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for

U.S. Department of Commerce
National Oceanographic and Atmospheric Administration
National Ocean Service
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Marine and Estuarine Management Division
Washington, D.C.

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Approved
R. C. Francis
Director

ABSTRACT

Dungeness crab, *Cancer magister*, and marine fish were sampled in Padilla Bay, Washington, from June 1987 through September 1988 using a variety of sampling gear. Dungeness and related crab species were sampled with a 3-m beam trawl on 7 occasions at 9 stations (3 each, intertidal eelgrass, subtidal eelgrass and subtidal channel) during an annual period and with shovel and screen at 2 intertidal stations. The resulting data on crab abundance and distribution have been added to a long-term data series on Dungeness crab to help define relationships between juvenile yearclass strengths and future fisheries.

Marine fish were sampled by beam trawl, trammel net and beach seine. Forty-one species of fish were collected, 12 of those being previously unreported for Padilla Bay. Stomach content analyses of 18 species of fish indicated that only staghorn sculpin, *Leptocottus armatus*, had an index of relative importance greater than 3% for crab. The diets of sculpin were variable but reflected a preference for amphipods, isopods and crabs. Pea crabs (*Pinnixa* spp.) were the foremost crab prey item, and megalopae and juvenile Dungeness crab accounted for <1% of the average diet. Staghorn sculpin showed a gradual shift in feeding preferences with growth, switching to larger prey, including fish, at lengths of >120 mm.

Laboratory studies of sculpin feeding on Dungeness crab showed that 70- to 90-mm sculpin could consume crab megalopae at an average rate of 17 megalopae/day under controlled lab conditions. Similar tests showed that 88- to 102-mm fish could consume an average of 15 new juvenile crab/day, and that larger sculpin preferred to feed on larger crab (up to 37 mm carapace width). Gut evacuation experiments showed that sculpin digested meals at the rate of about 50% in 12 h and 95% in 48-72 h, depending on size of fish and its meal.

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PREFACE

This work was funded by a grant from the National Oceanic and Atmospheric Administration (NOAA), Division of Marine and Estuarine Management (Grant # NA87AADCZ009) administered by Bill Thomas and Jaunice Yates. Additional support was provided by Terry Stevens, Director, Padilla Bay National Estuarine Research Reserve. We sincerely thank Terry and his staff for their professional support.

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INTRODUCTION

Padilla Bay, situated just east of Anacortes, Washington in northern Puget Sound (Fig. 1), contains one of the largest concentrations of eelgrass (*Zostera marina* and *Z. japonica*) on the Pacific Coast and harbors a collection of invertebrates, fish, birds and marine mammals representative of the inland waters of Washington State.

The Padilla Bay National Estuarine Research Reserve, containing approximately 1,000 hectares within the administrative boundary, was jointly established by the state and federal governments in the early 1980s. The Reserve is managed by the Washington Department of Ecology (WDOE) for the purposes of conservation, research and public education (WDOE 1984).

Fishing has been an important part of the history of Padilla Bay. Clams and oysters have been harvested commercially in past years, with clams still providing a small sports harvest in selected areas. Crabbing and salmon fishing occur in and around Padilla Bay, although these fisheries are reportedly not as productive as they were at the turn of the century (WDOE 1984).

The Dungeness crab, *Cancer magister*, supports an important commercial and sport fishery in the inland waters of Washington state, with annual harvests averaging about 1.5 million pounds per year (PMFC 1985). Although these crab are the object of an important fishery, very little was known about their distribution, growth, settlement, reproduction and habitat requirements until a series of studies were initiated in 1984. The studies included detailed observations on recruitment of juvenile crab (Dinnel et al. 1986a, 1988a); general distribution studies of both juvenile and adults (Armstrong et al. 1987; Dinnel et al. 1985a, 1985b, 1986b, 1987, 1988a, 1988b; Weitkamp et al. 1986); and studies specific to female crab and their reproductive behavior (Armstrong et al. 1987; Dinnel et al. 1988a).

These studies generally indicated that larvae settled during the summer, generally in intertidal and shallow subtidal areas of eelgrass. First year growth (0+ age group) takes place in these shallow areas prior to movement of one-year-olds (1+) to shallow subtidal areas and the subsequent movement of the 2-year-olds (2+) to deeper areas. Of special note was the observation that newly settled larvae appear to be highly dependent on habitats that provide a refuge from predation, and that survival of young crab instars is usually only a few percent of the initial settlement densities. Hence, yearclass success depends highly on factors that affect early instar survival.

Past studies in California have shown that various demersal fish species prey on Dungeness crab megalopae and post-larval benthic instar crab (Prince and Gotshall 1976; Reilly 1983). We suspect that the survival rates of newly settled crab are highly dependent on the interactive factors of fish predation and protective cover (both quantity and quality). Thus, the primary

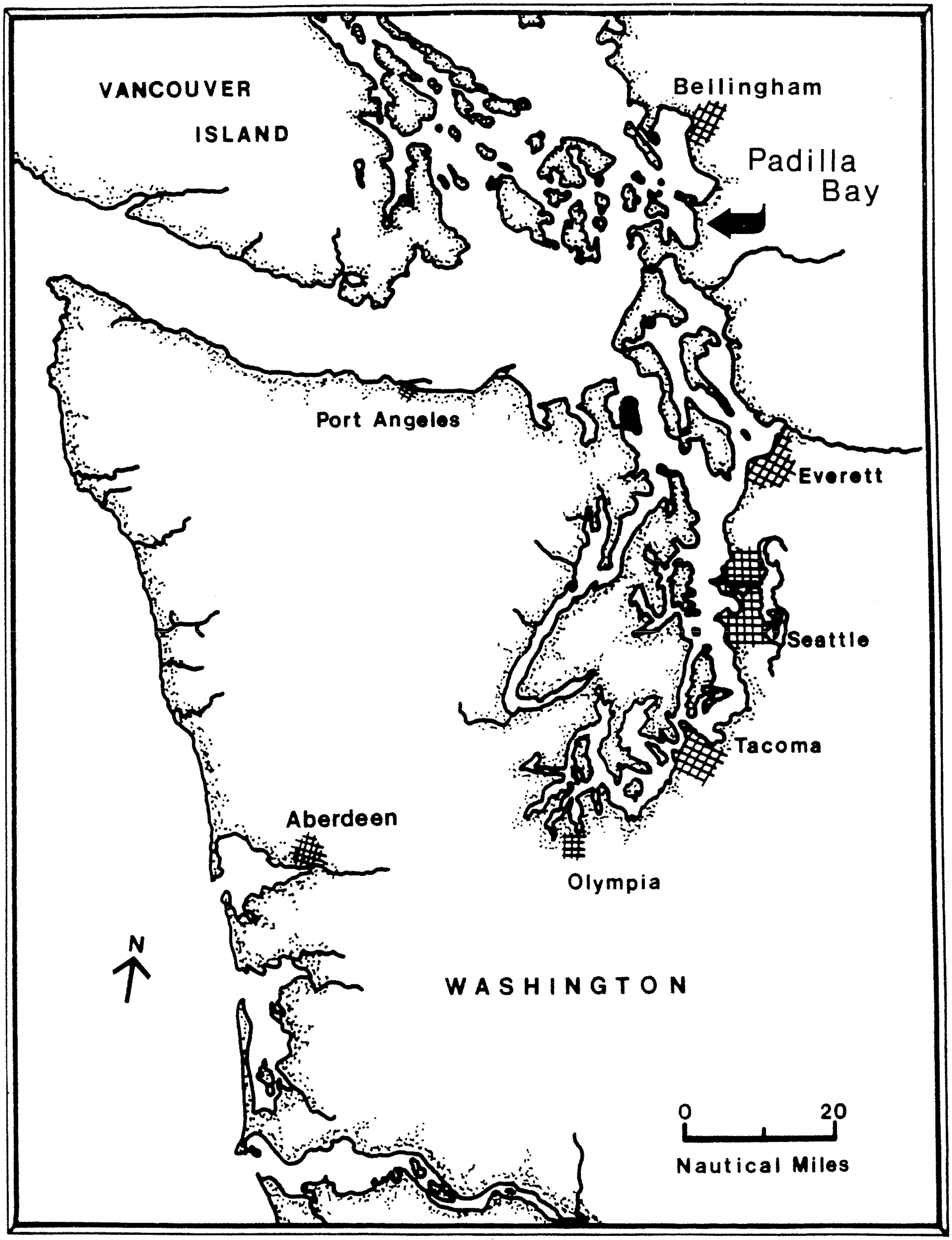


Figure 1. Map of Western Washington showing the location of Padilla Bay.

objective of this study was to investigate the relationships between juvenile crab survival and fish predation in a natural field environment and in the laboratory. A second objective was the long-term continuation of a Dungeness crab sampling program in Padilla Bay to provide multiple-year recruitment and abundance data with the future goal of defining a relationship between settlement success and eventual recruitment to the fishery. A third objective of this study was to provide baseline data on fish species residing in Padilla Bay—their seasonality, relative abundances and general habitat associations.

MATERIAL AND METHODS

SAMPLE METHODS AND SITES

Dungeness crab in Padilla Bay were sampled in the subtidal with a small research beam trawl and in the intertidal by digging and screening samples during periods of low tide. Marine fish were primarily sampled with the beam trawl concurrent with the crab sampling. Additional information on marine fish was gathered by using a surface-to-bottom trammel net and a small beach seine. These latter two types of gear were used to obtain additional staghorn sculpin (*Leptocottus armatus*) stomach content data, while the beach seines also provided live staghorn sculpin for the field and laboratory experiments.

BEAM TRAWLS

Trawl sampling for crab and fish was conducted on seven occasions from June 1987 to April 1988. Nine stations were sampled during each occasion, three each in the following habitat types (strata) (Fig. 2): (1) intertidal eelgrass beds (Stations 12, 13 & 15; sampled at high tide); (2) subtidal eelgrass beds (Stations 6, 8 & 11; 0- to 3-m depth); and (3) subtidal, unvegetated channels (Stations 9, 14 and 16; 3 to 10-m depth).

Trawling was conducted with a 3-m beam trawl with an effective fishing width of 2.3 m (Fig. 3). This trawl was designed by Gunderson and Ellis (1986) for sampling demersal organisms and has been routinely used in the Washington coastal areas of Willapa Bay and Grays Harbor (Armstrong and Gunderson 1985; Gunderson et al. 1985; Dinnel et al. 1986a, 1986b; Dumbauld et al. 1988) and in north and central Puget Sound (Armstrong et al. 1987; Dinnel et al. 1985a, 1985b, 1986c, 1986d, 1987, 1988a, 1988b; Weitkamp et al. 1986).

