Differential habitat use by California halibut, *Paralichthys californicus,* barred sand bass, *Paralabrax nebulifer*, and other juvenile fishes in Alamitos Bay, California

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Abstract.–Economically valuable California halibut, *Paralichthys californicus*, and barred sand bass, *Paralabrax nebulifer*, along with other fishes, are often abundant in the shallow areas of California bays during their early life history. However, little is known about their habitat use within these areas. We investigated habitat use of juvenile fishes in the shallow waters of an embayment by towing a 1.6-m beam trawl with 3-mm mesh through eelgrass beds (*Zostera marina*) and unvegetated areas at depths ≤1.1 m in Alamitos Bay. Tows were conducted monthly or bimonthly from May 1992 through November 1995. A total of 435 tows during 31 months yielded 52,787 fishes comprising 46 species. However, the catch was dominated by only a few species and consisted mostly of juveniles and gobiid larvae. A total of 1157 California halibut and 225 barred sand bass were collected. California halibut were 2–6 times more abundant in unvegetated areas than in eelgrass beds, whereas barred sand bass were captured almost exclusively in eelgrass. Abundance of both species significantly decreased as distance from the bay mouth increased. Abundances of most other fishes also varied considerably between habitats and among sites. In contrast to California halibut and barred sand bass, abundances of other species were higher at sites farther inside the bay. Variations in water temperature, dissolved oxygen, salinity, eelgrass shoot density, and eelgrass blade length failed to explain differences in abundance for most fishes. Habitat and site selection for juvenile California halibut and barred sand bass may be related to larval supply and to the first suitable area encountered, but may be modified subsequently by movement into other areas in search of preferred food items.

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It is widely recognized that bays and estuaries are important nursery grounds for many marine species. Within these areas, numerous studies have documented the importance of eelgrass, *Zostera marina*, and other seagrasses as habitat for fishes. The composition and abundance of fishes in these habitats can vary considerably from unvegetated areas (Orth and Heck, 1980; Borton, 1982; reviewed in Orth et al., 1984; Heck et al., 1989; Ferrell and Bell, 1991; Sogard and Able, 1991). Seagrass habitats may be important because of their associated food resources or because they provide a refuge from predation (Adams, 1976; Heck and Thoman, 1981; reviewed in Orth et al., 1984; Leber, 1985; Sogard and Olla, 1993).

The association of fishes with seagrass beds has been related to various physical characteristics of seagrass, such as shoot density, blade length, and biomass (Adams, 1976; Orth and Heck, 1980; reviewed in Orth et al., 1984; Bell and Westoby, 1986a). However, evidence suggests that physical characteristics of seagrasses may only affect fish abundances on a local scale such as within a seagrass bed, but not over larger scales such as different beds within a bay (Bell and Westoby, 1986b; Bell et al., 1988; Sogard, 1989; Worthington et al., 1992). Instead, it has been suggested that differing fish abundances in seagrass beds across an estuary are due to availability of competent larvae; pelagic larvae of some seagrass fishes settle indiscriminately in the first seagrass bed encountered regardless of seagrass physical characteristics (Bell and Westoby, 1986b; Bell et al., 1987, 1988). According to this "settle and stay" hypothesis, once within a seagrass bed, fishes would move around selecting microsites but would not leave the seagrass bed because of greater predation risks associated with moving over unvegetated substrata. However, others have found that initial settlement patterns in habitats may be altered considerably by postsettlement mortality (Levin, 1994), migration to other areas (Sogard, 1989), or by both in response to available food (Jenkins et al., 1996).

Much of the work on seagrasses and associated fishes has taken place on the east coast of the United States or in other parts of the world. Although several studies have described the ichthyofauna of southern California bays (Allen and Horn, 1975; Horn and Allen, 1976; Allen, 1982; Allen and Herbinson, 1991), few studies have described the relation of fishes with eelgrass and other habitats. Understanding these relationships within bays is particularly important owing to the destruction and severe alteration of about 75% of coastal estuary and wetland habitats in southern California since 1900 (California Coastal Zone Conservation Commissions, 1975). Reduced catches of California halibut, *Paralichthys californicus*, may be due to the alteration or loss of this nursery habitat within bays and estuaries, or to both (Plummer et al., 1983; Kramer and Sunada, 1992; Kramer and Hunter[1]).

California halibut is an important commercial and sport fish in southern and central California. Barred sand bass, *Paralabrax nebulifer*, is also an important sport fish in southern California and ranks annually among the top three species caught aboard commercial passenger fishing vessels (Love et al., 1996a). Both of these fishes spawn in nearshore waters (Frey, 1971; Ono, 1992) and occupy embayments during their early life history; newly settled and larger juvenile California halibut are frequently found over shallow, sandy substrata (Haaker, 1975; Allen, 1988; Allen and Herbinson, 1990, 1991; Kramer, 1990, 1991a, 1991b), whereas juvenile barred sand bass are found in eelgrass beds (Feder et al., 1974; Rosales-Casián, 1997). However, little additional information is available on habitat use by these and other fishes within these areas.

Therefore, the purpose of our study was to determine 1) if abundances of juvenile California halibut, barred sand bass, and other fishes differed between eelgrass and unvegetated habitats, 2) whether these abundances differed among sites within the bay, and 3) whether these differences were related to physical characteristics of eelgrass or abiotic factors. We examined habitat use by collecting fishes with a beam trawl towed in shallow eelgrass beds and nearby unvegetated areas at three sites within a single bay. A beam trawl was used because it collects smaller halibut and other flatfishes more effectively than beach seines and otter trawls (Gunderson and Ellis, 1986; Kramer, 1990; Kuipers et al., 1992) and allows comparison with other studies where similar gear was used.

Materials and methods

Study area and sampling

Our study was conducted in Alamitos Bay (lat. 33°45'N, long. 118°07'W), which is a small embayment located at the southeastern boundary of Los Angeles County in southern California. Alamitos Bay was once an estuary of tidal marshes and mud flats. It has been considerably modified by dredging, filling, and construction of homes, marinas, and two jetties that mark the entrance. The bay is exposed to semidiurnal tides with a mean range of 1.1 m. Water circulation is further enhanced by large amounts of water drawn by two power stations that flush the bay every 19 hours (Phillips[2]). Regardless of tidal flux, there is a consistent flow of water into the bay (Brown and Caldwell[3]).

