THE UTILIZATION OF SHALLOW MARSH HABITATS BY COMMERCIALLY IMPORTANT FISHES IN ELKHORN SLOUGH, CALIFORNIA

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ABSTRACT.

Samples taken by various gear from October 1978 to May 1980 indicate that many fish species, some of which are commercially important, utilize the tidal creeks and inland portions of Elkhorn Slough, a shallow coastal embayment in Monterey Bay, California. In order of abundance, fishes important to commercial fisheries were northern anchovy, Pacific herring, shiner surfperch, starry flounder, black surfperch, leopard shark, California halibut, bat ray, and english sole. Most of these species occurred in the tidal creeks and upper slough primarily as juveniles, while individuals of some species were captured in lower numbers as reproductively active adults (Pacific herring, shiner perch, black perch, leopard shark, bat ray). Most species exhibited seasonal patterns of occupation with the highest densities of juveniles occurring in spring ans summer; these patterns reflected the reproductive habits of the species.

These fishes fed on a variety of prey types, including zooplankton, epifaunal crustacea, infaunal worms and mollusca, and larger mobile crustaceans and fishes. Plant material and detritus constituted a small portion of the diets of most species, but were much less important overall than the above prey types.

Although the relative importance of Elkhorn Slough to commercial fish production in Monterey Bay and the California continental shelf is difficult to assess, it appears that shallow turbid areas in Elkhorn Slough function as a nursery and/or spawning area for various economically important fishes. Factors responsible for this utilization may include high primary and secondary production, beneficial temperature and salinity regimes, and relatively low predation pressure due to high turbidity and/or low predator densities.

INTRODUCTION

Numerous studies have evaluated the role of estuaries and shallow areas as nursery and/or spawning grounds for fishes (Gunter, 1938; McErlean, et al., 1973; Pearcy and Myers, 1974; Carr and Giesel, 1975; Darnell and Soniat, 1979; and others). Many of these fishes are important to commercial and sport fisheries on the west coast (Misitano, 1977; Laroche and Holton, 1979) and other areas (McHugh, 1966; Carr and Adams, 1973; Bozeman and Dean, 1980). Within most estuaries and bays, tidal creeks and intertidal marshes appear to be utilized by many economically important fishes (Shenker and Dean, 1979; Bozeman and Dean, 1980). However, few studies of these habitats have been conducted, particularly on the west coast of North America. Quantitative studies of the fish fauna in tidal creeks have begun only in the past decade or so. The development of various techniques for sampling these areas more quantitatively (Lewis, et al., 1970; Weinstein and Davis, 1980) has greatly aided this work.

This study concerns the extent to which tidal creeks and other shallow areas of Elkhorn Slough are utilized by economically important fishes.

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METHODS

This study was conducted in Elkhorn Slough, California, a shallow coastal embayment covering an area of approximately 2,500 acres (Figure 1). This slough has a narrow main channel extending inland about 11 km and is surrounded by about 1,440 acres of salt marsh, dominated by Salicornia virginicus (Browning, 1972). The slough is flushed by semi-diurnal mixed tides with a maximum range greater than 2 m. A tidal prism is present 4-5 km up the axis of the slough, above which water residence time is long (> 300 days; Smith, 1973). Temperature and salinity vary seasonally, with the lower slough approaching oceanic values while the upper slough is hypersaline (~ $40^0/_{00}$) and warm (~ 25^0C) in summer and hyposaline (~ $21\text{-}30^0/_{00}$) and cool ($10\text{-}15^0$C) during periods of heavy winter runoff (Nybakken, et al., 1977).

Three locations were sampled from October 1978 through May 1980. Stations 1 and 2 were tidal and intertidal creeks and marshes below or at the tidal prism, and station 3 was located at the extreme inland reaches of Elkhorn Slough.

A variety of collection techniques was employed during the study period. All locations were sampled at least monthly using an otter trawl with a 4.3-m headrope, 18-m bridles and a 1.3-cm mesh cod-end liner. The trawl was towed a fixed distance through the site behind a 4.9-m Boston whaler. Physical and environmental factors such as temperature, salinity, tidal height and weather conditions were recorded during each collection. Intertidal creeks and marshes were sampled periodically with channel nets similar to those used by Bozeman and Dean (1980) and block nets and beach seines as used by Weinstein and Davis (1980).

