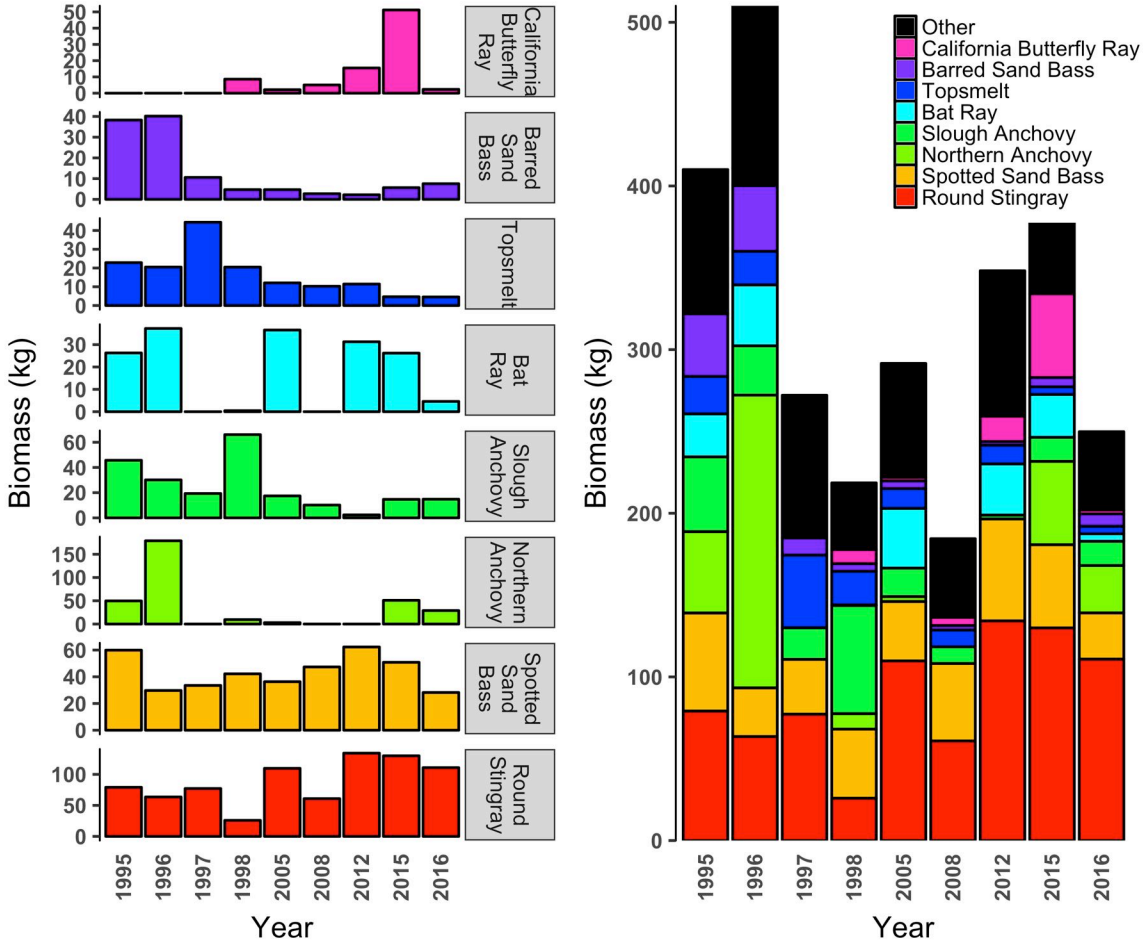


Figure 29. Total biomass (kg) of the highest biomass fishes captured during April and July surveys, shown by species over time (left) and as a proportion of the annual catch (right).

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 in R (R Core Team 2016). The matrix used fourth-root transformed taxon-specific abundance data summed across all replicates throughout the bay during each April and July. Seven significantly different fish community groups (a-f) 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; Figure 30). The driving species behind each community group can be visualized in Figure 31, where circles are scaled to mean abundance by community group of twelve typical San Diego Bay fish taxa.

Sampling periods during the previous major El Niño event showed strong differentiation between most other surveys. The April and July 1997 sampling periods form their own distinct fish community ('d'), 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 was dominated by Striped Mullet (*Mugil cephalus*) and Cortez Bonefish, two estuarine residents that thrive in brackish water, with relatively little else being captured. By July 1998, the fish community returned to a typical mid-1990's July pattern (group 'b').