Sampling was conducted at three sites (Bay Entrance, Belmont Shore, and Marine Stadium) separated by at least one km (Fig. 1). At each site, sampling occurred in two habitats, eelgrass (*Zostera marina*) beds and nearby unvegetated sandy-mud areas located about 40 m away. A weighted 1.6-m beam trawl, equipped with skis, tickler chain, and 3.0-mm stretched-mesh netting, was towed parallel to shore by two people on foot at low tide during the lowest tides of the month. Tows were made during daylight hours at depths from 0.3 m to 1.1 m, lasted 90 seconds, and covered approximately 56 m^2. We completed 2–5 tows, depending on tide height, in each habitat at each site over four consecutive days. Sampling was conducted monthly from May 1992 through April 1993 (excluding February) and from November 1993 through December 1994. Bimonthly sampling occurred from January 1995 through November 1995. All fishes were sorted, identified, counted, and returned to the water. Most fishes were measured to the nearest mm standard length (SL) from May 1992 through October 1994, whereas California halibut and barred sand bass were measured throughout the study. Although California halibut and barred sand bass undergo transformation at about 7–9 mm SL and 11 mm SL, respectively (Butler et al., 1982; Ahlstrom et al., 1984; Gadomski et al., 1990), all individuals ≤20 mm SL were considered to be “newly settled” or “newly recruited” (Allen and Herbinson, 1990; Kramer, 1990; Love et al., 1996b). Larval and postlarval gobies (Brothers, 1975) that were not identified further were classified as “goby larvae.” Other fishes not sexually mature based on size at first maturity information were considered to be juveniles. Water temperature, dissolved oxygen, and salinity data were collected for most tows,

[1] Kramer, S. H., and J. R. Hunter. 1987. Southern California wetland/shallow water habitat investigation. Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038. Ann. Rep. for Fiscal Year 1987, 12 p.

[2] Phillips, K. W. 1978. A water and sediment study of Alamitos Bay correlated with peak and minimal recreational aquatic activities. City of Long Beach Chemical and Physical Testing Laboratory, Long Beach, California. Unpubl. data.

[3] Brown and Caldwell Environmental Sciences Division. 1979. Embayment ecology studies: physical oceanographic and water quality data report. Southern California Edison. Unpubl. data.

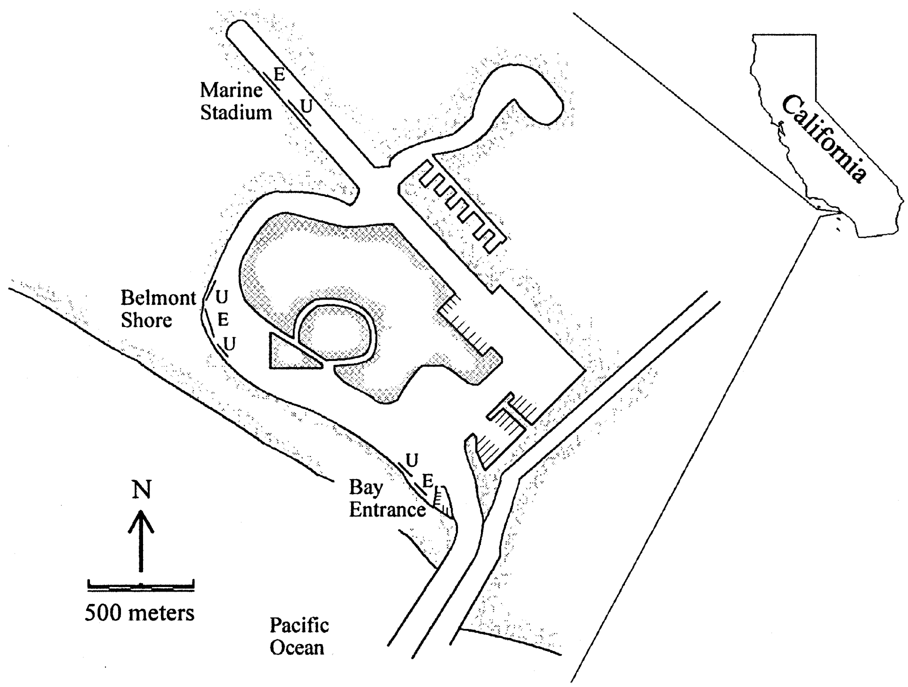

Figure 1

Location of sampling sites (Bay Entrance, Belmont Shore, and Marine Stadium) in Alamitos Bay, California. U=unvegetated habitats, E=eelgrass habitats.

except during September 1994 through December 1994, when dissolved oxygen values were not taken owing to equipment failure. Bottom water temperature and dissolved oxygen were recorded with a YSI Model 51B oxygen meter. Surface salinity was measured with a temperature-compensated refractometer.

Eelgrass bed length, bed width, shoot density, and blade lengths were measured by two divers using SCUBA. A 300-m transect tape was laid out in the center of the bed along its longest axis. Width was measured perpendicular to the tape at three equidistant points. Divers sampled 1/16 m^2 quadrats in the bed at predetermined random points perpendicular to the tape. Within each quadrat, all shoots were counted and the lengths of two randomly selected blades were measured. A total of 10–20 quadrats were sampled at each site during August 1992, March 1993, December 1993, and December 1995.

Data analysis

Nonparametric statistics were used because data and their transformations were heteroscedastic and not normally distributed. A nonparametric two-factor analysis of variance (ANOVA) on ranked data (Zar, 1984) was performed separately on the number of California halibut, barred sand bass, and 13 other common fishes captured per tow with habitat and site as factors. If significant main effects with no significant interactions were found, Tukey-Kramer multiple comparisons were performed to determine which pairs of means were significantly different. The results were considered significant if P was <0.05. If significant interactions between habitat and site were found, analyses of main effects were considered dubious and subsets of data were formed for each level of one factor within each level of the other factor and *vice-versa* (Underwood, 1981). Kruskal-Wallis and Dunn multiple comparisons (Hollander and Wolfe, 1973) were performed on these subsets. For example, a Kruskal-Wallis test was used to determine if there was an overall difference in abundance among sites for unvegetated habitats, and then for eelgrass habitats. If a significant difference was found, Dunn multiple comparisons were made to determine which pairs of sites were significantly different. For fishes other than California halibut and barred sand bass, comparisons among sites were made only for the habitat where they were most abundant overall. Abundance differences between habitats were determined by a Wilcoxon two-sample test on unvegetated and eelgrass habitat data within each site.

Two-sample Kolmogorov-Smirnov tests were used to compare length-frequency distributions between

Table 1

Physical characteristics of eelgrass (*Zostera marina*) at three sites in Alamitos Bay. Data were collected in August 1992, March 1993, December 1993, and December 1995. Values represent mean ± one standard error. Sample sizes for bed length and width measurements were 4 and 12, respectively. Sample sizes for density: Bay Entrance=79, Belmont Shore=70, and Marine Stadium=80. Sample sizes for blade length: Bay Entrance=154, Belmont Shore=138, and Marine Stadium=155.

Site	Bed length (m)	Bed width (m)	Density (no. shoots per quadrat)	Blade length (cm)
Bay Entrance	82.9 ± 18.6	16.3 ± 2.9	10.1 ± 0.5	68.3 ± 2.2
Belmont Shore	102.9 ± 2.5	8.8 ± 0.3	7.9 ± 0.5	37.2 ± 1.5
Marine Stadium	54.1 ± 5.9	15.8 ± 1.3	10.6 ± 0.7	47.9 ± 1.9

habitats and sites for California halibut and barred sand bass. Subsets of these data (see above) were used in these analyses.

