

FISHERIES INVENTORY AND UTILIZATION
OF SAN DIEGO BAY, SAN DIEGO, CALIFORNIA
FOR SURVEYS CONDUCTED IN APRIL AND JULY 2008



Daniel J. Pondella, II, MA, Ph.D, and Jonathan P. Williams, MS.



Vantuna Research Group
Moore Laboratory of Zoology
Occidental College
1600 Campus Rd.
Los Angeles, CA 90041

February 2009

Vantuna Research Group

Daniel J. Pondella, II, Ph.D., Principal Investigator

Jonathan P. Williams, M.S., Research Associate

Field and laboratory research assistants:

Diana Birney

Brianna Bowman

Logan Brown

Ben Chubak

Paul Cutter

Jean Davis

Amanda Haas

Brent Haggin

Mackenzie Hansler

Bridget McCann

Chelsea Muñoz

David Panek

Evan Poirson

Makenzie Mabry

Report Authors: Dan Pondella and Jonathan Williams

Acknowledgments

We are very grateful for the field assistance from the Port of San Diego. The following employees of the Port of San Diego also assisted in field sampling: David Merk, Marshall Olson, Kelly Makley, and Stephanie Bauer. We greatly appreciate Eileen Maher's oversight and management of this project. We would also like to thank Mitch Perdue for his assistance and review of this project.



TABLE OF CONTENTS

List of Tables	iv
List of Figures	v
Executive Summary	1
Methods and Materials	
Field Surveys	4
Sampling Procedures	5
Results and Discussion	
Water Quality Parameters	11
Numerical Catch and Biomass	12
Species Diversity and Richness	20
Catch by Sampling Period and Ecoregion	21
Catch in Bay Habitats	25
Nursery Area Function	28
Ecological Importance of Species	29
Principle Species	31
Catch by Sampling Method	41
Ecoregion Comparisons: Best Estimates of Density and Standing Stock	49
Avian Forage Species	55
Fishery Species	58
Southern Species Found in San Diego Bay	61
Indigenous Bay and Estuary Fishes	63
Comparison of the Current and Historical April and July Surveys	64
Literature Cited	68

LIST OF TABLES

Table 1.	Lambert Coordinates for San Diego Bay Fisheries Inventory	5
Table 2.	Total abundance of fishes collected in San Diego Bay	14
Table 3.	Total biomass of fishes collected in San Diego Bay	15
Table 4.	Total abundance and biomass in the North Ecoregion	16
Table 5.	Total abundance and biomass in the North-Central Ecoregion	17
Table 6.	Total abundance and biomass in the South-Central Ecoregion	18
Table 7.	Total abundance and biomass in the South Ecoregion	19
Table 8.	Total abundance by sampling period	23
Table 9.	Total biomass by sampling period	24
Table 10.	Total abundance of fishes by subhabitat	26
Table 11.	Total abundance by strata (vegetated, non-veg and channel)	27
Table 12.	Percent of juveniles by species	28
Table 13.	Ecological Index of fishes	30
Table 14.	Total catch by sampling method	42
Table 15.	Total biomass by sampling method	45
Table 16.	Density and biomass estimates by gear type	48
Table 17.	Estimates of Aerial Coverage of depth strata by Ecoregion	50
Table 18.	Best estimate of fish density and estimated stock size	51
Table 19.	Best estimate of fishes, forage fishes, and fishery species	54
Table 20.	Best estimate of forage fish species	55
Table 21.	Best estimate of fishery species	58
Table 22.	Exotic southern species from San Diego Bay	61
Table 23.	Abundance of southern species in San Diego Bay	61
Table 24.	Indigenous bay/estuarine species taken in San Diego Bay, 2008	63
Table 25.	Shannon-Weiner Diversity Historical Comparison	64
Table 26.	Species Richness Historical Comparison	65
Table 27.	Historical Comparison of Total Catch	66
Table 28.	Historical Comparison of Total Biomass	67

LIST OF FIGURES

Figure 1.	Sampling locations in San Diego Bay	4
Figure 2.	Sampling events for the North Ecoregion	7
Figure 3.	Sampling events for the North-Central Ecoregion	8
Figure 4.	Sampling events for the South-Central Ecoregion	9
Figure 5.	Sampling events for the South Ecoregion	10
Figure 6.	Summary of physical-chemical measurements by ecoregion	11
Figure 7.	Catch of fishes by Ecoregion	12
Figure 8.	Catch of the five numerically dominant species by ecoregion	13
Figure 9.	Shannon-Weiner Diversity and species richness by Ecoregion	20
Figure 10.	Shannon-Weiner Diversity and richness by sampling month	20
Figure 11.	Total abundance by sampling month	22
Figure 12.	Total biomass by sampling month	22
Figure 13.	Top 20 species ranked by Ecological Index	29
Figure 14.	Length frequency of slough anchovy	31
Figure 15.	Disc width frequency of round stingray	32
Figure 16.	Length frequency of spotted sand bass	33
Figure 17.	Length frequency of topsmelt	34
Figure 18.	Length frequency of shiner perch	35
Figure 19.	Length frequency of arrow goby	36
Figure 20.	Length frequency of giant kelpfish	37
Figure 21.	Length frequency of bay pipefish	38
Figure 22.	Length frequency of California halibut	39
Figure 23.	Length frequency of barred sand bass	40
Figure 24.	Abundance of southern species in San Diego Bay	62
Figure 25.	Shannon-Weiner diversity historical comparison	64
Figure 26.	Species richness historical comparison	65
Figure 27.	Historical comparison of total catch	66
Figure 28.	Historical Comparison of Total Biomass	67

Executive Summary

The Vantuna Research Group at Occidental College surveyed the estuarine fishes of San Diego Bay in April and July 2008 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). The goals of the current study were to update the previous study and address the following objectives:

- Identify, determine and quantify the utilization of the fishery populations in San Diego Bay
- Identify habitats that support juvenile fish species and describe nursery utilization
- Determine geographic and/or habitat areas of San Diego Bay that support significant populations of fish species utilized as forage by endangered avian species

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
 - 'southern' species unique to San Diego Bay

Composition and Abundance

During this study, 15,692 (48 species) fishes weighing 183 kg were collected during April and July 2008. The most numerous species comprising 35.3% of the catch was slough anchovy (*Anchoa delicatissima*), followed by topsmelt (*Atherinops affinis*; 21.6%), shiner perch (*Cymatogaster aggregata*; 10.8%), salema (*Xenistius californiensis*; 5.7%) and arrow goby (*Clevelandia ios*; 5.9%). In terms of biomass, round stingrays (*Urobatis halleri*) dominated the catch comprising 33.2% of the biomass. The spotted sand bass (*Paralabrax maculatofasciatus*; 25.7%) followed by topsmelt (5.6%), slough anchovy (5.5%) and California butterfly ray (2.8%) rounded out the top five fishes for total biomass.

Nursery Area Function

San Diego Bay continues to be a nursery area for the great majority of the fishes found there. Approximately 62% of all fishes sampled in San Diego Bay were juveniles

Ecological Importance of Species

The principle fishes surveyed during these sampling periods as determined by the Ecological Index were the following estuarine species: slough anchovy, round stingray, spotted sand bass, topsmelt and shiner perch. Slough anchovy ranked first with an E.I. of 4,083 while round stingray ranked second (E.I. 3,562). Both species were found ubiquitously throughout the bay, round stingray were dominant in terms of biomass and topsmelt in terms of numerical abundance. These species were followed by spotted sand bass (E.I. 2,797), topsmelt (E.I. 2,723) and shiner perch (E.I. 1,369).

Best Estimates of Density and Standing Stock

The best total estimate for the total stock size was 24,776,133 fishes. With an estimated surface area of 4858 ha (Table 13) this gives an overall fish density 0.51 ind/m² (Table 23). Nearly half of this estimate was slough anchovy (12 million). Salema (2.6 million) arrow goby (2.2 million) shiner perch (2.2 million), topsmelt (1.7 million) bay pipefish (1.2 million) and giant kelpfish (1.2 million) dominated the stock estimate. The stock estimate for the bay was unsurprisingly dominated by schooling and forage fishes.

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. Seven species of important avian forage species were captured during this study. These species were: deepbody anchovy, slough anchovy, northern anchovy, California halfbeak, topsmelt, jacksmelt and shiner perch. The most abundant forage fishes were slough anchovy; topsmelt, and shiner perch. These species were primarily found at small sizes, less than 50 mm in length. These small forage fishes were present during both sampling periods (April and July) indicating that there was a plentiful source of small fishes needed by the nesting birds in the area. The stock estimate for forage fish was over 16 million fishes and an estimate of 60 metric tons (mt). Slough anchovy (25 mt) accounted for nearly half of this biomass followed by shiner perch (9.5 mt) and topsmelt (5.4 mt). During these sampling periods the bay supported more than enough fish biomass at the appropriate size classes for the birds of the region.

Fisheries Species

During this study, 15 species were captured which have importance in either the recreational or commercial fisheries in California. Including all Ecoregions, standing stock estimates of fisheries species totaled 89.9 (mt). Estimates were greatest at the South-Central Ecoregion (37.7 mt), followed by the South (35.8 mt), North-Central (12.4 mt) and North Ecoregions (4.0 mt).

Trends and Comparisons

In 2008, the South Ecoregion had the highest diversity recorded ($H' = 2.00$). At the remaining ecoregions diversity was roughly equal to the 2005 sampling season and as high as has been observed in the study. Overall, 2008 Shannon-Wiener Diversity estimates were very strong. By contrast to the diversity values, species richness values for 2008 are at the middle or low end of the range of values for each ecoregion.

San Diego Bay as a Unique Fish Habitat

San Diego Bay is known for being the northern edge of the range for a number of southern fishes that are not normally distributed in the Southern California Bight. As an example, at least nineteen northern range extensions have been reported for the bay. During the study the following six species (bonefish, shortfin corvina, California butterfly ray, Pacific seahorse, California halfbeak, California needlefish) with primarily southern distributions were taken. These fishes were mostly found in the south ecoregion. 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 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 49% of the total catch in this survey.

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 locations of the North (1), North-Central (2), South-Central (3) and South (4) Ecoregions in San Diego Bay.



Table 1. Lambert Coordinates (LAT, LONG) for San Diego Bay Fisheries Inventory and Utilization study, 2008.

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 2008 (April 12,13,19, 20 and July 1, 2, 21, 22, 2008). One Ecoregion was sampled per day. Collections were made off the 5-m *R/V Blennius* and the 6-m *R/V Larvae*. 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 X 1.8 m large seine equipped with a 1.8 X 1.8 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 sampling area was randomly selected within Ecoregions. The net was set parallel to the shoreline and pulled in shore by 15 m rope lines, covering an area of about 220 m² per haul. Three replicates per habitat were conducted for a total of six per Ecoregion.
- 2) A 4.6 m X 1.2 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, covering an area of approximately 62 m². Three replicates per subhabitat were conducted for a total of six per Ecoregion.
- 3) A 1 m² square enclosure constructed of 2.5 cm 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 isoproponal-2-quinoline solution was added to the enclosed water and then searched for 10 minutes using a 1 mm mesh dipnet.
- 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 behind the 5-m research vessel, covering an area of approximately 290 m² per replicate.

- 5) A 66 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. The purse seine was randomly set within each subhabitat and sampled a total area of approximately 296 m² per replicate. Three replicates per subhabitat were conducted during each sampling period.
- 6) An 8 m semi-balloon otter trawl (2 cm mesh wings and 0.8 cm mesh codend) towed behind the 5-m research vessel was used to survey fishes from the deepest portions of the channel subhabitat. The otter trawl was towed for 10 minutes and sampled a total area of approximately 2,417 m² per each replicate. Three replicates were conducted per Ecoregion.

All fishes or subsamples of large catches were returned to the laboratory where all individuals were identified to species, measured to the nearest 0.01 mm (Standard Length or Disk Width) with a Mitutoyo Digital Caliper and weighed with a Sartorius Analytical Balance. Large fishes were measured aboard ship to the nearest millimeter and gram using Pesola hanging scales and returned. Lambert coordinates of each sampling effort were recorded for all sampling events. For otter and beam trawls the start and finish of each tow was recorded. The station events are plotted in Figures 2-5.

Figure 2. Sampling events for the North Ecoregion.

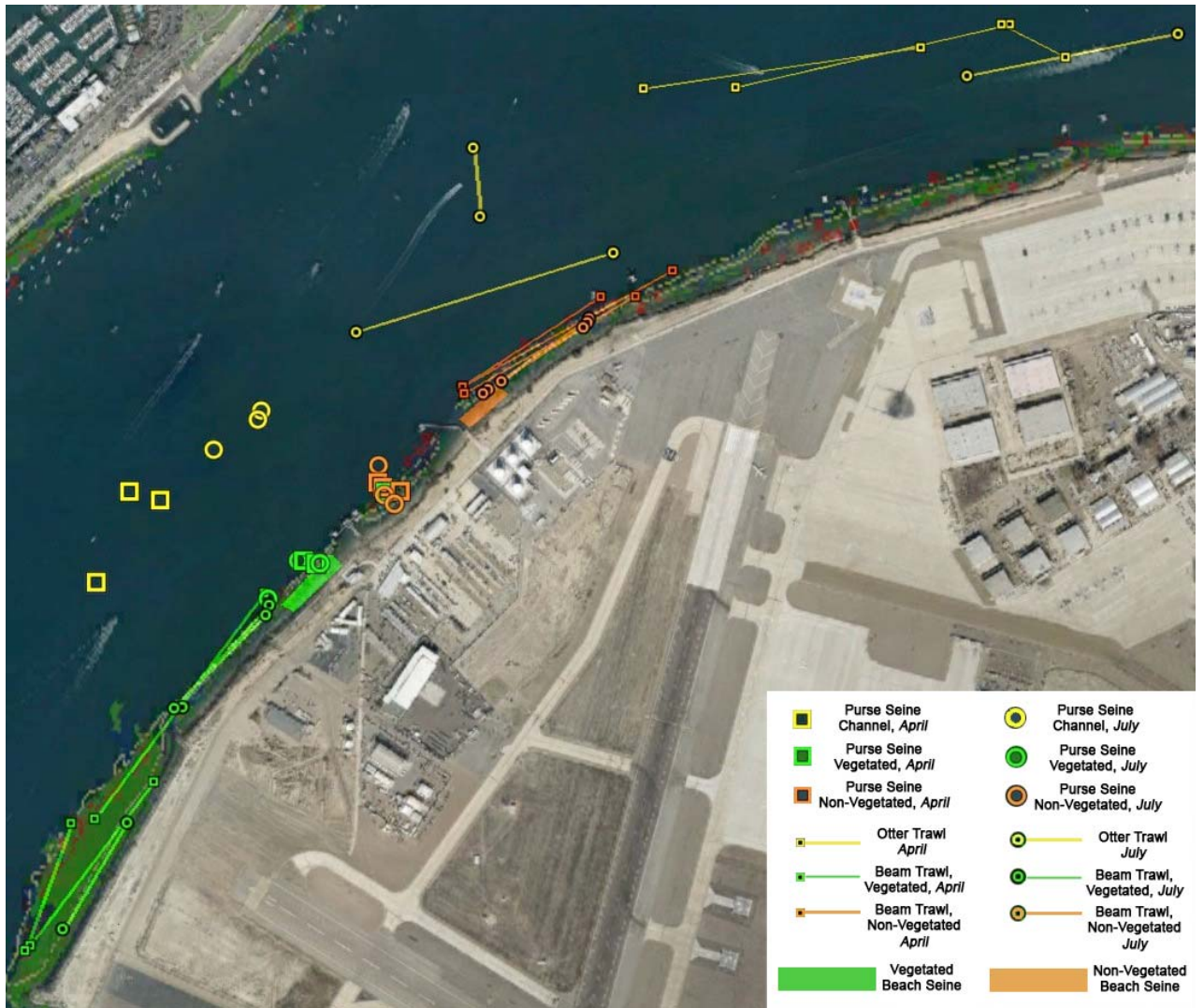


Figure 3. Sampling events for the North-Central Ecoregion.

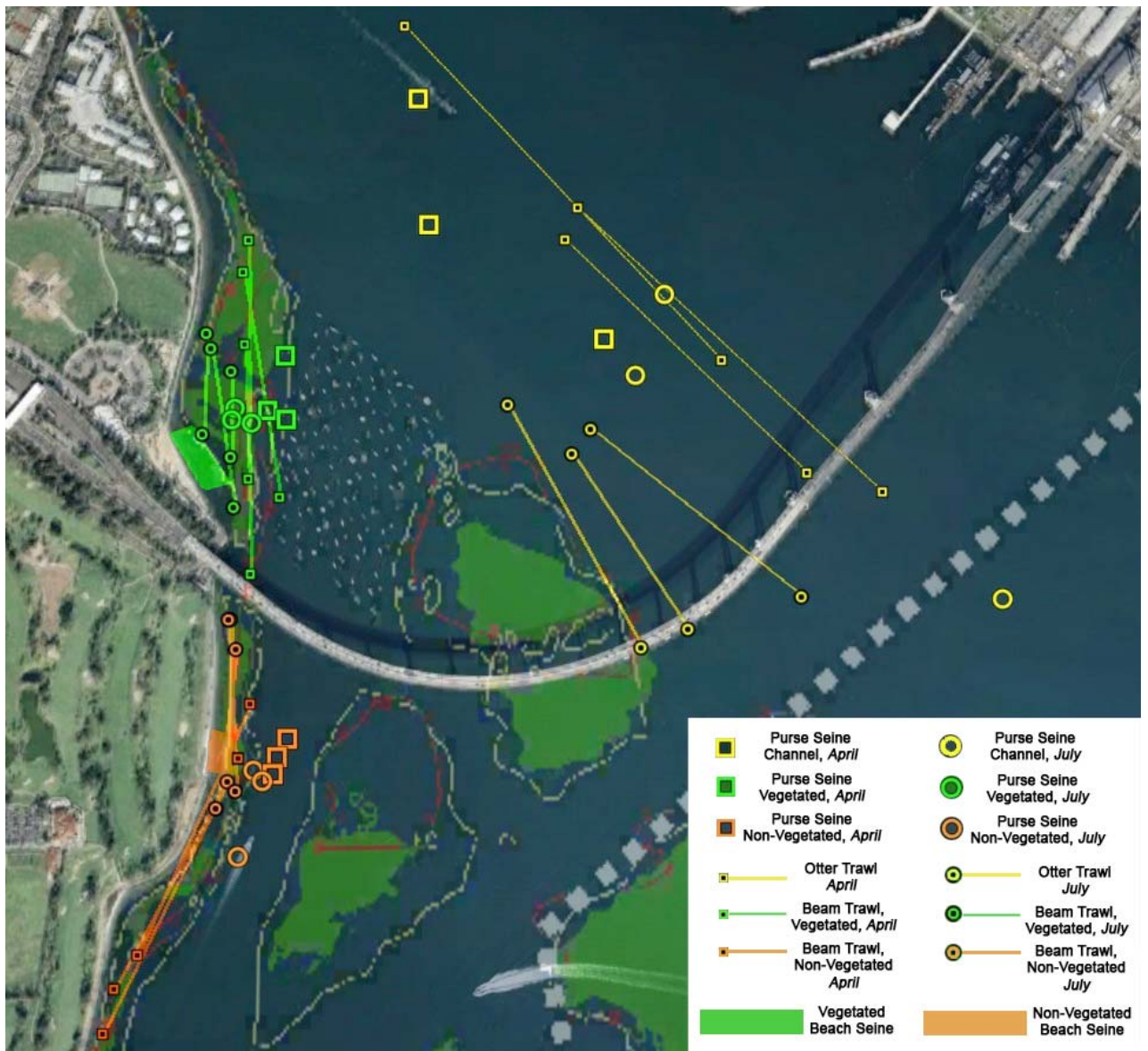


Figure 4. Sampling events for the South-Central Ecoregion.

