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Abundance, Diversity and Seasonality of Fishes in Colorado Lagoon, Alamitos Bay, California

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A total of 152 169 fishes from 23 species were caught in monthly beach seine hauls during 1973 in Colorado Lagoon, the small, Y-shaped, upper arm of Alamitos Bay in southern California. Four species, northern anchovy, topsmelt, slough anchovy and shiner surfperch, comprised 99% of the catch. Numbers of species and individuals were highest during the summer (May–September) and both were highly correlated with lagoon temperature which ranged from 12·8–25·0 °C. Juveniles of northern anchovy were extremely abundant in August and September. Seven species were collected in only one month and six of these only in one of the warmer months (June–August). Five species, topsmelt, shiner surfperch, California killifish, staghorn sculpin and slough anchovy, occurred in wide size ranges and during most or all of the year and were considered to be residents. Three diversity indices (Shannon-Wiener, evenness and richness) reflected the changes that occur in numbers of species and individuals during the year.

Introduction

Knowledge of the fishes inhabiting California's semi-enclosed bays and estuaries is largely confined to lists of species occurrence (Peeling, 1974, San Diego Bay; Chapman, 1963, Mission Bay; Frey *et al.*, 1970, Newport Bay; Lane & Hill, 1975, Anaheim Bay; Reish, 1968, Alamitos Bay; Fierstine *et al.*, 1973, Morro Bay; Aplin, 1967, San Francisco Bay; Bane & Bane, 1971, Tomales-Bodega Bay; Monroe *et al.*, 1973, Humboldt Bay). Studies of abundance and seasonality and of life histories are relatively few. However, recognition of the importance of bays and estuaries as feeding and nursery grounds for fishes and the need to assess existing or potential alterations by man have resulted in increased attention to these areas as fish habitats in California (Lane & Hill, 1975) and other coastal regions (Bechtel & Copeland, 1970; Dahlberg & Odum, 1970; Oviatt & Nixon, 1973; Derickson & Price, 1973; Haedrich & Haedrich, 1974; Recksiek & McCleave, 1973; McErlean *et al.*, 1973; Targett & McCleave, 1974).

Impetus for the present study was gained not only from the general lack of knowledge of fish populations in Alamitos Bay, but also when one of us (LGA) during a study of an introduced clam population in Colorado Lagoon (Crane *et al.*, 1975) noticed the disparity in kinds and numbers of fishes between summer and winter months. The objectives of the study were then to assess in relation to temperature and possibly other environmental factors the kinds, abundance and seasonality of fishes occurring in the lagoon by periodic sampling with a beach seine.

Description of the study area

Colorado Lagoon (Figure 1) is a Y-shaped body of water forming the uppermost, northwestern portion of Alamitos Bay (33° 46′ N, 118° 08′ W). It is connected to the rest of the bay by tide gates and an underground waterway. Six storm drains empty into the lagoon at various sites along each arm (Figure 2). The surface area of the lagoon is approximately 4·8 ha at MHHW and 1·7 ha at MLLW. Average volume is about 2×10^8 l. Maximum depth at MHHW ranges from 4 m in the western arm to about 8 m in the northern arm. Surface temperature ranged from 12·8 °C in November to 25·0 °C in August and salinity from 30·0 ‰ in February to 33·5 ‰ in October during the monthly sampling in 1973 (Figure 3). Mean monthly surface temperature, transparency and dissolved oxygen for the period 1961–1971 and salinity for 1972 are also presented in Figure 3.