Kruskal-Wallis and Dunn multiple comparisons were also made on the mean number of eelgrass shoots and mean blade length per quadrat to determine differences in these eelgrass characteristics among the three sites. Water temperature, dissolved oxygen, and salinity values for each tow were used in a two-way nonparametric ANOVA to test for differences in each of these abiotic factors between habitats and among sites.

Results

Eelgrass characteristics and abiotic factors

Physical characteristics of eelgrass beds at the three sites were very different. Belmont Shore had the longest bed but mean bed width, eelgrass shoot density, and eelgrass blade length were lowest (Table 1). Eelgrass densities at Bay Entrance and Marine Stadium were significantly greater than at Belmont Shore ($P<0.05$), and all blade length comparisons among sites were significantly different ($P<0.05$).

Abiotic factors varied temporally but showed little spatial variation. Mean monthly values ranged from 14.5 to 23.0°C for water temperature, 4.8–8.1 mg/L for dissolved oxygen, and 23.2–36.0 ppt for salinity. These abiotic factors were very similar between habitats and among sites except for slightly lower dissolved oxygen in eelgrass and higher water temperatures at Marine Stadium. However, none of these abiotic factors were significantly different between habitats or among sites ($P>0.05$).

Fish community

A total of 52,787 fish representing 46 species was collected from 435 tows (Table 2). The catch was dominated by a few species that were often captured in large numbers.

Numbers of species varied among habitats and sites. Many more species were captured in eelgrass beds (n=42) than in unvegetated areas (n=26). We collected 19 species exclusively in eelgrass beds but captured only three species solely in unvegetated areas (Table 2). Species numbers decreased as distance from the bay mouth increased; more species were collected at Bay Entrance (n=40) than at Belmont Shore (n=35) and Marine Stadium (n=28).

California halibut

California halibut ranked eighth in abundance; 1157 individuals were collected from 50.8% of the tows (Table 2). The number of California halibut captured per tow ranged from 0 to 81 with a mean of 2.7 ± 0.32 SE. The abundance of newly settled California halibut was greatest from March through May (Fig. 2). A total of 325 newly settled California halibut was captured. For all sites and habitats combined, maximum mean density per month of newly settled individuals was 15/100 m^2 (May 1995). Maximum mean density per month at an individual site and habitat was 81/100 m^2 (May 1995, Bay Entrance unvegetated area).

California halibut abundance varied considerably among habitats and sites (Fig. 3A). The magnitude of these differences depended upon the habitat and site as indicated by a significant interaction term in the two-way ANOVA (P=0.002). Abundance was significantly different between habitats at all three sites, for all three site comparisons in unvegetated areas, and for two of three comparisons in eelgrass beds (Table 3). Within sites, Marine Stadium and Belmont Shore unvegetated areas contained about 2–3 times as many California halibut as eelgrass beds, and Bay Entrance unvegetated area had more than six times as many California halibut as nearby eelgrass (Fig. 3A). Within both habitats, California

Table 2

Total number of fishes captured by habitat type and frequency of occurrence in Alamitos Bay, California, from May 1992 through November 1995.

Common name	Scientific name	Unvegetated habitat *n*=251	Eelgrass habitat *n*=184	Total number captured	Frequency of occurrence (%) *n*=435
Goby larvae	unidentified Gobiidae	6491	10336	16827	57.7
Cheekspot goby	*Ilypnus gilberti*	8836	1009	9845	74.9
Bay pipefish	*Syngnathus leptorhynchus*	70	8203	8273	49.0
Shiner perch	*Cymatogaster aggregata*	5	4121	4126	23.2
Topsmelt	*Atherinops affinis*	2463	1163	3626	33.1
Giant kelpfish	*Heterostichus rostratus*	9	2454	2463	36.8
Arrow goby	*Clevelandia ios*	1216	840	2056	18.6
California halibut	*Paralichthys californicus*	1024	133	1157	50.8
Queenfish	*Seriphus politus*	662	253	915	13.1
Diamond turbot	*Hypsopsetta guttulata*	625	53	678	37.9
Spotted kelpfish	*Gibbonsia elegans*	1	478	479	19.3
Shadow goby	*Quietula y-cauda*	20	394	414	12.9
Pacific staghorn sculpin	*Leptocottus armatus*	241	129	370	37.0
Bay blenny	*Hypsoblennius gentilis*	3	326	329	20.5
Barred sand bass	*Paralabrax nebulifer*	4	221	225	12.4
Salema	*Xenistius californiensis*	0	180	180	4.6
California killifish	*Fundulus parvipinnis*	42	128	170	8.5
Black perch	*Embiotoca jacksoni*	0	86	86	5.3
Sargo	*Anisotremus davidsonii*	0	86	86	3.7
Spotted turbot	*Pleuronichthys ritteri*	54	12	66	8.7
Kelp bass	*Paralabrax clathratus*	0	56	56	6.7
Snubnose pipefish	*Cosmocampus arctus*	2	46	48	7.4
California clingfish	*Gobiesox rhessodon*	4	41	45	5.1
Black croaker	*Cheilotrema saturnum*	0	42	42	4.4
Mussel blenny	*Hypsoblennius jenkinsi*	7	35	42	3.9
Spotted sand bass	*Paralabrax maculatofasciatus*	0	38	38	4.6
Reef finspot	*Paraclinus integripinnis*	0	30	30	3.2
Dwarf surfperch	*Micrometrus minimus*	0	28	28	2.5
Yellowfin goby	*Acanthogobius flavimanus*	8	8	16	2.8
Mozambique tilapia	*Tilapia mossambica*	0	14	14	2.1
Blenny larvae	*Hypsoblennius* spp.	0	9	9	1.2
California tonguefish	*Symphurus atricauda*	3	5	8	1.4
California scorpionfish	*Scorpaena guttata*	0	6	6	1.2
Senorita	*Oxyjulis californica*	0	4	4	0.9
White seabass	*Atractoscion nobilis*	1	3	4	0.7
Bonefish	*Albula vulpes*	2	2	4	0.5
Unidentified larvae	unidentified Teleosti	4	0	4	0.5
Opaleye	*Girella nigricans*	0	3	3	0.7
Rockpool blenny	*Hypsoblennius gilberti*	0	3	3	0.2
Pacific sardine	*Sardinops sagax*	2	0	2	0.5
Pile perch	*Rhacochilus vacca*	0	2	2	0.5
Anchovy larva	unidentified Engraulidae	1	0	1	0.2
Chocolate pipefish	*Syngnathus euchrous*	0	1	1	0.2
Hornyhead turbot	*Pleuronichthys verticalis*	0	1	1	0.2
Longjaw mudsucker	*Gillichthys mirabilis*	0	1	1	0.2
Pacific barracuda	*Sphyraena argentea*	1	0	1	0.2
Rock wrasse	*Halichoeres semicinctus*	0	1	1	0.2
Striped mullet	*Mugil cephalus*	1	0	1	0.2
White seaperch	*Phanerodon furcatus*	0	1	1	0.2