All trawls were conducted from a 7-m Boston Whaler equipped with a towing frame and winch. Each tow was 2 to 4 min in duration, and the distance towed was measured by

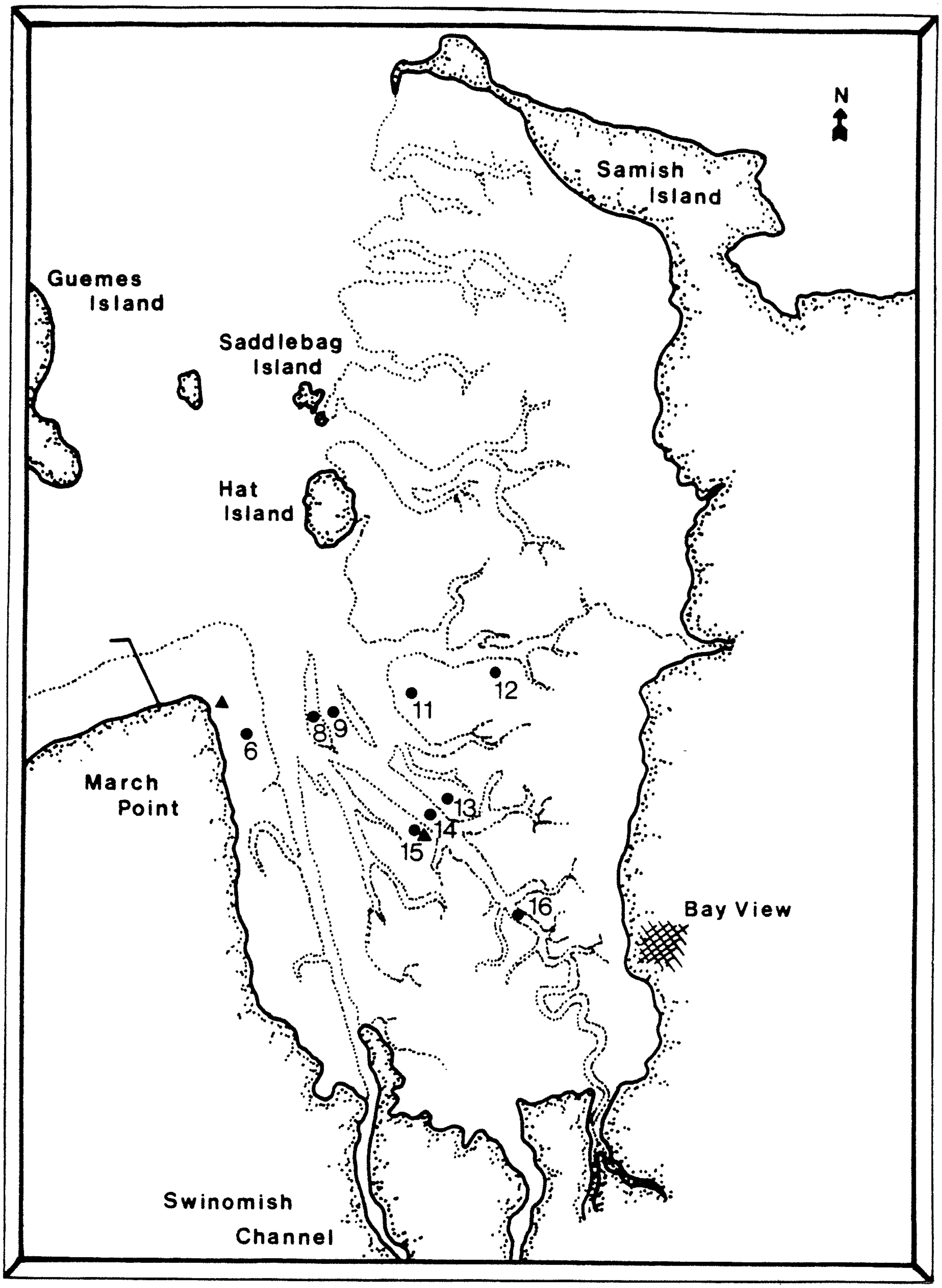


Figure 2. Map of Padilla Bay showing the locations of the beam trawl stations (solid circles) and the two intertidal stations (solid triangles).

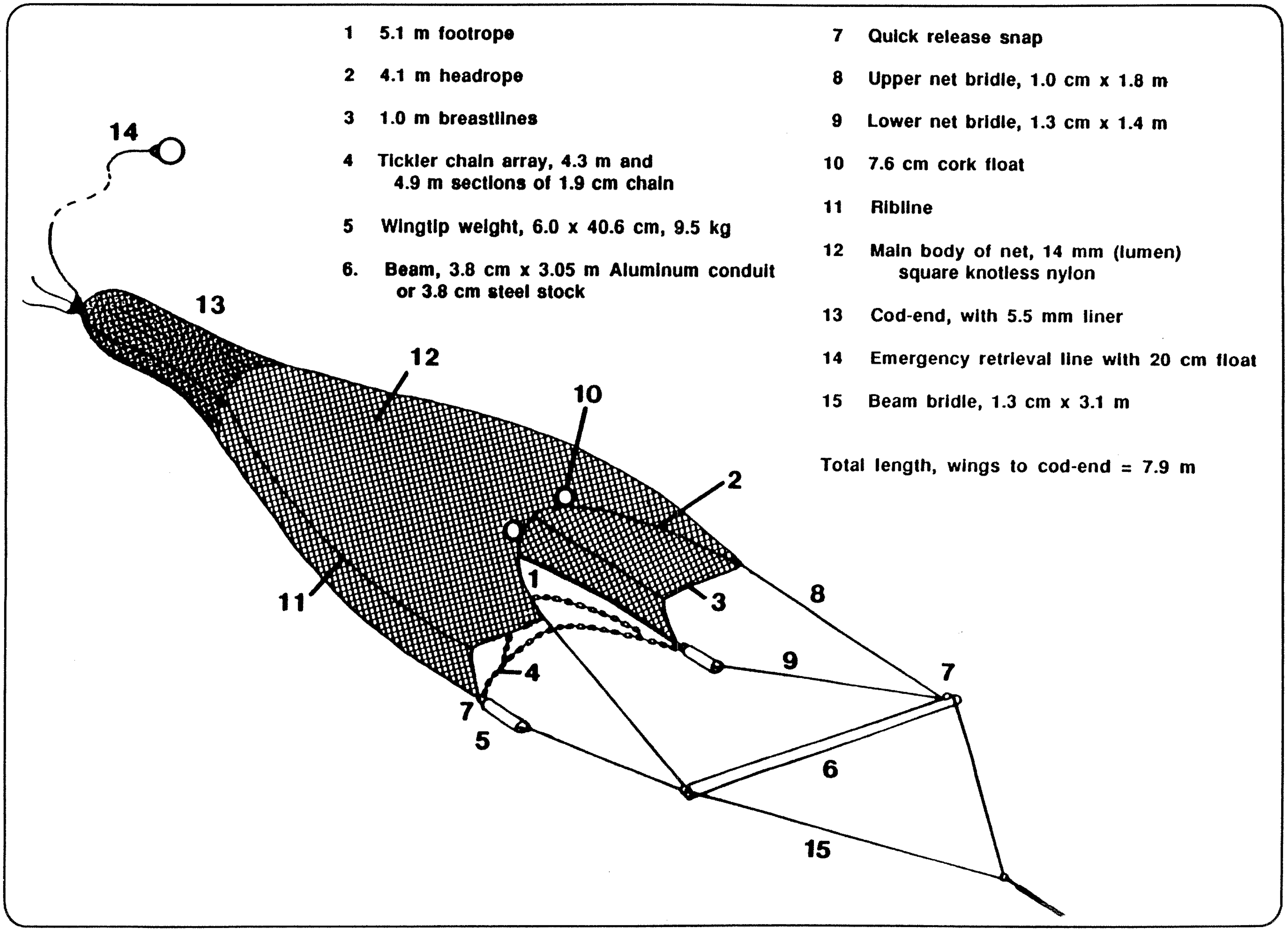


Figure 3. Illustration of the 3-m beam trawl used in this study and designed by Gunderson and Ellis (1986).

calibrated optical rangefinder (accurate to ±10%) from buoys set at the beginning and end of each tow.

All crabs, excluding kelp and decorator crabs (*Pugettia* spp. and *Hyas* spp.), were identified to species, sexed, measured for carapace width (CW), checked for molt condition (degree of shell softness) if over 100 mm CW, and examined for reproductive condition (eggs present or absent on mature females). All except the largest marine fish were preserved in formalin for later identification, measurements of length and weight, and stomach content analyses. Large fish were identified in the field, weighed, measured, and only the stomachs preserved in formalin in cloth bags for later laboratory analyses.

INTERTIDAL SAMPLING

Intertidal samples for juvenile Dungeness crab were collected in 1987-88 at one station adjacent to trawl Station 15 in the middle of South Padilla Bay and in 1987-1989 at one station at March Point (Fig. 2). The intertidal samples were collected randomly within 50 X 50 m plots by digging 0.25 m^2 samples to a depth of approximately 3 cm. Each sample was washed through 4-mm mesh nets and sorted in the field. All *Cancer* crabs were identified, measured for CW, sexed if >20 mm CW, and returned to the beach. Also, for each sample, percent vegetative cover and general substrate composition were recorded.

TRAMMEL NET

A two-panel trammel net (Hubert 1983) of approximately 100-m length and 10-m depth was used to catch larger fish that might escape a beam trawl. A trammel net was set once each cruise cross-current near trawl Station 15 in a depth of about 10 m. The trammel net was picked after about 24 h, and stomachs from larger fish of interest were preserved for later analyses of contents.

BEACH SEINE

A small 2-person (<10 m length) beach seine was used near the two intertidal sampling stations to catch staghorn sculpin for the experimental studies and to provide additional fish for stomach content analyses.

EXPERIMENTAL STUDIES

Cage Studies

Field experiments during the summer of 1987 utilized predator inclusion/exclusion cages in the vicinity of trawl Station 15. Cages were 0.5-m X 0.5-m X 0.3-m PVC frames covered with 2-mm polypropylene stretch mesh net to prevent uncontrolled egress/ingress of fish and crab. During low tide periods in August and September, cages were partially buried and sand or sand/eelgrass substrate added to anchor them and provide juvenile crab with substrate in which to bury. On incoming tides, 20 1st and 2nd instar Dungeness crab were placed in the cages. A staghorn sculpin, 90-100 mm in length, was added to each cage while identical control cages were left without a fish. After approximately 48 h, the cages were retrieved, rinsed in the field, and the contents sorted in the lab. Staghorn sculpin from the experimental cages were preserved in formalin for later content analyses.

Laboratory Experiments

Laboratory studies of predator/prey interactions were conducted during the summer of 1988 because we concluded that the 1987 field cage studies were neither time nor cost effective relative to the amount of data collected, and because such data could be ambiguous. The 1988 lab studies were conducted at the Shannon Point Marine Laboratory located on the northwest corner of Fidalgo Island. Staghorn sculpin and juvenile Dungeness crab used in the lab experiments were collected at March Point and Ship Harbor, adjacent to the Shannon Point lab. Our supply of Dungeness crab was also supplemented by catching megalopae with dip nets at night from a dock in Anacortes and by digging and screening early instar crab from intertidal areas. Some early instar crab were also obtained by allowing megalopae to molt and settle in laboratory tanks.

All predator/prey feeding experiments were conducted in glass dishes or aquaria exposed to natural outdoor lighting on a glass-enclosed balcony. Seawater temperatures remained at 12 ± 2 °C during the test period.

Prey Size Selectivity Experiments

The first set of laboratory experiments tested the prey size preferences of six staghorn sculpin ranging in size from 54 to 263 mm total length (TL). Each fish, following a 3-day period of acclimation and starvation, was presented with a mixture of crab stages (and sizes) in a 40-L aquarium without substrate for a period of 24 h. Three fish <100 mm TL were each offered five megalopae and five 1st and 2nd instar crab. Three fish >100 mm were offered five 3rd to 5th instar crab. The sizes of these crab were as follows:

Crab stage	Size range (mm CW)
Megalops	~ 3 mm
1st instar	5-7 mm
2nd instar	8-11 mm
3rd instar	12-18 mm
4th instar	19-25 mm
5th instar	26-37 mm

After 24 h, the remaining crab in each aquarium were counted and the fish sacrificed for stomach content analyses.

Megalopae Predation Rates

The second experiment was designed to measure the rate at which smaller staghorn sculpin could consume *C. magister* megalopae. Five sculpin, 70-90 mm TL, were acclimated to individual 40-L aquaria without substrate and starved for 3 days. At the start of the experiment, 20 megalopae were added to each tank. The number of megalopae eaten was recorded at the following elapsed times: 0.5, 1, 2, 3, 4, 5, 6, 8, 12 and 24 h. The number of megalopae remaining at the end of the test (24 h) was recorded and the fish weighed, measured, and dissected to assess percent digestion of the megalopae.

Juvenile Crab Instar Predation Rates

The third experiment was designed to estimate the daily mean predation rate on juvenile crab by staghorn sculpin. This test was conducted by adding 20 crab instars (fifteen 1st plus five 2nd instars) to each of six 2-L glass dishes containing a single staghorn sculpin (80-110 mm TL) which had been acclimated and starved for 3 days. The number of crab instars eaten was recorded at 0.5, 1, 2, 3, 4, 6, 12 and 24 h, at which time the numbers and sizes of remaining crab were tallied and the fish weighed, measured, and sacrificed for stomach content analyses and degree of crab digestion.

Gut Evacuation Rates

The fourth experiment was designed to measure the time required for staghorn sculpin to digest discrete crab meals. The first of two tests used 30 staghorn sculpin in a size-range of 85-110 mm TL, acclimated and starved for 3 days in individual 2-L glass dishes covered with Nytex screen and placed in a flowing seawater bath. The test began by introducing a combined total of 11 1st and 2nd instar *C. magister* to each dish. Sculpin were allowed to feed for 3 h. After this time, the remaining crab were recorded and removed. An estimated weight of meal per fish was calculated from the original crab batch weight minus the weight of crab not consumed. Sculpin were then sampled at 6, 9, 12, 18, 21, 24, 27, 30, 36 and 48 h, post-feeding. Three fish per time period were chosen at random, sacrificed, and the stomach contents analyzed for contents and degree of digestion based on visual estimates to the nearest 10%.