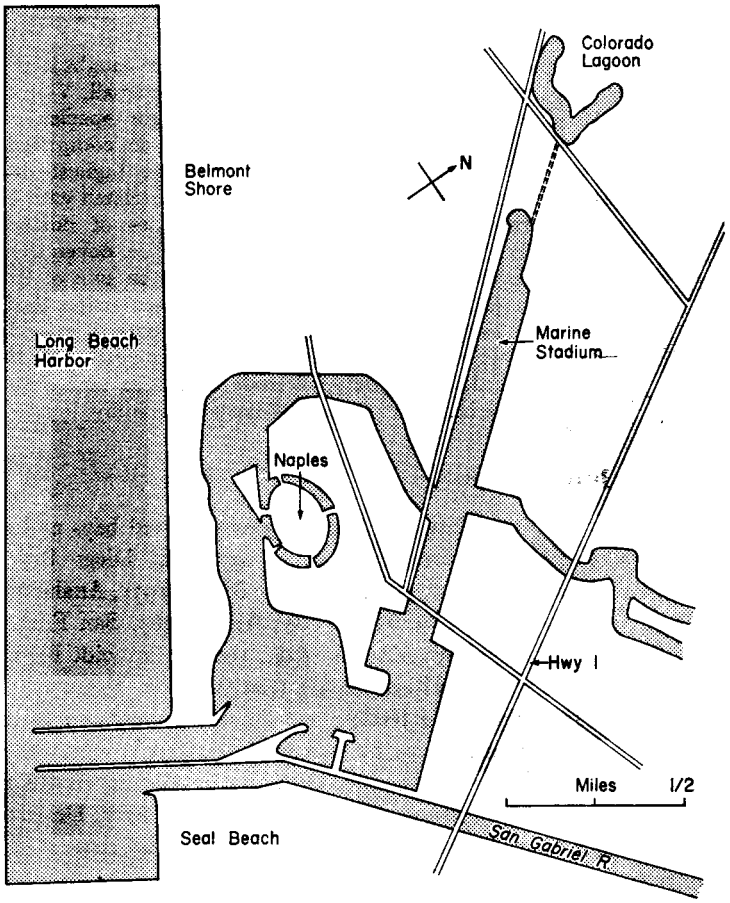

Figure 1. Alamitos Bay, California.

The substrate of the lagoon was originally mud but dredging and addition of sand for recreational purposes have altered the bottom so that it is now a combination of sediment types. Portions of the bottom contain hydrogen sulfide as a result of bacterial action. A small rock outcropping occurs near the tide gates.

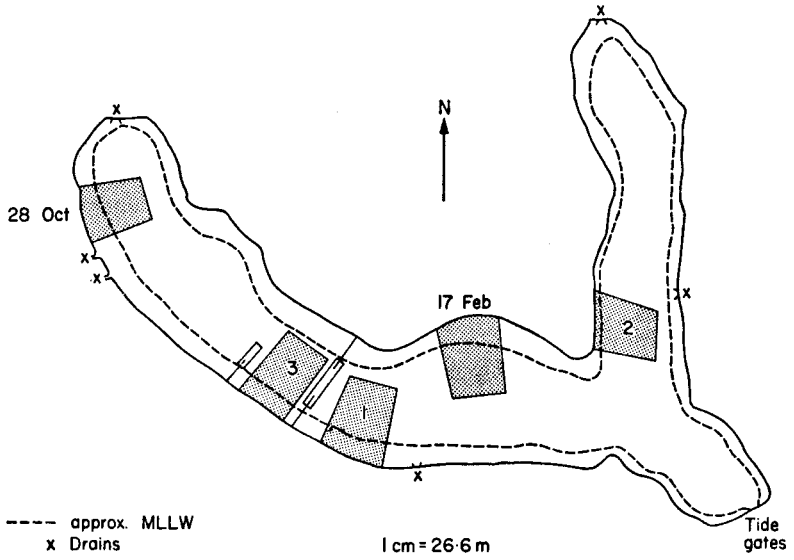

Figure 2. Beach seining stations in Colorado Lagoon.

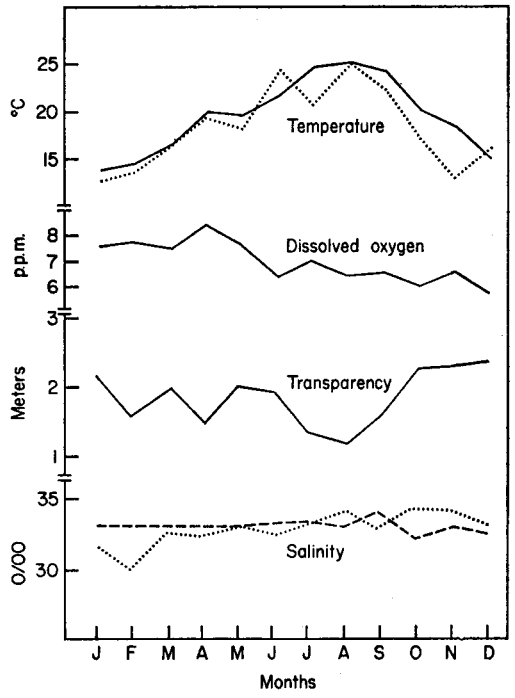

Figure 3. Mean temperature, dissolved oxygen and transparency values (———) for 1961–1971, salinity values (— — —) for 1972, and temperature and salinity values (- - - - -) for 1973 in Colorado Lagoon. (1961–1971 data courtesy Y. Ibata, Engineering Dept., Long Beach, Calif.; 1972 data courtesy Connie Eisemann and Jules Crane, Cerritos College.)