Fishes collected were identified, measured and either released or preserved for further study. Stomach content analysis was performed on the nine commercially important species, which were defined as those which comprised greater than 0.5% of the total catch and had value to California commercial fisheries of more than $10,000 in 1976 (Oliphant, 1979). Fishes so analyzed were measured, weighed and dissected, gonads were removed and sex was determined. The digestive tract was removed and the contents emptied into a dish. Stomach fullness and state of digestion were ranked on a scale of 0 to 4, as per DeWitt and Cailliet (1972). Each item was identified to the lowest possible taxon and the total number of items in each category was summed. The relative volume of each prey category was estimated so that the total of all items equaled 100 percent.

RESULTS

During the 20-month study of the tidal creek and upper slough locations, 8,725 fish from 200 samples were collected, comprising 38 species from sl families. Nine of 38 species and more than 29% of the total catch consisted of fishes directly important to commercial fisheries. These species were, in order of abundance, Engraulis mordax (northern anchovy), Clupea pallasi (Pacific herring), Cymatogaster aggregata (shiner surfperch), Platichthys stellatus (starry flounder), Embiotoca jacksoni (black surfperch), Triakis semifasciata (leopard shark), Paralichthys californicus (California halibut), Myliobatis californica (bat ray) and Parophrys vetulus (English sole). Of these fishes, E. mordax and C. pallasi comprised over 70% of the total number of individuals (Table 1).

Most of the species occurred in the samples primarily as juveniles, though individuals of some species were present as reproductively active adults (Table 2). Few adult northern anchovy were seen during the study. Adult Pacific herring were captured in Elkhorn Slough during late fall and winter months, when they entered to spawn in shallow slough areas. Both embiotocids were present as adults in tidal creeks. Pregnant female shiner perch were common in spring of 1980. Leopard sharks were common during certain times of the year, although few adults were captured in this study.

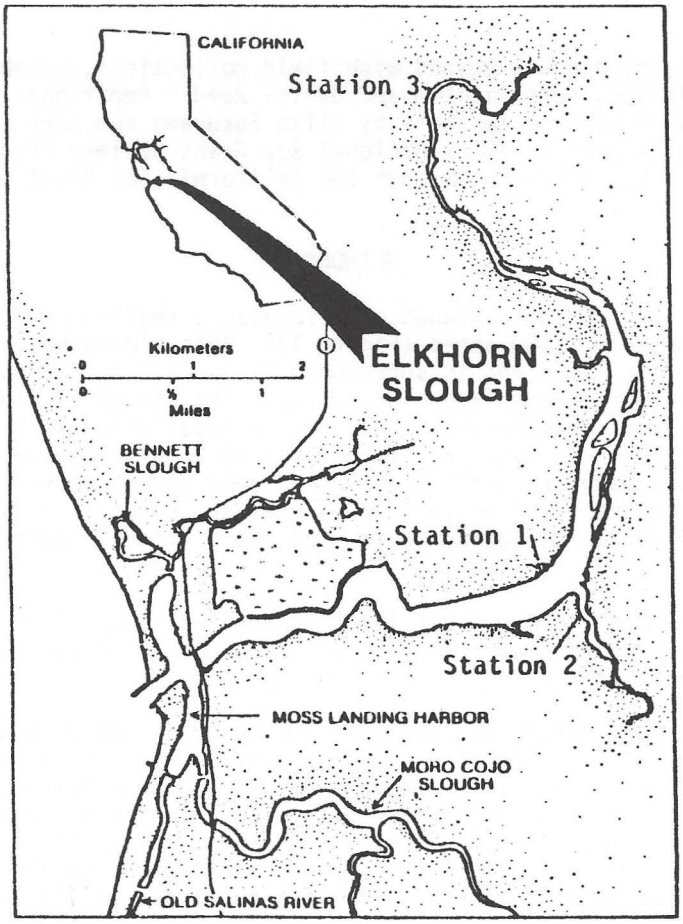

Figure 1. Map of Elkhorn Slough locating collection sites.

Table 1. The abundance of commercially important fishes in shallow marsh habitats of Elkhorn slough and their value in California fisheries (1976).