The second test investigated predator size as related to digestion rate, using larger staghorn sculpin. The same basic procedures of the first test were followed, although with a slightly different experimental design. Seawater tables were divided into 4 compartments each using plastic frames covered with Nytex screen. Eighteen sculpin, 124-180 mm TL, were placed one to a compartment, and acclimated and starved for 3 days. Each fish was then allowed to feed on 14 2nd to 4th instar crab for 3 h, after which uneaten crab were removed from each chamber. Again, the estimated meal weight per fish was calculated by subtracting the weight of the crab not consumed from the original batch weight of 14 crab. Three fish, selected at random, were sampled at the following times: 6, 12, 24, 36, 48 and 72 h, post-feeding, and processed as in test 1.

LABORATORY FISH PROCESSING

All fish were identified to species and measured for total length (TL) and weight. Each intact stomach was weighed and an estimate of stomach fullness recorded. The stomach contents were then removed, the empty stomach weighed, and the stomach content weight determined by the difference in weights between the full and empty stomachs. The contents of each stomach were sorted to species, genus, family or other convenient taxonomic ranking depending on the animal group. The number, volume and weight of each group of animals were then determined. Volumes, expressed as mm^3, were determined by estimating the size of a faunal "pile" using a dissecting microscope and a grid-lined petri dish. Faunal weights were then calculated as a function of the relative volume of each group.

DATA ANALYSES

Dungeness Crab Indices

Beam trawls varied in the distance fished owing to the interaction of many variables, including wind, waves, currents, motor speed and amount of material caught by the net. The total area swept by the net was calculated by multiplying the tow distances by the effective fishing width of the net (2.3 m). Crab catches from each tow were converted to a standard abundance measure of estimated crab/hectare (ha) by the following formula:

$$\text{Estimated crab/ha} = \frac{10{,}000\ m^2}{\text{Area swept by the net}} \text{X (\# crab caught)}$$

Intertidal quadrat crab catches are reported as estimated densities of crab/m^2. These densities were derived by simply multiplying the catches/0.25 m^2 by a factor of 4.

Fish Indices

Estimated fish densities were calculated as described above for crab where:

$$\text{Estimated fish/ha} = \frac{10{,}000\ m^2}{\text{Area swept by the net}} \text{X (\# fish caught)}$$

Species richness is defined as the total number of species caught. Species diversity was calculated using the Shannon-Wiener Index (H') (Pielou 1974) as follows:

$$H = -\sum_{i=1}^{n} p_i \ln p_i$$

where: n = number of fish species

p_i = proportion of community belonging to the i th species

Fish Stomach Content Analyses

Prey species were quantified by using a modified version of the Index of Relative Importance (IRI) of Pinkas et al. (1971). This index combines three measures of dietary importance: Frequency of Occurrence (FO = percentage of stomachs containing a given prey item), Percentage Numerical Composition (NC = percentage of the total number of prey items in the sample) and Percentage Gravimetric Composition (GC = percentage of total weight of all contents in the sample). These values were then used to calculate the IRIs for each prey taxon in a sample as follows:

$$IRI = (NC + GC)(FO)$$

All fish species diversity and stomach content IRI values were calculated using a Macintosh™ SE computer with Excel™ spreadsheet software.

RESULTS

FIELD STUDIES

Dungeness Crab

Beam trawl catches. Trawls conducted during this study added to our Padilla Bay database for this type of sampling, which was initiated in the summer of 1985 (and previously reported by Dinnel et al. 1987).

Estimated Dungeness crab densities for the intertidal eelgrass stratum (Stations 12, 13, 15), the subtidal eelgrass stratum (Stations 6, 8, 11) and the subtidal channel stratum (Stations 9, 14, 16) for each cruise since 1985 are shown in Figure 4. Average densities ±1 standard deviation (n = 16 cruises, 3 stations/stratum) by stratum of crab caught over all 4 years were:

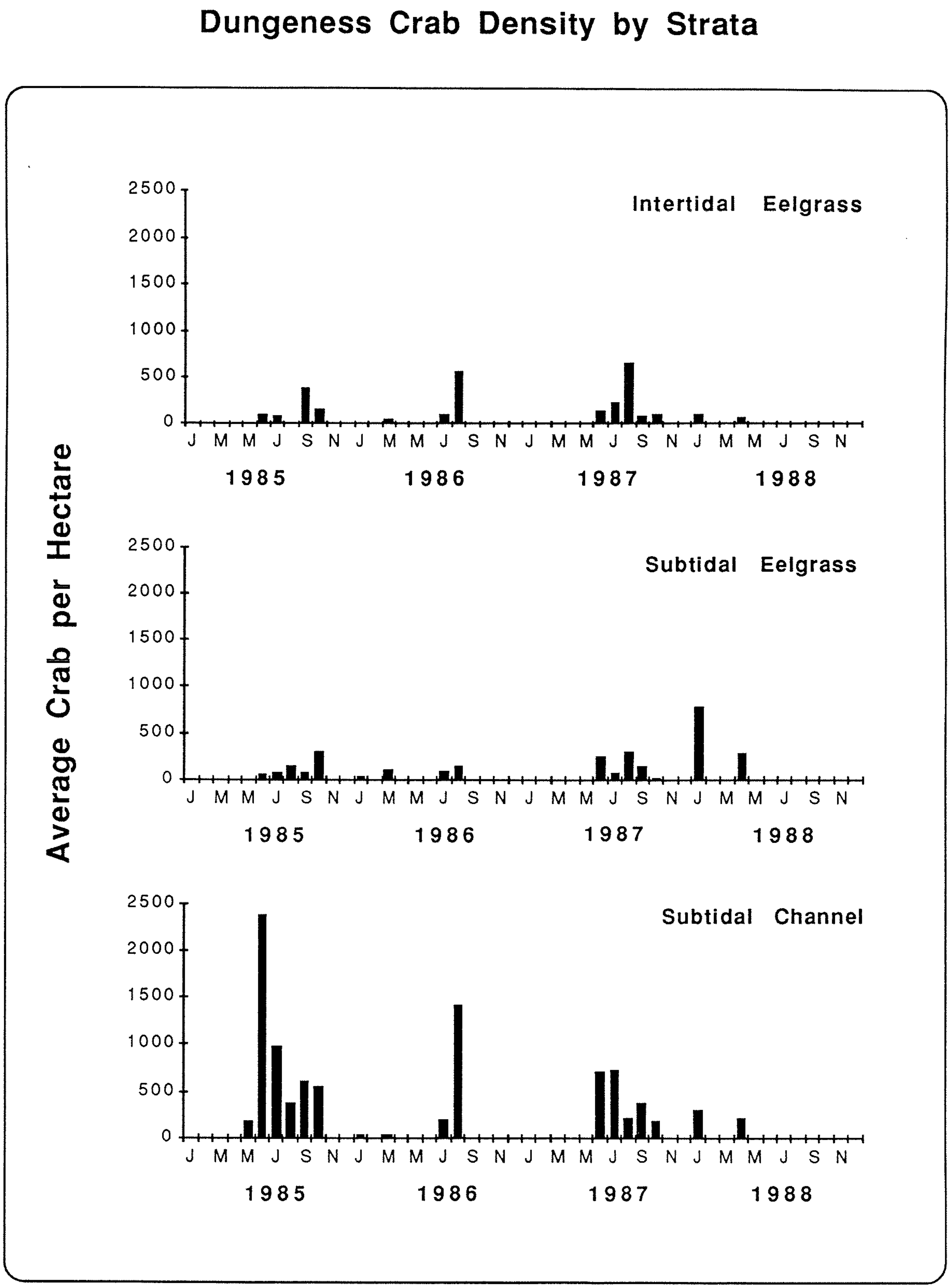


Figure 4. Average Dungeness crab densities estimated by year and by stratum from the beam trawl catches.

intertidal eelgrass = 172 ± 194 crab/ha; subtidal eelgrass = 182 ± 186 crab/ha; and subtidal channel = 583 ± 606 crab/ha. Thus, the crab catches for the intertidal and subtidal eelgrass strata were essentially equal, while catches at the channel stations were approximately 3X higher.

Intertidal quadrat crab catches. Intertidal quadrat sampling at low tide for juvenile Dungeness crab began in Padilla Bay in May 1985. Sampling during this project took place at two of the Padilla Bay intertidal stations previously sampled (Dinnel et al. 1987), thus extending our long-term database for these stations. The two stations sampled were March Point and South Padilla Bay near trawl Station 15 (Fig. 2).

The 4-year average density of juvenile crab found at these stations was approximately 1.5 crab/m^2 for March Point and 0.4 crab/m^2 for the South Bay station. Peak densities of crab observed at any one sampling time were 48 crab/m^2 at March Point in August 1986 and 7.6 crab/m^2 at South Padilla Bay in September 1985 (Fig. 5). These average and peak densities are based on an average of about 14 0.25 m^2 samples per sample period with a total 4-year sample size of about 350 samples for March Point and 150 samples at the South Padilla site. In each case, samples selected for inclusion in this data set were characterized by sand or silty-sand substrates with at least 25% vegetative (eelgrass or algae) cover. Samples from silty substrates or with <25% cover, or both, were deleted from the analyses.

Figure 5 shows that (1) intertidal Dungeness crab densities were consistently higher by several-fold at March Point, (2) peak densities coincided with summer recruitment of newly settled post-larval instars, and (3) observed settlement densities were highest in 1985 and 1986.

Fish

Beam trawl catches. A total of 40 species of marine fishes was caught during the seven trawl cruises in Padilla Bay (Table 1). Twenty-eight of those species had previously been described from Padilla Bay (WDOE 1984) while 12 species were new to the bay fauna (these species are flagged in Table 1). However, none of the 12 new species are uncommon to Puget Sound and would be expected to reside in areas like Padilla Bay.

Average fish/ha, species richness and species diversity by cruise and by stratum are listed in Table 2. CPUEs were lowest during winter and spring (145 to 159 fish/ha for all stations combined) and highest during July and August (1,415 to 2,072 fish/ha for all stations combined). Likewise, species richness and diversity measures were also lowest during January and April and uniformly high from June to October (Table 2).

The most abundant fish caught in trawls was English sole (essentially all juveniles) followed by shiner perch, threespined stickleback and bay pipefish. Estimated densities of each