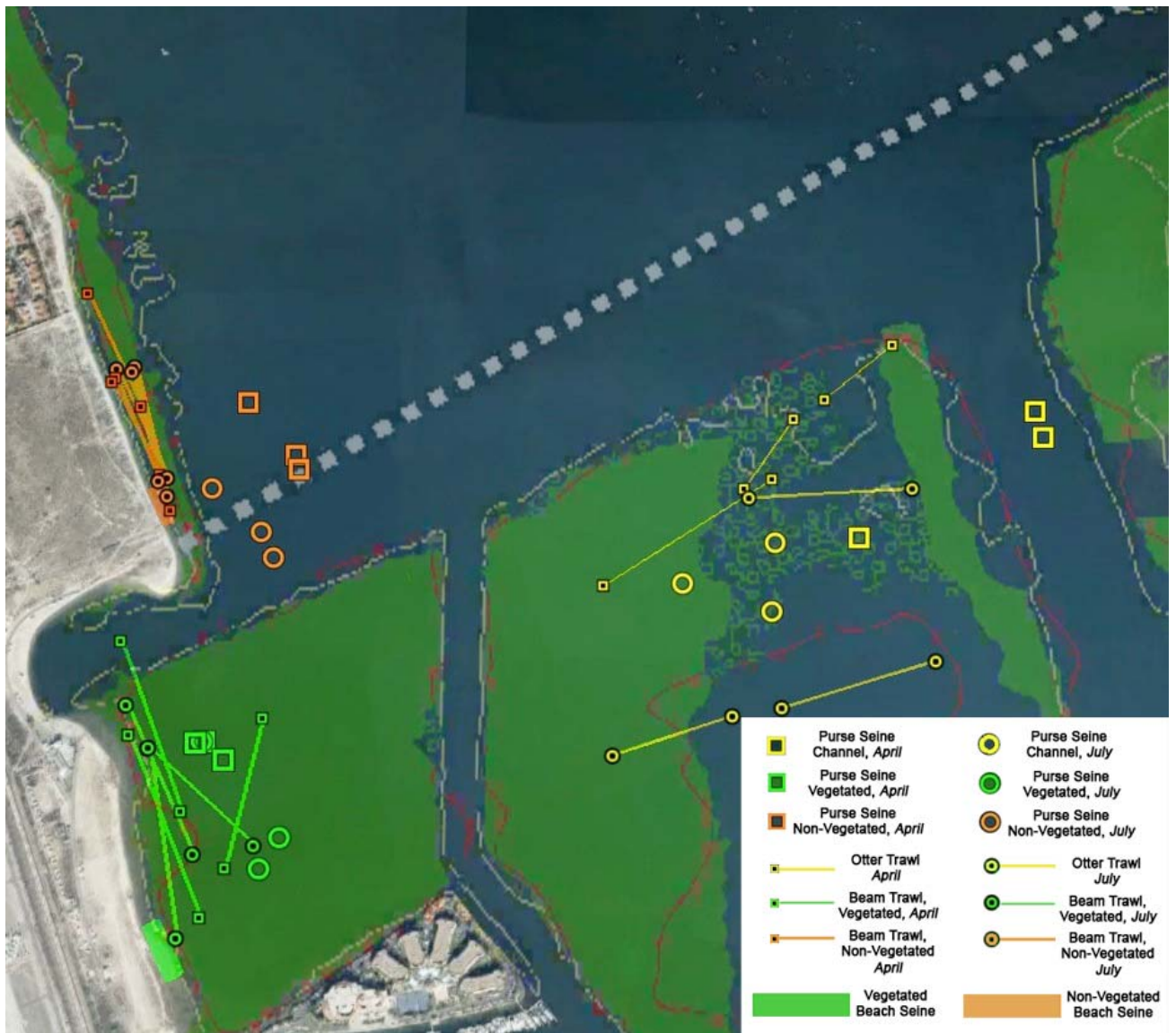
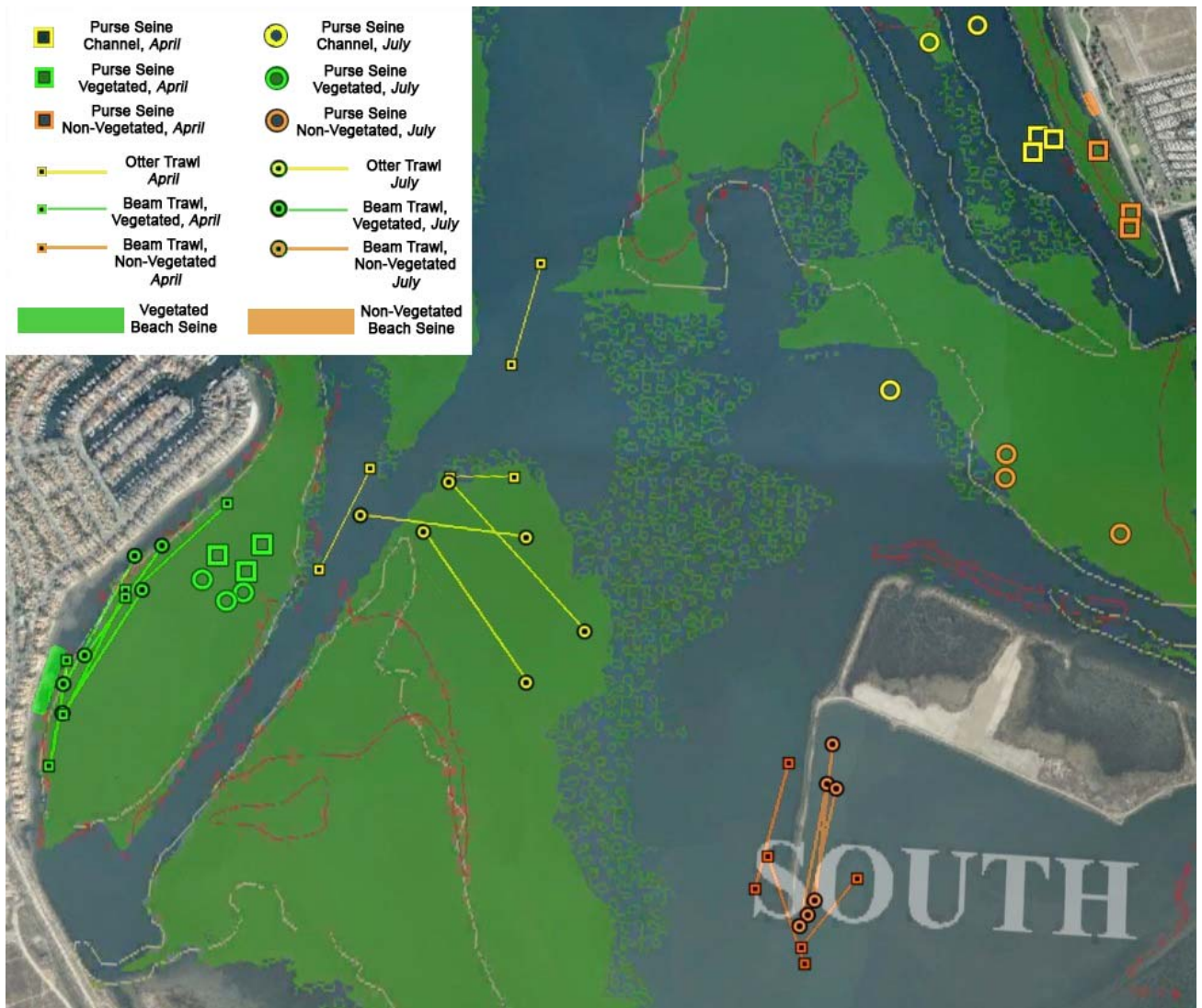


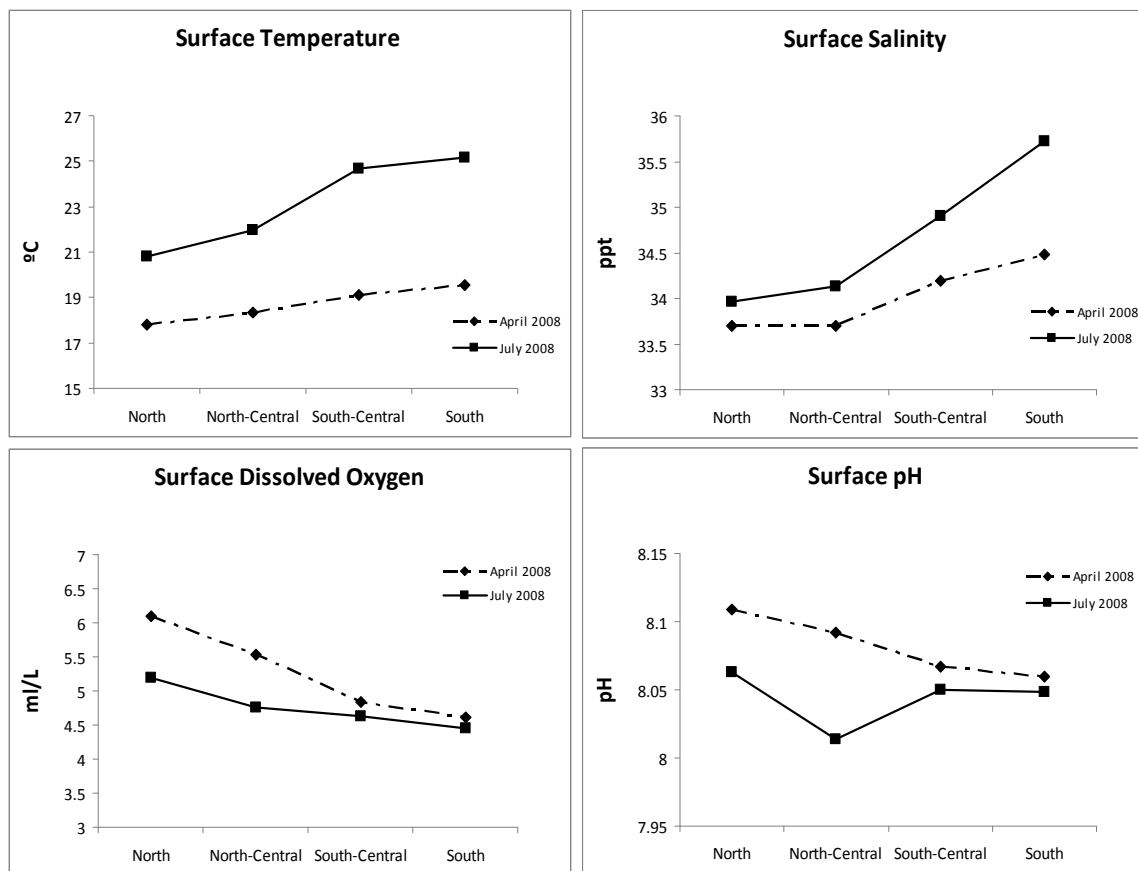
Figure 5. Sampling events for the South Ecoregion.



Water Quality Parameters

Water temperature ($^{\circ}\text{C}$), salinity (ppt), dissolved oxygen (mgO_2/l), and pH was measured at each Ecoregion. Data entry, summarization, graphing, and descriptive analyses were accomplished using *Microsoft Excel* for Windows. *Microsoft Excel* was also used to tabulate the physical and chemical parameters of each Ecoregion sampled by the Sea-Bird oceanographic profiler. Temperature and salinity increased from north to south in the bay during April and July sampling periods. Dissolved oxygen and pH were relatively stable and decreased slightly from north to south (Figure 6).

Figure 6. Summary of mean physical-chemical measurements by Ecoregion over the sampling months, 2008.

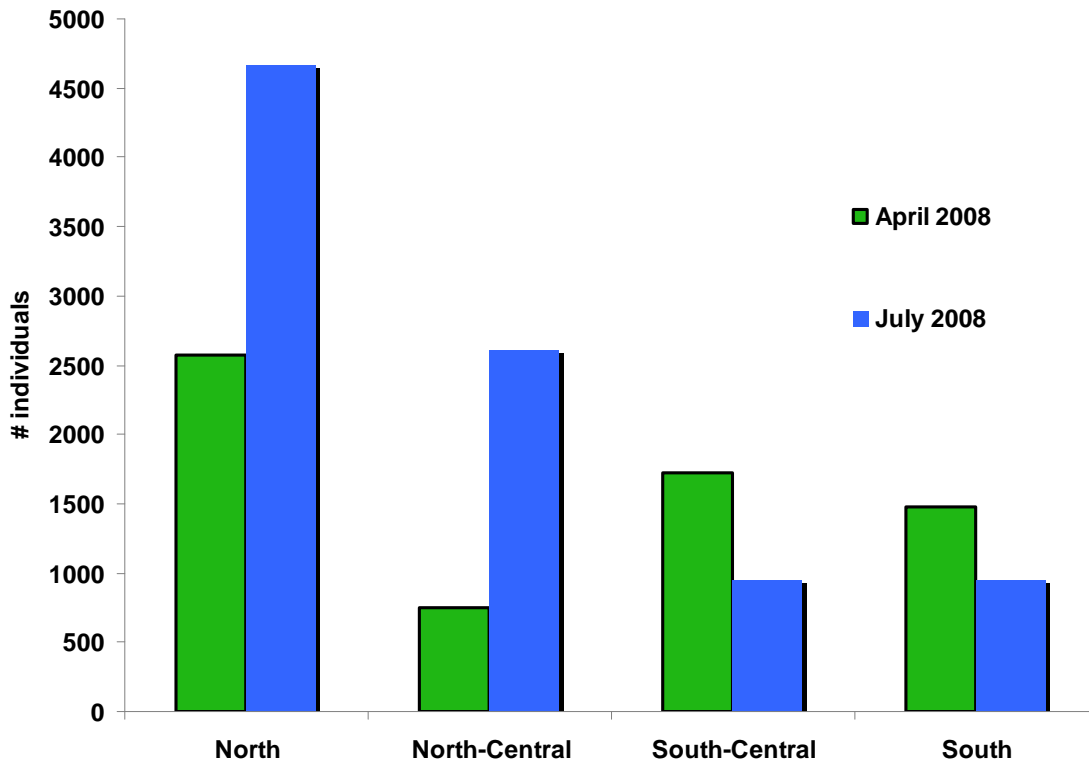


Numerical Catch and Biomass

During this study, 15,692 (48 species) fishes weighing 183 kg were collected during April and July 2008 (Tables 2 and 3). The most numerous species comprising 35.3% of the catch was slough anchovy (*Anchoa delicatissima*), followed by topsmelt (*Anchoa Atherinops affinis*; 21.6%), shiner perch (*Cymatogaster aggregata*; 10.8%), salema (*Xenistius californiensis*; 5.7%) and arrow goby (*Clevelandia ios*; 5.9%). In terms of biomass, round stingrays (*Urobatis halleri*) dominated the catch comprising 33.2% of the biomass. The spotted sand bass (*Paralabrax maculatofasciatus*; 25.7%) followed by topsmelt (5.6%), slough anchovy (5.5%) and California butterfly ray (2.8%) rounded out the top five fishes for total biomass.

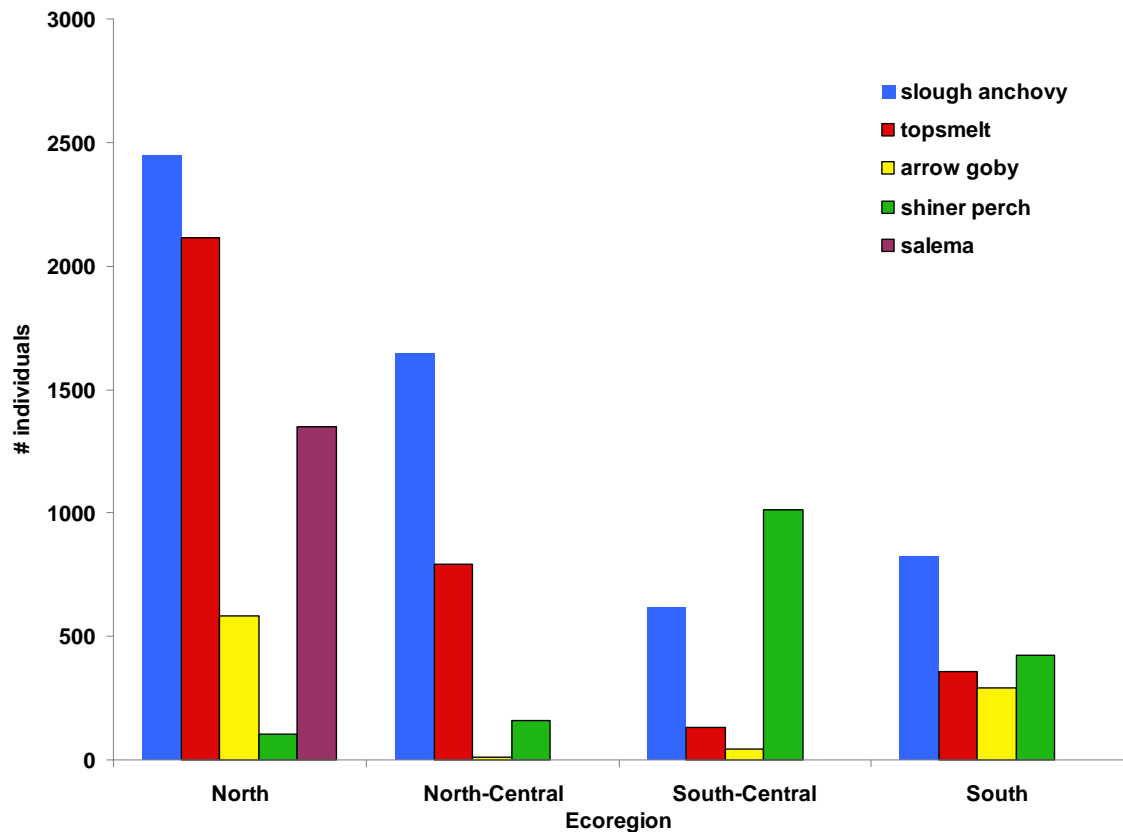
Total catch varied substantially by Ecoregion and was greatest at the North Ecoregion (7,233; Table 4), followed by the North-Central Ecoregion (3,355; Table 5), South-Central Ecoregion (2,666; Table 6), and South Ecoregion (2,438; Table 7) (Figure 7). The North Ecoregion was dominated by slough anchovy (2448), topsmelt (2113) and salema (1346). In the North-Central Ecoregion slough anchovy (1645) and topsmelt (793) also dominated the catch. In this region we had high catches of giant kelpfish (*Heterostichus rostratus*; 227) and bay pipefish (*Syngnathus leptorhynchus*; 223). Shiner perch (1014), slough anchovy (617) and bay pipefish (279) dominated the south-central catch. In the South Ecoregion slough anchovy (828), shiner perch (422), topsmelt (358) and arrow goby (290) comprised most of the catch. Slough anchovy was either the most abundant or second most abundant at all four ecoregions.

Figure 7. Catch of San Diego Bay fishes by Ecoregion, April and July 2008.



Overall the catch of the five numerically dominant fishes had mixed patterns over the four ecoregions (Figure 8). Catch of shiner perch increased to the south with a high in the South-Central Ecoregion. Both slough anchovy and topsmelt decreased from the North to South Ecoregion with their lowest catch at the South-Central ecoregion. Arrow gobies were caught in greater numbers in the North and South Ecoregions, while salemas were only caught in the North Ecoregion.

Figure 8. Total catch of the five numerically dominant species by Ecoregion.



Spotted sand bass had the highest catch in terms of biomass at three ecoregions (North-Central, 13.7 kg; South-Central, 15.4 kg; and South, 15.2 kg). It was fifth in biomass (2.7 kg) in the North Ecoregion. Biomass in the North Ecoregion was dominated by salemas (8.7 kg), slough anchovy (5.7 kg), topsmelt (5.1 kg), round stingray (*Urobatis halleri*, 3.5 kg) and spotted sand bass (2.7 kg). For the North-Central Ecoregion after spotted sand bass, shortfin corvina (*Cynoscion parvipinnis*, 4.8 kg) was dominant. In the South-Central Ecoregion California corbina (*Menticirrhus undulatus*, 2.5 kg) and shiner perch (2.3 kg) had the second and third highest biomass values, respectively. Finally in the South Ecoregion, California butterfly ray (*Gymnura marmorata*, 5.0 kg), shiner perch (1.4 kg), slough anchovy (1.3 kg) and topsmelt (1.2 kg) were the second through fifth highest biomass values, respectively.

Table 2. Total abundance of fishes collected in San Diego Bay during April and July 2008 by Ecoregion.

SCIENTIFIC NAME	COMMON NAME	ECOREGIONS				TOTAL	%
		North	North-Central	South-Central	South		
<i>Albula vulpes</i>	bonefish				1	1	0.01
<i>Anchoa compressa</i>	deepbody anchovy			4	68	72	0.46
<i>Anchoa delicatissima</i>	slough anchovy	2448	1645	617	828	5538	35.29
<i>Atherinops affinis</i>	topsmelt	2113	793	130	358	3394	21.63
<i>Atherinopsis californiensis</i>	jacksmelt	1				1	0.01
<i>Atractoscion nobilis</i>	white seabass			1		1	0.01
<i>Cheilotrema saturnum</i>	black croaker	1	5			6	0.04
<i>Clevelandia ios</i>	arrow goby	584	11	42	290	927	5.91
<i>Cosmocampus arctus</i>	snubnose pipefish	1				1	0.01
<i>Cymatogaster aggregata</i>	shiner perch	103	161	1014	422	1700	10.83
<i>Cynoscion parvipinnis</i>	shortfin corvina		7		2	9	0.06
<i>Embiotoca jacksoni</i>	black surfperch	15				15	0.10
<i>Engraulis mordax</i>	northern anchovy	8		2		10	0.06
<i>Fundulus parvipinnis</i>	California killifish			1	53	54	0.34
<i>Gibbonsia elegans</i>	spotted kelpfish	9	3			12	0.08
<i>Girella nigricans</i>	opaleye	2				2	0.01
<i>Gymnura marmorata</i>	California butterfly ray				6	6	0.04
<i>Halichoeres semicinctus</i>	rock wrasse	5	2			7	0.04
<i>Heterostichus rostratus</i>	giant kelpfish	213	227	96	14	550	3.50
<i>Hippocampus ingens</i>	Pacific seahorse			1		1	0.01
<i>Hyperprosopon argenteum</i>	walleye surfperch	1				1	0.01
<i>Hyporhamphus rosae</i>	California halfbeak			9	5	14	0.09
<i>Hypsoblennius gentilis</i>	bay blenny	7	2	3		12	0.08
<i>Ilypnus gilberti</i>	cheekspot goby	1	1		18	20	0.13
<i>Leptocottus armatus</i>	staghorn sculpin	8	2	20	3	33	0.21
<i>Menticirrhus undulatus</i>	California corbina			1		1	0.01
<i>Micrometrus minimus</i>	dwarf surfperch	81	1			82	0.52
<i>Mugil cephalus</i>	striped mullet				2	2	0.01
<i>Paraclinus integripinnis</i>	reef finspot	1		2		3	0.02
<i>Paralabrax clathratus</i>	kelp bass	52	20	1	2	75	0.48
<i>P. maculatofasciatus</i>	spotted sand bass	16	65	203	75	359	2.29
<i>P. nebulifer</i>	barred sand bass	20	31	93	14	158	1.01
<i>Paralichthys californicus</i>	California halibut	21	20	10	11	62	0.40
<i>Pleuronichthys guttulatus</i>	diamond turbot	8	7	15	17	47	0.30
<i>Pleuronichthys ritteri</i>	spotted turbot	10	14			24	0.15
<i>Porichthys myriaster</i>	specklefin midshipman	30	5		10	45	0.29
<i>Quietula y-cauda</i>	shadow goby				1	1	0.01
<i>Scorpaena guttata</i>	California scorpionfish	3				3	0.02
<i>Seriphus politus</i>	queenfish		1			1	0.01
<i>Sphyaena argentea</i>	California barracuda		1			1	0.01
<i>Strongylura exilis</i>	California needlefish		1		2	3	0.02
<i>Symphurus atricaudus</i>	California tonguefish	10	11			21	0.13
<i>Syngnathus leptorhynchus</i>	bay pipefish	95	223	279	76	673	4.29
<i>Synodus lucioceps</i>	California lizardfish	5		2		7	0.04
<i>Umbrina roncadore</i>	yellowfin croaker		1		4	5	0.03
<i>Urobatis halleri</i>	round stingray	11	95	120	156	382	2.43
<i>Xenistius californiensis</i>	salema	1346				1346	8.58
<i>Xystreurus liolepis</i>	fantail sole	4				4	0.03
Number of Species = 48		7233	3355	2666	2438	15692	

Table 3. Total biomass of fishes collected in San Diego Bay during April and July 2008 by Ecoregion.