Species	No. Collected	% of Total	Commercial Value ($1000s)
Engraulis mordax	1221	14.0	4627
Clupea pallasi	637	7.3	482
Cymatogaster aggregata	265	3.0	57*
Platichthys stellatus	124	1.4	155
Embiotoca jacksoni	113	1.3	57*
Triakis semifasciata	79	0.9	205**
Paralichthys californicus	75	0.9	536
Myliobatis californica	60	0.7	13***
Parophrys vetulus	49	0.6	873

* Value of commercial catch of all Embiotocidae.
** Value of commercial catch of members of Alopiidae, Carcharhinidae (previously included Triakidae), Lamnidae, Squalidae.
***Value of commercial catch of members of Rhinobatidae, Rajidae, Myliobatidae, Myliobatis forms a small portion of this total.

Table 2. The habits, life stages and seasonality of commercially important fishes from shallow marsh habitats in Elkhorn Slough.

Species	Life Stages, Habits	Seasonality
Engraulis mordax	trans. juv.	spring - summer
Clupea pallasi	trans. juv., breeding adult	winter - spring
Cymatogaster aggregata	trans. juv., breeding adult	spring - summer
Platichthys stellatus	trans. juv.	spring, year-round
Embiotoca jacksoni	resident	year-round
Triakis semifasciata	trans. juv., breeding adult?	spring - summer
Paralichthys californicus	trans. juv.	spring, year-round
Myliobatis californicus	trans. juv., breeding adult?	summer
Parophrys vetulus	trans. juv.	spring

Most species exhibited seasonal patterns of occupation and were most abundant during spring and summer. Figure 2 shows a seasonal pattern characteristic of many of these species. Juvenile northern anchovy appear in the samples in early spring of both years and perisisted through the summer of 1979. Pacific herring recruits were abundant only during late winter and spring. Shiner surfperch were most abundant during spring and early summer. Black surfperch were most abundant during spring and early summer. Black surfperch were present year-round, but unlike most other species, were most abundant in the fall and were never captured at station 3. Though most of the embiotocids captured were adults, juveniles were present in late spring and early summer. Starry flounder were present during most months of the year, mostly as juveniles from 13 to 20 cm, with peak abundances in late winter and spring. Likewise, young California halibut were present year-round, with peaks in late winter and spring. Juvenile elasmobranchs (bat ray, leopard shark) were most abundant during spring and summer.

In addition to the above-mentioned species, many forage fishes (i.e., topsmelt, gobies, staghorn sculpin) secondarily important to commercial fisheries utilized tidal creeks and shallow areas of Elkhorn Slough to a great extent. Many of these species also exhibited similar patterns of distribution and abundance as those discussed above.

Analysis of the stomach contents revealed a wide variety of prey types fed upon by these nine species of commercially important fishes. The dominant prey categories included zooplankton, epifaunal crustecea, infaunal worms and molluscs, and larger mobile crustacea and fishes. Plant material and detritus constituted a small portion of the diet of most species, but was much less important overall than the above prey types (Table 3).

Five basic types of feeding modes were used by these fishes. The California halibut and leopard shark both fed predominantly on relatively large mobile fauna, such as small fishes, shrimps and crabs (Figure 3). The northern anchovy and Pacific herring were water column feeders and/or epibenthic packers, feeding mainly on items such as calanoid and harpacticoid copepods (Figure 4). The starry flounder and bat ray were grovelers, feeding primarily on infaunal worms and molluscs (Figure 5). Both embiotocids fed as epibenthic pickers on isopods and amphipods (Figure 6). The English sole fed on a wide variety of prey, as an epibenthic picker or groveler.

Stomach fullness was high, averaging more than 62% full for all species; few individuals had empty stomachs (5.7%). Most individuals of most species had food items in their stomachs. Embiotocids, which were present predominantly as adults, had the greatest proportion of empty stomachs (25%).

Table 3. A summary of the feeding habits of commercially important fishes in shallow marsh habitats of Elkhorn Slough.