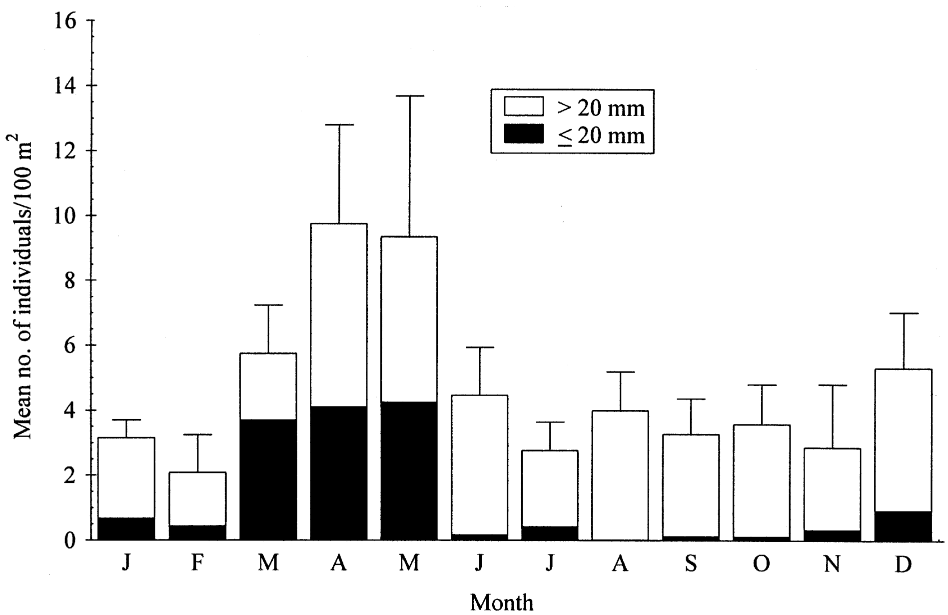

Figure 2

Mean number per 100 m^2 of newly settled (≤20 mm SL) and larger California halibut (*Paralichthys californicus*) captured by month in Alamitos Bay from May 1992 through November 1995 (n=435 tows). Error bars represent + one standard error for the total number of halibut per 100 m^2 captured by month.

halibut abundance decreased as distance from the bay mouth increased. Within unvegetated areas, California halibut were approximately 6 and 14 times more abundant at Bay Entrance than at Belmont Shore and Marine Stadium, respectively.

California halibut length ranged from 7 to 253 mm SL, but few were larger than 140 mm SL; no adults were captured. Lengths were similar among habitats and sites except that many more newly settled individuals were captured in unvegetated areas than in eelgrass beds, particularly at Bay Entrance (Fig. 4). The length-frequency distribution of California halibut in unvegetated habitat at Bay Entrance was significantly different from nearby eelgrass (P=0.007) and from Belmont Shore unvegetated area (P=0.001). No other length-frequency comparisons were significantly different (P>0.05).

Barred sand bass

We collected 225 barred sand bass from 12.4% of the tows (Table 2). The number of barred sand bass captured per tow ranged from 0 to 42 with a mean of 0.5 ± 0.14 SE. Newly recruited barred sand bass and most larger juveniles were captured from September through November (Fig. 5). Barred sand bass were captured almost exclusively (98.2%) in eelgrass beds and none were captured at Marine Stadium (Fig. 3B), leading to a significant interaction term in the two-way ANOVA (P=0.003). Because barred sand

Table 3

Results of Kruskal-Wallis test (KW) and Dunn multiple comparisons (D) of California halibut (*Paralichthys californicus*) abundance between habitats and among sites. df=degrees of freedom, H=Kruskal-Wallis statistic. BE=Bay Entrance, BS=Belmont Shore, MS=Marine Stadium, U=unvegetated habitat, and E=eelgrass (*Zostera marina*) habitat. *=significant at P<0.05.

Comparison	Test	df	Statistic	P-value
Habitat (U vs. E)				
BE	KW	1	H=55.58*	0.0001
BS	KW	1	H=16.03*	0.0001
MS	KW	1	H=5.80*	0.0161
Site (U)	KW	2	H=115.23*	0.0001
BE vs. BS	D		*	<0.05
BE vs. MS	D		*	<0.05
BS vs. MS	D		*	<0.05
Site (E)	KW	2	H=22.65*	0.0001
BE vs. BS	D		*	<0.05
BE vs. MS	D		*	<0.05
BS vs. MS	D			>0.05

bass were not captured at Marine Stadium and few were captured in unvegetated areas, only numbers within eelgrass beds at Bay Entrance and Belmont Shore were tested. Although approximately twice as many individuals were caught at Bay Entrance than at Belmont Shore, these results were not significantly different (P=0.68).

Lengths of barred sand bass ranged from 16 to 92 mm SL but most (66.2%) were ≤40 mm SL; no adults were captured. Average length at Bay Entrance (34.1 mm ±1.1 SE, n=156) was smaller than at Belmont Shore (43.5 mm ±1.4 SE, n=67), primarily due to the greater abundance of new recruits and small juveniles (21–30 mm SL) at Bay Entrance (Fig. 6).

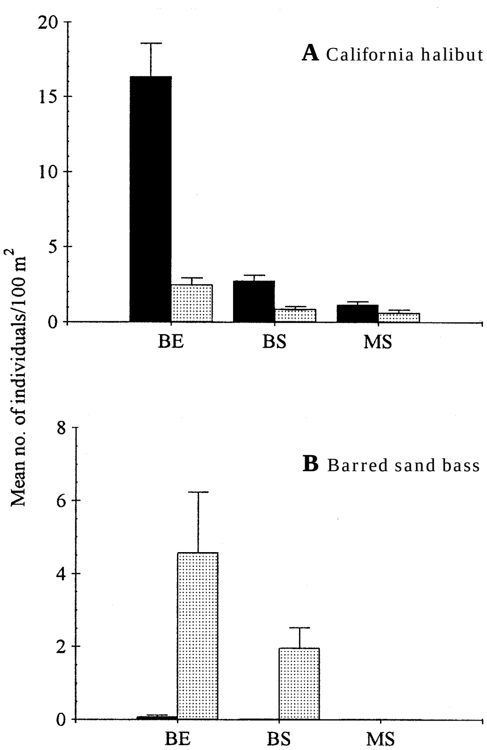

Figure 3

Mean number per 100 m^2 of (**A**) California halibut (*Paralichthys californicus*) and (**B**) barred sand bass (*Paralabrax nebulifer*) captured in unvegetated and eelgrass (*Zostera marina*) habitats at three sites in Alamitos Bay from May 1992 through November 1995. Dark bars represent unvegetated habitats and stippled bars represent eelgrass habitats. BE=Bay Entrance, BS=Belmont Shore, and MS=Marine Stadium. Number of tows in unvegetated habitats at BE, BS, and MS were 95, 61, and 95, respectively. Number of tows in eelgrass habitats at BE, BS, and MS were 60, 62, and 62, respectively. Error bars represent + one standard error.

Length-frequency distributions of barred sand bass at these two sites were significantly different (P= 0.0001).