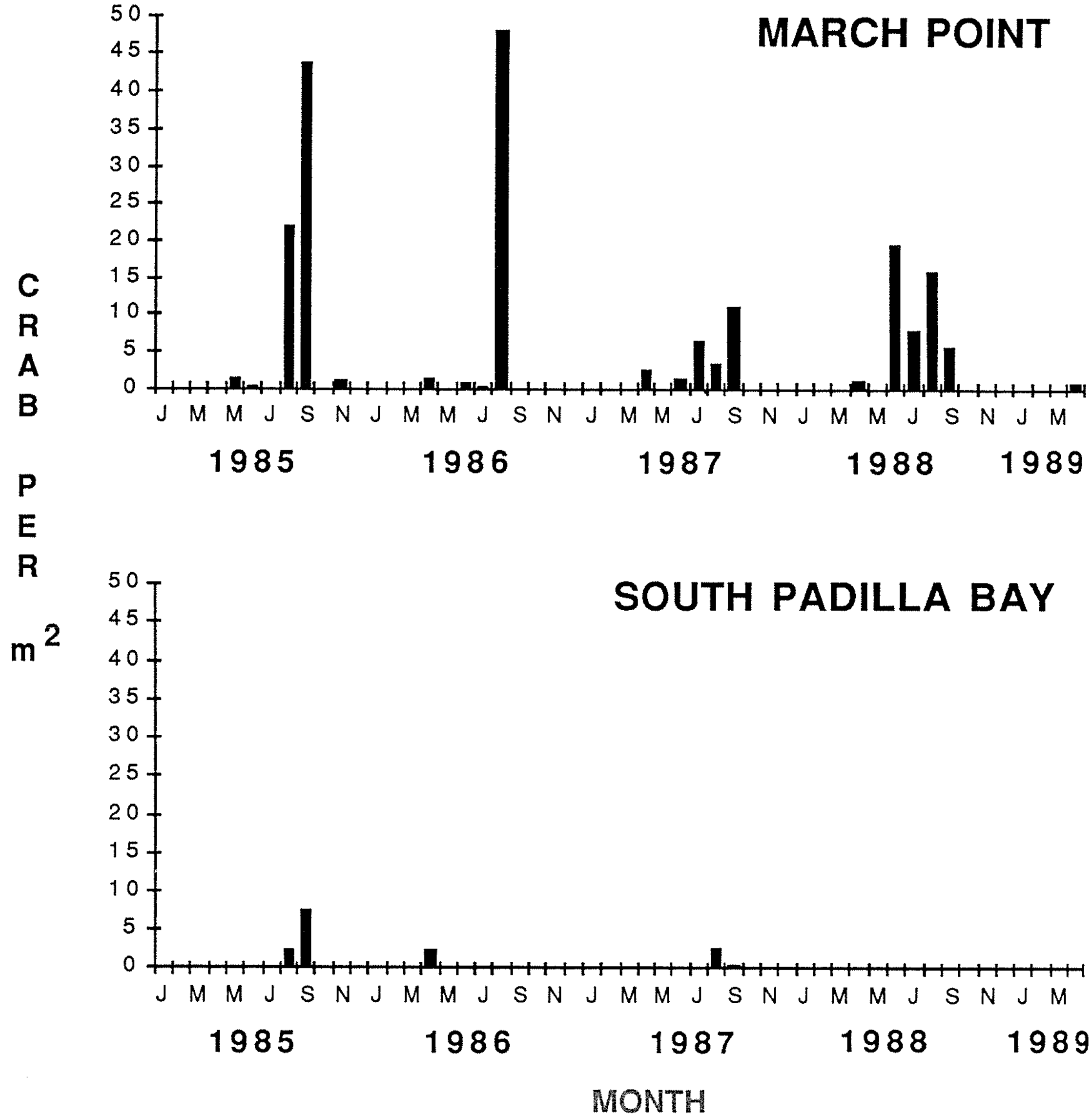


Figure 5. Average Dungeness crab densities estimated by year and by location from the intertidal crab catches.

Table 1. List of common and scientific names of fishes caught by beam trawl in Padilla Bay during 1987 and 1988. * = First time reported for Padilla Bay.

Common name	Scientific name
Bay pipefish	*Syngnathus griseolineatus*
Big skate	*Raja binoculata*
Buffalo sculpin	*Enophrys bison*
Butter sole*	*Isopsetta isolepis*
Cabezon*	*Scorpaenichthys marmoratus*
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Crescent gunnel	*Pholis laeta*
English sole	*Parophrys vetulus*
Great sculpin	*Myoxocephalus polyacanthocephalus*
Grunt sculpin	*Rhamphocottus richardsoni*
Marbled sculpin*	*Liparis dennyi*
Pacific sandlance	*Ammodytes hexapterus*
Pacific spiny lumpsucker	*Eumicrotremus orbis*
Pacific tomcod	*Microgadus proximus*
Padded sculpin	*Artedius fenestralis*
Penpoint gunnel	*Apodichthys flavidus*
Pile perch*	*Rhaccochilus vacca*
Plainfin midshipman*	*Porichthys notatus*
Ribbed sculpin	*Triglops pingeli*
Ribbon snailfish*	*Liparis cyclopus*
Rock greenling*	*Hexagrammos lagocephalus*
Rock sole	*Lepidopsetta bilineata*
Saddleback gunnel	*Pholis ornata*
sand sole	*Psettichthys melanostictus*
Sharpnose sculpin*	*Clinocottus acuticeps*
Shiner perch	*Cymatogaster aggregata*
Showy snailfish*	*Liparis pulchellus*
Silverspotted sculpin	*Blepsias cirrhosus*
Snake prickleback	*Lumpenus sagitta*
Speckled sanddab	*Citharichthys stigmaeus*
Staghorn sculpin	*Leptocottus armatus*
Starry flounder	*Platichthys stellatus*
Striped perch*	*Embiotoca lateralis*
Sturgeon poacher	*Agonus acipenserinus*
Tadpole sculpin	*Psychrolutes paradoxus*
Threespined stickleback	*Gasterosteus aculeatus*
Tubenose poacher	*Pallasina barbata aix*
Tubesnout*	*Aulorhynchus flavidus*
Whitespotted greenling*	*Hexagrammos stelleri*

Table 2. Average fish/hectare, species richness and species diversity measures for marine fish caught in the beam trawl during sampling in 1987 and 1988.

Month	Average fish per hectare	Species richness	Species diversity
June 1987			
Intertidal eelgrass	878	14	2.05
Subtidal eelgrass	1,149	14	2.12
Subtidal channel	1,210	19	1.97
All	1,121	27	2.53
July 1987			
Intertidal eelgrass	2,455	12	1.66
Subtidal eelgrass	4,112	18	2.11
Subtidal channel	1,107	20	2.15
All	2,072	28	2.43
August 1987			
Intertidal eelgrass	1,545	18	2.02
Subtidal eelgrass	1,510	17	2.01
Subtidal channel	1,300	20	2.46
All	1,415	26	2.62
September 1987			
Intertidal eelgrass	684	15	2.23
Subtidal eelgrass	1,717	17	2.36
Subtidal channel	313	14	1.92
All	640	27	2.76
October 1987			
Intertidal eelgrass	630	14	2.24
Subtidal eelgrass	1,307	15	2.11
Subtidal channel	194	14	2.39
All	557	26	2.64
January 1988			
Intertidal eelgrass	53	5	1.49
Subtidal eelgrass	201	7	1.16
Subtidal channel	173	12	2.06
All	145	16	2.13
April 1988			
Intertidal eelgrass	183	8	1.61
Subtidal eelgrass	145	7	1.69
Subtidal channel	151	8	1.81
All	159	15	2.26
All samples	855	40	2.81

fish species by cruise, by stratum and by station, together with species richness and diversity, are listed in Appendix Table 1.

Fish were not randomly distributed in time or across habitats. Density pictograms (Fig. 6) for the 12 most abundant fish species show that many of these species were absent or very sparse in the trawl catches during the winter/early spring period. Many species were limited almost entirely to the eelgrass habitats (e. g., threespine stickleback, silverspotted sculpin, tubesnout) while others were in greatest abundance in the subtidal channels (English sole, buffalo sculpin).

Trammel net catches. Only a few of the larger species of fish, especially spiny dogfish (*Squalus acanthias*) and larger staghorn and buffalo sculpin, were caught in the trammel net. The only species sampled by the trammel net and not by the beam trawl was the spiny dogfish, which has previously been recorded from Padilla Bay (WDOE 1984).

Beach seine catches. The only use of the beach seine was for collecting staghorn sculpin for stomach content analyses and for use in the laboratory predator/prey experiments. Hence, no species list was tabulated for this piece of gear.

STOMACH CONTENT ANALYSES

Beam Trawl Catches

Stomach contents were analyzed from 18 species of fish caught in the beam trawl. IRIs were calculated for the six most abundant fish species that were considered plausible predators of Dungeness crab megalopae or juveniles. The percent IRIs for eight major faunal prey groups are listed for these six fish species in Table 3. This table shows that staghorn sculpin consumed the most crab (% IRI = 14%) and that all other fish species had percent IRI compositions of about 3% or less for crab. Figure 7 (which illustrates the data contained in Table 3) shows that staghorn sculpin are very general feeders with prey items in all categories (including 6.7% algae and detritus). The other five fish species were more specific feeders with three species (silverspotted sculpin, padded sculpin and saddleback gunnel) feeding primarily on amphipods, or isopods in the case of whitespotted greenling.

Twelve other species of less commonly caught fish were also analyzed for their gut contents. Few fish were found to contain crabs, but those consumed were primarily pea crab (*Pinnixa* spp.) (Table 4). The only fish in this group observed to contain Dungeness crab remains was one specimen of the big skate, which contained a single juvenile crab.

Staghorn sculpin feeding habits were intensively investigated during this study because of their relatively high abundance and because they had previously been identified as a major crab predator (as substantiated by the data in Table 3 above). Figure 8 shows the results of the

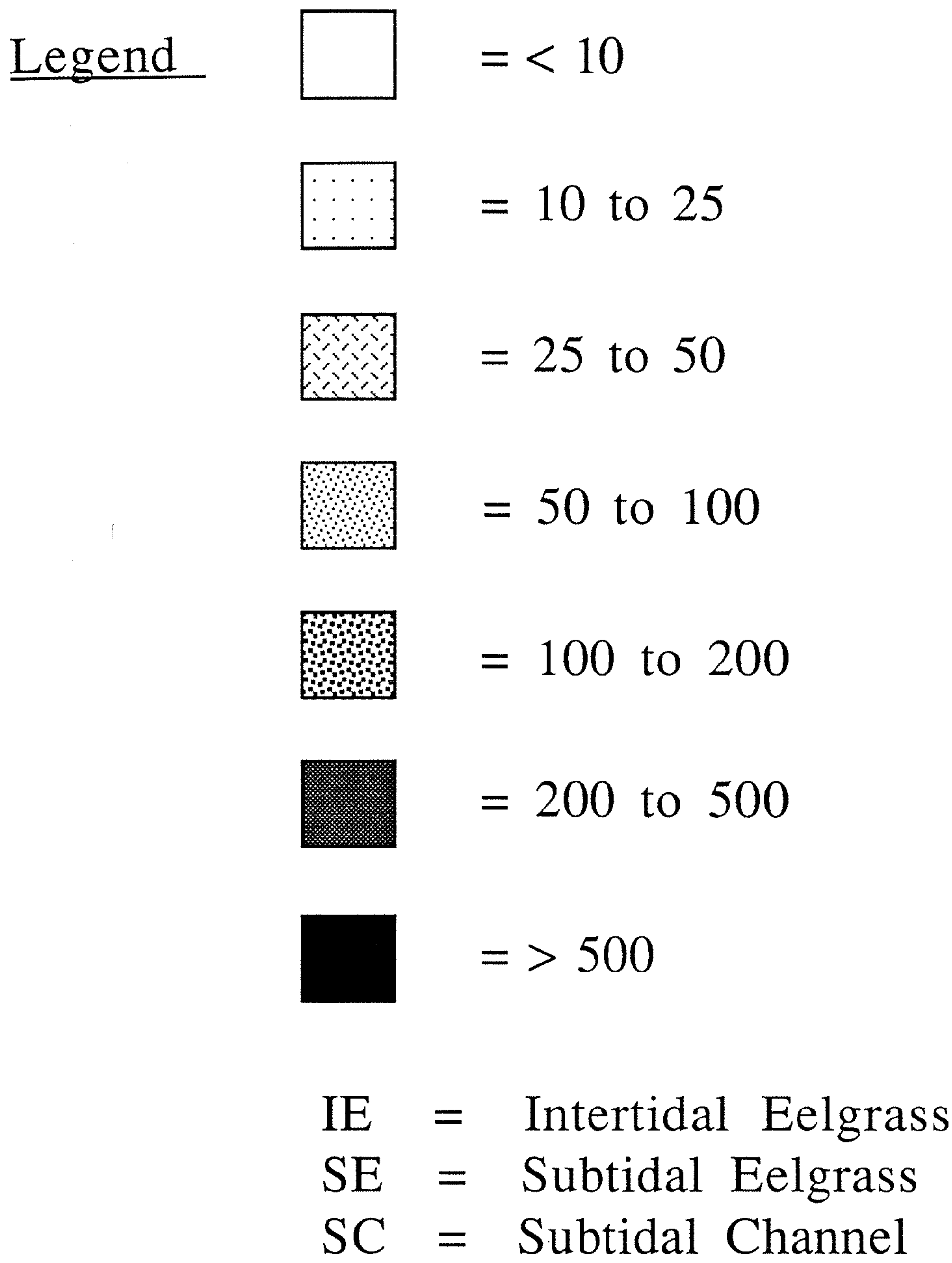
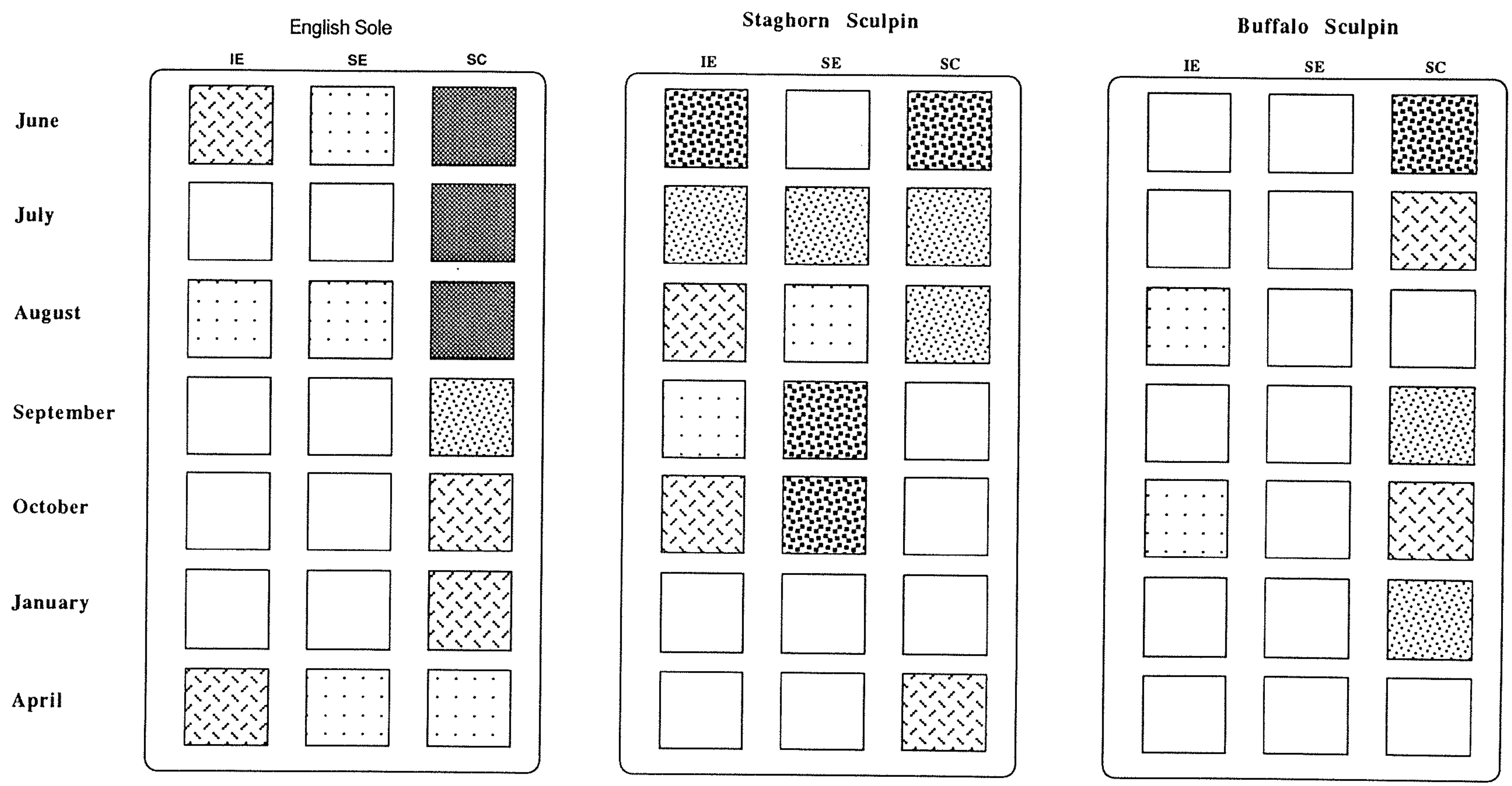