About 700 m of the perimeter of the lagoon is reserved as a recreational area for the city of Long Beach. The tide gates are closed for as long as 3–4 days/week from early May until mid-September to insure adequate water for swimming. More than 2000 people may visit the lagoon on a peak summer day.

Nutrients in the lagoon come from algal and animal decomposition, human excretions and street run-off via the storm drains (Crane *et al.*, 1975). During the summer when nutrient levels and temperatures are high, algal blooms occur and water transparency reaches its lowest value (Figure 3).

Methods

Fishes were sampled monthly during 1973 at varying tidal heights using a beach seine 3 m deep by 29·2 m long with a 2·2 m by 2·2 m by 2·2 m bag of 6 mm mesh size. Three stations in the lagoon were sampled each month except in June when two stations were sampled and in February and October when four stations were sampled (Figure 2). Seine hauls at the different stations did not appear noticeably heterogeneous and were not quantitatively compared. The seine was set parallel to the beach from a 4 m skiff and hauled to shore with 50 m polypropylene lines. An estimated 10% of the MHHW area or 16% of the MLLW area of the lagoon were sampled each month (based in three stations/month). The number of specimens of each species and the fork length (FL) and standard length (SL) of each specimen were recorded. Estimates of the number of the most abundant species, especially of the northern anchovy in August and September, were made from dipnet or four-liter aliquots. Individuals of each aliquot were measured. Except for specimens fixed in 10% formalin for reference or identification, the fishes were returned live to the water. High mortality after capture occurred in only three species, northern anchovy, topsmelt and shiner surfperch and each at only one station of one month. A representative collection of fishes from the lagoon is maintained at California State University, Fullerton, and at Cerritos College, Norwalk, California.

Temperature and salinity (‰) were measured at 30 cm below the surface and recorded concurrently with fish collections each month. Salinity was determined with a refractometer.

Three diversity indices were calculated. The Shannon-Wiener information function:

$$H' = -\sum_{i=1}^{s} P_i \log P_i \qquad (1)$$

where P_i is the proportion of individuals in the ith species. This index increases as both the number of species (richness) and the equitability of species abundance (evenness) increase. As stated by Dahlberg & Odum (1970), it is desirable to consider indices that treat the above aspects since the two components of diversity may react differently to certain types of factors. For the 'species richness' component of diversity the following was calculated:

$$D = (S-1)/\log N \qquad (2)$$

where S is the number of species and N the number of individuals (Margalef, 1969). For the equitability of species abundance, the 'evenness' index of Pielou (1966) was used:

$$J = H'/H_{max} = H'/\log S \qquad (3)$$

in which $\log S$ is the maximum possible value of H'. $H' = H_{max}$ when all species are equally abundant.

All diversity calculations are based on use of natural logs ($\log_e$).

TABLE 1. Monthly totals (by collection date) of fish species collected by beach seine in Colorado Lagoon, 1973