SCIENTIFIC NAME	COMMON NAME	ECOREGIONS				TOTAL	%
		North	North-Central	South-Central	South		
<i>Albula vulpes</i>	bonefish				759	759	0.41
<i>Anchoa compressa</i>	deepbody anchovy			32	627	658	0.36
<i>Anchoa delicatissima</i>	slough anchovy	5721	2399	770	1269	10158	5.54
<i>Atherinops affinis</i>	topsmelt	5146	2940	975	1204	10265	5.60
<i>Atherinopsis californiensis</i>	jacksmelt	218				218	0.12
<i>Atractoscion nobilis</i>	white seabass			291		291	0.16
<i>Cheilotrema saturnum</i>	black croaker	139	444			583	0.32
<i>Clevelandia ios</i>	arrow goby	46	3	4	63	116	0.06
<i>Cosmocampus arctus</i>	snubnose pipefish	0				0	0.00
<i>Cymatogaster aggregata</i>	shiner perch	693	918	2262	1358	5231	2.85
<i>Cynoscion parvipinnis</i>	shortfin corvina		4765		222	4987	2.72
<i>Embiotoca jacksoni</i>	black perch	620				620	0.34
<i>Engraulis mordax</i>	northern anchovy	12		2		14	0.01
<i>Fundulus parvipinnis</i>	California killifish			3	59	62	0.03
<i>Gibbonsia elegans</i>	spotted kelpfish	43	26			69	0.04
<i>Girella nigricans</i>	opaleye	132				132	0.07
<i>Gymnura marmorata</i>	California butterfly ray				5055	5055	2.76
<i>Halichoeres semicinctus</i>	rock wrasse	12	130			143	0.08
<i>Heterostichus rostratus</i>	giant kelpfish	1495	2518	314	63	4390	2.39
<i>Hippocampus ingens</i>	Pacific seahorse			30		30	0.02
<i>Hyperprosopon argenteum</i>	walleye surfperch	59				59	0.03
<i>Hyporhamphus rosae</i>	California halfbeak			35	16	51	0.03
<i>Hypsoblennius gentilis</i>	bay blenny	122	56	68		246	0.13
<i>Ilypnus gilberti</i>	cheekspot goby	0	0		6	6	0.00
<i>Leptocottus armatus</i>	staghorn sculpin	60	15	225	19	319	0.17
<i>Menticirrhus undulatus</i>	California corbina			2450		2450	1.34
<i>Micrometrus minimus</i>	dwarf surfperch	684	2			686	0.37
<i>Mugil cephalus</i>	striped mullet				1220	1220	0.67
<i>Paraclinus integripinnis</i>	reef finspot	3		2		5	0.00
<i>Paralabrax clathratus</i>	kelp bass	1006	346	29	58	1438	0.78
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	2746	13731	15442	15181	47100	25.68
<i>Paralabrax nebulifer</i>	barred sand bass	291	970	1010	435	2706	1.48
<i>Paralichthys californicus</i>	California halibut	1178	902	1338	1198	4617	2.52
<i>Pleuronichthys guttulatus</i>	diamond turbot	1025	1013	564	240	2842	1.55
<i>Pleuronichthys ritteri</i>	spotted turbot	571	683			1254	0.68
<i>Porichthys myriaster</i>	specklefin midshipman	595	304		23	923	0.50
<i>Quietula y-cauda</i>	shadow goby				1	1	0.00
<i>Scorpaena guttata</i>	California scorpionfish	528				528	0.29
<i>Seriphus politus</i>	queenfish		88			88	0.05
<i>Sphyrna argentea</i>	California barracuda		839			839	0.46
<i>Strongylura exilis</i>	California needlefish		2		51	53	0.03
<i>Symphurus atricaudus</i>	California tonguefish	76	139			215	0.12
<i>Syngnathus leptorhynchus</i>	bay pipefish	85	218	108	27	439	0.24
<i>Synodus lucioceps</i>	California lizardfish	134		23		156	0.09
<i>Umbrina roncadore</i>	yellowfin croaker		272		906	1178	0.64
<i>Urobatis halleri</i>	round stingray	3505	21547	16883	18941	60876	33.19
<i>Xenistius californiensis</i>	salema	8755				8755	4.77
<i>Xystreurus liolepis</i>	fantail sole	568				568	0.31
Number of Species = 48		36269	55269	42858	49001	183396	

Table 4. Total number of individuals and biomass (g) of fish species captured April and July 2008 in the North Ecoregion.

SCIENTIFIC NAME	COMMON NAME	TOTAL		TOTAL MASS	
		#	%	(g)	%
<i>Anchoa delicatissima</i>	slough anchovy	2448	33.84	5721	15.77
<i>Atherinops affinis</i>	topsmelt	2113	29.21	5146	14.19
<i>Atherinopsis californiensis</i>	jacksmelt	1	0.01	218	0.60
<i>Cheilotrema saturnum</i>	black croaker	1	0.01	139	0.38
<i>Clevelandia ios</i>	arrow goby	584	8.07	46	0.13
<i>Cosmocampus arctus</i>	snubnose pipefish	1	0.01	0	0.00
<i>Cymatogaster aggregata</i>	shiner perch	103	1.42	693	1.91
<i>Embiotoca jacksoni</i>	black perch	15	0.21	620	1.71
<i>Engraulis mordax</i>	northern anchovy	8	0.11	12	0.03
<i>Gibbonsia elegans</i>	spotted kelpfish	9	0.12	43	0.12
<i>Girella nigricans</i>	opaleye	2	0.03	132	0.36
<i>Halichoeres semicinctus</i>	rock wrasse	5	0.07	12	0.03
<i>Heterostichus rostratus</i>	giant kelpfish	213	2.94	1495	4.12
<i>Hyperprosopon argenteum</i>	walleye surfperch	1	0.01	59	0.16
<i>Hypsoblennius gentilis</i>	bay blenny	7	0.10	122	0.34
<i>Ilypnus gilberti</i>	cheekspot goby	1	0.01	0	0.00
<i>Leptocottus armatus</i>	staghorn sculpin	8	0.11	60	0.17
<i>Micrometrus minimus</i>	dwarf surfperch	81	1.12	684	1.89
<i>Paraclinus integripinnis</i>	reef finspot	1	0.01	3	0.01
<i>Paralichthys californicus</i>	California halibut	21	0.29	1178	3.25
<i>Paralabrax clathratus</i>	kelp bass	52	0.72	1006	2.77
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	16	0.22	2746	7.57
<i>Paralabrax nebulifer</i>	barred sand bass	20	0.28	291	0.80
<i>Pleuronichthys guttulatus</i>	diamond turbot	8	0.11	1025	2.83
<i>Pleuronichthys ritteri</i>	spotted turbot	10	0.14	571	1.57
<i>Porichthys myriaster</i>	specklefin midshipman	30	0.41	595	1.64
<i>Scorpaena guttata</i>	California scorpionfish	3	0.04	528	1.46
<i>Symphurus atricaudus</i>	California tonguefish	10	0.14	76	0.21
<i>Syngnathus leptorhynchus</i>	bay pipefish	95	1.31	85	0.24
<i>Synodus lucioceps</i>	California lizardfish	5	0.07	134	0.37
<i>Urobatis halleri</i>	round stingray	11	0.15	3505	9.66
<i>Xenistius californiensis</i>	salema	1346	18.61	8755	24.14
<i>Xystreurys liolepis</i>	fantail sole	4	0.06	568	1.57
Number of Species = 33		7,233		36,269	

Table 5. Total number of individuals and biomass (g) of fish species captured in the North-Central Ecoregion, April and July 2008.

SCIENTIFIC NAME	COMMON NAME	TOTAL		TOTAL MASS	
		#	%	(g)	%
<i>Anchoa delicatissima</i>	slough anchovy	1645	49.03	2399	4.34
<i>Atherinops affinis</i>	topsmelt	793	23.64	2940	5.32
<i>Cheilotrema saturnum</i>	black croaker	5	0.15	444	0.80
<i>Clevelandia ios</i>	arrow goby	11	0.33	3	0.00
<i>Cymatogaster aggregata</i>	shiner perch	161	4.80	918	1.66
<i>Cynoscion parvipinnis</i>	shortfin corvina	7	0.21	4765	8.62
<i>Gibbonsia elegans</i>	spotted kelpfish	3	0.09	26	0.05
<i>Halichoeres semicinctus</i>	rock wrasse	2	0.06	130	0.24
<i>Heterostichus rostratus</i>	giant kelpfish	227	6.77	2518	4.56
<i>Hypsoblennius gentilis</i>	bay blenny	2	0.06	56	0.10
<i>Ilypnus gilberti</i>	cheekspot goby	1	0.03	0	0.00
<i>Leptocottus armatus</i>	staghorn sculpin	2	0.06	15	0.03
<i>Micrometrus minimus</i>	dwarf surfperch	1	0.03	2	0.00
<i>Paralabrax clathratus</i>	kelp bass	20	0.60	346	0.63
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	65	1.94	13731	24.84
<i>Paralabrax nebulifer</i>	barred sand bass	31	0.92	970	1.75
<i>Paralichthys californicus</i>	California halibut	20	0.60	902	1.63
<i>Pleuronichthys guttulatus</i>	diamond turbot	7	0.21	1013	1.83
<i>Pleuronichthys ritteri</i>	spotted turbot	14	0.42	683	1.24
<i>Porichthys myriaster</i>	specklefin midshipman	5	0.15	304	0.55
<i>Seriphus politus</i>	queenfish	1	0.03	88	0.16
<i>Sphyraena argentea</i>	California barracuda	1	0.03	839	1.52
<i>Strongylura exilis</i>	California needlefish	1	0.03	2	0.00
<i>Symphurus atricaudus</i>	California tonguefish	11	0.33	139	0.25
<i>Syngnathus leptorhynchus</i>	bay pipefish	223	6.65	218	0.39
<i>Umbrina roncadore</i>	yellowfin croaker	1	0.03	272	0.49
<i>Urobatis halleri</i>	round stingray	95	2.83	21547	38.99
Number of Species = 27		3,355		55,269	

Table 6. Total number of individuals and biomass (g) of fish species captured in the South-Central Ecoregion, April and July 2008.

SCIENTIFIC NAME	COMMON NAME	TOTAL		TOTAL MASS (g)	%
		#	%		
<i>Anchoa compressa</i>	deepbody anchovy	4	0.15	32	0.07
<i>Anchoa delicatissima</i>	slough anchovy	617	23.14	770	1.80
<i>Atherinops affinis</i>	topsmelt	130	4.88	975	2.28
<i>Atractoscion nobilis</i>	white seabass	1	0.04	291	0.68
<i>Clevelandia ios</i>	arrow goby	42	1.58	4	0.01
<i>Cymatogaster aggregata</i>	shiner perch	1014	38.03	2262	5.28
<i>Engraulis mordax</i>	Pacific sardine	2	0.08	2	0.00
<i>Fundulus parvipinnis</i>	California killifish	1	0.04	3	0.01
<i>Heterostichus rostratus</i>	giant kelpfish	96	3.60	314	0.73
<i>Hippocampus ingens</i>	Pacific seahorse	1	0.04	30	0.07
<i>Hyporhamphus rosae</i>	California halfbeak	9	0.34	35	0.08
<i>Hypsoblennius gentilis</i>	bay blenny	3	0.11	68	0.16
<i>Leptocottus armatus</i>	staghorn sculpin	20	0.75	225	0.52
<i>Menticirrhus undulatus</i>	California corbina	1	0.04	2450	5.72
<i>Pleuronichthys guttulatus</i>	diamond turbot	15	0.56	564	1.32
<i>Paraclinus integripinnis</i>	reef finspot	2	0.08	2	0.01
<i>Paralabrax clathratus</i>	kelp bass	1	0.04	29	0.07
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	203	7.61	15442	36.03
<i>Paralabrax nebulifer</i>	barred sand bass	93	3.49	1010	2.36
<i>Paralichthys californicus</i>	California halibut	10	0.38	1338	3.12
<i>Syngnathus leptorhynchus</i>	bay pipefish	279	10.47	108	0.25
<i>Synodus lucioceps</i>	California lizardfish	2	0.08	23	0.05
<i>Urobatis halleri</i>	round stingray	120	4.50	16883	39.39
Number of Species = 23		2,666		42,858	

Black Perch



Table 7. Total number of individuals and biomass (g) of fish species captured in the South Ecoregion, April and July 2008.

SCIENTIFIC NAME	COMMON NAME	TOTAL		TOTAL MASS	
		#	%	(g)	%
<i>Albula vulpes</i>	bonefish	1	0.04	759	1.55
<i>Anchoa compressa</i>	deepbody anchovy	68	2.79	627	1.28
<i>Anchoa delicatissima</i>	slough anchovy	828	33.96	1269	2.59
<i>Atherinops affinis</i>	topsmelt	358	14.68	1204	2.46
<i>Clevelandia ios</i>	arrow goby	290	11.89	63	0.13
<i>Cymatogaster aggregata</i>	shiner perch	422	17.31	1358	2.77
<i>Cynoscion parvipinnis</i>	shortfin corvina	2	0.08	222	0.45
<i>Fundulus parvipinnis</i>	California killifish	53	2.17	59	0.12
<i>Gymnura marmorata</i>	butterfly ray	6	0.25	5055	10.32
<i>Heterostichus rostratus</i>	giant kelpfish	14	0.57	63	0.13
<i>Hyporhamphus rosae</i>	California halfbeak	5	0.21	16	0.03
<i>Ilypnus gilberti</i>	cheekspot goby	18	0.74	6	0.01
<i>Leptocottus armatus</i>	staghorn sculpin	3	0.12	19	0.04
<i>Mugil cephalus</i>	striped mullet	2	0.08	1220	2.49
<i>Paralabrax clathratus</i>	kelp bass	2	0.08	58	0.12
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	75	3.08	15181	30.98
<i>Paralabrax nebulifer</i>	barred sand bass	14	0.57	435	0.89
<i>Paralichthys californicus</i>	California halibut	11	0.45	1198	2.45
<i>Pleuronichthys guttulatus</i>	diamond turbot	17	0.70	240	0.49
<i>Porichthys myriaster</i>	specklefin midshipman	10	0.41	23	0.05
<i>Quietula y-cauda</i>	shadow goby	1	0.04	1	0.00
<i>Strongylura exilis</i>	California needlefish	2	0.08	51	0.10
<i>Syngnathus leptorhynchus</i>	bay pipefish	76	3.12	27	0.06
<i>Umbrina roncadore</i>	yellowfin croaker	4	0.16	906	1.85
<i>Urobatis halleri</i>	round stingray	156	6.40	18941	38.66
Number of Species = 25		2,438		49,001	

Opaleye



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'): $H' = -\sum p_i (\ln p_i)$ where p_i = proportion of species i , was calculated for total catches by Ecoregion and by sampling month. This index utilizes both species richness and evenness in the diversity index. Despite the variation in species composition and catch, both Shannon-Wiener Diversity (H') and species richness were fairly uniform among the four ecoregions (Figure 9). Both species richness and diversity declined from April to July 2008 (Figure 10).

Figure 9. Shannon-Weiner Diversity (H') and number of species (richness) in San Diego Bay Ecoregion.

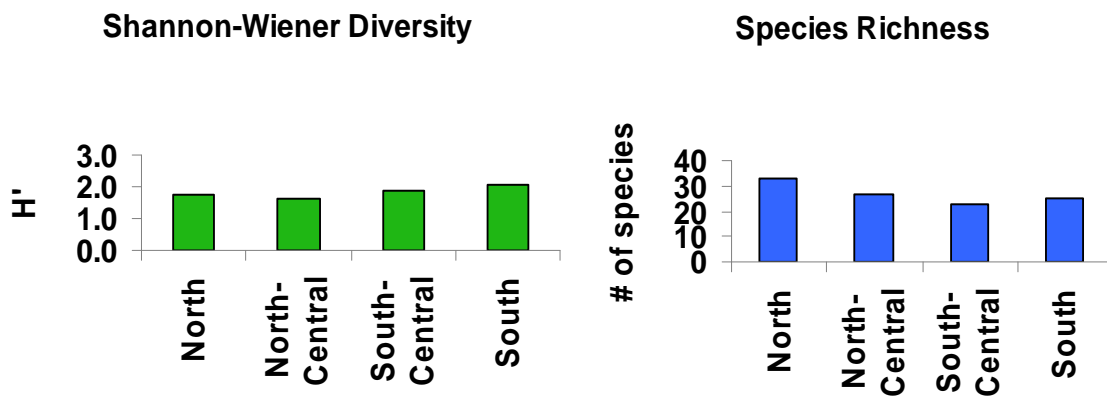
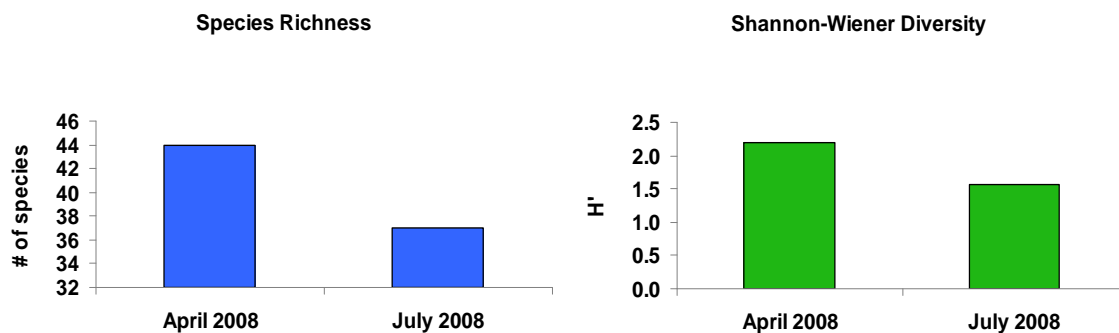


Figure 10. Number of species (richness) and Shannon-Weiner Diversity (H') of fishes in San Diego Bay by sampling month, 2008.



Catch by Sampling Period and Ecoregion

North (Ecoregion 1) – A total of 7,233 fishes belonging to 33 species, weighing 36.2 kg were collected in the North Ecoregion over two sampling periods in 2008 (Table 6). Slough anchovy was the most abundant species (33.8%), followed by topsmelt (29.2%), salema (18.6%), arrow goby (8.1%) and giant kelpfish (2.9%). Salema led in total biomass (24.1%), followed by slough anchovy (5.7%), topsmelt (5.1%), round stingray (3.5%) and spotted sand bass (2.7%).

North-Central (Ecoregion 2) - A total of 3,355 fishes belonging to 27 species, weighing 55 kg were collected in the North-Central Ecoregion over two sampling periods in 2008 (Table 7). Slough anchovy was the most abundant species (49.0%), followed by topsmelt (23.6%), giant kelpfish (6.8%), bay pipefish (6.7%) and shiner perch (4.8%). Spotted sand bass led in total biomass (24.8%), followed by shortfin corvina (8.6%), topsmelt (5.3%), giant kelpfish (4.6%) and slough anchovy (4.3%).

South-Central (Ecoregion 3) - A total of 2,666 fishes belonging to 23 species, weighing 43 kg were collected in the South-Central Ecoregion over the two sampling periods in 2008 (Table 8). Shiner perch was the most abundant species (38.0%), followed by slough anchovy (23.1%), bay pipefish (10.5%), spotted sand bass (7.6%) and topsmelt (4.9%). Spotted sand bass led in total biomass (36.0%), followed by California corbina (5.7%), shiner perch (5.3%), California halibut (3.1%) and barred sand bass (2.4%).

South (Ecoregion 4) - A total of 2,438 fishes belonging to 25 species, weighing 49 kg were collected in the South Ecoregion in April and July 2008 (Table 9). Slough anchovy was the most abundant species (34.0%), followed by shiner perch (17.3%), topsmelt (14.7%), arrow goby (11.9%) and round stingray (6.4%). Spotted sand bass led in total biomass (31.0%), followed by butterfly ray (10.3%), shiner perch (2.8%), slough anchovy (2.6%) and topsmelt (2.5%).

In April 2008, 6,523 individuals comprising 44 species of fishes were captured (Figure 11, Table 8). In July, the catch increased to 9,169 fish, but species richness decreased to 37 species. Total biomass was greater in April (103 kg) than July (81 kg) (Figure 12, Table 9). With the exception of the North-Central Ecoregion, biomass decreased in all ecoregions in the July survey (Figure 12).

Figure 11. Total catch of fishes (above) and biomass (below) in San Diego Bay by sampling period, 2008.

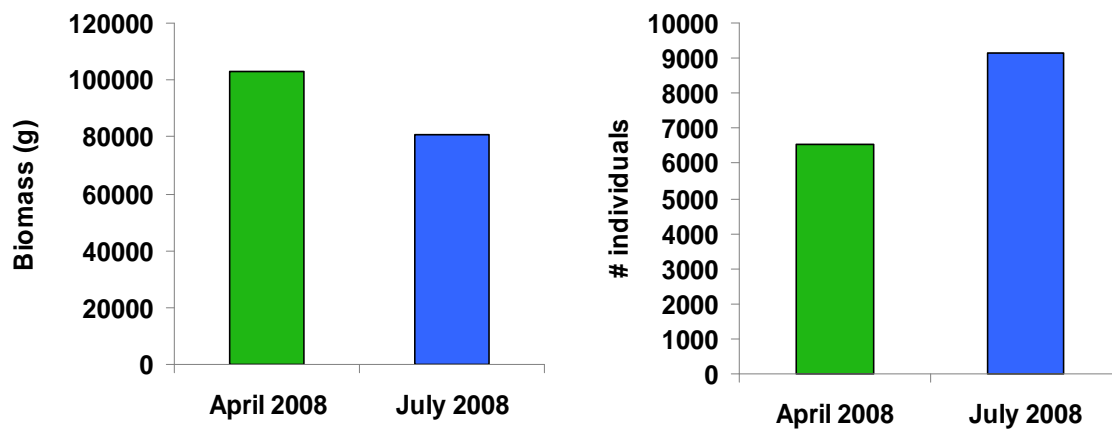


Figure 12. Biomass (kg) of fishes by Ecoregion and sampling month in San Diego Bay, 2008.

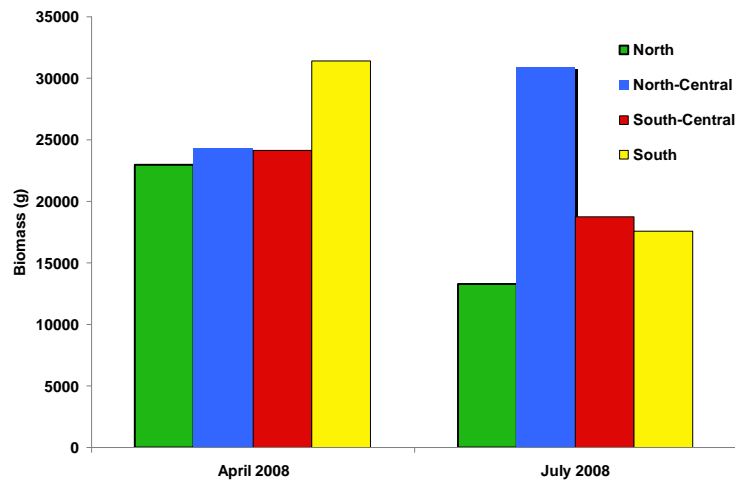


Table 8. Total catch of fish species taken in San Diego Bay by 2008 sampling period.