Figure 6. Fish density "pictograms" (following four pages) showing relative abundances by month (June 1987 to April 1988) and by stratum of the 12 most common fish species caught in the beam trawl tows. The legend values noted above are in terms of fish/hectare.



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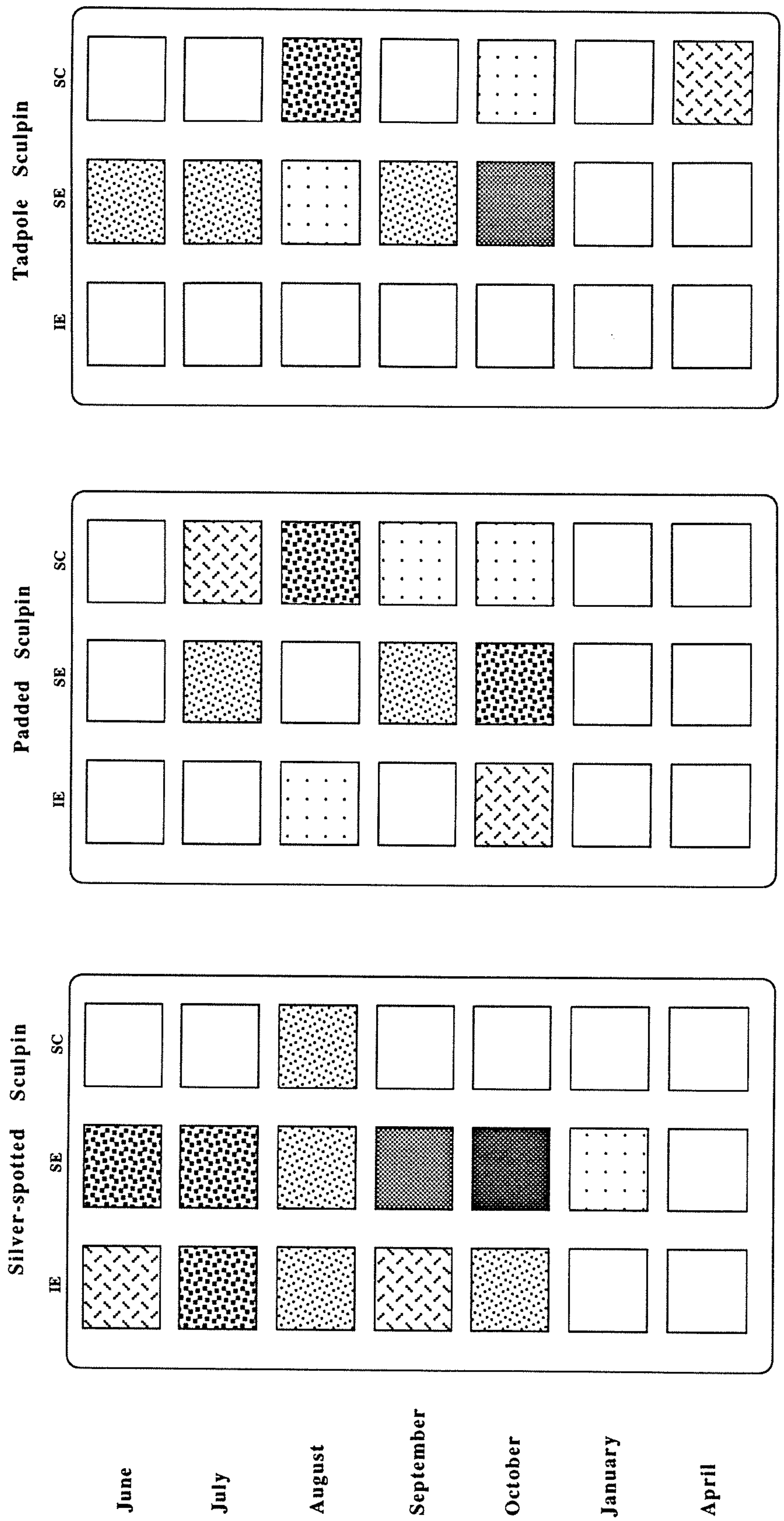

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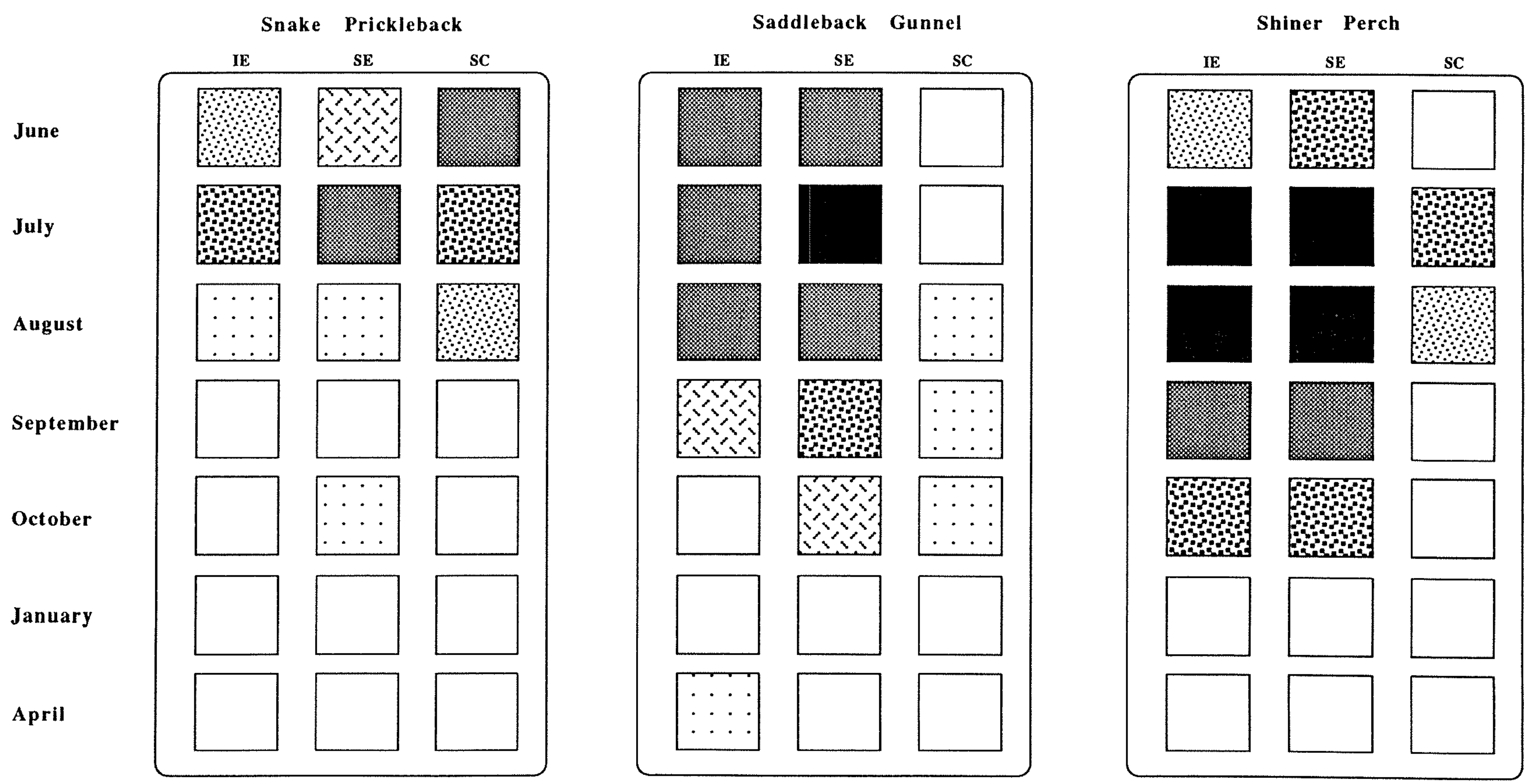