Species	Jan 5	Feb 17	Mar 2	Apr 21	May 19	Jun 23	Jul 28	Aug 24	(Oct)[a] 1	Oct 28	Nov 27	Dec 31	Totals
Northern Anchovy (*Engraulis mordax*)	2				5	324	6432	23 750	106 250		1	6	136 770
Topsmelt (*Atherinops affinis*)	340	358	555	696	400	180	230	285	188	1600	414	1102	6348
Slough Anchovy (*Anchoa delicatissima*)				35	3	2024	356	2250	18	44		27	4757
Shiner Surfperch (*Cymatogaster aggregata*)	2	2	5	630	923	616	157	455	97	193	2	9	3091
California Killifish (*Fundulus parvipinnis*)	84	187	10	60	21	4	25	21	41	17	1		471
California Grunion (*Leuresthes tenuis*)	15					8	276	30	11	6			346
Staghorn Sculpin (*Leptocottus armatus*)	1	1	11	64	56	20	11	52	7	1			224
Deepbody Anchovy (*Anchoa compressa*)						25			26				51
Striped Mullet (*Mugil cephalus*)		41											41
Pile Surfperch (*Damalichthys vacca*)		5		9	9		1					1	25
Shadow Goby (*Quietula y-cauda*)			3		1	1		3	2				10
Threadfin Shad (*Dorosoma petenense*)								8					8
Black Surfperch (*Embiotoca jacksoni*)		1			4								5
Spotted Sand Bass (*Paralabrax maculofasciatus*)					1	1	2				1		5
Diamond Turbot (*Hypsopsetta guttulata*)			1			3							4
Bat Ray (*Myliobatis californica*)								3					3
Round Stingray (*Urolophus halleri*)					1		1						2
White Surfperch (*Phanerodon furcatus*)				1		1							2
Arrow Goby (*Clevelandia ios*)					1				1				2
White Croaker (*Genyonemus lineatus*)						1							1
California Corbina (*Menticirrhus undulatus*)						1							1
Spotfin Croaker (*Roncador stearnsii*)						1							1
Queenfish (*Seriphus politus*)							1						1
Total individuals	444	595	585	1495	1425	3210	7492	26 857	106 641	1861	419	1145	152 169
Total species	6	7	6	7	12	15	11	10	10	6	5	5	23

[a]Counted as September sample.

Results

A total of 152 169 fishes from 23 species were caught in 37 beach seine hauls during the 12 sampling dates (Table 1). Four species, northern anchovy (*Engraulis mordax*), topsmelt (*Atherinops affinis*), slough anchovy (*Anchoa delicatissima*) and shiner surfperch (*Cymatogaster aggregata*), together comprised 99% of the total number collected. Northern anchovy alone made up 90% of the catch.

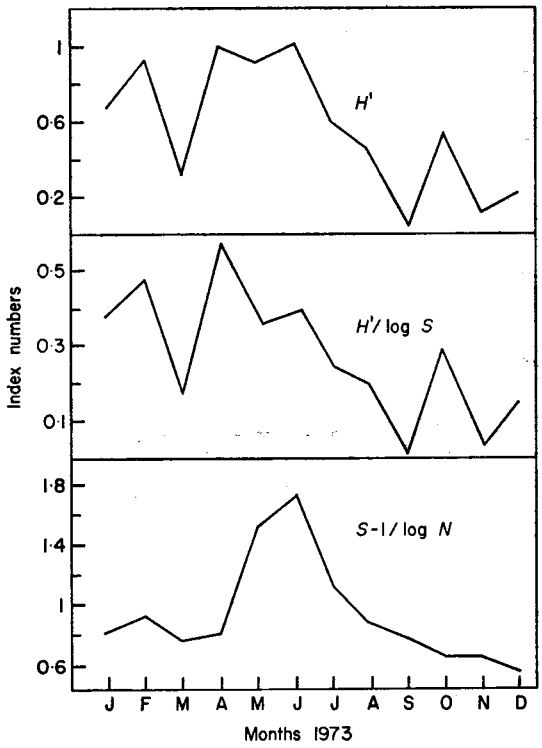

Figure 4. Monthly species diversity indices in Colorado Lagoon. H' is Shannon–Wiener index, $H'/\log S$ is the eveness index J, and $S\text{-}1/\log N$ is species richness index D.

Seasonality was expressed in several species and was evident in the overall patterns of occurrence and abundance during the year. Seven species (26% of total) were collected in only one month and six of these in one of the warmer months (June–August). The northern anchovy, extremely abundant in August and September but rare or absent in eight of the 12 sampling periods, was considered to be a seasonal species. Only two species, topsmelt and shiner surfperch, were captured in all 12 months; three other species, California killifish (*Fundulus parvipinnis*), staghorn sculpin (*Leptocottus armatus*) and slough anchovy, occurred in 11, 10 and eight months, respectively. These last five species were considered to be residents of the lagoon.

Values of the Shannon-Wiener (H') index ranged from 1·11 in April and June to 0·03 in September when northern anchovy greatly dominated the catch (Figure 4). The overall H' value based on all data for the year was 0·47. The evenness index (J) fluctuated in a similar pattern with the high value (0·57) in April and low value (0·01) in September (Figure 4). Species richness (D) reached a pronounced peak in June (1·73) when the largest number of

species (15) were recorded and a low in December (0·57) when, as in November, the fewest species (5) were captured (Figure 4). All three indices decreased during the four months of warmest temperatures, June through September, again, largely as a result of the increasing abundance of northern anchovy which reached a peak in September.