Species	Feeding Mode	Prey Types
Leptocottus armatus	picker / groveler	amphipods, worms
Engraulis mordax	water column	calanoid, harpacticoid copepods
Clupea pallasii	water column	calanoid, harpacticoid copepods
Cymatogaster aggregata	picker	isopods, amphipods
Platichthys stellatus	groveler	worms, amphipods
Embiotoca jacksoni	picker	isopods, amphipods
Triakis semifasciata	active predator	crabs
Paralichthys californicus	active predator	fish
Myliobatis californica	groveler	molluscs
Parophrys vetulus	picker / groveler	worms, amphipods

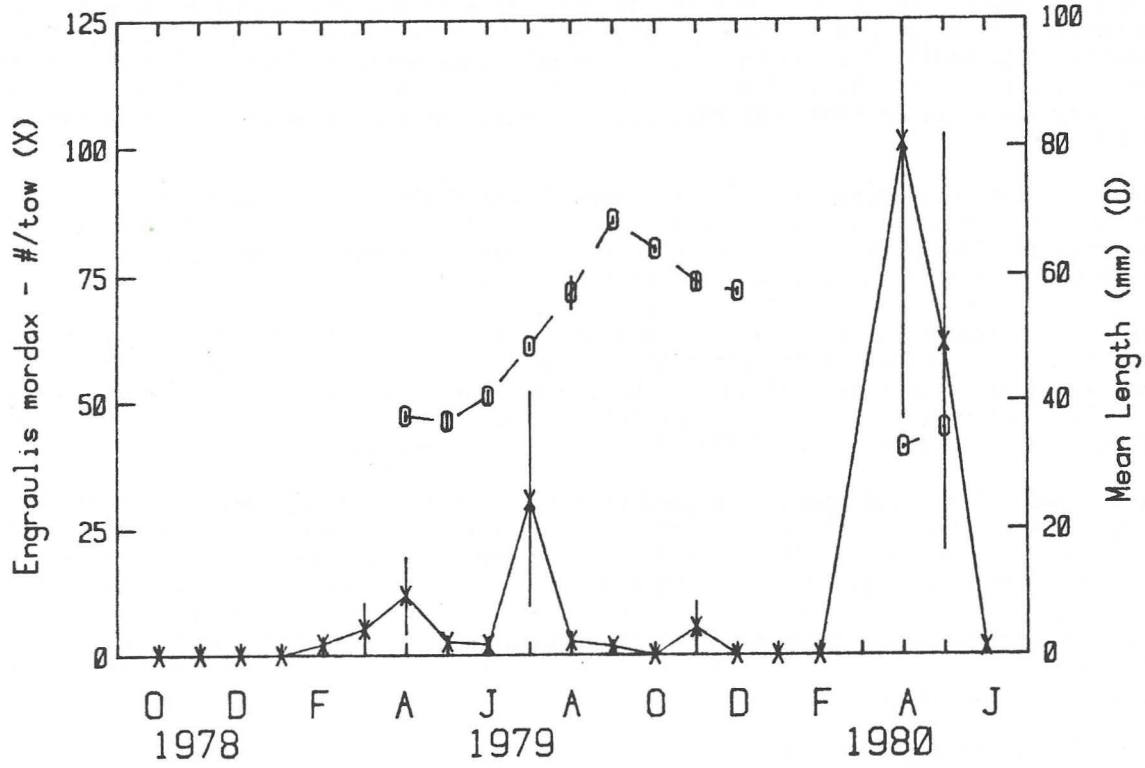

Figure 2. Monthly variation in number / 10min.tow and mean size of a seasonal transient fish species in shallow marsh habitats of Elkhorn Slough. Bars indicate standard errors. X = mean number / tow. O = mean size.