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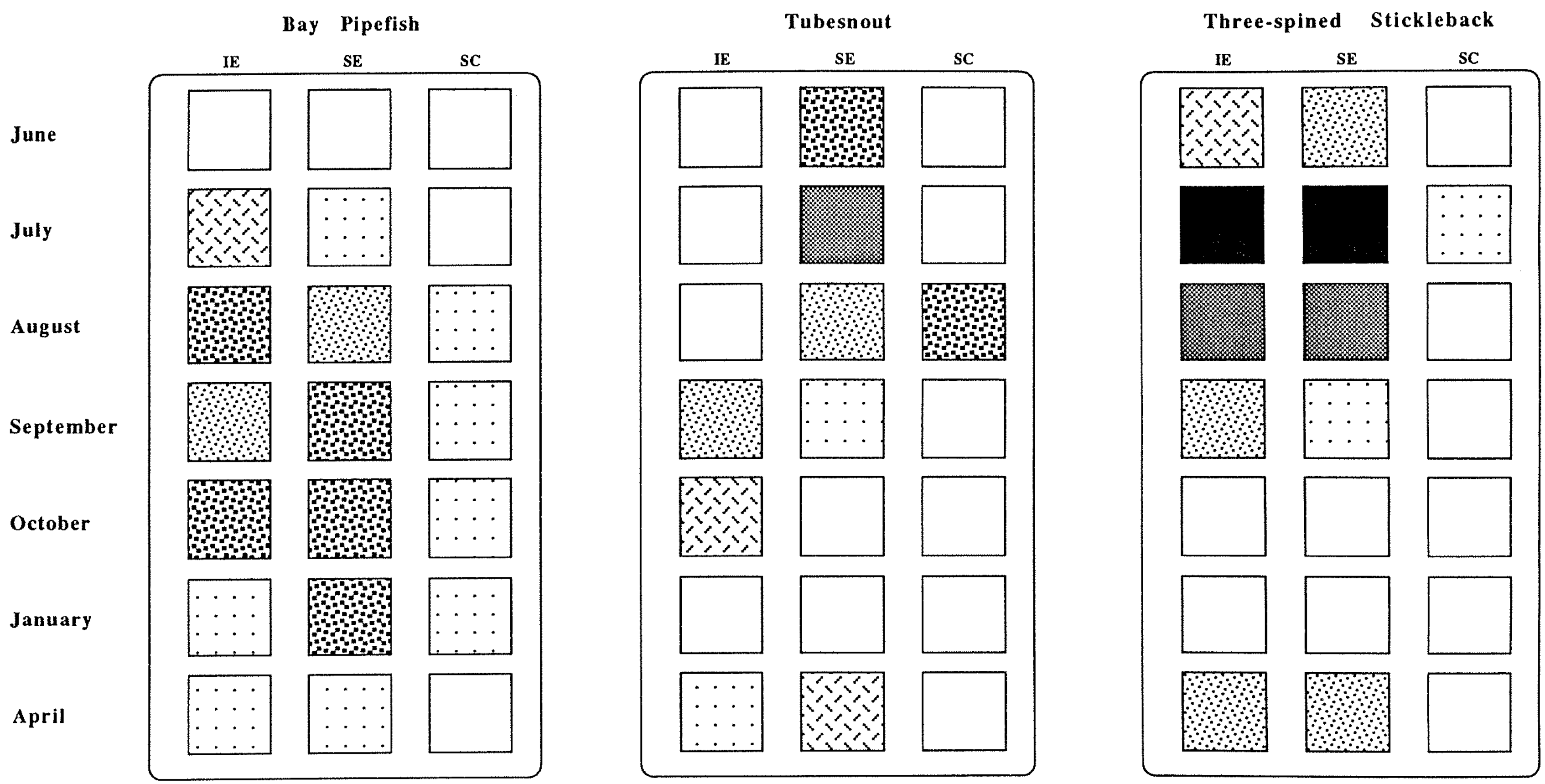


Figure 6—cont.

Table 3. Percent IRIs for six common marine fish caught by beam trawl in Padilla Bay.

Group	Staghorn sculpin (n = 160 fish)	Silverspotted sculpin (n = 22 fish)	Great sculpin (n = 13 fish)	Padded sculpin (n = 12 fish)	Whitespotted greenling (n = 12 fish)	Saddleback gunnel (n = 10 fish)
Amphipod	42.8	90.1	9.1	96.9	18.9	82.3
Isopod	17.8	9.6	29.2	0.0	68.2	16.4
Crab	14.0	0.1	1.0	0.3	3.1	0.0
Shrimp	3.1	0.2	13.0	0.0	6.3	0.0
Other crustacean	3.5	0.0	0.0	2.6	0.1	1.0
Mollusc	2.3	0.0	1.9	0.0	0.6	0.1
Polychaete	8.7	0.0	0.0	0.2	2.8	0.2
Fish	1.1	0.0	43.8	0.0	0.0	0.0
Algae, detritus, etc.	6.7	0.0	2.0	0.0	0.0	0.0

analyses of 160 staghorn sculpin stomachs from all cruises and stations combined as well as a breakdown by stratum. Sculpin caught subtidally tended to feed most heavily on amphipods, while sculpin inhabiting the eelgrass beds showed less prey specificity, although crab, including Dungeness crab, were most common in the diet of the eelgrass sculpin. However, Dungeness crab comprised only a small portion of the total crab diet (Table 5), with pea crabs being the dominant crab prey of staghorn sculpin.

A more detailed summary of the stomach contents by prey species/groups for the beam trawl-caught staghorn sculpin appears in Appendix Table 2.

Trammel Net Catches

Stomachs from staghorn sculpin caught in the trammel net set at trawl Station 15 during each cruise (except April 1988) were also analyzed. Figure 9 shows that these sculpin fed primarily on isopods (52% of the total IRI) and crab (31%), although none of the crab were identified as *C. magister* (Appendix Table 3).

Beach Seine Catches

Beach seine sampling in both 1987 and 1988 focused exclusively on gathering additional stomach content data for staghorn sculpin. Sixty-seven sculpin were caught near the South Padilla Bay intertidal station during July and August 1987. This is the time of the year when most larval/post-larval metamorphosis and settlement of Dungeness crab takes place in Puget Sound. The IRI summary by major prey group (Appendix Table 4) shows that the major components of the sculpin diets were (as % IRI): amphipods = 60%, isopods = 19%, and crab = 12%. Thus, these three groups of prey items comprised over 90% of the total diet.

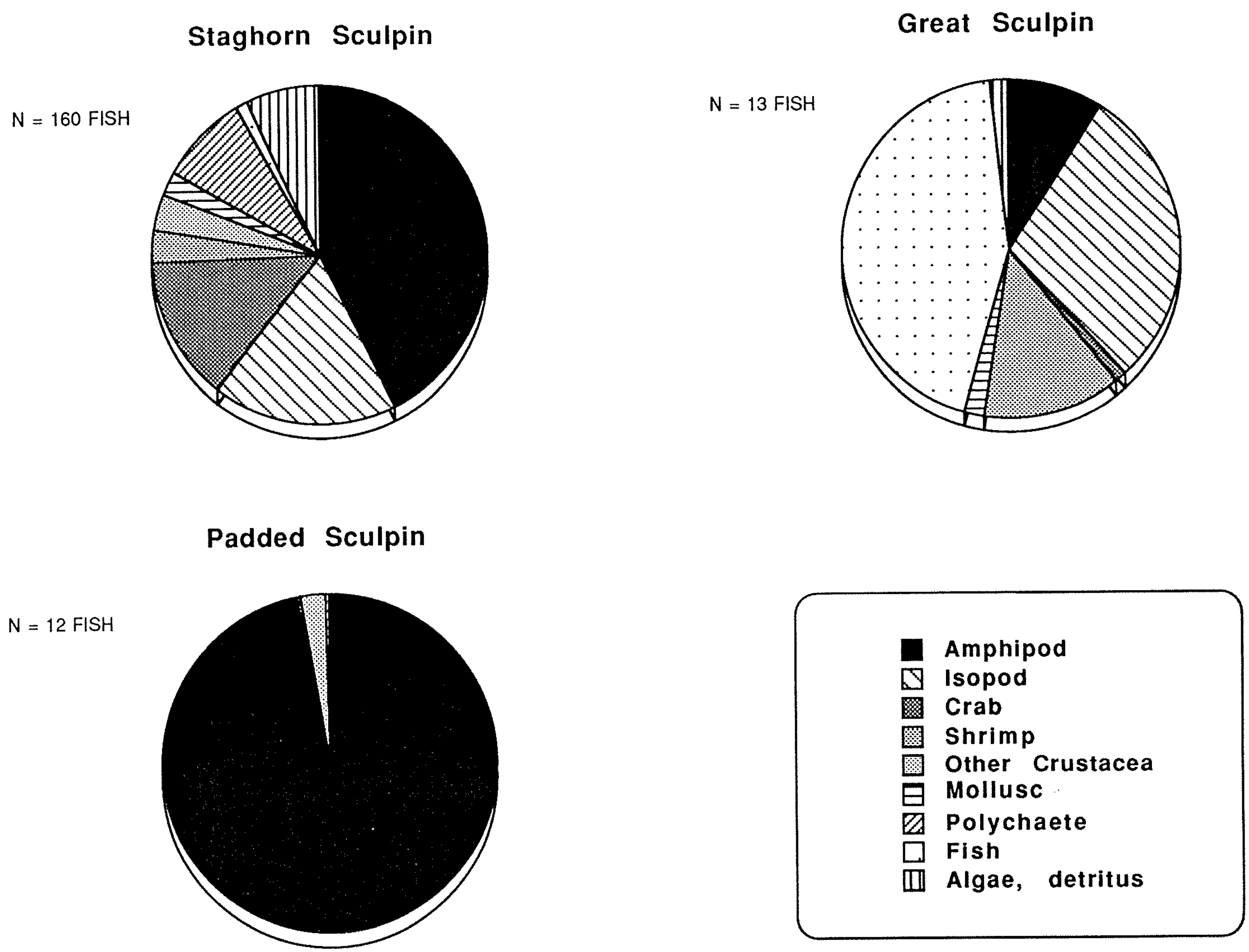


Figure 7. Average stomach contents (by % IRI) of six marine fish caught by beam trawl from Padilla Bay.

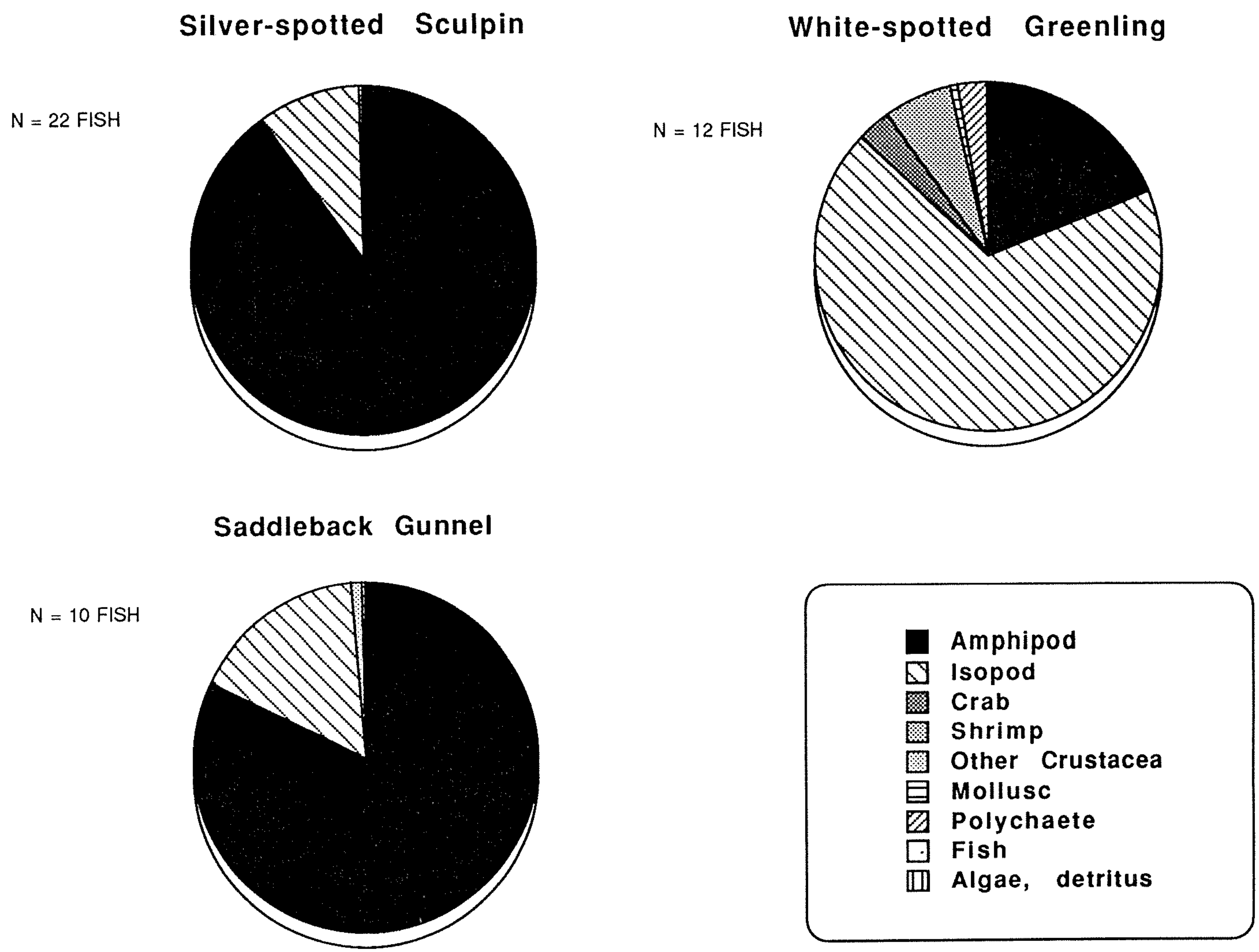


Figure 7—cont.