Other species

Gobies were the most abundant group of fishes, accounting for 55.2% of the total (Table 2). This group comprised mostly arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and numerous goby larvae that were probably arrow goby and cheekspot goby. Bay pipefish (*Syngnathus leptorhynchus*), shiner perch (*Cymatogaster aggregata*), topsmelt (*Atherinops affinis*), and giant kelpfish (*Heterostichus rostratus*) were the other most abundant fishes, and along with gobies represented 87.9% of all individuals collected. These fishes, along with queenfish (*Seriphus politus*), diamond turbot (*Hypsopsetta guttulata*), spotted kelpfish (*Gibbonsia elegans*), shadow goby (*Quietula y-cauda*), Pacific staghorn sculpin (*Leptocottus armatus*), and bay blenny (*Hypsoblennius gentilis*), were considered “common fishes.” The common fishes, along with California halibut and barred sand bass, accounted for 96.5% of the total number collected. Abundances for most of these fishes peaked from March through May or from June through August; most of these fishes were juveniles.

All of the common fishes were found in both habitats and at all sites; however the number of individuals varied considerably (Fig. 7). Only queenfish and Pacific staghorn sculpin had no significant interactions between habitat and site in the nonparametric two-factor ANOVA (P>0.05). Queenfish were significantly more abundant in unvegetated areas than in eelgrass beds (P=0.0003). No significant habitat differences were found for Pacific staghorn sculpin (P=0.41). Queenfish were significantly more abundant at Marine Stadium than at Belmont Shore (P<0.05), whereas Pacific staghorn sculpin were significantly more abundant at Belmont Shore than at Bay Entrance (P<0.05).

For 11 of the 13 common fishes, the nonparametric two-way ANOVA yielded significant interactions between habitat and site (P<0.05). Stratifying by site and comparing abundances between eelgrass and unvegetated areas, we found that bay pipefish, shiner perch, giant kelpfish, spotted kelpfish, shadow goby, and bay blenny were significantly more abundant in eelgrass than in unvegetated areas at all three sites (P<0.05). Cheekspot goby and diamond turbot were significantly more abundant in unvegetated areas than eelgrass at all three sites, whereas goby larvae and arrow goby were significantly more abundant in unvegetated areas at Belmont Shore (P<0.05).

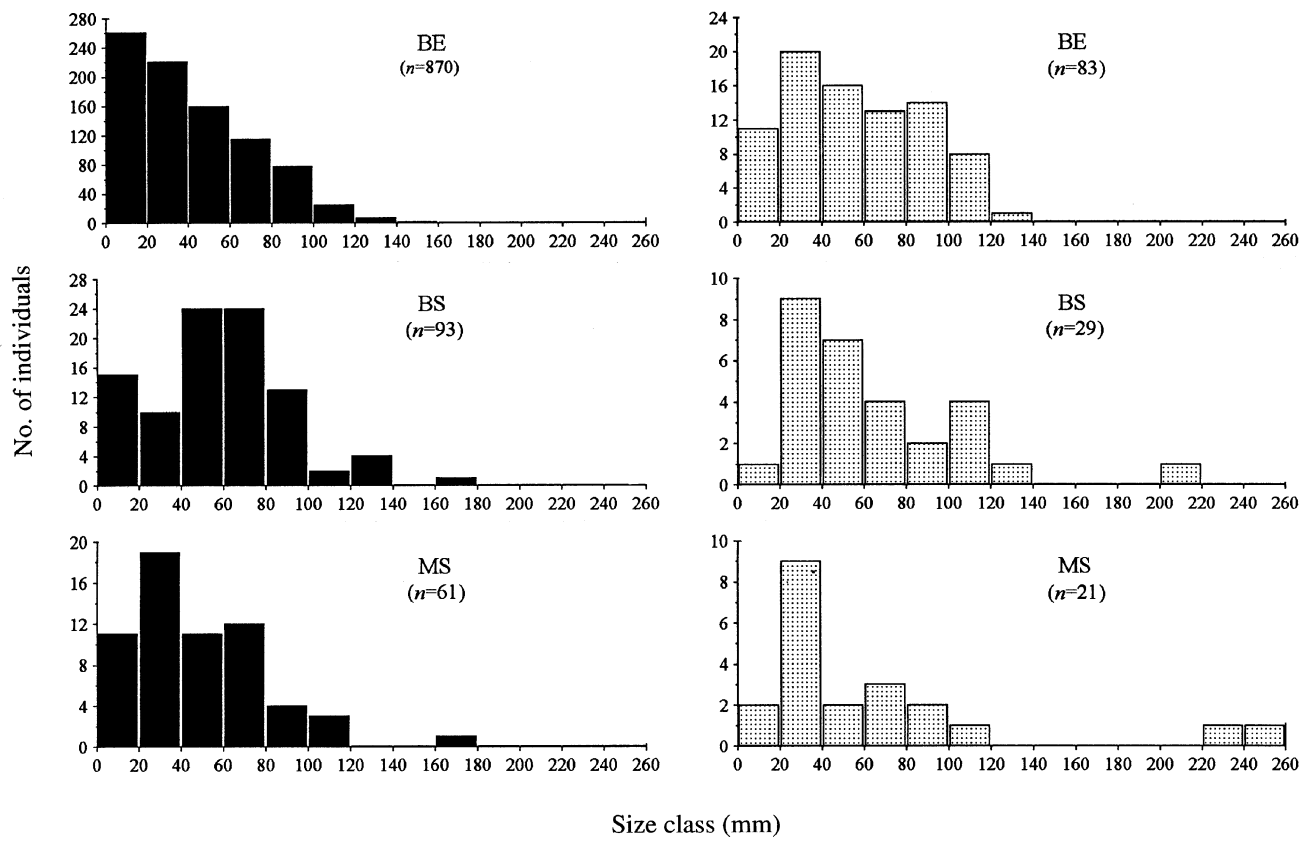

Figure 4

Length-frequency distributions of California halibut (*Paralichthys californicus*) captured in unvegetated and eelgrass (*Zostera marina*) habitats in Alamitos Bay from May 1992 through November 1995. Dark bars represent unvegetated habitats and stippled bars represent eelgrass habitats. See Figure 3 for further explanation.

Topsmelt showed a mixed pattern; they were significantly more abundant in eelgrass at Marine Stadium (P<0.05) but significantly more abundant in unvegetated area at Belmont Shore (P<0.05).

Stratifying by habitat and comparing abundances among sites, we found that most fishes were significantly more abundant at Marine Stadium or at Belmont Shore (P<0.05) (Table 4). Only shiner perch, giant kelpfish, and bay blenny had significantly more individuals at Bay Entrance than at one of the other two sites, but abundances at Bay Entrance were never significantly greater than at both of the other sites.