SCIENTIFIC NAME	COMMON NAME	April 2008	July 2008	TOTAL	%
<i>Albula vulpes</i>	bonefish	1		1	0.01
<i>Anchoa compressa</i>	deepbody anchovy	57	15	72	0.46
<i>Anchoa delicatissima</i>	slough anchovy	778	4760	5538	35.29
<i>Atherinops affinis</i>	topsmelt	1192	2202	3394	21.63
<i>Atherinopsis californiensis</i>	jacksmelt	1		1	0.01
<i>Atractoscion nobilis</i>	white seabass		1	1	0.01
<i>Cheilotrema saturnum</i>	black croaker	2	4	6	0.04
<i>Clevelandia ios</i>	arrow goby	260	667	927	5.91
<i>Cosmocampus arctus</i>	snubnose pipefish		1	1	0.01
<i>Cymatogaster aggregata</i>	shiner perch	1559	141	1700	10.83
<i>Cynoscion parvipinnis</i>	shortfin corvina	9		9	0.06
<i>Embiotoca jacksoni</i>	black surfperch	8	7	15	0.10
<i>Engraulis mordax</i>	northern anchovy	8	2	10	0.06
<i>Fundulus parvipinnis</i>	California killifish	1	53	54	0.34
<i>Gibbonsia elegans</i>	spotted kelpfish	3	9	12	0.08
<i>Girella nigricans</i>	opaleye	1	1	2	0.01
<i>Gymnura marmorata</i>	California butterfly ray	4	2	6	0.04
<i>Halichoeres semicinctus</i>	rock wrasse	5	2	7	0.04
<i>Heterostichus rostratus</i>	giant kelpfish	220	330	550	3.50
<i>Hippocampus ingens</i>	Pacific seahorse		1	1	0.01
<i>Hyperprosopon argenteum</i>	walleye surfperch	1		1	0.01
<i>Hyporhamphus rosae</i>	California halfbeak	11	3	14	0.09
<i>Hypsoblennius gentilis</i>	bay blenny	3	9	12	0.08
<i>Ilypnus gilberti</i>	cheekspot goby	5	15	20	0.13
<i>Leptocottus armatus</i>	staghorn sculpin	32	1	33	0.21
<i>Menticirrhus undulatus</i>	California corbina	1		1	0.01
<i>Micrometrus minimus</i>	dwarf surfperch	22	60	82	0.52
<i>Mugil cephalus</i>	striped mullet	2		2	0.01
<i>Paraclinus integripinnis</i>	reef finspot	1	2	3	0.02
<i>Paralabrax clathratus</i>	kelp bass	44	31	75	0.48
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	253	106	359	2.29
<i>Paralabrax nebulifer</i>	barred sand bass	103	55	158	1.01
<i>Paralichthys californicus</i>	California halibut	35	27	62	0.40
<i>Pleuronichthys guttulatus</i>	diamond turbot	36	11	47	0.30
<i>Pleuronichthys ritteri</i>	spotted turbot	3	21	24	0.15
<i>Porichthys myriaster</i>	specklefin midshipman	8	37	45	0.29
<i>Quietula y-cauda</i>	shadow goby	1		1	0.01
<i>Scorpaena guttata</i>	California scorpionfish	3		3	0.02
<i>Seriphus politus</i>	queenfish	1		1	0.01
<i>Sphyræna argentea</i>	California barracuda	1		1	0.01
<i>Strongylura exilis</i>	California needlefish	2	1	3	0.02
<i>Symphurus atricaudus</i>	California tonguefish	9	12	21	0.13
<i>Syngnathus leptorhynchus</i>	bay pipefish	291	382	673	4.29
<i>Synodus lucioceps</i>	California lizardfish	5	2	7	0.04
<i>Umbrina roncadore</i>	yellowfin croaker	3	2	5	0.03
<i>Urobatis halleri</i>	round stingray	192	190	382	2.43
<i>Xenistius californiensis</i>	salema	1346		1346	8.58
<i>Xystreurus liolepis</i>	fantail sole		4	4	0.03
Total:		6523	9169	15692	
Species Richness:		44	37	48	

Table 9. Total biomass of fish species taken in San Diego Bay by sampling period.

SCIENTIFIC NAME	COMMON NAME	April 2008	July 2008	TOTAL	%
<i>Albula vulpes</i>	bonefish	759		759	0.41
<i>Anchoa compressa</i>	deepbody anchovy	497	161	658	0.36
<i>Anchoa delicatissima</i>	slough anchovy	1192	8967	10158	5.54
<i>Atherinops affinis</i>	topsmelt	7345	2920	10265	5.60
<i>Atherinopsis californiensis</i>	jacksmelt	218		218	0.12
<i>Atractoscion nobilis</i>	white seabass		291	291	0.16
<i>Cheilotrema saturnum</i>	black croaker	190	393	583	0.32
<i>Clevelandia ios</i>	arrow goby	42	73	116	0.06
<i>Cosmocampus arctus</i>	snubnose pipefish		0	0	0.00
<i>Cymatogaster aggregata</i>	shiner surfperch	4448	782	5231	2.85
<i>Cynoscion parvipinnis</i>	shortfin corvina	4987		4987	2.72
<i>Embiotoca jacksoni</i>	black perch	416	204	620	0.34
<i>Engraulis mordax</i>	northern anchovy	12	2	14	0.01
<i>Fundulus parvipinnis</i>	California killifish	3	59	62	0.03
<i>Gibbonsia elegans</i>	spotted kelpfish	34	34	69	0.04
<i>Girella nigricans</i>	opaleye	132	1	132	0.07
<i>Gymnura marmorata</i>	California butterfly ray	3830	1225	5055	2.76
<i>Halichoeres semicinctus</i>	rock wrasse	12	130	143	0.08
<i>Heterostichus rostratus</i>	giant kelpfish	837	3553	4390	2.39
<i>Hippocampus ingens</i>	Pacific seahorse		30	30	0.02
<i>Hyperprosopon argenteum</i>	walleye surfperch	59		59	0.03
<i>Hyporhamphus rosae</i>	California halfbeak	36	15	51	0.03
<i>Hypsoblennius gentilis</i>	bay blenny	31	215	246	0.13
<i>Ilypnus gilberti</i>	cheekspot goby	2	5	6	0.00
<i>Leptocottus armatus</i>	staghorn sculpin	315	4	319	0.17
<i>Menticirrhus undulatus</i>	California corbina	2450		2450	1.34
<i>Micrometrus minimus</i>	dwarf surfperch	373	313	686	0.37
<i>Mugil cephalus</i>	striped mullet	1220		1220	0.67
<i>Paraclinus integripinnis</i>	reef finspot	3	2	5	0.00
<i>Paralabrax clathratus</i>	kelp bass	806	633	1438	0.78
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	25931	21170	47100	25.68
<i>Paralabrax nebulifer</i>	barred sand bass	1233	1473	2706	1.48
<i>Paralichthys californicus</i>	California halibut	2970	1647	4617	2.52
<i>Pleuronichthys guttulatus</i>	diamond turbot	1560	1282	2842	1.55
<i>Pleuronichthys ritteri</i>	spotted turbot	94	1160	1254	0.68
<i>Porichthys myriaster</i>	specklefin midshipman	910	12	923	0.50
<i>Quietula y-cauda</i>	shadow goby	1		1	0.00
<i>Scorpaena guttata</i>	California scorpionfish	528		528	0.29
<i>Seriphus politus</i>	queenfish	88		88	0.05
<i>Sphyrna argentea</i>	California barracuda	839		839	0.46
<i>Strongylura exilis</i>	California needlefish	51	2	53	0.03
<i>Symphurus atricaudus</i>	California tonguefish	106	109	215	0.12
<i>Syngnathus leptorhynchus</i>	bay pipefish	179	260	439	0.24
<i>Synodus lucioceps</i>	California lizardfish	33	123	156	0.09
<i>Umbrina roncadore</i>	yellowfin croaker	862	316	1178	0.64
<i>Urobatis halleri</i>	round stingray	28504	32372	60876	33.19
<i>Xenistius californiensis</i>	salema	8755		8755	4.77
<i>Xystreurus liolepis</i>	fantail sole		568	568	0.31
Number of Species = 48		102,891	80,505	183,396	

Catch in Bay Habitats

Of three bay habitats (intertidal, nearshore and channel) the greatest catch of fishes was in the nearshore (8,572; Table 10). 3,195 fishes from 24 species were captured in the channel stations and 3,925 were surveyed in the intertidal stations (Table 10). A total of 7,582 fishes were taken in vegetated areas (Table 11). In the vegetated areas 43 of the 48 species surveyed in these study periods were found. 4,915 fishes comprising 32 species were caught in the nearshore non-vegetated areas.



Dwarf Surfperch

Table 10. Total catch of fish species taken from San Diego Bay by subhabitat, April and July 2008.

SCIENTIFIC NAME	COMMON NAME	INTERTIDAL	NEARSHORE	CHANNEL	TOTAL
<i>Albula vulpes</i>	bonefish			1	1
<i>Anchoa compressa</i>	deepbody anchovy	2	69	1	72
<i>Anchoa delicatissima</i>	slough anchovy	99	2601	2838	5538
<i>Atherinops affinis</i>	topsmelt	3105	284	5	3394
<i>Atherinopsis californiensis</i>	jacksmelt		1		1
<i>Atractoscion nobilis</i>	white seabass			1	1
<i>Cheilotrema saturnum</i>	black croaker		2	4	6
<i>Clevelandia ios</i>	arrow goby	259	668		927
<i>Cosmocampus arctus</i>	snubnose pipefish		1		1
<i>Cymatogaster aggregata</i>	shiner perch	121	1576	3	1700
<i>Cynoscion parvipinnis</i>	shortfin corvina		9		9
<i>Embiotoca jacksoni</i>	black perch		15		15
<i>Engraulis mordax</i>	northern anchovy	10			10
<i>Fundulus parvipinnis</i>	California killifish	54			54
<i>Gibbonsia elegans</i>	spotted kelpfish		12		12
<i>Girella nigricans</i>	opaleye	1	1		2
<i>Gymnura marmorata</i>	California butterfly ray		4	2	6
<i>Halichoeres semicinctus</i>	rock wrasse		7		7
<i>Heterostichus rostratus</i>	giant kelpfish	43	505	2	550
<i>Hippocampus ingens</i>	Pacific seahorse			1	1
<i>Hyperprosopon argenteum</i>	walleye surfperch		1		1
<i>Hyporhamphus rosae</i>	California halfbeak	14			14
<i>Hypsoblennius gentilis</i>	bay blenny	1	11		12
<i>Ilypnus gilberti</i>	cheekspot goby	2	17	1	20
<i>Leptocottus armatus</i>	staghorn sculpin	31	2		33
<i>Menticirrhus undulatus</i>	California corbina	1			1
<i>Micrometrus minimus</i>	dwarf surfperch		82		82
<i>Mugil cephalus</i>	striped mullet		2		2
<i>Paraclinus integripinnis</i>	reef finspot		3		3
<i>Paralabrax clathratus</i>	kelp bass		75		75
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	34	271	54	359
<i>Paralabrax nebulifer</i>	barred sand bass	13	124	21	158
<i>Paralichthys californicus</i>	California halibut	16	24	22	62
<i>Pleuronichthys guttulatus</i>	diamond turbot	16	16	15	47
<i>Pleuronichthys ritteri</i>	spotted turbot		1	23	24
<i>Porichthys myriaster</i>	specklefin midshipman	3	6	36	45
<i>Quietula y-cauda</i>	shadow goby		1		1
<i>Scorpaena guttata</i>	California scorpionfish		2	1	3
<i>Seriphus politus</i>	queenfish		1		1
<i>Sphyraena argentea</i>	California barracuda		1		1
<i>Strongylura exilis</i>	California needlefish	2	1		3
<i>Symphurus atricaudus</i>	California tonguefish		1	20	21
<i>Syngnathus leptorhynchus</i>	bay pipefish	92	560	21	673
<i>Synodus lucioceps</i>	California lizardfish		5	2	7
<i>Umbrina roncadore</i>	yellowfin croaker		2	3	5
<i>Urobatis halleri</i>	round stingray	6	262	114	382
<i>Xenistius californiensis</i>	salema		1346		1346
<i>Xystreureys liolepis</i>	fantail sole			4	4
Number of Species = 48	TOTAL	3925	8572	3195	15692

Table 11. Total catch of fish species taken from San Diego Bay, 2008 by vegetated, non-vegetated and channel stations.

SCIENTIFIC NAME	COMMON NAME	CHANNEL	NON-VEG	VEG	TOTAL
<i>Albula vulpes</i>	bonefish	1			1
<i>Anchoa compressa</i>	deepbody anchovy	1	21	50	72
<i>Anchoa delicatissima</i>	slough anchovy	2838	920	1780	5538
<i>Atherinops affinis</i>	topsmelt	5	2156	1233	3394
<i>Atherinopsis californiensis</i>	jacksmelt			1	1
<i>Atractoscion nobilis</i>	white seabass	1			1
<i>Cheilotrema saturnum</i>	black croaker	4	1	1	6
<i>Clevelandia ios</i>	arrow goby		245	682	927
<i>Cosmocampus arctus</i>	snubnose pipefish			1	1
<i>Cymatogaster aggregata</i>	shiner perch	3	374	1323	1700
<i>Cynoscion parvipinnis</i>	shortfin corvina		1	8	9
<i>Embiotoca jacksoni</i>	black perch		4	11	15
<i>Engraulis mordax</i>	northern anchovy		1	9	10
<i>Fundulus parvipinnis</i>	California killifish			54	54
<i>Gibbonsia elegans</i>	spotted kelpfish		5	7	12
<i>Girella nigricans</i>	opaleye			2	2
<i>Gymnura marmorata</i>	California butterfly ray	2	2	2	6
<i>Halichoeres semicinctus</i>	rock wrasse		1	6	7
<i>Heterostichus rostratus</i>	giant kelpfish	2	305	243	550
<i>Hippocampus ingens</i>	Pacific seahorse	1			1
<i>Hyperprosopon argenteum</i>	walleye surfperch		1		1
<i>Hypsoblennius gentilis</i>	bay blenny		9	3	12
<i>Hyporhamphus rosae</i>	California halfbeak		7	7	14
<i>Ilypnus gilberti</i>	cheekspot goby	1	6	13	20
<i>Leptocottus armatus</i>	staghorn sculpin		4	29	33
<i>Menticirrhus undulatus</i>	California corbina			1	1
<i>Micrometrus minimus</i>	dwarf surfperch		40	42	82
<i>Mugil cephalus</i>	striped mullet		1	1	2
<i>Paralichthys californicus</i>	California halibut	22	14	26	62
<i>Paralabrax clathratus</i>	kelp bass		23	52	75
<i>Paraclinus integripinnis</i>	reef finspot		2	1	3
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	54	175	130	359
<i>Paralabrax nebulifer</i>	barred sand bass	21	97	40	158
<i>Pleuronichthys guttulatus</i>	diamond turbot	15	3	29	47
<i>Pleuronichthys ritteri</i>	spotted turbot	23		1	24
<i>Porichthys myriaster</i>	specklefin midshipman	36	8	1	45
<i>Quietula y-cauda</i>	shadow goby			1	1
<i>Scorpaena guttata</i>	California scorpionfish	1		2	3
<i>Seriphus politus</i>	queenfish			1	1
<i>Sphyrna argentea</i>	California barracuda			1	1
<i>Strongylura exilis</i>	California needlefish		1	2	3
<i>Symphurus atricaudus</i>	California tonguefish	20		1	21
<i>Syngnathus leptorhynchus</i>	bay pipefish	21	344	308	673
<i>Synodus lucioceps</i>	California lizardfish	2	4	1	7
<i>Umbrina roncadore</i>	yellowfin croaker	3		2	5
<i>Urobatis halleri</i>	round stingray	114	106	162	382
<i>Xenistius californiensis</i>	salema		34	1312	1346
<i>Xystreurys liolepis</i>	fantail sole	4			4
Total:		3195	4915	7582	15692
Species Richness:		24	32	43	48

Nursery Area Function

San Diego Bay continues to be a nursery area for the great majority of the fishes found there. Approximately 62% of all fishes sampled in San Diego Bay were juveniles (Table 12). In terms of percent juveniles captured, the top four species (northern anchovy, California halibut, kelp bass and barred sand bass) are all critical commercial and recreational species. The high catch of juvenile fishes in San Diego 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 35 species of fish from San Diego Bay.

SCIENTIFIC NAME	COMMON NAME	% JUVENILES
<i>Engraulis mordax</i>	northern anchovy	100
<i>Paralichthys californicus</i>	California halibut	100
<i>Paralabrax clathratus</i>	kelp bass	100
<i>Paralabrax nebulifer</i>	barred sand bass	100
<i>Xenistius californiensis</i>	salema	100
<i>Heterostichus rostratus</i>	giant kelpfish	97.8
<i>Porichthys myriaster</i>	specklefin midshipman	95.6
<i>Fundulus parvipinnis</i>	California killifish	94.4
<i>Gibbonsia elegans</i>	spotted kelpfish	91.7
<i>Embiotoca jacksoni</i>	black perch	86.7
<i>Cymatogaster aggregata</i>	shiner perch	86.1
<i>Halichoeres semicinctus</i>	rock wrasse	85.7
<i>Clevelandia ios</i>	arrow goby	80.8
<i>Syngnathus leptorhynchus</i>	bay pipefish	80.5
<i>Urobatis halleri</i>	round stingray	80.4
<i>Atherinops affinis</i>	topsmelt	75.6
<i>Pleuronichthys guttulatus</i>	diamond turbot	57.4
<i>Synodus lucioceps</i>	California lizardfish	57.1
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	57.1
<i>Micrometrus minimus</i>	dwarf surfperch	42.7
<i>Umbrina roncadore</i>	yellowfin croaker	40.0
<i>Cheilotrema saturnum</i>	black croaker	33.3
<i>Cynoscion parvipinnis</i>	shortfin corvina	33.3
<i>Paraclinus integripinnis</i>	reef finspot	33.3
<i>Scorpaena guttata</i>	California scorpionfish	33.3
<i>Anchoa delicatissima</i>	slough anchovy	26.5
<i>Xystreurys liolepis</i>	fantail sole	25.0
<i>Gymnura marmorata</i>	California butterfly ray	16.7
<i>Hypsoblennius gentilis</i>	bay blenny	16.7
<i>Hyporhamphus rosae</i>	California halfbeak	7.1
<i>Anchoa compressa</i>	deepbody anchovy	6.9
<i>Ilypnus gilberti</i>	cheekspot goby	5.0
<i>Pleuronichthys ritteri</i>	spotted turbot	4.2
<i>Leptocottus armatus</i>	staghorn sculpin	3.0
<i>Symphurus atricaudus</i>	California tonguefish	0.0
Total:		61.8

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 over month ($E.I. = (\%N + \%Wt) * \%F.O$)(Table 13). This index is indicative of the importance of each species to the energy flow within the San Diego Bay ecosystem. Slough anchovy ranked first with an E.I. of 4,083 while round stingray ranked second (E.I. 3,562). Both species were found ubiquitously throughout the bay, round stingray were dominant in terms of biomass and slough anchovy in terms of numerical abundance. These species were followed by spotted sand bass (E.I. 2,797), topsmelt (E.I. 2,723) and shiner perch (E.I. 1,369; Figure 13).

Figure 13. Top 20 species of San Diego Bay fishes ranked by Ecological Index, April and July 2008.

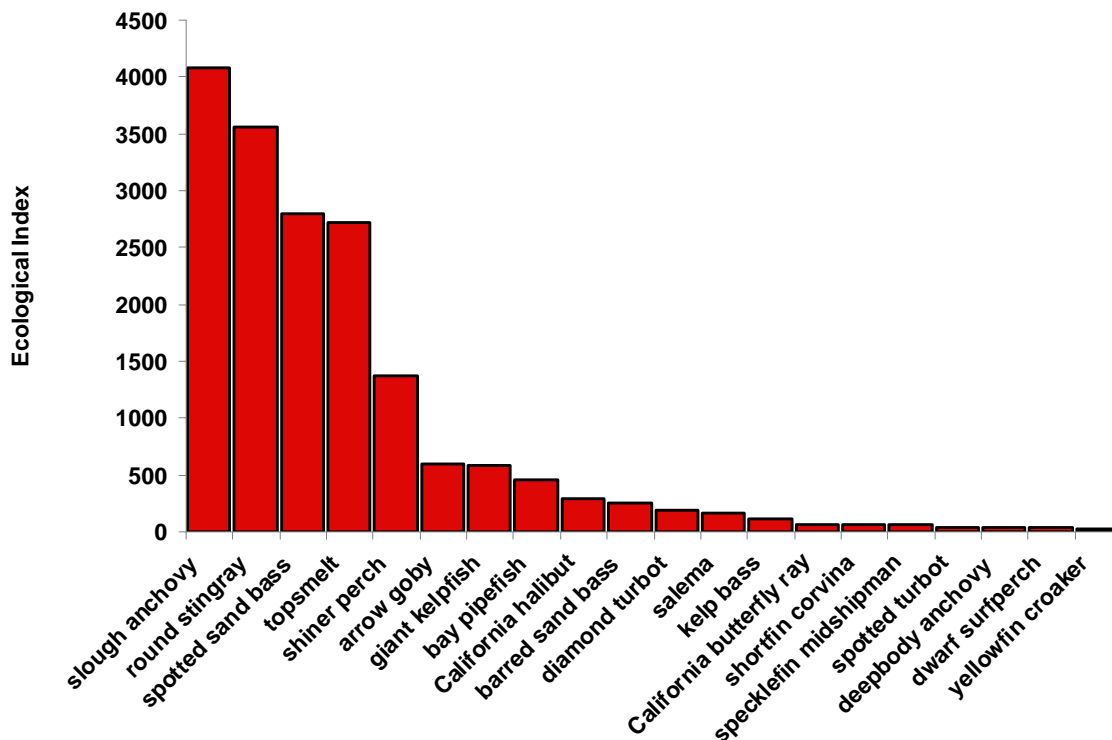


Table 13. Relative abundance (%N), relative biomass (%WT), frequency of occurrence, and ecological index (EI) of San Diego Bay fishes, April and July, 2008.