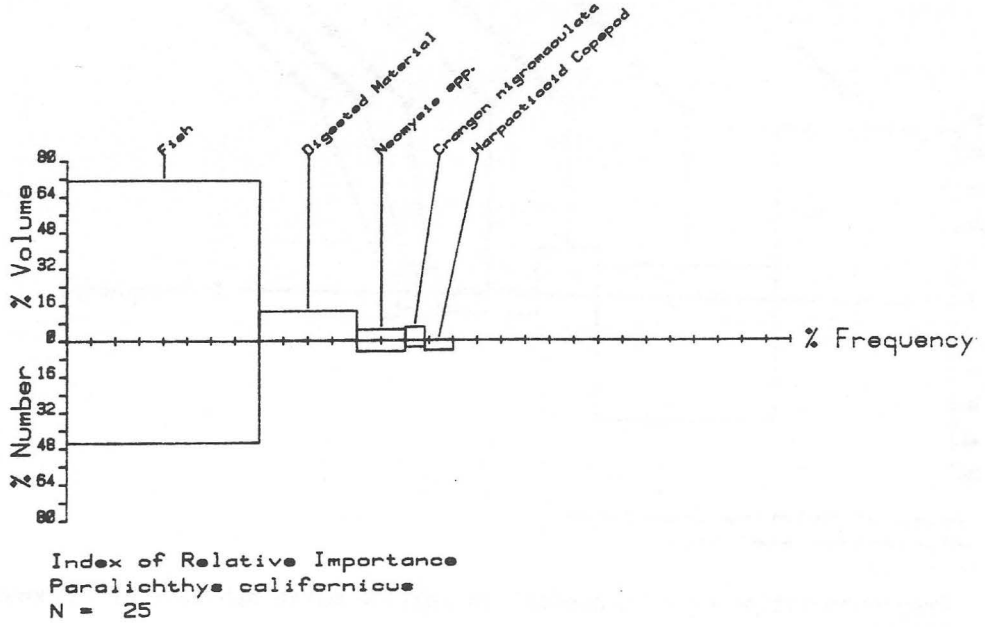

Figure 3. Prey composition of an "active predator" in shallow marsh habitats of Elkhorn Slough.

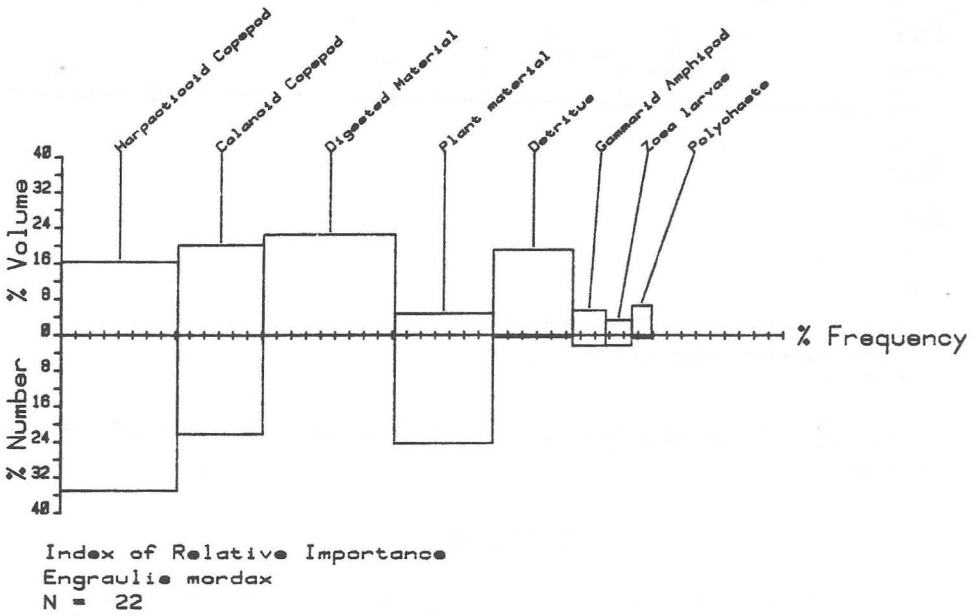

Figure 4. Prey composition of a "water column" feeder in shallow marsh habitats of Elkhorn Slough.