Discussion

California halibut and barred sand bass

Abundance of California halibut was habitat specific. California halibut was one of the few fishes whose abundance was much higher in unvegetated areas than in eelgrass beds. Although eelgrass blades may provide shelter from predation for some inhabitants (Heck and Thoman, 1981; Sogard and Olla, 1993), California halibut typically avoid detection by predators and prey by partially burying themselves in sediment (Haaker, 1975). Other flatfishes show substrate preferences (Tanda, 1990; Burke et al., 1991; Rogers, 1992), and California halibut ≤63 mm SL prefer bare sand over eelgrass in the laboratory (Drawbridge, 1990). Thus, sediments supporting eelgrass beds may not be preferable for settlement. It is also possible that eelgrass physically impedes halibut from settling there. If this were solely the case, then fewer halibut would be expected in eelgrass beds where distances between shoots were shorter (dense beds) than in beds where distances between shoots were greater (sparse beds). However, we found this not to be true; more halibut were found in a dense eelgrass bed (Bay Entrance) than in a sparse bed (Belmont Shore).

Barred sand bass abundance was also habitat specific; they were almost exclusively found in eelgrass

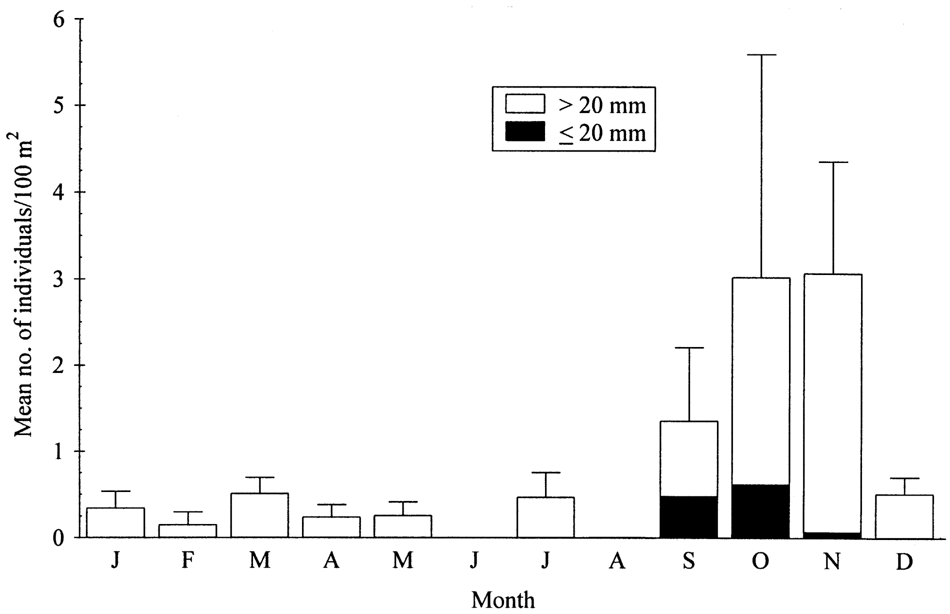

Figure 5

Mean number per 100 m^2 of newly recruited (≤20 mm SL) and larger barred sand bass (*Paralabrax nebulifer*) captured by month in Alamitos Bay from May 1992 through November 1995 (n=435 tows). Error bars represent + one standard error for the total number of barred sand bass per 100 m^2 captured by month.

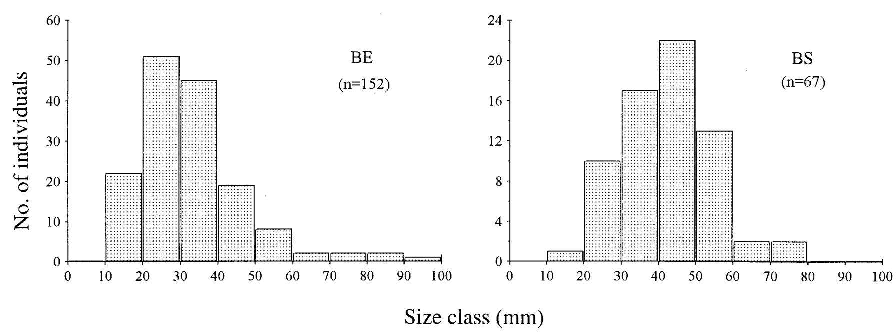

Figure 6

Length-frequency distributions of barred sand bass (*Paralabrax nebulifer*) captured in eelgrass (*Zostera marina*) habitat in Alamitos Bay from May 1992 through November 1995. See Figure 3 for further explanation.

beds. Eelgrass beds may be productive foraging areas for them. Although the diet of newly recruited and small juvenile barred sand bass is not known, larger juvenile barred sand bass (123–239 mm SL) consume amphipods, shrimps, and other small crustaceans (Roberts et al., 1984). These items are often abundant in eelgrass beds, and this plentiful food supply may enable them to achieve faster growth rates, enabling them to achieve a size that is less vulnerable to predation more quickly (Levin et al., 1997). Additionally, eelgrass may offer shelter because most newly recruited and juvenile barred sand bass have been observed around eelgrass or other structure such as mussels, rocks, or debris during SCUBA surveys (senior author's unpubl. data). Larger juveniles and adults are mostly found over sandy bottoms and among rocks (Turner et al., 1969; Feder et al.,1974) and are scarce in eelgrass beds (senior author's unpubl. data).