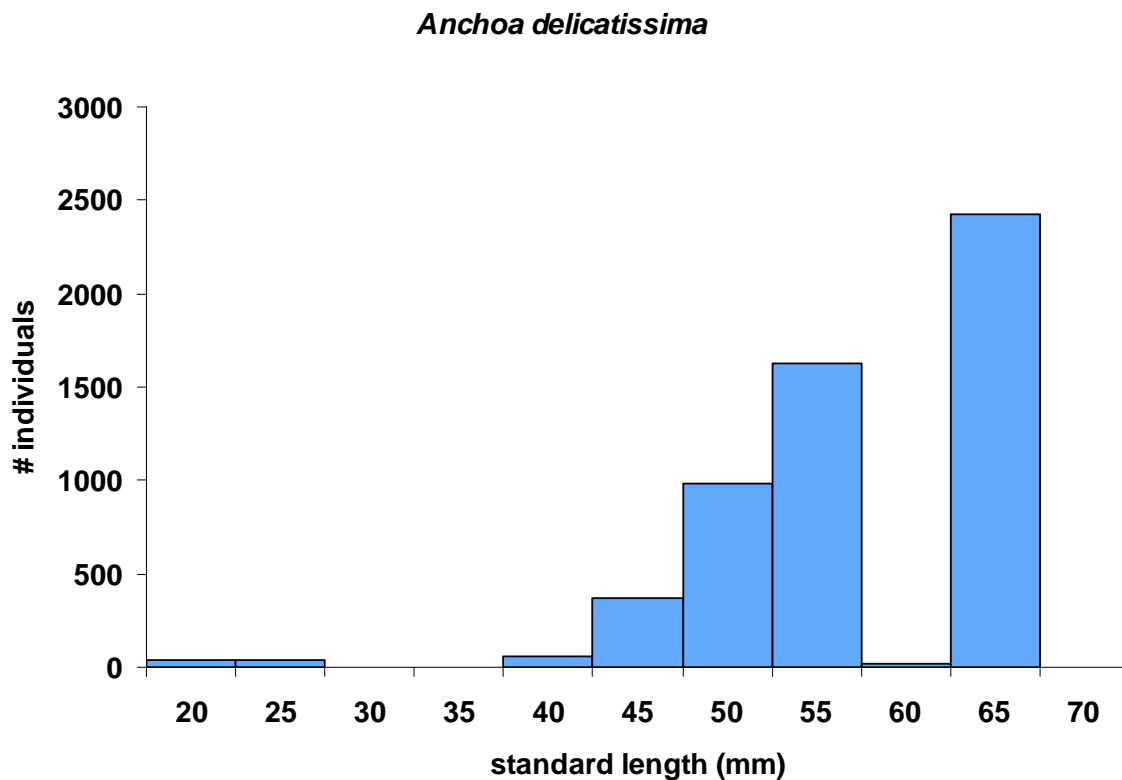
RANK	SCIENTIFIC NAME	COMMON NAME	%N	%WT	%FREQ	EI
1	<i>Anchoa delicatissima</i>	slough anchovy	35.29	5.54	100	4083.09
2	<i>Urobatis halleri</i>	round stingray	2.43	33.19	100	3562.82
3	<i>Paralabrax maculatofasciatus</i>	spotted sand bass	2.29	25.68	100	2797.01
4	<i>Atherinops affinis</i>	topsmelt	21.63	5.60	100	2722.59
5	<i>Cymatogaster aggregata</i>	shiner perch	10.83	2.85	100	1368.58
6	<i>Clevelandia ios</i>	arrow goby	5.91	0.06	100	597.05
7	<i>Heterostichus rostratus</i>	giant kelpfish	3.50	2.39	100	589.87
8	<i>Syngnathus leptorhynchus</i>	bay pipefish	4.29	0.24	100	452.81
9	<i>Paralichthys californicus</i>	California halibut	0.40	2.52	100	291.25
10	<i>Paralabrax nebulifer</i>	barred sand bass	1.01	1.48	100	248.26
11	<i>Pleuronichthys guttulatus</i>	diamond turbot	0.30	1.55	100	184.90
12	<i>Xenistius californiensis</i>	salema	8.58	4.77	12.5	166.89
13	<i>Paralabrax clathratus</i>	kelp bass	0.48	0.78	87.5	110.45
14	<i>Gymnura marmorata</i>	California butterfly ray	0.04	2.76	25	69.86
15	<i>Cynoscion parvipinnis</i>	shortfin corvina	0.06	2.72	25	69.41
16	<i>Porichthys myriaster</i>	specklefin midshipman	0.29	0.50	75	59.23
17	<i>Pleuronichthys ritteri</i>	spotted turbot	0.15	0.68	50	41.83
18	<i>Anchoa compressa</i>	deepbody anchovy	0.46	0.36	50	40.89
19	<i>Micrometrus minimus</i>	dwarf surfperch	0.52	0.37	37.5	33.62
20	<i>Umbrina roncadore</i>	yellowfin croaker	0.03	0.64	37.5	25.28
21	<i>Leptocottus armatus</i>	staghorn sculpin	0.21	0.17	62.5	24.02
22	<i>Menticirrhus undulatus</i>	California corbina	0.01	1.34	12.5	16.78
23	<i>Cheilotrema saturnum</i>	black croaker	0.04	0.32	37.5	13.35
24	<i>Hypsoblennius gentilis</i>	bay blenny	0.08	0.13	62.5	13.15
25	<i>Symphurus atricaudus</i>	California tonguefish	0.13	0.12	50	12.56
26	<i>Embiotoca jacksoni</i>	black perch	0.10	0.34	25	10.85
27	<i>Fundulus parvipinnis</i>	California killifish	0.34	0.03	25	9.44
28	<i>Mugil cephalus</i>	striped mullet	0.01	0.67	12.5	8.47
29	<i>Ilypnus gilberti</i>	cheekspot goby	0.13	0.00	50	6.55
30	<i>Sphyræna argentea</i>	California barracuda	0.01	0.46	12.5	5.79
31	<i>Albula vulpes</i>	bonefish	0.01	0.41	12.5	5.25
32	<i>Synodus lucioceps</i>	California lizardfish	0.04	0.09	37.5	4.87
33	<i>Hyporhamphus rosae</i>	California halfbeak	0.09	0.03	37.5	4.39
34	<i>Gibbonsia elegans</i>	spotted kelpfish	0.08	0.04	37.5	4.27
35	<i>Xystreurys liolepis</i>	fantail sole	0.03	0.31	12.5	4.19
36	<i>Scorpaena guttata</i>	California scorpionfish	0.02	0.29	12.5	3.84
37	<i>Halichoeres semicinctus</i>	rock wrasse	0.04	0.08	25	3.06
38	<i>Girella nigricans</i>	opaleye	0.01	0.07	25	2.12
39	<i>Atractoscion nobilis</i>	white seabass	0.01	0.16	12.5	2.06
40	<i>Engraulis mordax</i>	northern anchovy	0.06	0.01	25	1.78
41	<i>Atherinopsis californiensis</i>	jacksmelt	0.01	0.12	12.5	1.56
42	<i>Strongylura exilis</i>	California needlefish	0.02	0.03	25	1.19
43	<i>Seriphus politus</i>	queenfish	0.01	0.05	12.5	0.68
44	<i>Paraclinus integripinnis</i>	reef finspot	0.02	0.00	25	0.55
45	<i>Hyperprosopon argenteum</i>	walleye surfperch	0.01	0.03	12.5	0.48
46	<i>Hippocampus ingens</i>	Pacific seahorse	0.01	0.02	12.5	0.28
47	<i>Quietula y-cauda</i>	shadow goby	0.01	0.00	12.5	0.08
48	<i>Cosmocampus arctus</i>	snubnose pipefish	0.01	0.00	12.5	0.08

Principle species

Slough anchovy (*Anchoa delicatissima*) – This species was ranked first in terms of ecological index (E.I.) because it was the highest catch (35.3%) of any species and the fourth highest biomass (5.5%). They were present at all subhabitats, ecoregions and depth strata (Intertidal, Nearshore and Channel). This ubiquitous species was the dominant forage fish during this study period. All of the slough anchovies were less than 70 mm SL (Figure 14).



Figure 14. Standard length (SL) versus total catch (# individuals) of slough anchovy.

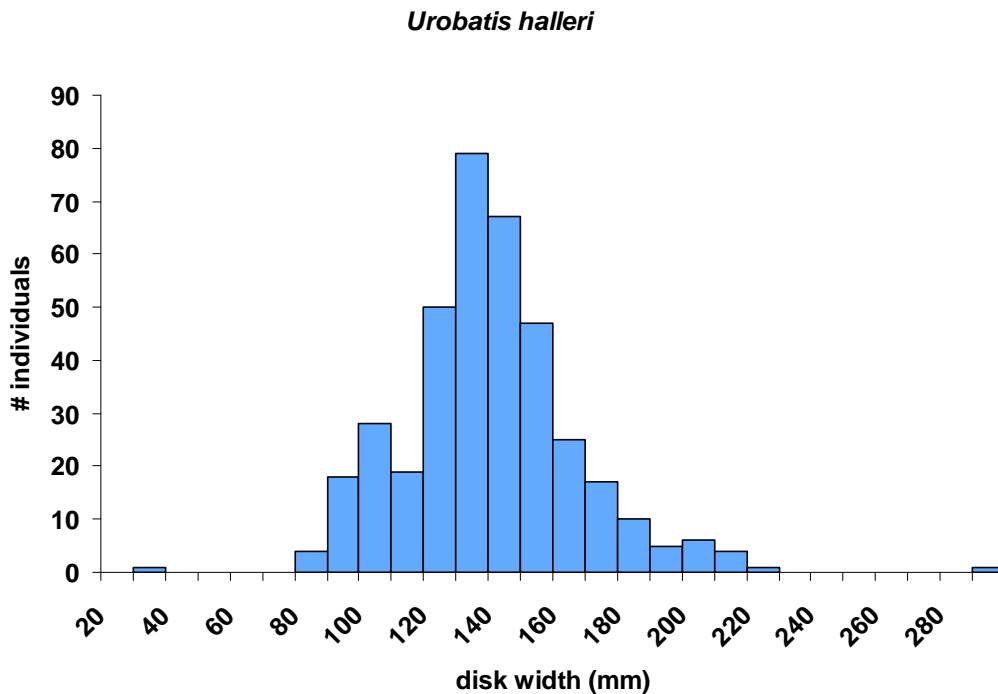


Round stingray (*Urobatis halleri*)

Round stingray are also ubiquitous throughout San Diego Bay during these surveys. They were found in all sampling periods, ecoregions and habitats. While they are not numerically dominant like the bait fishes, their high biomass, 33.2% of the total catch, elevates them as one of the key species in the bay. They were very few large adult round stingray captured during this period (Figure 15). The bay is a nursery area for this critical species.



Figure 15. Disc width (DW) versus total catch (# individuals) of round stingray.

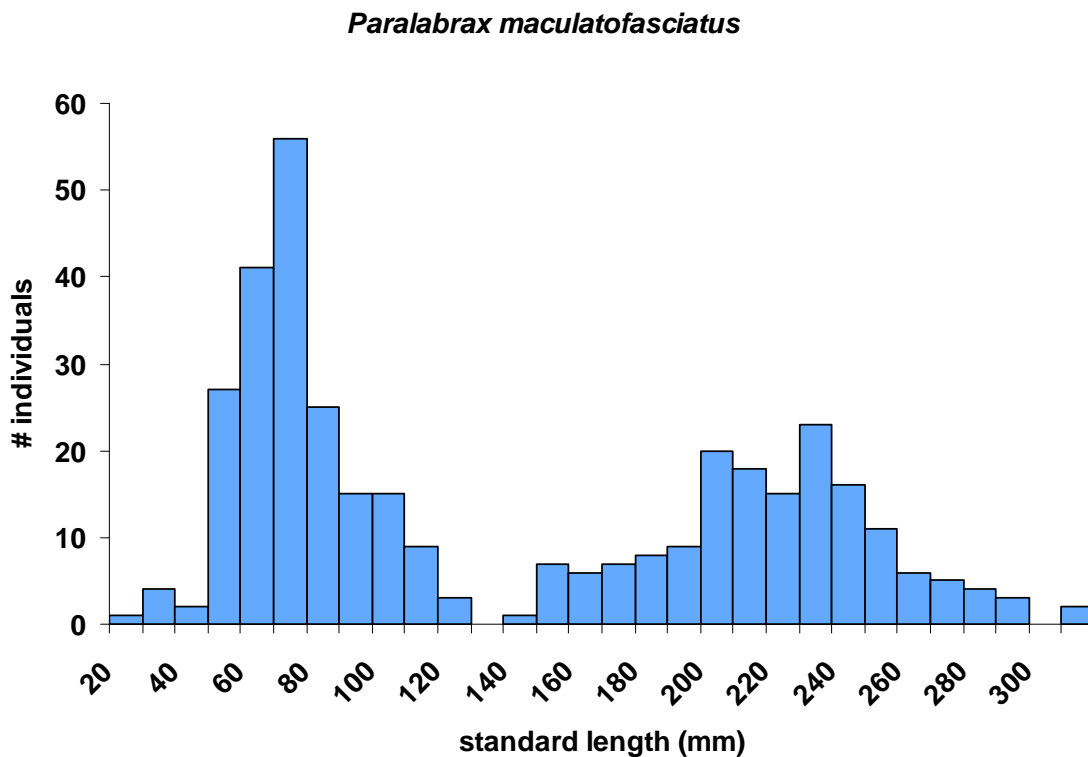


Spotted sand bass (*Paralabrax maculatofasciatus*)

Spotted sand bass are the ubiquitous mesocarnivore in San Diego Bay. They are dominant in terms of total catch and biomass. This important recreational fish species primarily utilizes bays and estuaries along the Southern California coastline. There was a bimodal distribution in size classes of spotted sand bass (Figure 16) indicating the presence of both juveniles and adult fish.



Figure 16. Standard length (SL) versus total catch (# individuals) of spotted sand bass.

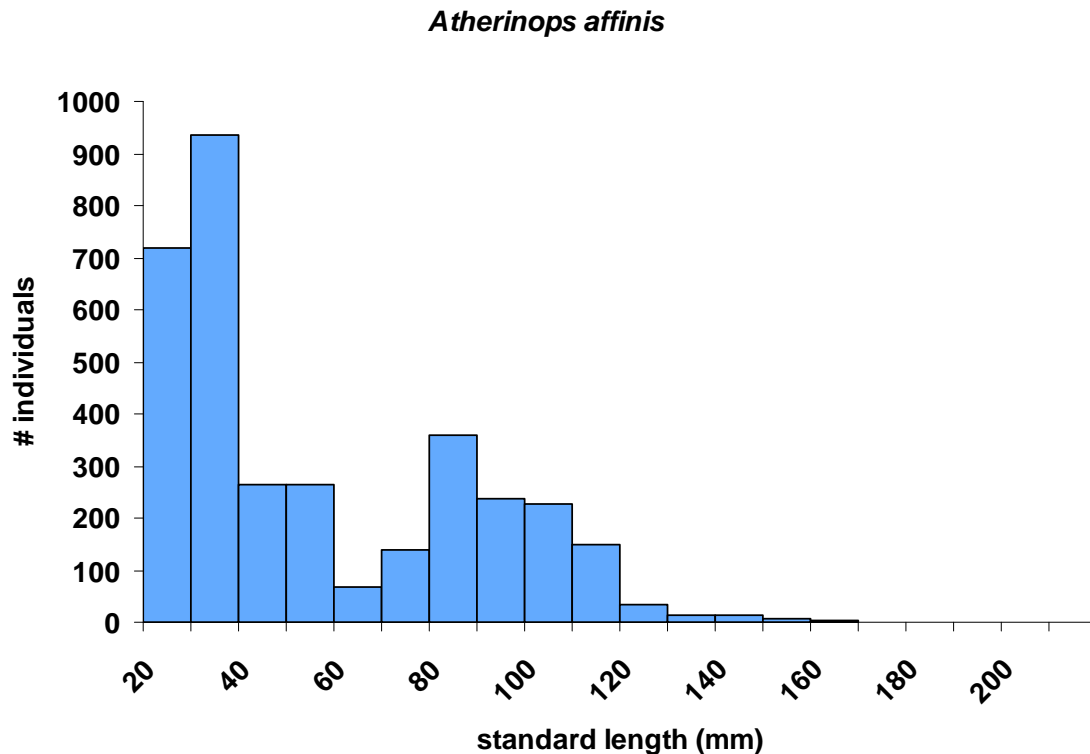


Topsmelt (*Atherinops affinis*)

The second most predominant forage fish in the bay in 2008 was topsmelt. This species was found in all of the bay ecoregions and various bay habitats during both sampling periods. The catch of topsmelt was primarily small individuals (20-40 mm SL) and another age class was present in the 80-110 mm SL size range (Figure 17). Topsmelt were caught primarily in the intertidal strata, with very few individuals captured in the channel. While they were observed in all four ecoregions, the highest catch (5,146) was in the North Ecoregion.



Figure 17. Standard length (SL) versus total catch (# individuals) of topsmelt.

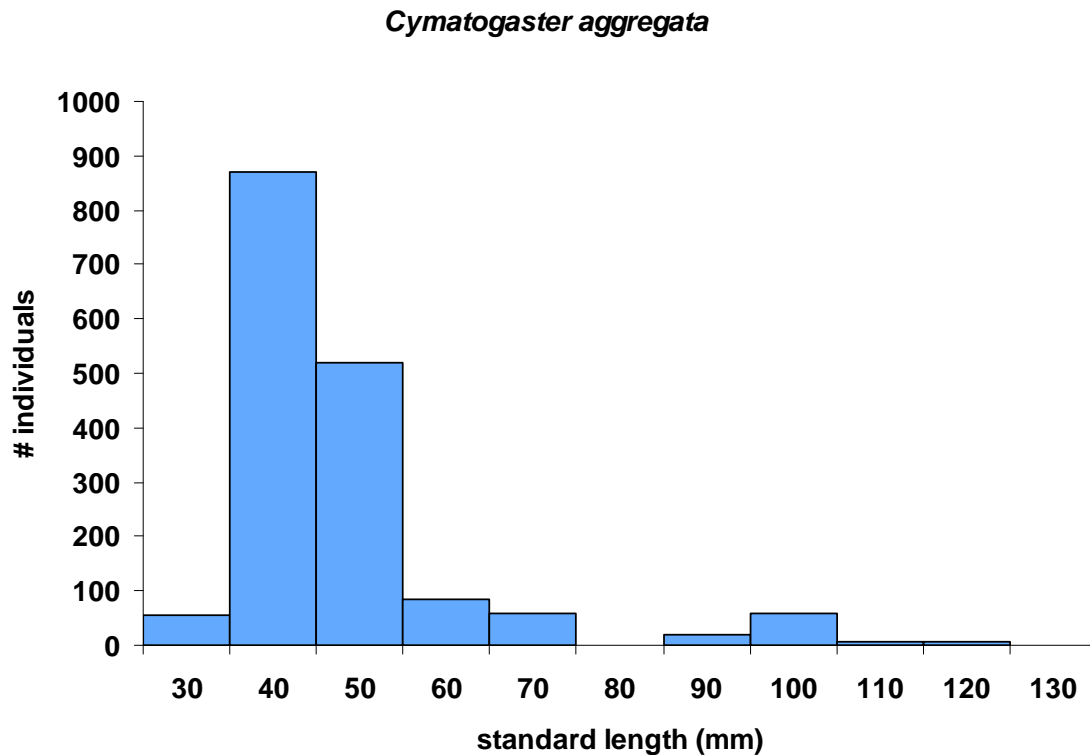


Shiner perch (*Cymatogaster aggregata*)

Shiner perch ranked fifth in the ecological index. They were found in all ecoregions and subhabitats. But, like topsmelt, there were very few individuals (3) found in the channel stations. Adult shiner perch, which live offshore, are known to utilize the bay for reproduction. Thus the bimodal distribution (Figure 18) is an indication of this life history pattern. Some larger individuals were present, but the bulk of the stock was young fishes who were typically associated with eelgrass beds.



Figure 18. Standard length (SL) versus total catch (# individuals) of shiner perch.

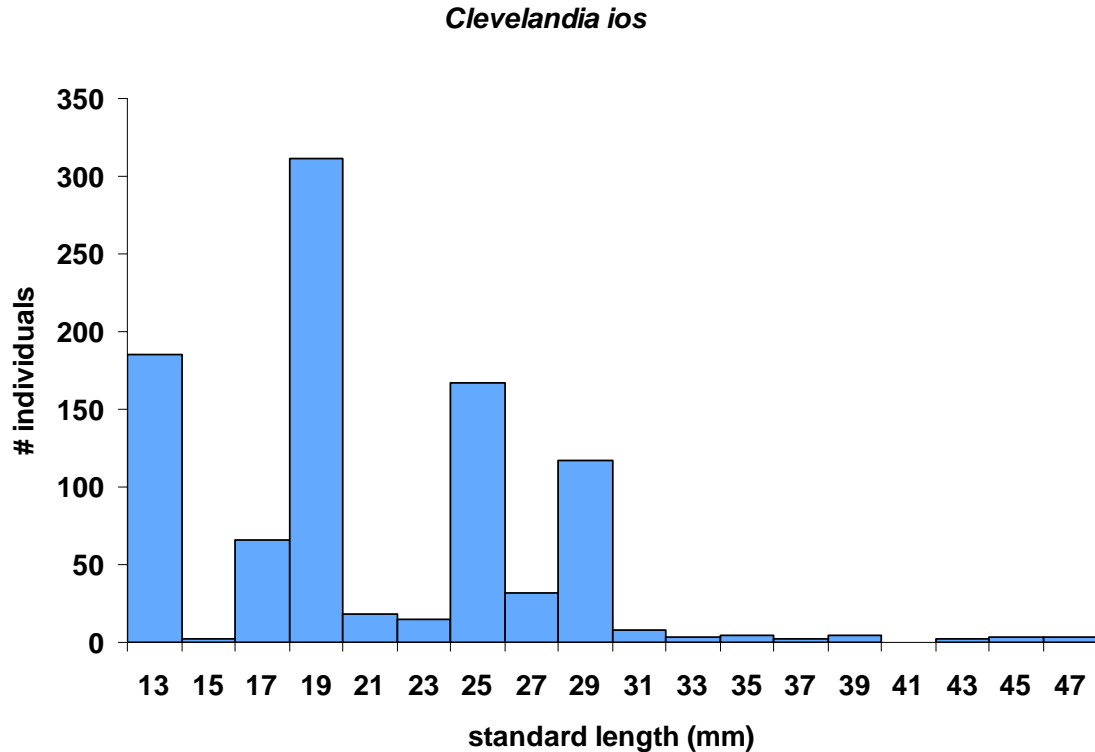


Arrow goby (*Clevelandia ios*)

Arrow gobies were found in all of the ecoregions but not in any of the channel collections. These small fish (Figure 19) were more abundant in the vegetated (682) versus non-vegetated (245) stations. They were the fifth most abundant fish in the survey comprising 5.9% of the catch, but due to their small size only 0.06% of the biomass.