Table 4. Stomach contents of 12 less common marine fish caught by beam trawl in Padilla Bay.

Species	No. of fish	Fish #1	Fish #2	Fish #3	Fish #4
Snake prickleback	4	23 amphipods 1 isopod 29 tanaids 2 cumaceans 12 copepods 4 brittle stars 6 clams 10 polychaetes some algae	82 amphipods 13 tanaids 24 ostracods 12 cumaceans 46 copepods 6 polychaetes 2 clams	55 amphipods 1 tanaid 13 cumaceans 7 ostracods	33 amphipods 10 tanaids 8 cumaceans 1 ostracod 2 clam siphons ~400 copepods
Tadpole sculpin	4	3 amphipods 1 isopod 1 tanaid 1 ostracod	1 pinnixed crab	1 isopod	unidentifiable material
Crescent gunnel	3	19 amphipods 9 isopods 1 tanaid	40 amphipods 12 isopods 2 tanaids 2 polychaetes	35 amphipods 1 tanaid 9 isopods	
Buffalo sculpin	2	1 pinnixed crab 1 polychaete some algae	2 pinnixed crab 1 shrimp some eelgrass		
Plainfin midshipman	2	8 polychaetes 3 pinnixed crab 2 isopods some algae	empty stomach		
Sturgeon poacher	1	1 shrimp			
Sand sole	1	1 eelpout			
Shiner perch	1	~75 tanaids ~25 clams			
Penpoint gunnel	1	17 isopods 1 shrimp			
Rock sole	1	3 amphipods 12 clam siphons			
Rock greenling	1	1 isopod some algae/eelgrass			
Big skate	1	1 juv. *C. magister* 4 shrimp			

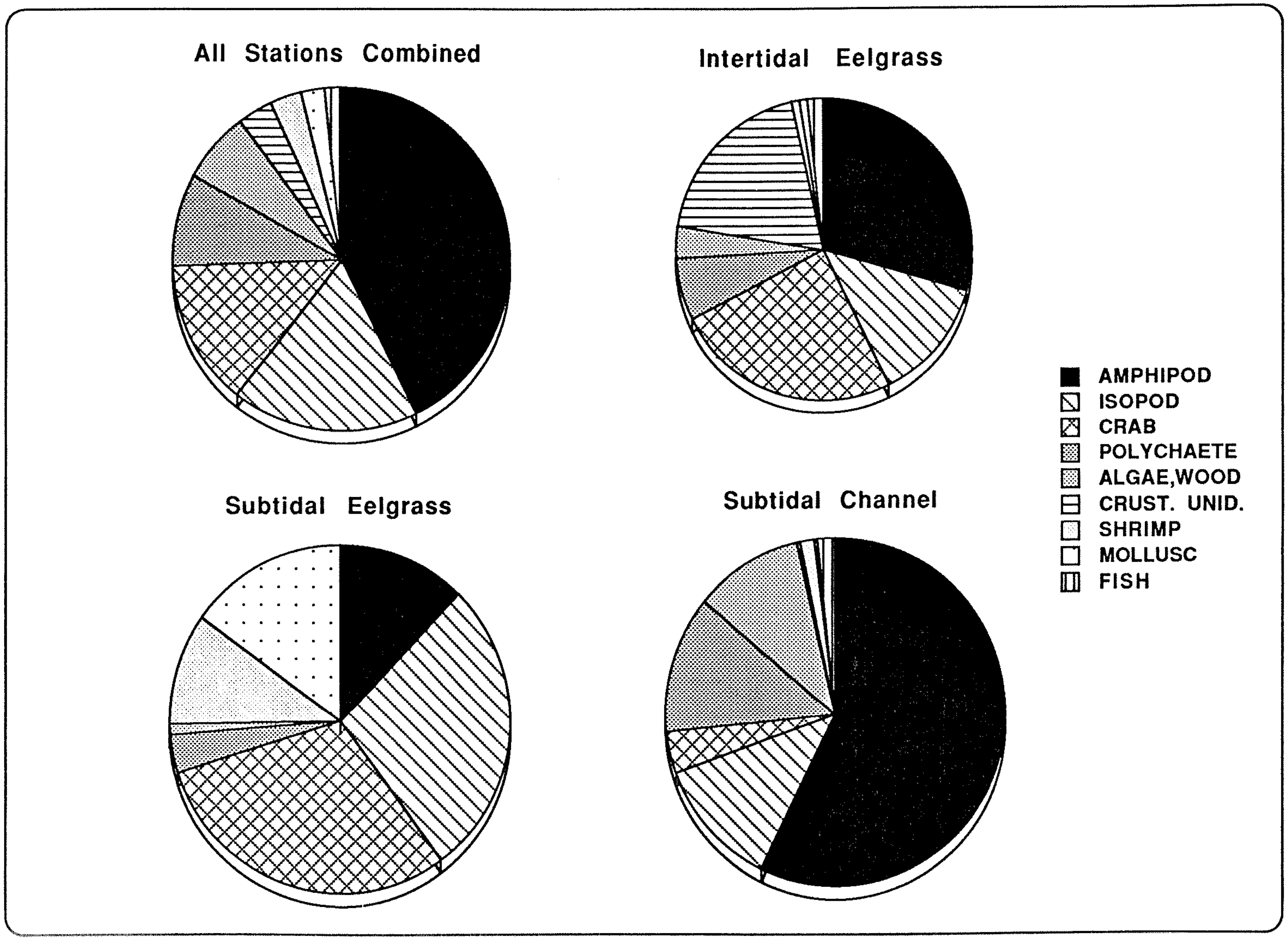


Figure 8. Average staghorn sculpin diet (% IRI's) by stratum for fish caught in the Padilla Bay beam trawl tows.

Table 5. Summary of crab species contained in stomachs of staghorn sculpin caught in the Padilla Bay beam trawls.

Species	Total number	Numerical percent	IRI	% of Crab IRI
Cancer magister	4	3.5	18.7	4.2
Cancer gracilis	4	3.5	17.4	3.9
Pinnixa spp.	102	89.5	407.5	91.8
Telmessus sp.	3	2.6	0.2	<0.1
Unidentified	1	0.9	<0.1	<0.1
TOTAL	114	100.0	443.9	100.0

A breakdown of the "crab only" portion of the diet of sculpin caught by beach seine in 1987 (Table 6) shows that pea crabs accounted for roughly 95% of the crab diet on the basis of IRI and 76% on the basis of numbers eaten. Dungeness crab early instars accounted for 20% of the number of crab eaten, but only about 4% in terms of IRI.

A more detailed analysis of staghorn sculpin diet was conducted during the summer of 1988. A total of 160 staghorn sculpin was caught by beach seine during August and early September at March Point, and an additional 17 fish caught at Ship Harbor, next to the Shannon Point Marine Lab, were included in the overall analyses. The sculpin ranged in size from 45 to 245 mm TL and had an average stomach fullness of 48%, with 93% having some stomach contents to analyze (Table 7). The major components of the diets of these fish were always amphipods, isopods and crabs, although the dominant group varied by sampling period (Table 7). A more detailed summary of the gut content data (Table 8) shows that crab accounted for 8.5% of the total number of items eaten, 26% by weight, and 18.8% as % IRI. Amphipods and isopods dominated the diets, with % IRIs of approximately 30% each.

Within the "crab" category, *C. magister* accounted for 20% of the total number of all crab eaten and 27% as IRI for staghorn sculpin caught by beach seine in 1988 (Table 9). Again, pea crabs accounted for the bulk of the crab component with 65% of the crab IRI.

Graphical summaries of the sculpin diets for the 1987 (South Padilla Bay) and 1988 (March Point and Ship Harbor) samples show that amphipods and isopods dominate the staghorn sculpin diets and that crabs are third in terms of % IRI (Fig. 10). These graphs also illustrate that staghorn sculpin are very general feeders that use any prey items available in a given area. Our laboratory observations also indicated that individual fish can target on specific prey items. Often, fish stomachs would contain almost all of one prey item such as pea crabs, amphipods or clam siphons.

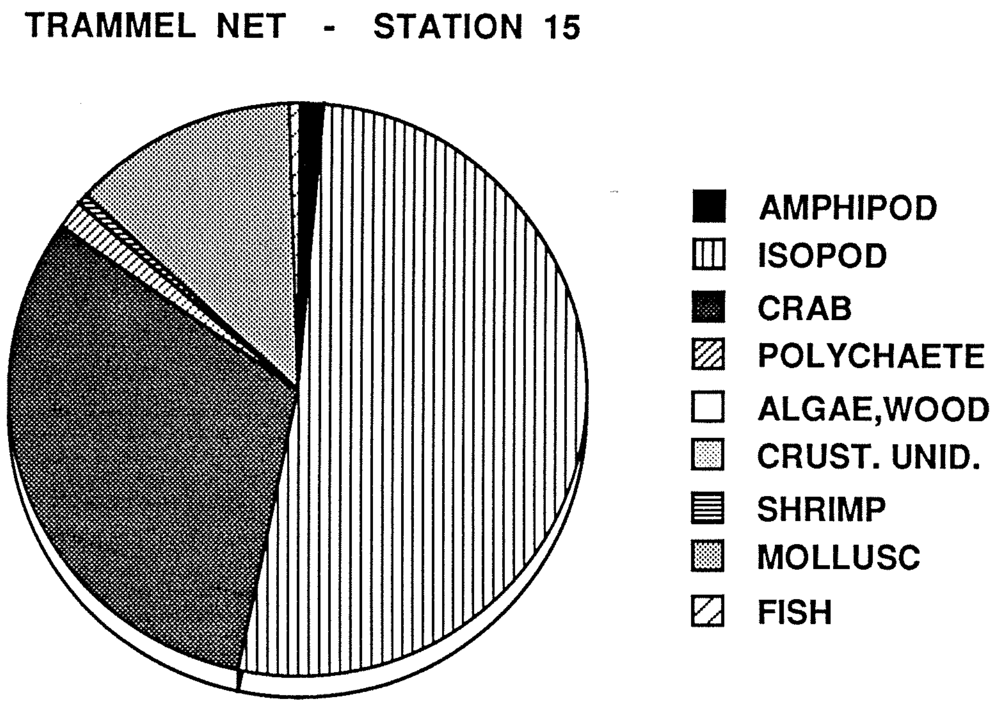


Figure 9. Average staghorn sculpin diet (% IRIs) for fish caught by trammel net in Padilla Bay.

Table 6. Summary of crab species contained in stomachs of staghorn sculpin caught in the 1987 beach seine samples from South Padilla Bay.

Species	Total number	Numerical percent	IRI	% of Crab IRI
Cancer magister	4	3.5	18.7	4.2
Cancer magister	20	20.0	53.4	4.4
Cancer gracilis	3	3.0	1.2	0.1
Pinnixa spp.	76	76.0	1,147	95.4
Telmessus sp.	1	1.0	0.9	0.1
Unidentified	0	0.0	0	0.0
TOTAL	100	100	1,202.5	100

Table 7. Summaries of the various stomach content measures for staghorn sculpin caught by beach seine at March Point and Ship Harbor during the summer of 1988.

Location	Date	No. fish examined	% with gut contents	Total wt. all prey items	Mean wt. (g/fish)	Total no. all prey items	Mean no. (no./fish)	Major IRI components: Prey category	Major IRI components: % total IRI	Mean % stomach fullness (X ±1 SD)
MP	8/10/88	54	94%	26.6	0.52	503	9.9	Isopods	31.2	40 ± 30
								Amphipods	29.2	
								Crab	24.2	
MP	8/15/88	40	90%	35.3	0.98	237	6.6	Crab	36.6	54 ± 33
								Isopod	25.2	
								Amphipod	19.5	
SH	8/18/88	17	88%	27.3	1.82	187	12.5	Isopod	40.7	43 ± 40
								Fish	39.5	
								Crab	7.3	
MP	8/24/88	39	95%	23.5	0.64	439	11.9	Amphipod	61.4	55 ± 32
								Isopod	11.4	
								Fish	7.3	
MP	9/5/88	27	93%	11.5	0.46	397	15.9	Isopod	32.5	49 ± 23
								Amphipod	27.3	
								Mollusc	15.9	
								Crab		
All combined		177	93%	124.2	0.76	1,781	10.9	Amphipod	31.7	48 ±31
								Isopod	28.3	
								Crab	18.8	

MP = March Point; SH = Ship Harbor.