A relationship was found between temperature and both numbers of species and numbers of individuals. Temperature was highly correlated (r=0·80 and 0·82, P<0·01) with numbers of species (Figure 5) and numbers of individuals (Figure 6).

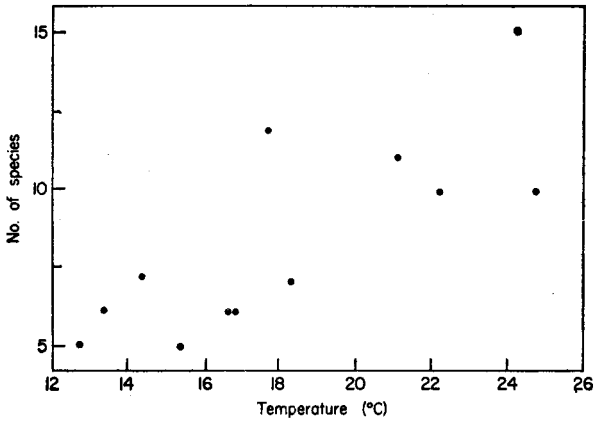

Figure 5. Relationship of temperature and number of species collected in Colorado Lagoon. r=0·80 (P<0·01).

All of the four most abundant species were collected in wide size ranges in the lagoon. Individuals of the northern anchovy ranged from 23 to 135 mm SL ($\bar{x}$ 53·2). Small juveniles were collected in January ($\bar{x}$ 37·0) and May ($\bar{x}$ 25·6). Larger fish were captured in June ($\bar{x}$ 95·2), but during the months of greatest abundance, July through September, individuals were smaller and more uniform in size (mean sizes for the three months, 57·4, 54·0 and 55·3, respectively). Topsmelt were collected in a size range of 9·0 to 175·5 mm SL and mean size (104·8) remained rather uniform throughout the year. The size range of slough anchovy was 46·5–93·0 mm SL ($\bar{x}$ 69·7). Mean size of individuals captured in the two months of greatest

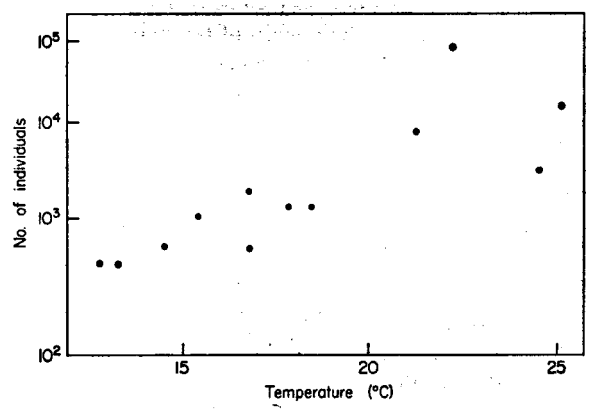

Figure 6. Relationship of temperature and number of individuals collected in Colorado Lagoon. r=0·82 (P<0·01).

abundance, June and August, was 71·6 and 83·7 mm, respectively. The fourth most abundant species, shiner surfperch, ranged from 26·4 to 132 mm SL ($\bar{x}$ 61·2). Juveniles were taken from February through July and pregnant females from March through May, the latter making up 23·5% of the species total in April and about 20% in May.

Discussion

Colorado Lagoon, although a relatively small and at times isolated arm of Alamitos Bay subject to heavy recreational use especially during the summer, was found to be occupied either permanently or temporarily by at least 23 species of fishes. Five species appear to have resident populations in the lagoon. Seasonality is marked, however, as the numbers of species and individuals are highest from May through September. Diversity indices reflect the changes in abundance of species and individuals with time of year. Overall diversity (H') and evenness ($\bar{J}$) measures had a similar, fluctuating pattern over the 12-month period. A richness index (D), however, showed a much different pattern indicating that the species richness and equitability components of diversity were not reacting in concord during the year.