Figure 19. Standard length (SL) versus total catch (# individuals) of arrow goby.

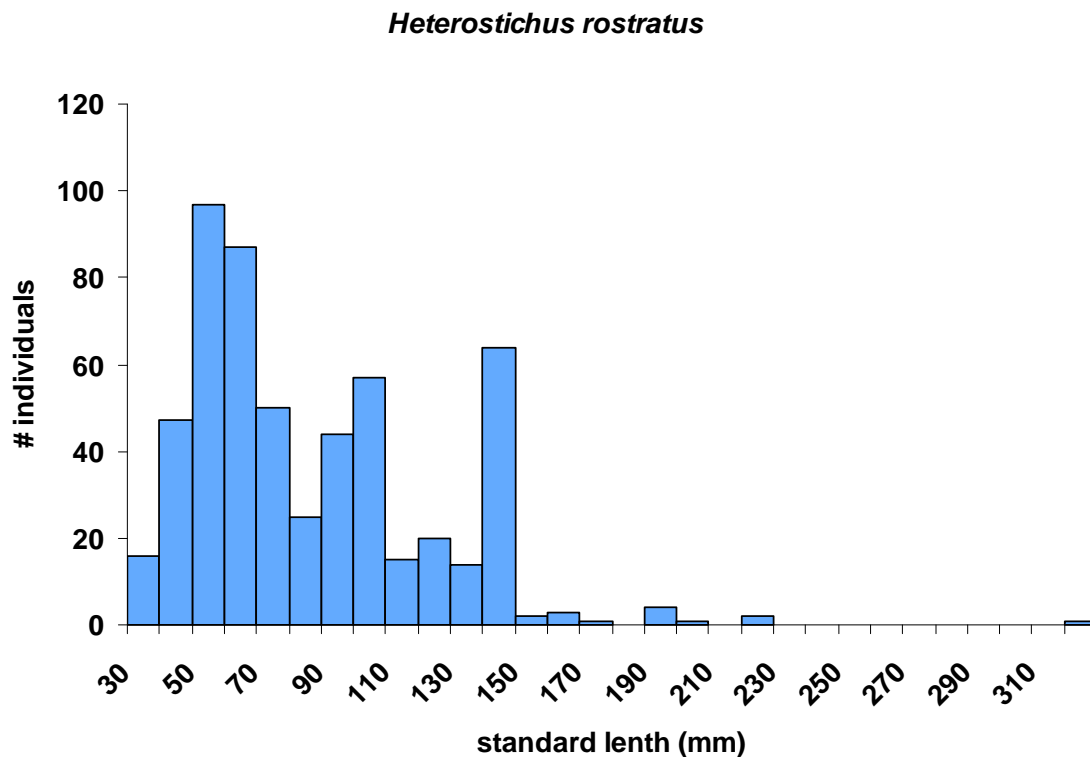


Giant kelpfish (*Heterostichus rostratus*)

Giant kelpfish were present in all ecoregions and habitats. However they were primarily found in the nearshore samples. Only 2 individuals were caught in the channel stations and an order of magnitude fewer were in the intertidal stations (43) when compared to the nearshore stations (505). 97.8% of the fishes captured were juveniles (Figure 20).



Figure 20. Standard length (SL) versus total catch (# individuals) of giant kelpfish.

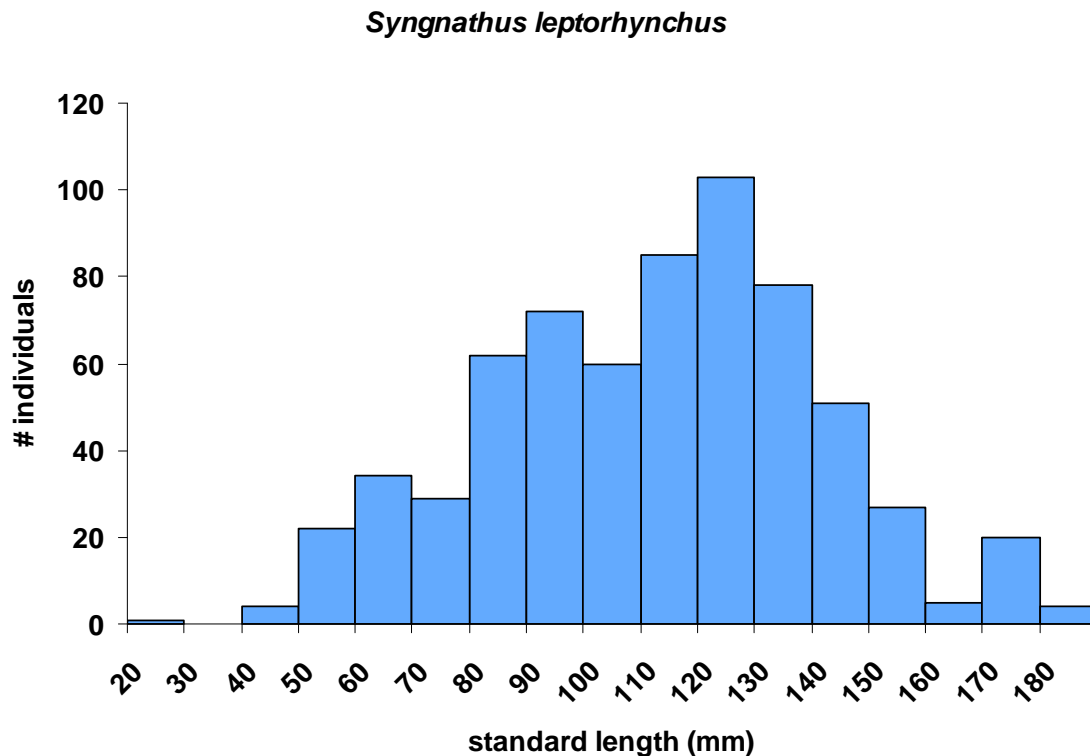


Bay pipefish (*Syngnathus leptorhynchus*)

439 bay pipefish were surveyed in all four ecoregions. In addition to being found in all four ecoregions, they were also found in all subhabitats and depth zones. They were caught in greater numbers in the nearshore stations. The distribution of size classes (Figure 21) indicates that all age classes were present during this sampling period. Bay pipefish ranked eighth in the ecological index and are an important resident in the bay.



Figure 21. Standard length (SL) versus total catch (# individuals) of bay pipefish.

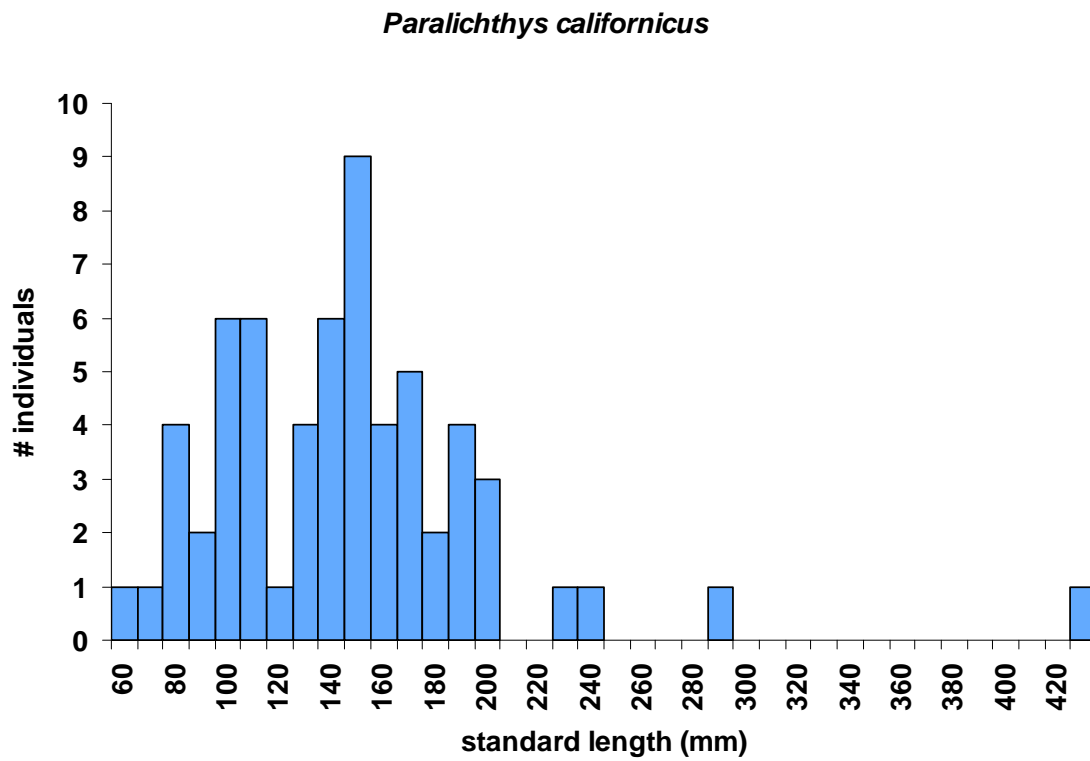


California halibut (*Paralichthys californicus*)

California halibut are known to recruit to estuaries and move in and out of them as adults. Our findings are consistent with this life history strategy. A few larger individuals were captured, but primarily the bay serves as a nursery area for young halibut that were found throughout the bay (Figure 22). This commercial and recreational species was surveyed in all ecoregions and habitats.



Figure 22. Standard length (SL) versus total catch (# individuals) of California halibut.

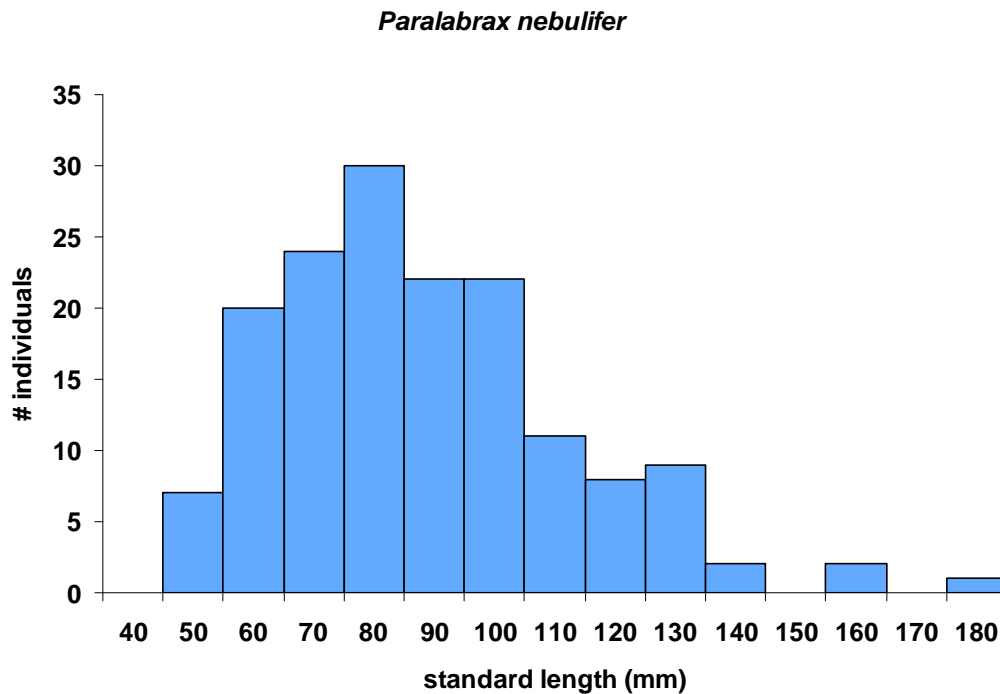


Barred sand bass (*Paralabrax nebulifer*)

Barred sand bass were ranked tenth in the ecological index. This important recreational species utilizes the bay primarily as juveniles. Based upon the sizes captured (Figure 23) all of these fishes were in their first year of growth. Barred sand bass were present in all ecoregions and habitats.



Figure 23. Standard length (SL) versus total catch (# individuals) of barred sand bass.



Catch by Sampling Method

The greatest number of species were collected in the beam trawl and purse seines (30 species each), followed by large seine (20), otter trawl (19), small seine (12) and square enclosure (5); (Table 14). The purse seine captured the greatest number of fish, catching a total of 8,310. Large numbers of fishes were also caught by the beam trawl (3,098) and the small seine (2,090). The large seine (1,809) had relatively high catches with fewer caught in the otter trawl (359) and were similar in total catch. Only 26 fishes were collected in the square enclosure.

The purse seine was most effective sampling the schooling fishes (slough anchovy, salema, shiner perch, and topsmelt). The beam trawl was most effective for catching benthic nearshore and eelgrass fishes (arrow goby, bay pipefish, shiner perch, and giant kelpfish). The square enclosure primarily caught arrow gobies. The large and small beach seines were particularly effective at catching topsmelt. The top species caught in the otter trawls was round stingray. The highest density of fishes were captured in the small seine (0.702 individuals/m²) followed by the square enclosure (0.542 individuals/m²); (Table 15 and 16). The square enclosure produced the highest biomass value (12.3 g/m²) due to the unusual capture of a single adult specklefin midshipmen. The purse seine and beam trawls produced similar amounts of biomass (3.9 and 3.5 g/m², respectively); (Table 22).

Bay Blenny



Table 14. Total catch of fish species taken in San Diego Bay, April and July 2008 by sampling method (gear).

BEAM TRAWL			PURSE SEINE		
COMMON NAME	Catch	%	COMMON NAME	Catch	%
arrow goby	668	21.56	slough anchovy	5198	62.55
bay pipefish	556	17.95	salema	1346	16.20
shiner perch	490	15.82	shiner perch	1089	13.10
giant kelpfish	490	15.82	topsmelt	284	3.42
slough anchovy	204	6.58	spotted sand bass	120	1.44
round stingray	167	5.39	round stingray	101	1.22
spotted sand bass	166	5.36	deepbody anchovy	70	0.84
barred sand bass	110	3.55	kelp bass	24	0.29
dwarf surfperch	81	2.61	barred sand bass	16	0.19
kelp bass	51	1.65	giant kelpfish	15	0.18
cheekspot goby	17	0.55	California halibut	10	0.12
diamond turbot	15	0.48	shortfin corvina	9	0.11
California halibut	14	0.45	bay pipefish	4	0.05
black surfperch	12	0.39	black surfperch	3	0.04
spotted kelpfish	12	0.39	California butterfly ray	3	0.04
bay blenny	11	0.36	striped mullet	2	0.02
rock wrasse	6	0.19	California lizardfish	2	0.02
topsmelt	5	0.16	yellowfin croaker	2	0.02
specklefin midshipman	5	0.16	bonefish	1	0.01
reef finspot	3	0.10	jacksmelt	1	0.01
California lizardfish	3	0.10	white seabass	1	0.01
California butterfly ray	2	0.06	black croaker	1	0.01
staghorn sculpin	2	0.06	rock wrasse	1	0.01
California scorpionfish	2	0.06	walleye surfperch	1	0.01
black croaker	1	0.03	diamond turbot	1	0.01
opaleye	1	0.03	dwarf surfperch	1	0.01
spotted turbot	1	0.03	specklefin midshipman	1	0.01
shadow goby	1	0.03	queenfish	1	0.01
California tonguefish	1	0.03	California barracuda	1	0.01
snubnose pipefish	1	0.03	California needlefish	1	0.01
Total	3,098		Total	8,310	
Number of species	30		# of species	30	

Table 14 cont. (2 of 3)

LARGE SEINE			OTTER TRAWL		
COMMON NAME	Catch	%	COMMON NAME	Catch	%
topsmelt	1394	77.06	round stingray	108	30.08
shiner perch	121	6.69	spotted sand bass	39	10.86
bay pipefish	50	2.76	slough anchovy	37	10.31
slough anchovy	41	2.27	specklefin midshipman	36	10.03
spotted sand bass	33	1.82	spotted turbot	23	6.41
staghorn sculpin	28	1.55	California halibut	22	6.13
California killifish	27	1.49	bay pipefish	21	5.85
giant kelpfish	25	1.38	California tonguefish	20	5.57
diamond turbot	16	0.88	barred sand bass	19	5.29
California halibut	16	0.88	diamond turbot	15	4.18
California halfbeak	13	0.72	black croaker	4	1.11
barred sand bass	13	0.72	fantail sole	4	1.11
arrow goby	10	0.55	yellowfin croaker	3	0.84
northern anchovy	10	0.55	giant kelpfish	2	0.56
round stingray	6	0.33	California lizardfish	2	0.56
deepbody anchovy	2	0.11	California butterfly ray	1	0.28
bay blenny	1	0.06	Pacific seahorse	1	0.28
California corbina	1	0.06	cheekspot goby	1	0.28
specklefin midshipman	1	0.06	California scorpionfish	1	0.28
California needlefish	1	0.06			
Total	1,809		Total	359	
# of species	20		# of species	19	

Table 14 cont. (3 of 3)

SMALL SEINE			SQUARE ENCLOSURE		
COMMON NAME	Catch	%	COMMON NAME	Catch	%
topsmelt	1711	81.87	arrow goby	21	80.77
arrow goby	228	10.91	giant kelpfish	1	3.846
slough anchovy	58	2.775	cheekspot goby	2	7.692
bay pipefish	41	1.962	specklefin midshipman	1	3.846
California killifish	27	1.292	bay pipefish	1	3.846
giant kelpfish	17	0.813			
staghorn sculpin	3	0.144			
opaleye	1	0.048			
California halfbeak	1	0.048			
spotted sand bass	1	0.048			
specklefin midshipman	1	0.048			
California needlefish	1	0.048			
Total			Total		
2,090			26		
Number of species			Number of species		
12			5		

Table 15. Total biomass (g) of fish species taken from San Diego Bay, April and July 2008, ranked by sampling method.

BEAM TRAWL			PURSE SEINE		
COMMON NAME	MASS	%	COMMON NAME	MASS	%
round stingray	25621	52.65	spotted sand bass	28808	34.57
spotted sand bass	9540	19.61	round stingray	13609	16.33
giant kelpfish	4060	8.34	slough anchovy	9808	11.77
California halibut	1676	3.44	salema	8755	10.50
California butterfly ray	1420	2.92	shortfin corvina	4987	5.98
barred sand bass	1209	2.48	shiner perch	3513	4.22
kelp bass	1018	2.09	topsmelt	3412	4.09
shiner perch	988	2.03	California butterfly ray	2725	3.27
dwarf surfperch	684	1.41	striped mullet	1220	1.46
black perch	522	1.07	California halibut	1128	1.35
California scorpionfish	459	0.94	California barracuda	839	1.01
bay pipefish	321	0.66	bonefish	759	0.91
diamond turbot	296	0.61	yellowfin croaker	751	0.90
slough anchovy	252	0.52	deepbody anchovy	644	0.77
bay blenny	244	0.50	barred sand bass	549	0.66
opaleye	132	0.27	kelp bass	421	0.50
arrow goby	72.9	0.15	white seabass	291	0.35
spotted kelpfish	68.5	0.14	jacksmelt	218	0.26
rock wrasse	18.1	0.04	diamond turbot	171	0.21
spotted turbot	15.3	0.03	black croaker	139	0.17
California lizardfish	10.5	0.02	giant kelpfish	126	0.15
staghorn sculpin	8.05	0.02	rock wrasse	125	0.15
California tonguefish	7.68	0.02	black perch	97.9	0.12
cheekspot goby	5.87	0.01	queenfish	88.0	0.11
reef finspot	5.03	0.01	walleye surfperch	58.5	0.07
topsmelt	2.64	0.01	California needlefish	51.0	0.06
black croaker	1.07	<0.01	California lizardfish	22.6	0.03
shadow goby	0.66	<0.01	specklefin midshipman	21.5	0.03
snubnose pipefish	0.40	<0.01	bay pipefish	2.27	<0.01
specklefin midshipman	0.36	<0.01	dwarf surfperch	1.91	<0.01
Total (g)	48,659		Total (g)	83,337	
Number of species	30		Number of species	30	

Table 15 cont. (2 of 2)

LARGE SEINE			OTTER TRAWL		
COMMON NAME	MASS	%	COMMON NAME	MASS	%
topsmelt	6648	47.91	round stingray	19511	53.94
California corbina	2450	17.65	spotted sand bass	8520	23.56
round stingray	2135	15.38	diamond turbot	2007	5.55
shiner perch	730	5.26	California halibut	1316	3.64
California halibut	497	3.58	spotted turbot	1239	3.42
diamond turbot	367	2.65	California butterfly ray	910	2.52
staghorn sculpin	288	2.08	barred sand bass	737	2.04
spotted sand bass	227	1.63	fantail sole	568	1.57
barred sand bass	212	1.53	black croaker	443	1.22
giant kelpfish	117	0.84	yellowfin croaker	427	1.18
slough anchovy	54.2	0.39	California tonguefish	208	0.57
California halfbeak	51.0	0.37	California lizardfish	123	0.34
California killifish	41.3	0.30	California scorpionfish	69.0	0.19
bay pipefish	26.6	0.19	slough anchovy	38.2	0.11
deepbody anchovy	14.3	0.10	Pacific seahorse	30.0	0.08
northern anchovy	13.7	0.10	specklefin midshipman	12.2	0.03
arrow goby	2.56	0.02	bay pipefish	10.0	0.03
bay blenny	1.82	0.01	giant kelpfish	0.33	<0.01
California needlefish	1.50	0.01	cheekspot goby	0.28	<0.01
specklefin midshipman	0.05	<0.01			
Total (g)			Total (g)	36,169	
Number of species			Number of species	19	

Table 15 cont. (3 of 3)

SMALL SEINE			SQUARE ENCLOSURE		
COMMON NAME	MASS	%	COMMON NAME	MASS	%
specklefin midshipman	301	39.54	specklefin midshipman	588	99.33
topsmelt	202	26.53	arrow goby	3.13	0.529
giant kelpfish	86.1	11.32	giant kelpfish	0.42	0.07
bay pipefish	79.1	10.4	cheekspot goby	0.28	0.047
arrow goby	37.0	4.862	bay pipefish	0.11	0.019
staghorn sculpin	22.7	2.977			
California killifish	20.3	2.666			
spotted sand bass	6.23	0.819			
slough anchovy	6.15	0.809			
opaleye	0.56	0.073			
California needlefish	0.06	0.008			
California halfbeak	0.02	<0.01			
Total (g)	761		Total (g)	591	
Number of species	12		Number of species	5	

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

1994-1999		San Diego Bay April, July 2005		April, July 2008	
Gear	#/m ²	Gear	#/m ²	Gear	#/m ²
LS	0.369	LS	0.676	LS	0.171
SS	2.338	SS	0.440	SS	0.702
SE	3.583	SE	1.042	SE	0.542
BT	0.080	BT	1.164	BT	0.223
PS	1.770	PS	0.569	PS	0.390
OT	0.009	OT	0.032	OT	0.004
Grand Mean	1.358	Grand Mean	0.654	Grand Mean	0.339

Gear	g/m ²	Gear	g/m ²	Gear	g/m ²
LS	1.051	LS	1.684	LS	1.314
SS	0.272	SS	0.216	SS	0.256
SE	0.636	SE	0.176	SE	12.313
BT	2.232	BT	5.137	BT	3.496
PS	6.306	PS	5.579	PS	3.910
OT	1.678	OT	1.425	OT	0.416
Grand Mean	2.029	Grand Mean	2.370	Grand Mean	3.617



Butterfly Ray

Ecoregion Comparisons: 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 aerial coverage of the three depth strata within the Ecoregion was determined previously by Allen et al. (2002) were used for the current study. These aerial 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 total estimate for the total stock size was 24,776,133 fishes (Table 18). With an estimated surface area of 4858 ha (Table 17) this gives an overall fish density 0.51 ind/m² (Table 18). Nearly half of this estimate was slough anchovy (12 million). Salema (2.6 million) arrow goby (2.2 million) shiner perch (2.2 million), topsmelt (1.7 million) bay pipefish (1.2 million) and giant kelpfish (1.2 million) dominated the stock estimate. The stock estimate for the bay was unsurprisingly dominated by schooling and forage fishes.