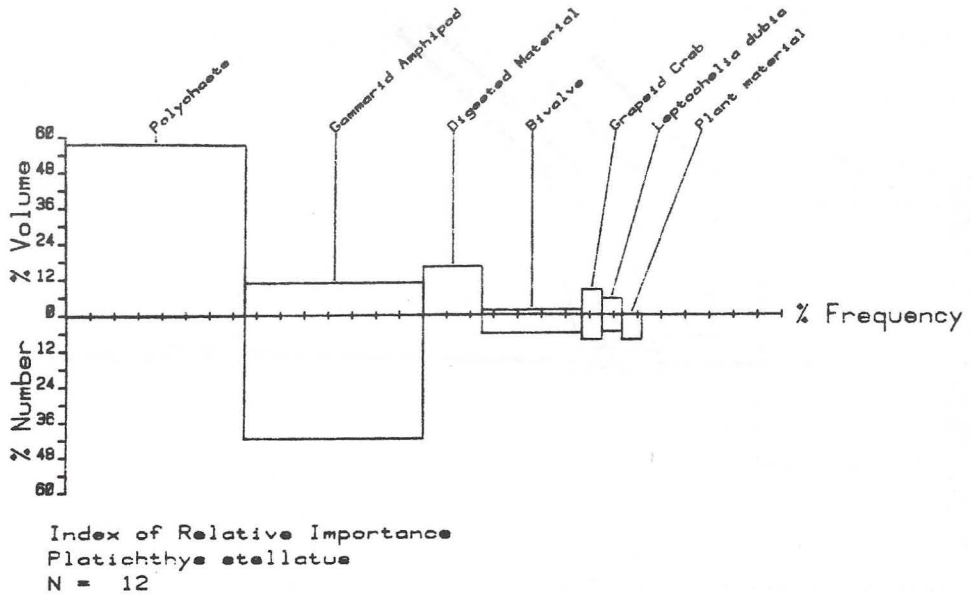

Figure 5. Prey composition of a "groveler" in shallow marsh habitats of Elkhorn Slough.

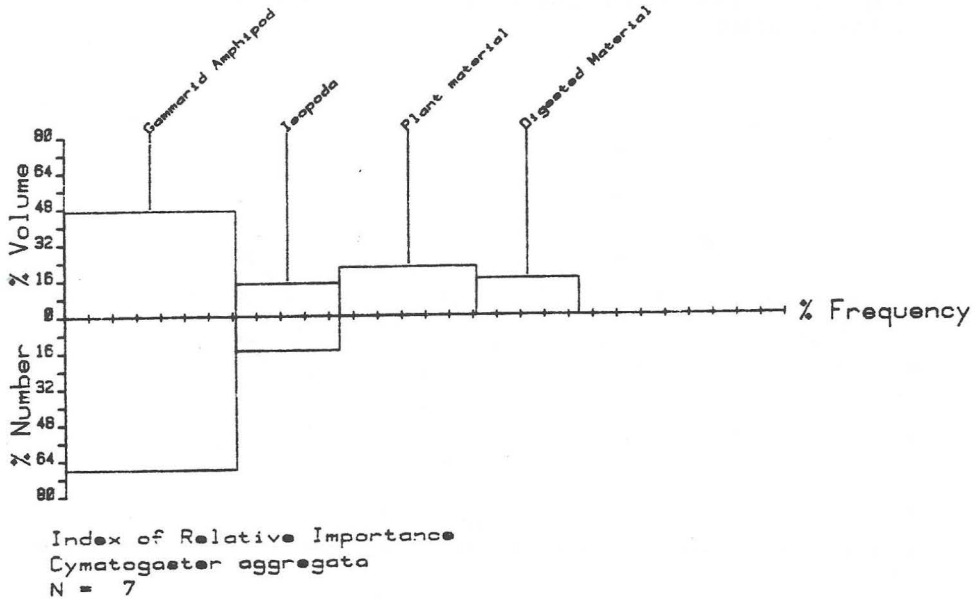

Figure 6. Prey composition of a "picker" in shallow marsh habitats of Elkhorn Slough.

DISCUSSION

Tidal creeks and shallow marsh habitats in Elkhorn Slough are utilized by a significant number of economically important fish species. At least nine such species, comprising more that 29% of the individuals of all species captured in this study, use such areas. The northern anchovy and Pacific herring accounted for over 70% of this catch. These two fishes exhibited seasonal patterns of utilization with density peaks during spring and summer when young fishes were born in, or entered, the area for a short time. Similar patterns have been shown in other temperate west coast bays and estuaries. In an intertidal creek of San Francisco Bay, northern anchovy and Pacific herring ranked 7th and 4th, respectively