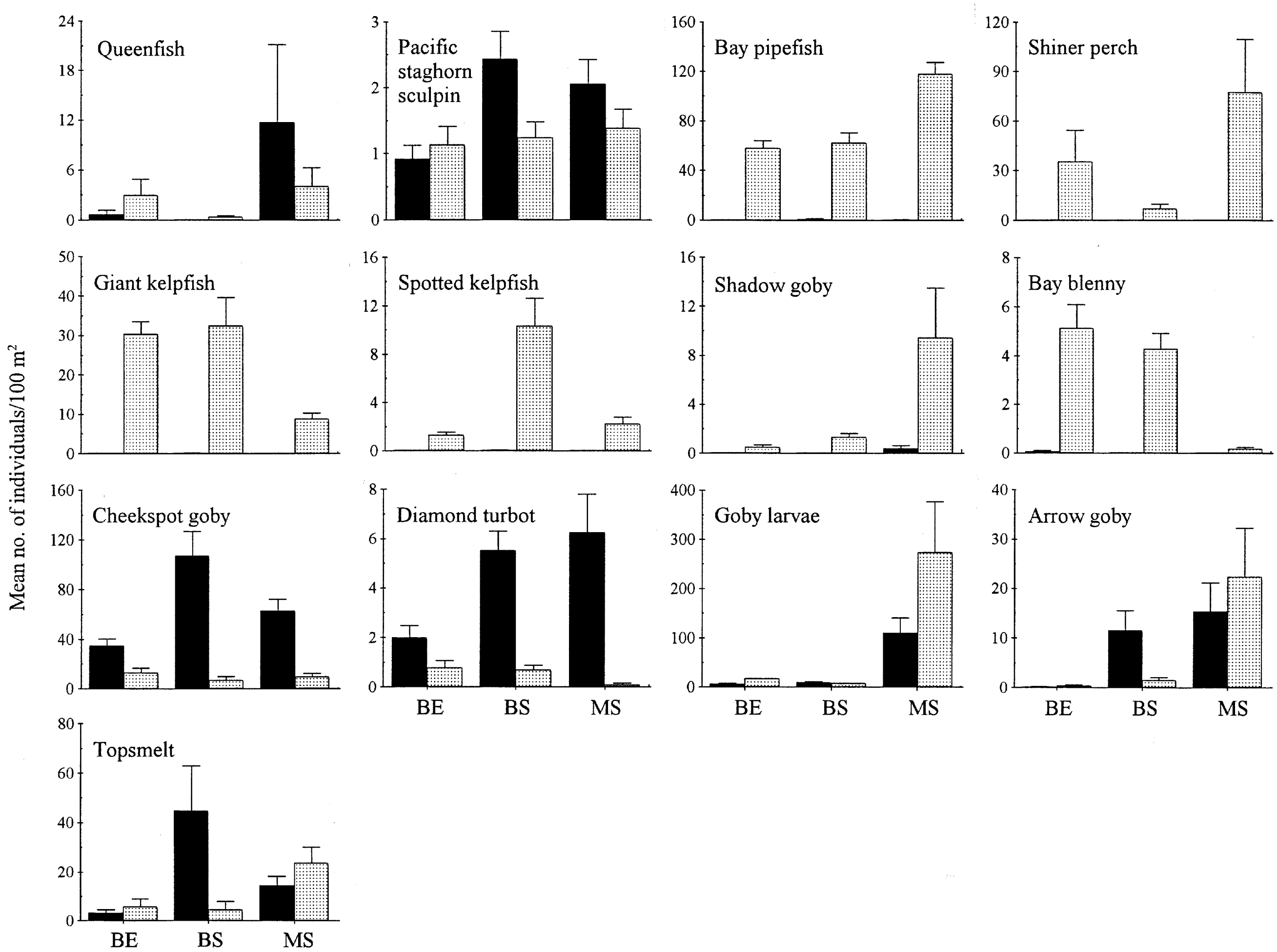

Figure 7

Mean number per 100 m^2 of the most abundant fishes (see text) captured in unvegetated and eelgrass (*Zostera marina*) habitats at three sites in Alamitos Bay from May 1992 through November 1995. Dark bars represent unvegetated habitats and stippled bars represent eelgrass habitats. See Figure 3 for further explanation.

The distribution patterns of California halibut and barred sand bass among sites were similar; abundances of individuals decreased with increasing distance from the bay mouth. These patterns in Alamitos Bay might be expected if abundances were related to larval supply because both species spawn outside the bay. Others have found that circulation patterns may limit dispersal of recruits to inner parts of an embayment (Sogard et al., 1987; Jenkins et al., 1996). However, this does not seem to be the case for Alamitos Bay because it is well circulated with a net inflow of water, and the distance between sites is relatively short. Instead, fewer halibut and barred sand bass may inhabit the inner parts of the bay because settlement and location of suitable habitat have occurred before reaching these areas. For California halibut, few larvae are found in embayments (White, 1977; Leithiser, 1981; Nordby, 1982; Yoklavich et al., 1992); the greatest densities of eggs and early larvae occur in nearshore waters with older larvae found less than 1 km from shore (Ahlstrom and Moser, 1975; Gruber et al., 1982; Barnett et al., 1984; Lavenberg et al., 1986; Walker et al., 1987; Moser and Watson, 1990). Most transforming halibut larvae are found on the open coast (Kramer, 1990, 1991a), and large numbers of halibut settle there and in embayments (Allen, 1988; Allen and Herbinson, 1990, 1991; Kramer, 1990, 1991a, 1991b). Those halibut that settle on the open coast move into embayments or die (Kramer, 1991a). Although it is not known where most barred sand bass recruitment occurs, spawning occurs in nearshore waters, and the planktonic larval phase is relatively short, lasting about one month (Butler et al., 1982). Therefore, if

Table 4

Results of Dunn multiple comparisons of fish abundance among sites. BE=Bay Entrance, BS=Belmont Shore, and MS=Marine Stadium. Comparisons among sites were done only for the habitat (eelgrass or unvegetated) where fishes were most abundant. * indicates which site showed a significantly greater abundance at $P<0.05$.

Common name	Scientific name	BE vs. BS	BE vs. MS	BS vs. MS
Eelgrass				
Bay pipefish	*Syngnathus leptorhynchus*		*MS	*MS
Shiner perch	*Cymatogaster aggregata*	*BE		*MS
Giant kelpfish	*Heterostichus rostratus*	*BS	*BE	*BS
Spotted kelpfish	*Gibbonsia elegans*	*BS		*BS
Shadow goby	*Quietula y-cauda*		*MS	
Bay blenny	*Hypsoblennius gentilis*		*BE	*BS
Goby larvae	Gobiidae		*MS	*MS
Unvegetated				
Cheekspot goby	*Ilypnus gilberti*	*BS	*MS	
Diamond turbot	*Hypsopsetta guttulata*	*BS	*MS	*MS
Arrow goby	*Clevelandia ios*	*BS	*MS	
Topsmelt	*Atherinops affinis*	*BS		

habitat is suitable, one would expect more newly settled California halibut and newly recruited barred sand bass at sites nearest the entrance because they are more likely to encounter these areas first. This might be especially true for embayments where the entrance is small, such as in Alamitos Bay, which could enhance chances of individuals encountering a shallow site nearest the mouth of the bay.

It is also possible that the distribution patterns we observed were due to active site selection. Diamond turbot, whose larvae also occur in nearshore waters (Barnett et al., 1984; Walker et al., 1987) and are thus exposed to the same hydrodynamic processes, were most abundant in the inner part of the bay and least abundant nearest the mouth of the bay. Kramer (1991b) also obtained opposite distribution patterns for juvenile California halibut and diamond turbot. Burke (1995) found that the distribution of two newly settled flounders that immigrated to an estuary were influenced by the availability of preferred prey types. Although we have no data on invertebrate prey distributions among sites, it is possible that California halibut and diamond turbot also select sites on the basis of availability of their preferred food items. Juvenile California halibut and diamond turbot have very different diets: small juvenile California halibut feed mainly on small crustaceans (Haaker, 1975; Plummer et al., 1983; Allen, 1988; Drawbridge, 1990), whereas juvenile diamond turbot feed mainly on polychaetes (Lane, 1975). As halibut grow larger, they become more piscivorous and gobies become an increasingly important part of their diet (Allen, 1988; Drawbridge, 1990). This might explain why we found relatively larger halibut at Belmont Shore than at Bay Entrance because this area contained more arrow gobies and cheekspot gobies. Inhabiting an area with preferred food items might lead to accelerated growth rates, which may be an advantage for reducing size-selective predation. Sogard (1992) found that winter flounder (*Pleuronectes americanus*) and tautog (*Tautoga onitis*) were most abundant in estuarine areas that supported faster growth rates. However, we can not discount that larval supply may also be a factor because the spawning locations of diamond turbot are not known. Lane (1975) suggested that spawning takes place in or very near the outer harbor. This area would be much closer than where halibut spawn, and inner parts of the bay would be closer to eggs and larvae. In addition, laboratory experiments indicate that diamond turbot larvae are able to survive longer periods of starvation than halibut larvae (Gadomski and Petersen, 1988). This may enable diamond turbot larvae to remain in the water column longer and reach inner parts of the bay whereas halibut larvae must settle earlier.