The total best estimate of biomass standing stock was 190,982 kg (Table 19). This gives an overall estimate of 3.93 g/m². The standing stock was highest in the South Ecoregion (70 mt) closely followed by South-Central Ecoregion (68 mt). The North Ecoregion (33 mt) and North-Central Ecoregion (20 mt) were much lower. South-Central (49 mt) and North (30 mt) respectively (Table 19).

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		

California Needlefish



Table 18. Best estimate of densities and estimated stock size.

COMMON NAME	SE	SS	LS	GEAR TYPE			
				PSN	BT	PSC	OT
slough anchovy		0.01949	0.00388	0.16871	0.01466	0.39428	0.00043
salema				0.09474			
arrow goby	0.43750	0.07661	0.00095		0.04799		
shiner surfperch			0.01146	0.07644	0.03520	0.00042	
topsmelt		0.57493	0.13201	0.01964	0.00036	0.00070	
bay pipefish	0.02083	0.01378	0.00473	0.00028	0.03994		0.00024
giant kelpfish	0.02083	0.00571	0.00237	0.00106	0.03520		0.00002
spotted sand bass		0.00034	0.00313	0.00739	0.01193	0.00211	0.00045
round stingray			0.00057	0.00669	0.01200	0.00084	0.00124
barred sand bass			0.00123	0.00099	0.00790	0.00028	0.00022
dwarf surfperch				0.00007	0.00582		
deepbody anchovy			0.00019	0.00486		0.00014	
cheekspot goby	0.04167				0.00122		0.00001
kelp bass				0.00169	0.00366		
specklefin midshipman	0.02083	0.00034	0.00009	0.00007	0.00036		0.00041
diamond turbot			0.00152	0.00007	0.00108		0.00017
California halibut			0.00152	0.00070	0.00101		0.00025
black surfperch				0.00021	0.00086		
spotted kelpfish					0.00086		
bay blenny			0.00009		0.00079		
California killfish		0.00907	0.00256				
shortfin corvina				0.00063			
rock wrasse				0.00007	0.00043		
staghorn sculpin		0.00101	0.00265		0.00014		
spotted turbot					0.00007		0.00026
California butterfly ray				0.00014	0.00014	0.00014	0.00001
California lizardfish				0.00014	0.00022		0.00002
California tonguefish					0.00007		0.00023
reef finspot					0.00022		
yellowfin croaker				0.00014			0.00003
California scorpionfish					0.00014		0.00001
striped mullet				0.00014			
black croaker				0.00007	0.00007		0.00005
bonefish						0.00014	
white seabass						0.00014	
opaleye		0.00034			0.00007		
California needlefish		0.00034	0.00009	0.00007			
California halfbeak		0.00034	0.00123				
shadow goby					0.00007		
snubnose pipefish					0.00007		
jacksmelt				0.00007			
walleye surfperch				0.00007			
queenfish				0.00007			
California barracuda				0.00007			
northern anchovy			0.00095				
fantail sole							0.00005
Pacific seahorse							0.00001
California corbina			0.00009				
Total: 0.541667 0.702285 0.171307 0.385276 0.222557 0.399212 0.004126							

Table 18. continued

COMMON NAME	BEST ESTIMATE OF DENSITY				STOCK ESTIMATE
	INTERTIDAL	NEARSHORE	CHANNEL	WTD MEAN	
slough anchovy	0.01949	0.16871	0.39428	0.25071	12,179,692
salema		0.09474		0.05400	2,623,279
arrow goby	0.43750	0.04799		0.04485	2,178,981
shiner surfperch	0.01146	0.07644	0.00042	0.04419	2,146,820
topsmelt	0.57493	0.01964	0.00070	0.03446	1,674,300
bay pipefish	0.02083	0.03994	0.00024	0.02369	1,151,089
giant kelpfish	0.02083	0.03520	0.00002	0.02091	1,015,660
spotted sand bass	0.00313	0.01193	0.00211	0.00775	376,296
round stingray	0.00057	0.01200	0.00124	0.00735	356,828
barred sand bass	0.00123	0.00790	0.00028	0.00466	226,546
dwarf surfperch		0.00582		0.00332	161,131
deepbody anchovy	0.00019	0.00486	0.00014	0.00283	137,512
cheekspot goby	0.04167	0.00122	0.00001	0.00237	115,002
kelp bass		0.00366		0.00209	101,453
specklefin midshipman	0.02083	0.00036	0.00041	0.00120	58,268
diamond turbot	0.00152	0.00108	0.00017	0.00074	36,049
California halibut	0.00152	0.00101	0.00025	0.00073	35,584
black surfperch		0.00086		0.00049	23,871
spotted kelpfish		0.00086		0.00049	23,871
bay blenny	0.00009	0.00079		0.00045	22,066
California killifish	0.00907			0.00036	17,630
shortfin corvina		0.00063		0.00036	17,540
rock wrasse		0.00043		0.00025	11,936
staghorn sculpin	0.00265	0.00014		0.00019	9,131
spotted turbot		0.00007	0.00026	0.00014	6,997
California butterfly ray		0.00014	0.00014	0.00014	6,565
California lizardfish		0.00022	0.00002	0.00013	6,403
California tonguefish		0.00007	0.00023	0.00013	6,344
reef finspot		0.00022		0.00012	5,968
yellowfin croaker		0.00014	0.00003	0.00009	4,551
California scorpionfish		0.00014	0.00001	0.00009	4,196
striped mullet		0.00014		0.00008	3,898
black croaker		0.00007	0.00005	0.00006	2,820
bonefish			0.00014	0.00005	2,667
white seabass			0.00014	0.00005	2,667
opaleye	0.00034	0.00007		0.00005	2,642
California needlefish	0.00034	0.00007		0.00005	2,602
California halfbeak	0.00123			0.00005	2,392
shadow goby		0.00007		0.00004	1,989
snubnose pipefish		0.00007		0.00004	1,989
jacksmelt		0.00007		0.00004	1,949
walleye surfperch		0.00007		0.00004	1,949
queenfish		0.00007		0.00004	1,949
California barracuda		0.00007		0.00004	1,949
northern anchovy	0.00095			0.00004	1,840
fantail sole			0.00005	0.00002	871
Pacific seahorse			0.00001	0.00000	218
California corbina	0.00009			0.00000	184
Total:	1.170455	0.537977	0.401390	0.510007	24,776,133

Table 18. continued

COMMON NAME	WEIGHTED BEST ESTIMATE OF DENSITY		
	INTERTIDAL	NEARSHORE	CHANNEL
slough anchovy	0.00078	0.09616	0.15377
salema		0.05400	
arrow goby	0.01750	0.02735	
shiner surfperch	0.00046	0.04357	0.00016
topsmelt	0.02300	0.01119	0.00027
bay pipefish	0.00083	0.02277	0.00009
giant kelpfish	0.00083	0.02006	0.00001
spotted sand bass	0.00013	0.00680	0.00082
round stingray	0.00002	0.00684	0.00048
barred sand bass	0.00005	0.00450	0.00011
dwarf surfperch		0.00332	
deepbody anchovy	0.00001	0.00277	0.00005
cheekspot goby	0.00167	0.00070	0.00000
kelp bass		0.00209	
specklefin midshipman	0.00083	0.00020	0.00016
diamond turbot	0.00006	0.00061	0.00007
California halibut	0.00006	0.00057	0.00010
black surfperch		0.00049	
spotted kelpfish		0.00049	
bay blenny	0.00000	0.00045	
California killfish	0.00036		
shortfin corvina		0.00036	
rock wrasse		0.00025	
staghorn sculpin	0.00011	0.00008	
spotted turbot		0.00004	0.00010
California butterfly ray		0.00008	0.00005
California lizardfish		0.00012	0.00001
California tonguefish		0.00004	0.00009
reef finspot		0.00012	
yellowfin croaker		0.00008	0.00001
California scorpionfish		0.00008	0.00000
striped mullet		0.00008	
black croaker		0.00004	0.00002
bonefish			0.00005
white seabass			0.00005
opaleye	0.00001	0.00004	
California needlefish	0.00001	0.00004	
California halfbeak	0.00005		
shadow goby		0.00004	
snubnose pipefish		0.00004	
jacksmelt		0.00004	
walleye surfperch		0.00004	
queenfish		0.00004	
California barracuda		0.00004	
northern anchovy	0.00004		
fantail sole			0.00002
Pacific seahorse			0.00000
California corbina	0.00000		
Total:	0.046818	0.306647	0.156542

Table 19. Best estimate of biomass densities and standing stocks for all fish species, forage species only and fisheries species only. Estimates are for each depth strata and within each Ecoregion of San Diego Bay.

<u>ALL FISH SPECIES</u>		<u>BEST ESTIMATE OF BIOMASS (g/m²)</u>			<u>STANDING STOCK</u>	
ECOREGION	INTERTIDAL	NEARSHORE	CHANNEL	WTD MEAN	(kg)	MT
NORTH	2.04	3.85	3.27	3.35	32942	33
NORTH-CENTRAL	1.01	5.23	0.74	2.46	19843	20
SOUTH-CENTRAL	1.58	4.47	1.72	3.39	68008	68
SOUTH	0.64	7.40	2.71	6.60	70190	70
				TOTAL:	190982	191
<u>FORAGE FISH SPECIES</u>		<u>BEST ESTIMATE OF BIOMASS (g/m²)</u>			<u>STANDING STOCK</u>	
ECOREGION	INTERTIDAL	NEARSHORE	CHANNEL	WTD MEAN	(kg)	MT
NORTH	1.23	0.65	3.27	2.25	22108	22
NORTH-CENTRAL	2.14	1.69	3.28	2.62	21182	21
SOUTH-CENTRAL	0.36	0.70	0.00	0.44	8770	9
SOUTH	0.34	0.80	0.22	0.72	7640	8
				TOTAL:	59699	60
<u>R/C FISH SPECIES</u>		<u>BEST ESTIMATE OF BIOMASS (g/m²)</u>			<u>STANDING STOCK</u>	
ECOREGION	INTERTIDAL	NEARSHORE	CHANNEL	WTD MEAN	(kg)	MT
NORTH	0.14	0.88	0.04	0.32	3150	3
NORTH-CENTRAL	0.03	3.51	0.32	1.52	12288	12
SOUTH-CENTRAL	1.04	2.04	1.23	1.72	34403	34
SOUTH	0.08	3.76	1.73	3.38	35995	36
				TOTAL:	85836	86

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. Seven species of important forage species were captured during this study. These species were: deepbody anchovy, slough anchovy, northern anchovy, California halfbeak, topsmelt, jacksmelt and shiner perch (Table 20). The most abundant forage fishes were slough anchovy; topsmelt, and shiner perch (Table 2). These species were primarily found at small (juvenile) size classes (<50 mm SL) appropriate for nesting birds to feed their young in the area (Figures 8, 11 and 12). 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 2008. The stock estimate for forage fish was over 16 million fishes and an estimate of 60 mt. Slough anchovy (25 mt) accounted for nearly half of this biomass followed by shiner perch (9.5 mt) and topsmelt (5.4 mt).

Table 20. Best estimate of standing stock and biomass densities for forage fish species.

ECOREGION	COMMON NAME	SE	SS	BIOMASS DENSITY (g/m ²)				OT
				LS	PSN	BT	PSC	
NORTH	slough anchovy			0.00176		0.01057	3.19797	
	topsmelt		0.17785	1.09290	0.56303		0.07225	
	jacksmelt				0.06130			
	shiner perch			0.13547	0.02737	0.06853		
	northern anchovy			0.00444				
	Total:		0.17785	1.23458	0.65171	0.07910	3.27022	
NORTH-CENTRAL	slough anchovy		0.00827	0.00823	0.65347	0.01223		0.00035
	topsmelt		0.04658	0.77440	0.23686		0.01112	
	shiner perch			0.12308	0.15243	0.01483		
	Total:		0.23270	2.14474	1.69447	0.10616	3.28134	0.00035
SOUTH-CENTRAL	deepbody anchovy			0.00540	0.00492			
	slough anchovy			0.00258	0.21255		0.00435	
	topsmelt		0.01050	0.33546	0.02298			
	shiner perch			0.00566	0.46138	0.17469		
	northern anchovy			0.00073				
	California halfbeak			0.01328				
	Total:		0.01050	0.35770	0.69691	0.17469	0.00435	
SOUTH	deepbody anchovy				0.17350		0.00583	
	slough anchovy			0.00797	0.19375	0.04950	0.20076	0.00141
	topsmelt		0.03648	0.31559	0.09593	0.00076		
	shiner perch			0.01211	0.34139	0.02595	0.01291	
	California halfbeak		0.00002	0.00606				
	Total:		0.03650	0.34174	0.80457	0.07620	0.21951	0.00141

Table 20. continued.

ECOREGION	COMMON NAME	INTERTIDAL	BEST ESTIMATE OF DENSITY				
			NEARSHORE	CHANNEL	WEIGHTED MEAN	STANDING STOCK (mt)	STANDING STOCK (mt)
NORTH	slough anchovy	0.00176	0.01057	3.19797	1.92237	18,878	18.9
	topsmelt	1.09290	0.56303	0.07225	0.29473	2,894	2.9
	jacksmelt		0.06130		0.02023	199	0.2
	shiner perch	0.13547	0.06853		0.03074	302	0.3
	northern anchovy	0.00444			0.00027	3	0.0
	Total:	1.23458	0.70344	3.27022	2.26834	22,275	22.3
NORTH-CENTRAL	slough anchovy	0.00827	0.65347	0.00035	0.24893	2,011	2.0
	topsmelt	0.77440	0.23686	0.01112	0.13506	1,091	1.1
	shiner perch	0.12308	0.15243		0.06408	518	0.5
	Total:	0.90575	1.04276	0.01147	0.44807	3,620	3.6
SOUTH-CENTRAL	deepbody anchovy	0.00540	0.00492		0.00314	63	0.1
	slough anchovy	0.00258	0.21255	0.00435	0.13129	2,632	2.6
	topsmelt	0.33546	0.02298		0.02241	449	0.4
	shiner perch	0.00566	0.46138		0.28158	5,646	5.6
	northern anchovy	0.00073			0.00002	0	0.0
	California halfbeak	0.01328			0.00033	7	0.0
	Total:	0.36310	0.70183	0.00435	0.43876	8,797	8.8
SOUTH	deepbody anchovy		0.17350	0.00583	0.14578	1,551	1.6
	slough anchovy	0.00797	0.19375	0.20076	0.18737	1,994	2.0
	topsmelt	0.31559	0.09593		0.09203	979	1.0
	shiner perch	0.01211	0.34139	0.01291	0.28747	3,059	3.1
	California halfbeak	0.00606			0.00023	2	0.0
	Total:	0.34174	0.80457	0.21951	0.71288	7,585	7.6

Table 20. continued.

ECOREGION	COMMON NAME	<u>WEIGHTED BEST ESTIMATE OF DENSITY</u>		
		INTERTIDAL	NEARSHORE	CHANNEL
NORTH	slough anchovy	0.00011	0.00349	1.91878
	topsmelt	0.06557	0.18580	0.04335
	jacksmelt		0.02023	
	shiner perch	0.00813	0.02262	
	northern anchovy	0.00027		
	Total:	0.07407	0.23214	1.96213
NORTH-CENTRAL	slough anchovy	0.00041	0.24832	0.00020
	topsmelt	0.03872	0.09001	0.00634
	shiner perch	0.00615	0.05792	
	Total:	0.04529	0.39625	0.00654
SOUTH-CENTRAL	deepbody anchovy	0.00013	0.00300	
	slough anchovy	0.00006	0.12965	0.00157
	topsmelt	0.00839	0.01402	
	shiner perch	0.00014	0.28144	
	northern anchovy	0.00002		
	California halfbeak	0.00033		
	Total:	0.00908	0.42812	0.00157
SOUTH	deepbody anchovy		0.14505	0.00073
	slough anchovy	0.00030	0.16198	0.02510
	topsmelt	0.01183	0.08019	
	shiner perch	0.00045	0.28540	0.00161
	California halfbeak	0.00023		
	Total:	0.01282	0.67262	0.02744

Fisheries Species

During this study, 15 species were captured which have importance in either the recreational or commercial fisheries in California (Table 21). Including all Ecoregions, standing stock estimates of fisheries species totaled 89.9 (mt). Estimates were greatest at the South-Central Ecoregion (37.7 mt), followed by the South (35.8 mt), North-Central (12.4 mt) and North Ecoregions (4.0 mt).

Table 21. Best estimate of standing stock and biomass densities for recreational/commercial fishery species.

ECOREGION	COMMON NAME	SE	SS	BIOMASS DENSITY (g/m ²)				PSC	OT
				LS	PSN	BT			
NORTH	black perch				0.02756	0.15014			
	northern anchovy			0.00444					
	California halibut			0.11970	0.03407	0.03277			0.02883
	kelp bass				0.02085	0.26780			
	spotted sand bass			0.00546	0.52168	0.25256			
	barred sand bass			0.01188	0.00446	0.04566			0.00391
	California scorpionfish					0.13196			0.00317
	Total:	0	0.00000	0.14148	0.60861	0.88089	0.00000		0.03591
NORTH-CENTRAL	shortfin corvina				1.34136				
	California halibut				0.09133	0.02391			0.02275
	kelp bass				0.07314	0.02469			
	spotted sand bass		0.00838	0.01103	1.60494	0.49798			0.28786
	barred sand bass			0.01661	0.06436	0.11627			0.01346
	queenfish				0.02477				
	California barracuda				0.23606				
	yellowfin croaker				0.07644				
	Total:	0	0.00838	0.02765	3.51240	0.66286	0.00000		0.32407
SOUTH-CENTRAL	white seabass							0.16357	
	northern anchovy			0.00073					
	California corbina			0.92803					
	California halibut			0.04087	0.02646	0.29773			0.00458
	kelp bass				0.00820				
	spotted sand bass			0.06935	1.82459	1.55403	1.04026		0.06999
	barred sand bass				0.02872	0.18543	0.02401		0.01011
	Total:	0	0.00000	1.03898	1.88797	2.03719	1.22784		0.08469
SOUTH	bonefish							0.42736	
	shortfin corvina				0.06250				
	striped mullet				0.34347				
	California halibut			0.02784	0.16558	0.12723			0.00432
	kelp bass				0.01622				
	spotted sand bass				2.98846	0.43672	1.30090		0.03383
	barred sand bass			0.05171	0.04499				0.00640
	yellowfin croaker				0.13485				0.01964
	Total:	0	0.00000	0.07955	3.75607	0.56396	1.72826		0.06418

Table 21. continued.

ECOREGION	COMMON NAME	BEST ESTIMATE OF BIOMASS DENSITY					
		INTERTIDAL	NEARSHORE	CHANNEL	WEIGHTED MEAN	STANDING STOCK (kg)	STANDING STOCK (mt)
NORTH	black perch		0.15014		0.04955	487	0.5
	northern anchovy	0.00444			0.00027	3	0.0
	California halibut	0.11970	0.03407	0.02883	0.03572	351	0.4
	kelp bass		0.26780		0.08837	868	0.9
	spotted sand bass	0.00546	0.52168		0.17248	1,694	1.7
	barred sand bass	0.01188	0.04566	0.00391	0.01812	178	0.2
	California scorpionfish		0.13196	0.00317	0.04545	446	0.4
	Total:	0.14148	1.15130	0.03591	0.40997	4,026	4.0
NORTH-CENTRAL	shortfin corvina		1.34136		0.50972	4,119	4.1
	California halibut		0.09133	0.02275	0.04767	385	0.4
	kelp bass		0.07314		0.02779	225	0.2
	spotted sand bass	0.01103	1.60494	0.28786	0.77451	6,258	6.3
	barred sand bass	0.01661	0.11627	0.01346	0.05269	426	0.4
	queenfish		0.02477		0.00941	76	0.1
	California barracuda		0.23606		0.08970	725	0.7
	yellowfin croaker		0.07644		0.02905	235	0.2
	Total:	0.02765	3.56432	0.32407	1.54054	12,448	12.4
SOUTH-CENTRAL	white seabass			0.16357	0.05889	1,181	1.2
	northern anchovy	0.00073			0.00002	0	0.0
	California corbina	0.92803			0.02320	465	0.5
	California halibut	0.04087	0.29773	0.00458	0.18429	3,695	3.7
	kelp bass		0.00820		0.00500	100	0.1
	spotted sand bass	0.06935	1.82459	1.04026	1.48923	29,859	29.9
	barred sand bass		0.18543	0.02401	0.12176	2,441	2.4
	Total:	1.03898	2.31595	1.23242	1.88238	37,742	37.7
SOUTH	bonefish			0.42736	0.05342	568	0.6
	shortfin corvina		0.06250		0.05225	556	0.6
	striped mullet		0.34347		0.28714	3,055	3.1
	California halibut	0.02784	0.16558	0.00432	0.14001	1,490	1.5
	kelp bass		0.01622		0.01356	144	0.1
	spotted sand bass		2.98846	1.30090	2.66096	28,313	28.3
	barred sand bass	0.05171	0.04499	0.00640	0.04035	429	0.4
	yellowfin croaker		0.13485	0.01964	0.11519	1,226	1.2
	Total:	0.07955	3.75607	1.75862	3.36289	35,781	35.8

Table 21. continued.