for 26 species, with the highest densities in March through May (Wild, 1969). In Yaquina Bay (Pearcy and Myers, 1974), Richardson Bay (Green, 1975), the Columbia River estuary (Misitano, 1977), Humboldt Bay (Gotshall, et al., 1980) and Morro Bay (Fierstine, et al., 1973), these fishes were present as larvae or juveniles with seasonal peaks of abundance. Further south in upper Newport Bay (Allen, ms) and Colorado Lagoon (Allen and Horn, 1975), Pacific herring were absent and northern anchovy were abundant only during summer months. Other commercially important fishes from this study have been recorded by various workers in bays and estuaries along the eastern Pacific coast and are generally most abundant in spring and summer (Wild, 1969; Anderson and Chew, 1972; Fierstine, et al., 1973; Hardwick, 1973; Allen and Horn, 1975; deWit, 1975; Misitano, 1977; Nybakken, et al., 1977). Sampling bias presents a problem in any analysis of community structure, in that all species may differ in their susceptibility to various types of collecting gear. Furthermore, these biases may vary with season, location and life stage (Allen, et al., 1960; Kjelson and Johnson, 1978; Weinstein and Davis, 1980). Avoidance and extrusion are noteworthy for many species in this study. Large active fishes (leopard shark, adult herring) probably avoid towed nets effectively, while juveniles (Pacific herring, northern anchovy) and less active species (California halibut, starry flounder, English sole) are less apt to avoid capture. Extrusion is high for small fishes such as juveniles of Pacific herring, staghorn sculpin and northern anchovy. Consequently, many of these species, particularly juveniles of the three dominant fishes, may be even more abundant than catch records indicate.

Studies of fish fauna from shallow inshore areas around the world have emphasized the importance of these areas as a nursery ground for a variety of fish species (Gunter, 1938; Hardwick, 1973; Pearcy and Myers, 1974; Carr and Geisel, 1975; McErlean, et al., 1977; Weinstein, 1979; Blaber and Blaber, 1980). Many commercially important fishes are dependent upon estuarine and shallow inshore areas at some life stage (McHugh, 1966). In Elkhorn Slough's tidal creeks, the nine species listed above are present, primarily as juveniles during various times of the year, with the greatest densities in spring and summer. This seasonal utilization pattern closely reflects the reproductive habits of each species. Some species spawn or bear young in the slough, while others spawn offshore with an inshore migration of recruits. Although these data indicate a nursery function of shallow marsh habitats in Elkhorn Slough to some commercially important fishes, notably, Pacific herring and northern anchovy, the dependence of fishes on these areas as nursery grounds still needs further study.

Physical and biological controls of macrofaunal distribution and abundance have been implicated in various studies. Salinity and/or temperature have been correlated with the structure of fish assemblages in estuaries and bays (Haertel and Osterberg, 1967; Allen and Horn, 1975; Subrahmanyam and Drake, 1975; Hoff and Ibara, 1977; and others) and in shallow marsh habitats (Hackney, et al., 1976; Allen, ms). Weinstein (1979) found that, in addition to salinity, fishes were distributed according to substratum preference. Shenker and Dean (1980) feel that fishes move toward intertidal creeks because they are energy-rich and relatively predator-free. Likewise, Blaber and Blaber (1980) feel that shallow, turbid areas are sought, perhaps due to abundant food and reduced predation. In shallow marsh habitats of Elkhorn Slough, many of these factors may regulate fish distribution.

Temperature and/or salinity were significantly correlated with the abundance of many of the commercially important fishes. Although there is a paucity of data concerning the abundance of food for fishes in such remote areas of Elkhorn Slough, food does not appear to be limited and may be plentiful. Data from other areas of Elkhorn Slough show that zooplankton and benthic faunal densities, even though variable and spatially and seasonally unpredictable, are high (Nybakken, et al., 1977). In addition to the apparent high food availability, predation appears to be low. Piscivorous predators are present (California halibut, leopard shark, striped bass, shorebirds), but limited in number of species and individuals.

Thus, it appears that transient juvenile fishes such as the northern anchovy, the Pacific herring and the starry flounder and others are born and remain in, or move into, shallow marsh habitats in Elkhorn Slough for a variety of reasons, both biological and physical. High primary and secondary production, beneficial water quality characteristics, low predation pressure and other, perhaps uninvestigated factors, may enhance the acceptability of these areas for juvenile fish production.

Estimates of the relative importance of shallow marsh habitats in Elkhorn Slough to the production of commercially important nearshore fish stocks are difficult to assess, although it appears that such areas function as an important nursery and/or spawning area for a number of economically important fishes.

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