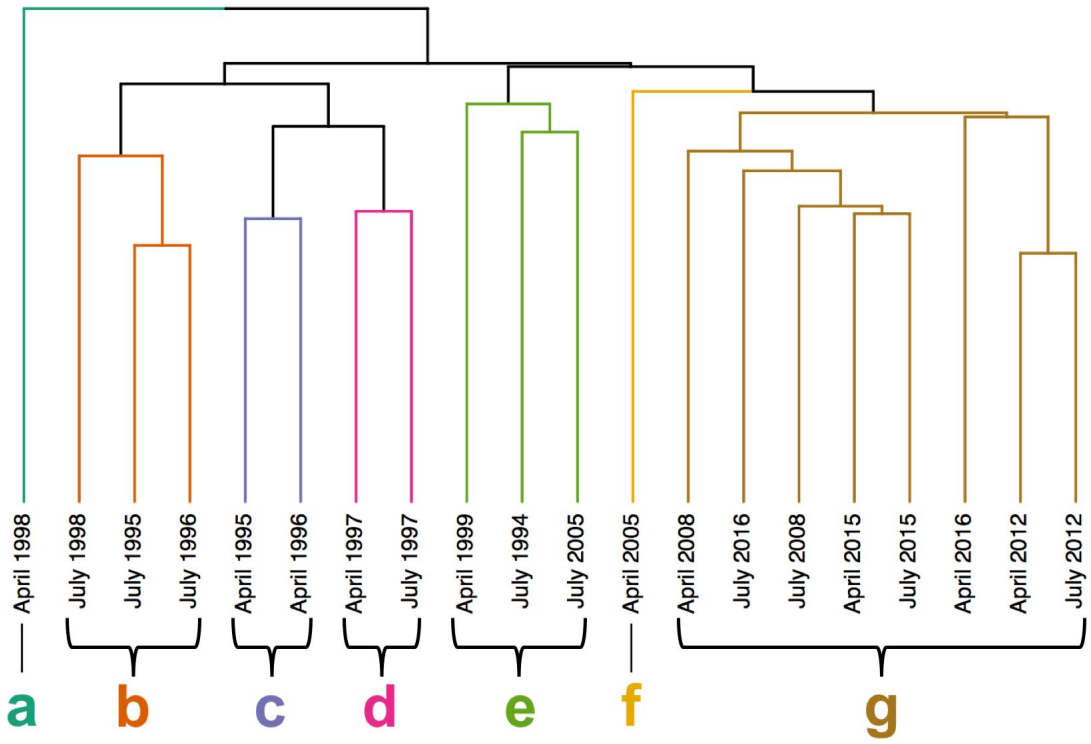


Figure 30. Fish communities for the twenty April and July surveys were clustered in this tree. Branch distances shown in this diagram represent the relative similarity of stations to each other using Bray-Curtis distances and group-average linkage. Significantly different (SIMPROF, α = 0.05) fish communities are indicated by letters (a-g) and color groupings.

Given the intensity of the 2015-2016 El Niño event, it would be expected that the fish communities during each of these sampling periods would either be clustered in a unique group or clustered with the 1997-1998 sampling periods. However, all four sampling periods (April 2015-July 2016) clustered into the largest group ('g') along with every other sampling period since 2008. This result suggests that fish communities in San Diego Bay did not show a significant response to the 2015-2016 El Niño event, and the assemblage during that time was more similar to other recent sampling periods than the sampling events that occurred during 1997-1998 El Niño.

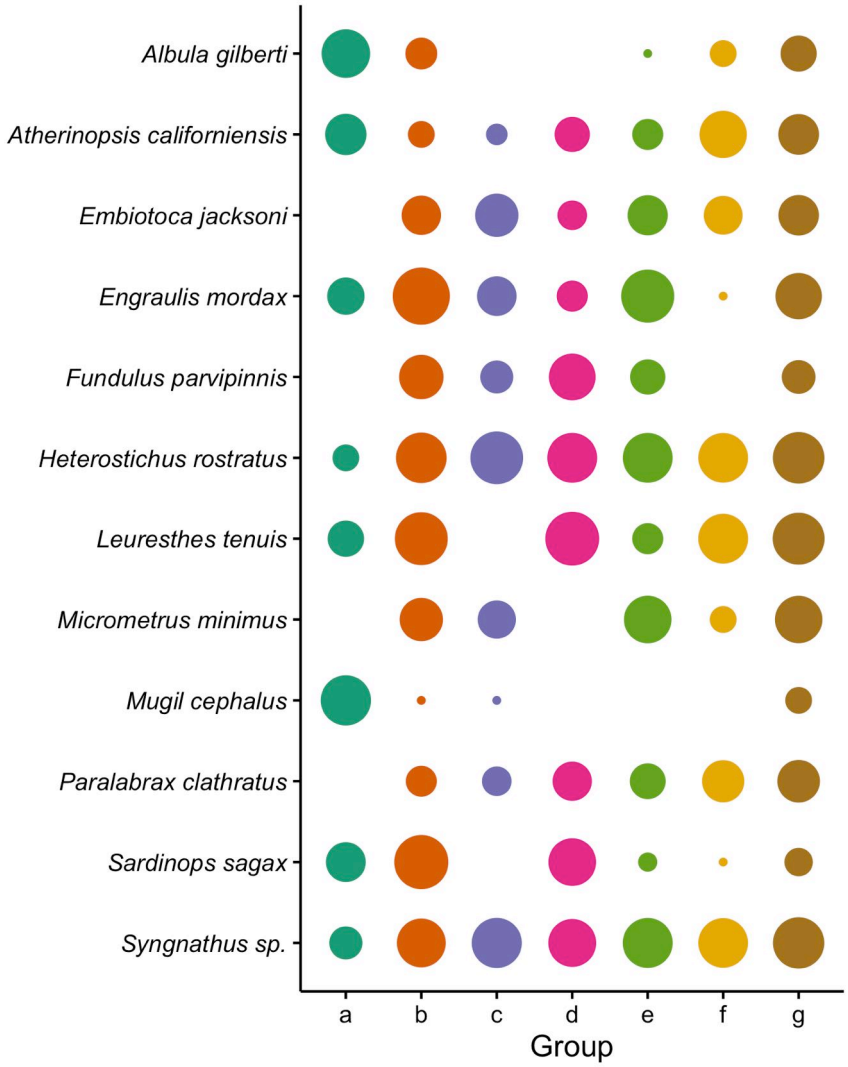


Figure 31. Relative mean abundance (circles scaled to value) per sampling period for select fish taxa in San Diego Bay by community group (as identified in Figure 28).

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