<u>WEIGHTED BEST ESTIMATE OF DENSITY</u>				
ECOREGION	COMMON NAME	INTERTIDAL	NEARSHORE	CHANNEL
NORTH	black perch		0.04955	
	northern anchovy	0.00027		
	California halibut	0.00718	0.01124	0.01730
	kelp bass		0.08837	
	spotted sand bass	0.00033	0.17215	
	barred sand bass	0.00071	0.01507	0.00234
	California scorpionfish		0.04355	0.00190
	Total:	0.00849	0.37993	0.02155
NORTH-CENTRAL	shortfin corvina		0.50972	
	California halibut		0.03471	0.01297
	kelp bass		0.02779	
	spotted sand bass	0.00055	0.60988	0.16408
	barred sand bass	0.00083	0.04418	0.00767
	queenfish		0.00941	
	California barracuda		0.08970	
	yellowfin croaker		0.02905	
	Total:	0.00138	1.35444	0.18472
SOUTH-CENTRAL	white seabass			0.05889
	northern anchovy	0.00002		
	California corbina	0.02320		
	California halibut	0.00102	0.18161	0.00165
	kelp bass		0.00500	
	spotted sand bass	0.00173	1.11300	0.37449
	barred sand bass		0.11311	0.00865
	Total:	0.02597	1.41273	0.44367
SOUTH	bonefish			0.05342
	shortfin corvina		0.05225	
	striped mullet		0.28714	
	California halibut	0.00104	0.13843	0.00054
	kelp bass		0.01356	
	spotted sand bass		2.49835	0.16261
	barred sand bass	0.00194	0.03761	0.00080
	yellowfin croaker		0.11274	0.00245
	Total:	0.00298	3.14008	0.21983

Southern Species Found in San Diego Bay

San Diego Bay is known for being the northern edge of the range for a number of southern fishes that are not normally distributed in the Southern California Bight. As an example, at least nineteen northern range extensions have been reported for the bay (Table 22). During the study the following six species with primarily southern distributions were taken (Table 23). These fishes were mostly found in the south ecoregion (Figure 24).

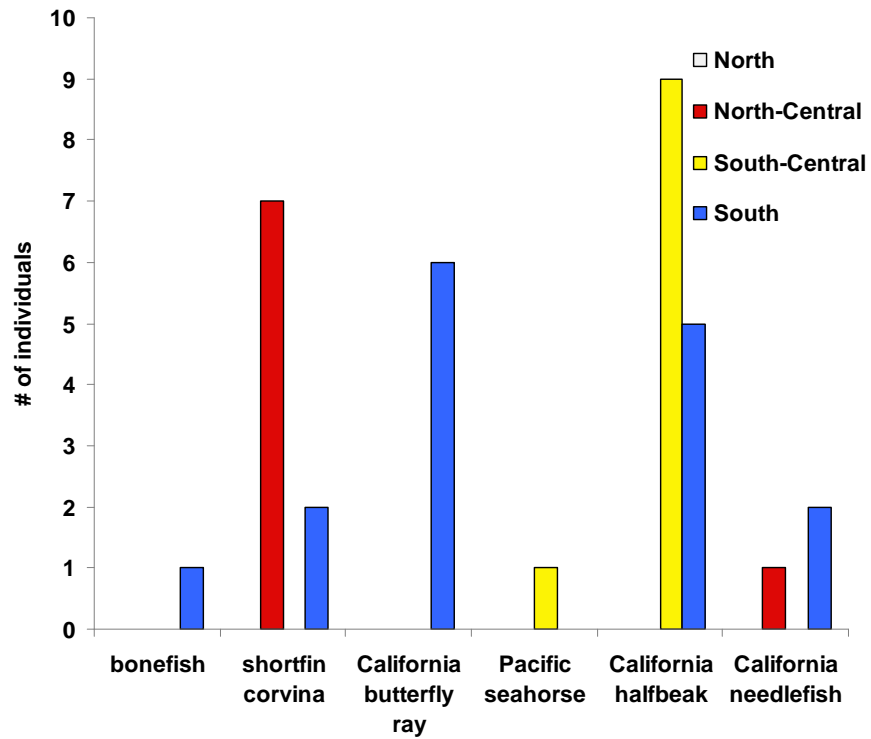
Table 22. Exotic, southern species recorded in San Diego Bay in the literature from 1985 to 1999.

Common name	Scientific name	Citation	Collection Date
Anchoveta	<i>Ctenogaulis mysticetus</i>	Duffy (1987)	1986?
Pacific cerval jack	<i>Caranx caninus</i>	Duffy (1987)	1986?
Bonefish	<i>Albula vulpes</i>	Duffy (1987); Allen (1999)	1986? ¹ ; 1995, 1998 ²
White mullet	<i>Mugil curema</i>	Lea et al. (1988)	May 1985
Milkfish	<i>Chanos chanos</i>	Duffy and Bernard (1985)	1985?
Pacific seahorse	<i>Hippocampus ingens</i>	Jones et al. (1988) ¹ ; Allen (1999) ²	? ¹ ; 1994-1999 ²
Cortez grunt	<i>Haemulon flaviguttatus</i>	Lea and Rosenblatt (1992)	May 1991
Bigeye trevally	<i>Caranx sexfasciatus</i>	Lea and Walker (1995)	Nov 1990
Mexican lookdown	<i>Selene brevoortii</i>	Lea and Walker (1995)	Nov 1990
California halfbeak	<i>Hyporhamphus rosae</i>	Allen (1999)	1994-1999
California needlefish	<i>Strongylura exilis</i>	Allen (1999)	1994-1999
Shortfin corvina	<i>Cynoscion parvipinnis</i>	Allen (1999)	1996-1999
Banded guitarfish	<i>Zapteryx exasperata</i>	Allen (1999)	1995, 1998
California butterfly ray	<i>Gymnura marmorata</i>	Allen (1999)	1998-1999
Red goatfish	<i>Pseudupeneus grandisquamis</i>	Allen (1999)	1998
Green jack	<i>Caranx caballus</i>	OREHP	1994-1999?
Middling thread herring	<i>Opistonema medirastre</i>	OREHP	1994-1999?
Pacific sierra	<i>Scomberomorus sierra</i>	OREHP	1994-1999?
Scalloped hammerhead	<i>Sphyrna lewini</i>	OREHP	1994-1999?

Table 23. Abundance of southern or “Panamic” species utilizing San Diego Bay as a warm water refuge, April and July 2005.

SCIENTIFIC NAME	COMMON NAME	<u>North</u>		<u>North-Central</u>		<u>South-Central</u>		<u>South</u>	
		April	July	April	July	April	July	April	July
<i>Albula vulpes</i>	bonefish							1	
<i>Cynoscion parvipinnis</i>	shortfin corvina			7				2	
<i>Gymnura marmorata</i>	California butterfly ray							4	2
<i>Hippocampus ingens</i>	Pacific seahorse						1		
<i>Hyporhamphus rosae</i>	California halfbeak					6	3	5	
<i>Strongylura exilis</i>	California needlefish			1				2	
TOTAL:		0	0	8	0	6	4	14	2

Figure 24 . Abundance of southern or “Panamic Province” species collected in San Diego Bay, 2008.



Pacific Seahorse

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. And, these fishes provide a critical forage base for important and endangered avian species. Southern California indigenous bay and estuary fishes represented 49% of the total catch in this survey (Table 24).

Table 24. Indigenous bay/estuarine species taken in San Diego Bay April and July, 2008.

SCIENTIFIC NAME	COMMON NAME	ECOREGIONS				TOTAL	%
		North	North-Central	South-Central	South		
<i>Anchoa compressa</i>	deepbody anchovy			4	68	72	0.94
<i>Anchoa delicatissima</i>	slough anchovy	2448	1645	617	828	5538	72.34
<i>Clevelandia ios</i>	arrow goby	584	11	42	290	927	12.11
<i>Fundulus parvipinnis</i>	California killifish			1	53	54	0.71
<i>Hypsoblennius gentilis</i>	bay blenny	7	2	3		12	0.16
<i>Ilypnus gilberti</i>	cheekspot goby	1	1		18	20	0.26
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	16	65	203	75	359	4.69
<i>Quietula y-cauda</i>	shadow goby				1	1	0.01
<i>Syngnathus leptorhynchus</i>	bay pipefish	95	223	279	76	673	8.79
TOTAL:		3,151	1,947	1,149	1,409	7,656	



California killifish

Comparison of the Current and Historical April and July Surveys

Diversity and richness were determined for April and July from the previous surveys (Allen 1999, Pondella et al. 2006) to allow direct comparisons of the data sets. The 1995-1998 survey years were used for the comparison because these were the only years where both April and July were sampled. In the 2005 survey Shannon-Wiener Diversity was highest at three of the four Ecoregions (North, North-Central and South-Central; Table 25, Figure 25). In 2008, the South Ecoregion had the highest diversity recorded ($H' = 2.00$). In the remaining ecoregions diversity was roughly equal to the 2005 sampling season and as high as has been observed in the study. Overall, 2008 Shannon-Wiener Diversity estimates were very strong. By contrast to the diversity values, species richness values for 2008 are at the middle or low end of the range of values for each ecoregion. (Table 26; Figure 26)

Table 25. Shannon-Wiener Diversity (H') values for April and July surveys by ecoregion and year.

H'	1995	1996	1997	1998	2005	2008
NORTH	0.74	0.39	0.89	1.34	1.77	1.70
NORTH-CENTRAL	1.46	0.66	1.34	0.87	1.47	1.60
SOUTH-CENTRAL	1.32	1.72	1.12	0.37	2.01	1.90
SOUTH	1.93	1.84	1.35	0.59	1.06	2.00

Figure 25. Estimate of Shannon-Weiner diversity from April and July 1995-1998, 2005 and 2008.

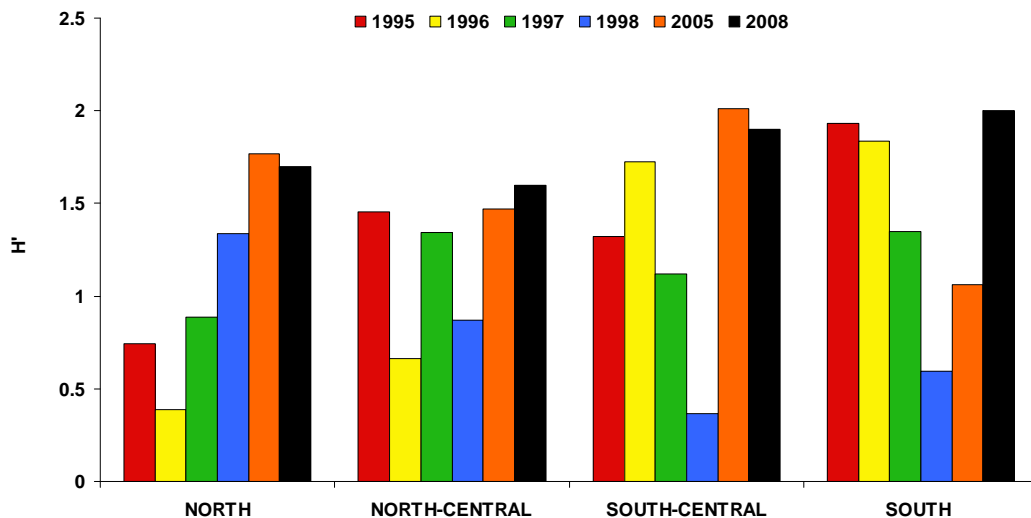
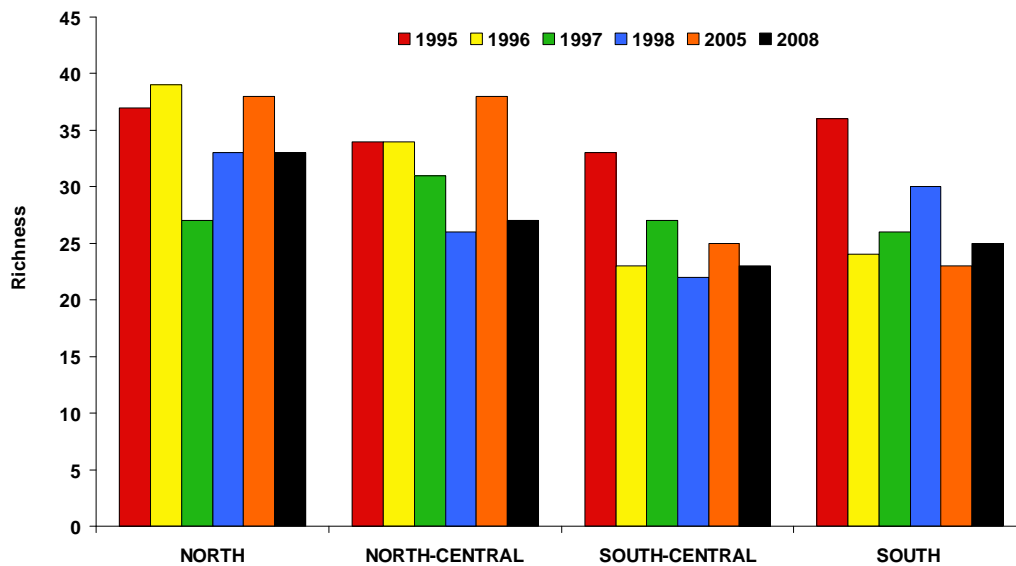


Table 26. Species richness values for April and July surveys by ecoregion.

Species Richness	1995	1996	1997	1998	2005	2008
NORTH	37	39	27	33	38	33
NORTH-CENTRAL	34	34	31	26	38	27
SOUTH-CENTRAL	33	23	27	22	25	23
SOUTH	36	24	26	30	23	25

Figure 26. Species richness of April and July sampling periods in San Diego Bay.



Juvenile Black Croaker

Total catch and biomass from the April and July sampling periods were also compared from 1995-1998, 2005 and 2008. Overall, catch was lower in 2005 at both North and South-Central Ecoregions than the 1995-1998 sampling period (Table 27; Figure 27). Total abundance in the North and North-Central Ecoregions were heavily influenced by large schools of northern anchovies that were captured during those years. Abundance at the North-Central and South Ecoregions were comparable to the prior abundance estimates. Estimates of total biomass were remarkably similar for the years from 1995-1998 and present surveys (Table 28; Figure 28). Biomass was intermediate at North-Central and South Ecoregions. However, biomass was only slightly greater in 2005 than the lowest estimate during the 1998 El Niño year. Biomass and abundance were negatively affected during 1997-1998 El Niño and the 2005 sampling occurred during a weak El Niño event thus partially explaining similarities in biomass and abundance between the 1998 and 2005 surveys. Overall, the current community statistics were comparable to the previous surveys.

Table 27. Total catch for April and July surveys by ecoregion.

Total Catch	1995	1996	1997	1998	2005	2008
NORTH	59178	91175	8978	14484	4,237	7233
NORTH-CENTRAL	19523	112964	8718	11603	12,537	3355
SOUTH-CENTRAL	22403	3623	10659	8267	2,346	2666
SOUTH	5063	3153	4735	14738	5,336	2438

Figure 27. Total abundance of fishes captured in San Diego Bay from April and July 1995-1998, 2005 and 2008 sampling periods.

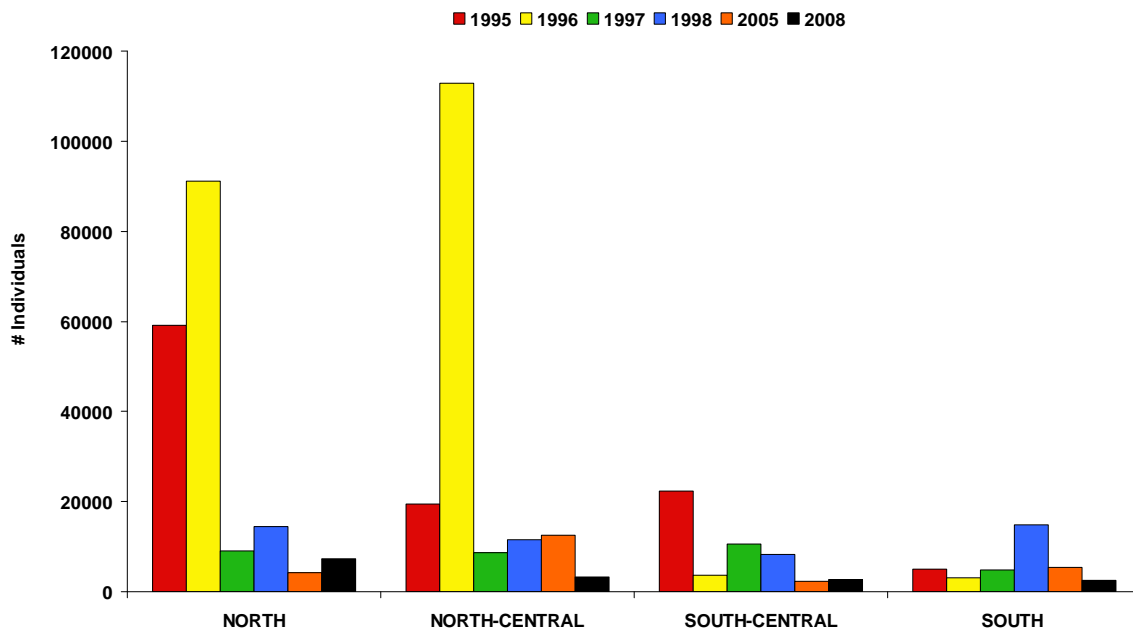
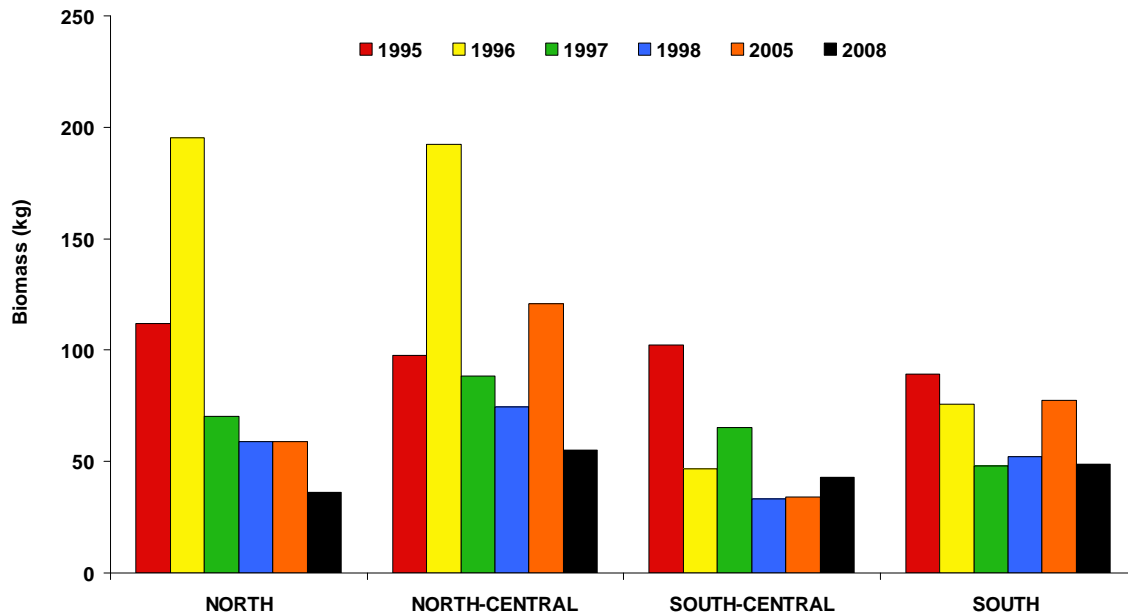


Table 28. Total biomass (mt) for April and July surveys by ecoregion.

Biomass (mt)	1995	1996	1997	1998	2005	2008
NORTH	111.9	195.4	70.1	58.7	58.9	36.3
NORTH-CENTRAL	97.5	192.3	88.4	74.4	121.0	55.3
SOUTH-CENTRAL	102.4	46.6	65.4	33.2	34.2	42.9
SOUTH	89.2	75.8	48.2	52.3	77.4	49.0

Figure 28. Total biomass of fishes captured in San Diego Bay from April and July 1995-1998, 2005 and 2008 sampling periods.



Literature Cited

- Allen, L. G. 1980. Seasonal abundance, composition, and productivity of the littoral fish assemblage in upper Newport Bay, California. U.S. Fish Bull., 80(4): 769-790.
- Allen, L. G., Findlay, A. M., Phalen, C. M. 2002. Structure and standing stock of the fish assemblages of San Diego Bay, California from 1994-1999. Bull. So. Calif. Acad. Sci. 101(2), 49-85.
- Allen, L. G. 1999. Fisheries inventory and utilization of San Diego Bay, San Diego, California. Final report for contract to the U.S. Navy Naval Engineering Naval Command Southwest Division and the San Diego Unified Port District, 138 pp.
- Duffy, J. M. 1987. A review of the San Diego Bay striped mullet, *Mugil cephalus*, fishery. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 56, 10 pp.
- Duffy, J. M. and H. J. Bernard. 1985. Milkfish, *Chanos chanos* (Forsskal, 1775), taken in southern California adds new family (Chanidae) to the California marine fauna. Calif. Fish Game, 71(2): 122-125.
- Jones, A. T., P. Dutton, and R. E. Snodgrass. 1988. Reoccurrence of the Pacific seahorse, *Hippocampus ingens*, in San Diego Bay. Calif. Fish Game, 74(4): 236-238.
- Lea, R. N., C. C. Swift, and R. J. Lavenberg. 1988. Records of *Mugil curema* Valenciennes, the white mullet, from southern California. Bull. So. Calif. Acad. Sci., 87(1): 31-34.
- Lea, R. N. and R. H. Rosenblatt. 1992. The Cortez grunt (*Haemulon flaviguttatum*) recorded from two embayments in southern California. Calif. Fish Game, 78(4): 163-165.
- Lea, R. N. and H. J. Walker, Jr. 1995. Record of the bigeye trevally, *Caranx sexfasciatus*, and Mexican lookdown, *Selene brevoorti*, with notes on other carangids from California. Calif. Fish Game, 81(3): 89-95.
- Lea, R. N. and R. H. Rosenblatt. 2000. Observations on fishes associated with the El Niño off California. CalCOFI Rep. 41: 117-129.
- Pondella, D. J., II, J. Froeschke and B. Young. 2006. Fisheries Inventory and Utilization of San Diego Bay, San Diego California for surveys conducted in April and July 2005. February 2006. 103 p.