Diversity values (H') obtained for Colorado Lagoon (range, 0·03–1·11; overall value, 0·47) are similar to or lower than those derived from other studies of bay and inshore fish populations. Dahlberg & Odum (1970) obtained values of about 0·7–1·6 for Georgia sounds, Bechtel & Copeland (1970) values of 0·13–0·91 for Upper Galveston Bay, Texas, Haedrich & Haedrich (1974) values of 0·33–1·03 for the Mystic River estuary, Massachusetts, and Stephens *et al.* (1974) indices of 0·65–2·08 ($\bar{x}$ 1·29) for Los Angeles Harbor. The lagoon, however, is much smaller than the areas of the above studies and isolated during certain days of the summer. Nine additional species have been observed or collected in the lagoon by methods other than beach seine bringing to 32 the total number of species known from the lagoon (Allen, 1975).

Temperature appeared to have an important relationship to numbers of species and individuals in the lagoon being positively correlated with both these variables. However, except for the extreme increase in abundance of northern anchovy, numbers of the other three principal species (topsmelt, slough anchovy and shiner surfperch) declined in September when the temperature decreased somewhat (to 22·2 °C) from the high in August of 25 °C. These data may indicate that northern anchovy competitively replace other species during peak periods and/or that the apparent relationship of temperature and abundance is due in part to conditions outside the lagoon. General seasonal movements of certain species such as northern anchovy, periods of high recruitment and utilization of the lagoon as a feeding and nursery ground during the summer months when productivity is high all may serve to account for the temperature–abundance relationship. Water transparency values were low from July through September and generally corresponded to the low or decreasing diversity values during the same interval. Other physical factors such as dissolved oxygen or salinity, which only varied from 30·0 to 33·5 ‰ during the study period, did not appear to have a direct relationship to number of species or individuals.

Several other studies of inshore fish populations in temperate regions (e.g. Nordan, 1966; Zilberberg, 1966; Dahlberg & Odum, 1970; Derickson & Price, 1973; Stephens *et al.*, 1974; Targett & McCleave, 1974) have found similar seasonal patterns and/or relationships of temperature to number of species and number of individuals. Recksiek & McCleave (1973) in their study of pelagic fish distribution in a Maine estuary concluded that differences in

abundance in space and time were apparently related to temperature. This conclusion seems to have wide application among temperate inshore, especially bay, fish populations.

Based on the high frequency of capture and the wide size range collected, three of the four most abundant species, topsmelt, slough anchovy and shiner surfperch, appear to be residents of the lagoon. The most abundant species, northern anchovy, is, however, seasonal in occurrence and abundance. Most individuals of northern anchovy were in the 40–60 mm SL range, a size representative of the 0 age class (Frey, 1971). They were extremely abundant in August and September and were probably recruits from spawning earlier in the year since according to Frey (1971) northern anchovy reach a spawning peak in late winter or early spring. Ganssle (1973) stated that adults are less available in inshore waters during periods of warming and that young-of-the-year fish seem to tolerate higher temperatures than adults. Our findings support this view in that the mean size of 95·2 mm SL in June dropped to 55·6 mm for the three-month period of greatest abundance, July through September. The data clearly indicate the seasonal nature of northern anchovy in the lagoon. Topsmelt were represented in the lagoon by age classes 0, I and II according to age–length relationships given by Frey (1971). Slough anchovy occurred in a relatively wide size range including, in August, individuals of 100 mm FL which exceeds the maximum previously known size of 94 mm TL (total length) (Miller & Lea, 1972).

Inshore fish populations are dominated in abundance by a small number of species. A common result of several studies of bay, estuarine and other inshore fishes (Nordan, 1966; Zilberberg, 1966; Derickson & Price, 1973; Oviatt & Nixon, 1973; Recksiek & McCleave, 1973; Haedrich & Haedrich, 1974; Stephens *et al.*, 1974; Targett & McCleave, 1974; and the present study) is that a small number of species ($\leqslant 5$) comprise a large percentage ($\geqslant 75\%$) of the total number of fishes sampled even though many more species (15–99 in the above studies) were collected. The five or fewer most abundant species are usually low in the trophic structure as would be expected from general ecological patterns of relative abundance at different trophic levels. These species are frequently planktivorous (e.g. anchovies and herrings), omnivorous (e.g. mullets, silversides, killifishes) or are low level carnivores (e.g. croakers and flatfishes) which may often feed on the planktivores and omnivores. Two of the four most abundant species in Colorado Lagoon, northern anchovy and slough anchovy, are plankton feeders and the other two, topsmelt and shiner surfperch, feed partially on plankton, the high seasonal productivity of the lagoon apparently supporting large numbers of these four fishes.

Acknowledgements

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