Barred sand bass may also actively select sites within Alamitos Bay. However, the differences in physical characteristics of eelgrass among sites appeared not to affect the abundance of new recruits and juveniles. Although Bay Entrance had significantly more eelgrass shoots and longer blade lengths than Belmont Shore, barred sand bass abundances at the two sites were not significantly different. This lack of difference suggests that the effect of seagrass physical characteristics on fish abundance breaks down over larger spatial scales. However, if barred sand bass settle indiscriminately into the first eelgrass bed encountered, we would have expected significantly more individuals nearest the bay mouth. Sogard (1989) found that initial settlement patterns for some fishes in seagrass beds were altered considerably by movement to other areas. Our results indicate that this may be also true for barred sand bass because significantly larger fish were found at Belmont Shore, indicating that movement to this site from the site nearest the entrance after initial settlement may have occurred. However, we are not able to resolve why barred sand bass were absent from the inner part of the bay.

Densities of newly settled and juvenile California halibut in our study were much greater than those reported by others using similar gear in other bays. Kramer (1990) obtained maximum monthly means for shoreline habitats in Agua Hedionda Lagoon of 3.7 newly settled California halibut per 100 m^2 for all stations combined and 9.2 per 100 m^2 for a single station. These densities are approximately 25% and 11%, respectively, of the values we obtained for Alamitos Bay. Our maximum monthly mean number of newly settled California halibut was approximately four times greater than that obtained for nearby Anaheim Bay in 1989 (Allen and Herbinson, 1990). Thus, our results support the conclusion by Allen and Herbinson (1990) that there is a great deal of annual variability in numbers of newly settled and juvenile California halibut within and among embayments in southern California.

Although the beam trawl may capture demersal fishes such as California halibut less effectively in eelgrass beds than in unvegetated areas, this seems an unlikely explanation for the great differences in habitat specific fish abundances that we observed. First, we collected large amounts of eelgrass blades (occasionally with attached rhizome) in many tows, and SCUBA observations indicated that the beam trawl maintained continuous contact with the substrate in both habitats. Second, staghorn sculpin, which rest on the substrate, and shadow goby, which often burrow in the sediment, were frequently captured in both habitats. Because we collected data only at low tides during daylight hours, we have no information on how sampling at different tide heights and times of the day would have affected our results. Diel differences in fish abundance can occur in southern California bays (Horn, 1980; Hoffman[4]); however, there are no data to suggest that these differences are related to habitats or locations within the bay.

Other species

Alamitos Bay was typical of other temperate bay-estuarine environments in having relatively few species account for a large proportion of the total number of individuals collected (reviewed in Allen and Horn, 1975; Horn, 1980; Allen, 1982; Onuf and Quammen, 1983; Allen and Herbinson, 1991; Hoffman[4]; MBC Applied Environmental Sciences[5]). Species composition and abundance were very similar to data collected using similar gear in Anaheim Bay and Agua Hedionda Lagoon (Allen and Herbinson, 1991; MBC Applied Environmental Sciences[5]). Our results, however, lacked high abundances of northern anchovy (*Engraulis mordax*), slough anchovy (*Anchoa delicatissima*), deepbody anchovy (*Anchoa compressa*), and California killifish (*Fundulus parvipinnis*) found by other studies in the inner part of Alamitos Bay and Newport Bay (Allen and Horn, 1975; Allen, 1982). Differences in sampling gear and location are probably responsible, but other factors may also play a role. As noted by Allen and Horn (1975), the abundance of northern anchovy may have been due to high periods of recruitment. Indeed, recruitment biomass of northern anchovy (age zero at 1 July) off southern California during their studies (1973 and 1979) was 2.6–3.1 times greater than during 1992–94 (Jacobson et al.[6])

For most species, greater abundances of individuals in either eelgrass or unvegetated areas suggested habitat preferences or differential mortality for these species in shallow water of Alamitos Bay. The large numbers of species and individuals in eelgrass beds indicated the importance of this habitat for many fishes, especially juveniles during spring and summer. Many of the fishes also differed in abundance across sites. More species were found near the bay mouth owing in part, to the occasional presence of more typical nearshore residents, but more individuals of several species were found farther inside the bay. However, the differences in eelgrass physical characteristics among sites did not appear to affect the abundances of most fishes. For example, abundances of bay blenny, bay pipefish, and shadow goby were not significantly different between Bay Entrance and Belmont Shore, although eelgrass density and blade lengths were significantly different between these sites. In addition, giant kelpfish and spotted kelpfish were most abundant at Belmont Shore, the site with the lowest eelgrass density and

[4] Hoffman, R. S. 1986. Fishery utilization of eelgrass (*Zostera marina*) beds and non-vegetated shallow water areas in San Diego Bay. National Marine Fisheries Service, Southwest Region, 501 W. Ocean Blvd, Suite 4200, Long Beach, CA, 90802. Admin. Rep. SWR-86-4, 29 p.

[5] MBC Applied Environmental Sciences. 1990. Distribution of juvenile California halibut (*Paralichthys californicus*) and other fishes in bay and coastal habitats of Los Angeles, Orange, and San Diego counties in 1989. MBC Applied Environmental Sciences, 947 Newhall Street, Costa Mesa, CA 92627. Final Rep. 90-RD-09, 27 p.

[6] Jacobson, L. D., N. C. H. Lo, S. F. Herrick Jr., and T. Bishop. 1995. Spawning biomass of the northern anchovy in 1995 and status of the coastal pelagic fishery during 1994. Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, P. O. Box 271, La Jolla, CA 92038. Admin. Rep. LJ-95-11, 49 p.

shortest blade lengths. Only shiner perch abundance appeared related to eelgrass physical characteristics. This was not surprising because shiner perch are closely associated with the amount of eelgrass cover (Onuf and Quammen, 1983).

In conclusion, we found that for Alamitos Bay: 1) shallow unvegetated and eelgrass habitats were important for many fishes, especially juveniles, 2) juvenile California halibut and barred sand bass used different habitats; California halibut inhabited unvegetated areas and barred sand bass inhabited eelgrass beds, 3) habitats nearest the bay mouth were particularly important for juvenile California halibut and barred sand bass, whereas habitats farther inside the bay were more important for other fishes, 4) habitat and site selection for juvenile California halibut, barred sand bass, and most other fishes appeared unrelated to physical characteristics of eelgrass or abiotic factors, 5) habitat and site selection for juvenile California halibut and barred sand bass may be related to larval supply and to the first suitable habitat and site encountered, but may be modified subsequently by movement into other areas in search of preferred food items. A closer look at shallow unvegetated and eelgrass habitats in other bays in relation to California halibut and barred sand bass abundance is warranted. Protection of these habitats from elimination or even alteration may be important for the successful management of these species.

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