Table 8. Summary of the IRI calculations for stomach contents of staghorn sculpin caught by beach seine at March Point during the summer of 1988.

Prey item	Total wt. (g)	Total no.	% by wt.	% by no.	% frequency occurrence	IRI	Total % IRI
Amphipod	6.2	656	5	36.8	59.3	2478.7	31.5
Isopod	15.3	467	12.3	26.2	57.6	2217.6	28.2
Crab	32.3	152	26	8.5	42.9	1480.1	18.8
Polychaete	13.2	67	10.6	3.8	29.9	430.6	5.5
Mollusc	1.6	206	1.3	11.6	31.1	401.2	5.1
Fish	42.7	31	34.4	1.7	10.7	386.3	4.9
Algae, wood, rock, etc.	5.9	118	4.8	6.6	27.7	315.8	4
Shrimp	4.1	44	3.3	2.5	19.8	114.8	1.5
Other crustaceans	2.9	40	2.4	2.2	7.9	36.3	0.5
Total	124.2	1781				7861.4	100

Mean prey wt./fish stomach = 0.7 ± 1.27 g.
Mean no. prey items/fish stomach = 10.06 ± 10.04.
Ratio gut contents:fish body wt. = .07 ± .04.
No. stomachs = 177.
No. empty = 13.
No. full = 164.
Stomach fullness index (X ± 1SD) = 48.2% ± 31.3%.

Table 9. Summary of crab species contained in stomachs of staghorn sculpin caught in the 1988 beach seine samples from March Point and Ship Harbor.

Species	Total number	Numerical percent	IRI	% of Crab IRI
Cancer magister	31	20.4	166.4	26.6
Pinnixa spp.	88	57.9	408.0	65.3
Hemigrapsus sp.	14	9.2	22.2	3.6
Unidentified	19	12.5	28.2	4.5
TOTAL	100	100	624.8	100

Length-frequency analysis of staghorn sculpin caught by beach seine in 1988 (Fig. 11) indicated 3 predominant size modes for the sculpin population: 45-79 mm TL (71 fish), 80-119 mm (60 fish) and ≥120 mm (46 fish, including a few distinctly larger fish ≥170 mm). Basic information about each group of these fish and their diets is summarized in Table 10, which shows that both fish weights and mean weight of the gut contents increased exponentially. However, the ratios of meal:fish body weight remained constant at 0.05 for each group. The total number of prey items was inversely related to sculpin size, indicating that larger sculpin fed on fewer, but larger prey. Gut fullness also changed with sculpin size (Fig. 12), with the larger fish having a higher proportion of fuller stomachs. This may be a reflection of two things: (1) larger prey and (2) slower digestion and gut evacuation rates.

There were also distinct shifts in the category of prey consumed by size group. Table 11 and Figure 13 show that, in terms of % IRIs, the smallest fish stomachs contained over 50% amphipods as compared to only 6.5% amphipods for the larger sculpin. The smallest sculpin ate few crabs (1.2%) versus the other two groups (34% and 29%). There was also an obvious switch to fish in the diet of the larger sculpin (18.8%) as compared to the smaller two groups.

EXPERIMENTAL STUDIES

Predator Inclusion/Exclusion Cages

Three cage experiments were conducted during summer 1987 low tides in the vicinity of trawl Station 15 (Fig. 2). Each of these 48-h experiments assessed predation by staghorn sculpin on juvenile Dungeness crab instars in experimental cages (vs. control cages with crab but without a sculpin predator). One of the three experiments was conducted without any

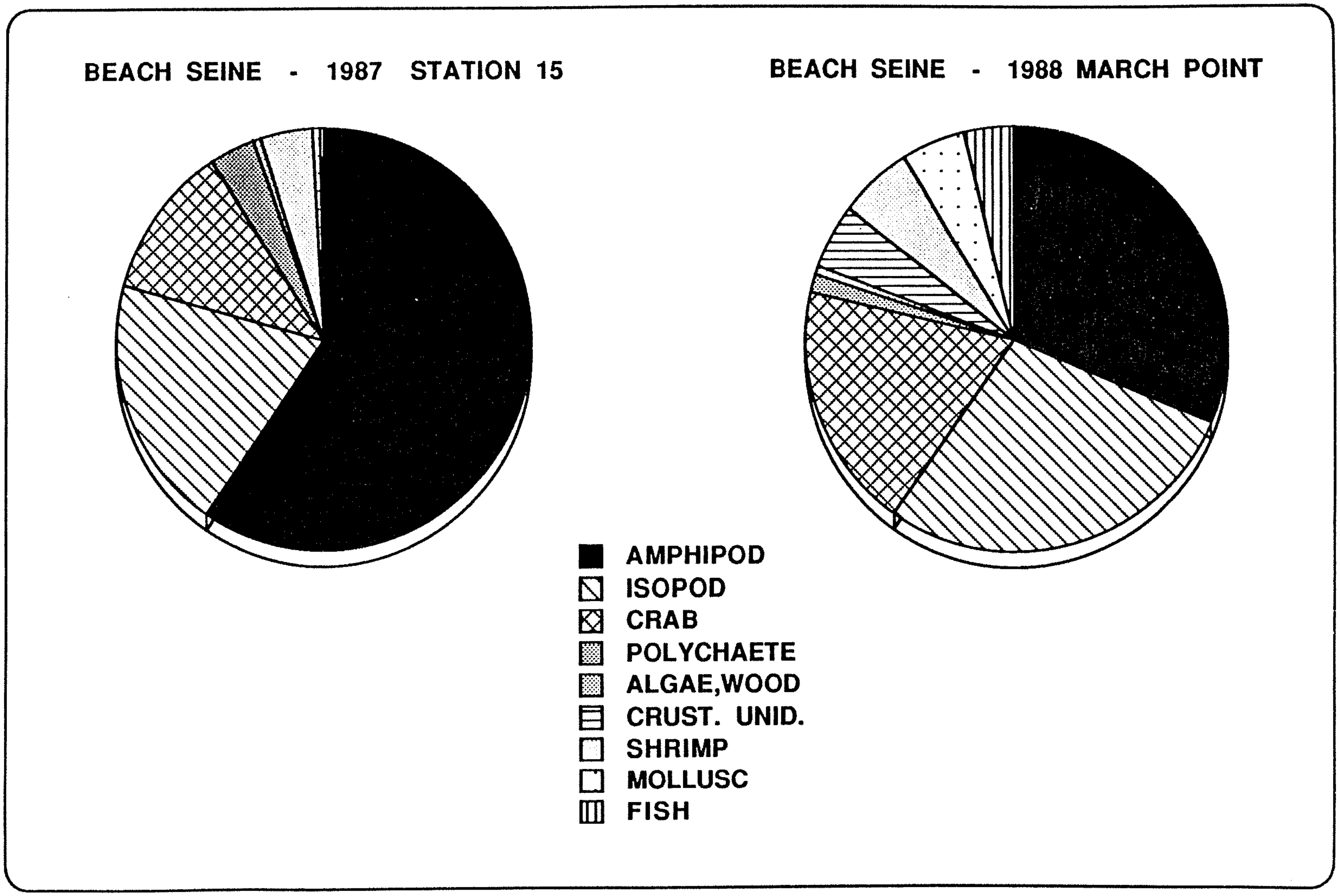


Figure 10. Average staghorn sculpin diet (% IRIs) for fish caught by beach seine at March Point (1988) and in South Padilla Bay (1987).

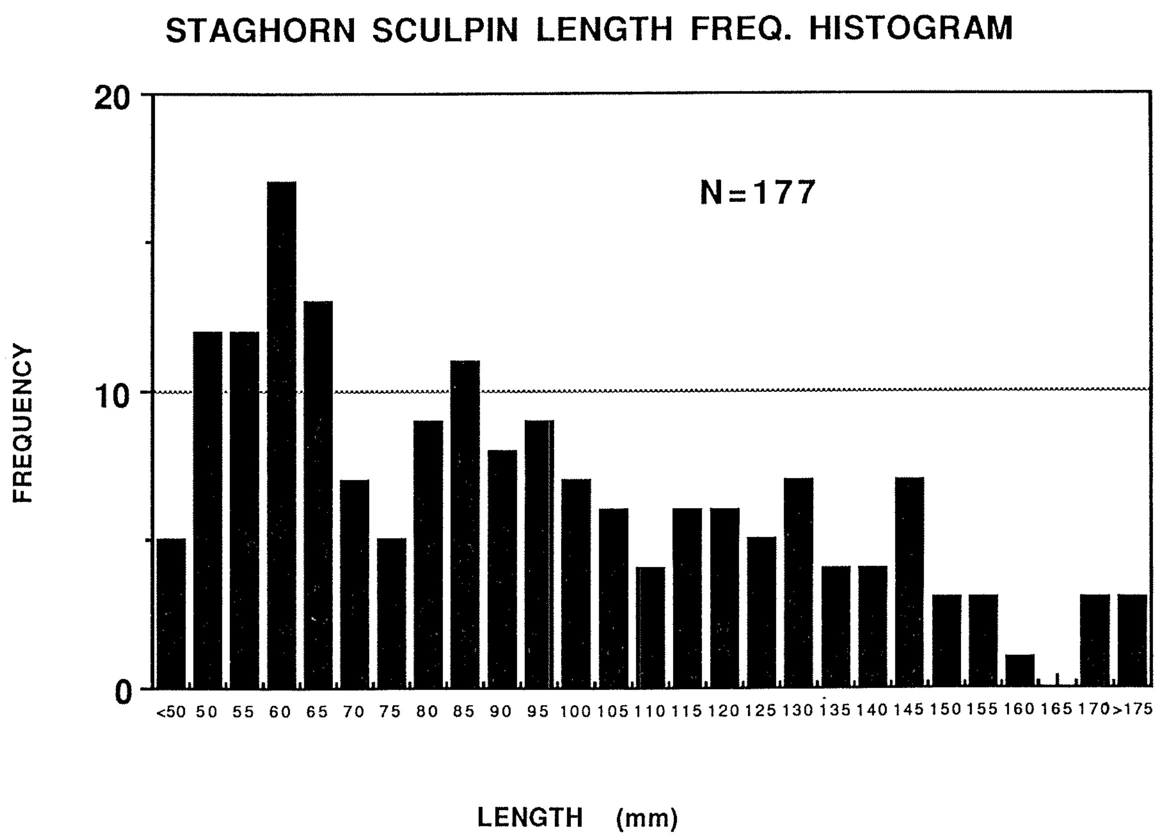


Figure 11. Length-frequency histogram showing the size composition of staghorn sculpin caught by beach seine at March Point and Ship Harbor during the summer of 1988.

Table 10. Summary of staghorn sculpin sizes and stomach contents for fish caught by beach seine at March Point and Ship Harbor during the summer of 1988.

Parameters	Size I (45-79 mm TL)	Size II (80-119 mm TL)	Size III (>120 mm TL)	All fish combined (45-260 mm TL)
No. fish examined	71	60	46	177
No. empty stomachs (%)	2 3%	7 12%	4 9%	13 7%
No. with gut contents (%)	69 97%	53 88%	42 91%	164 93%
Mean fish wet wt. (g)	3.08 ± 1.15	12.19 ± 5.23	45.98 ± 39.75	17.32 ± 26.82
Mean fish total length (mm)	61.44 ± 8.09	96.35 ± 11.16	145.57 ± 25.44	95.14 ± 36.83
Mean % stomach fullness	47.52 ± 27.79	41.67 ± 31.2	56.74 ± 35.75	48.22 ± 31.32
Mean gut content wt. per fish (g)	0.14 ± 0.10	0.59 ± 0.69	2.03 ± 1.87	0.70 ± 1.27
Mean no. prey per fish	13.1 ± 9.2	7.5 ± 7.5	8.65 ± 13.06	10.06 ± 10.04
Ratio meal wt:fish body wt.	0.05 ± 0.03	0.05 ± 0.03	0.05 ± 0.04	0.07 ± 0.04
Total no. prey eaten by group	931	452	398	1,781

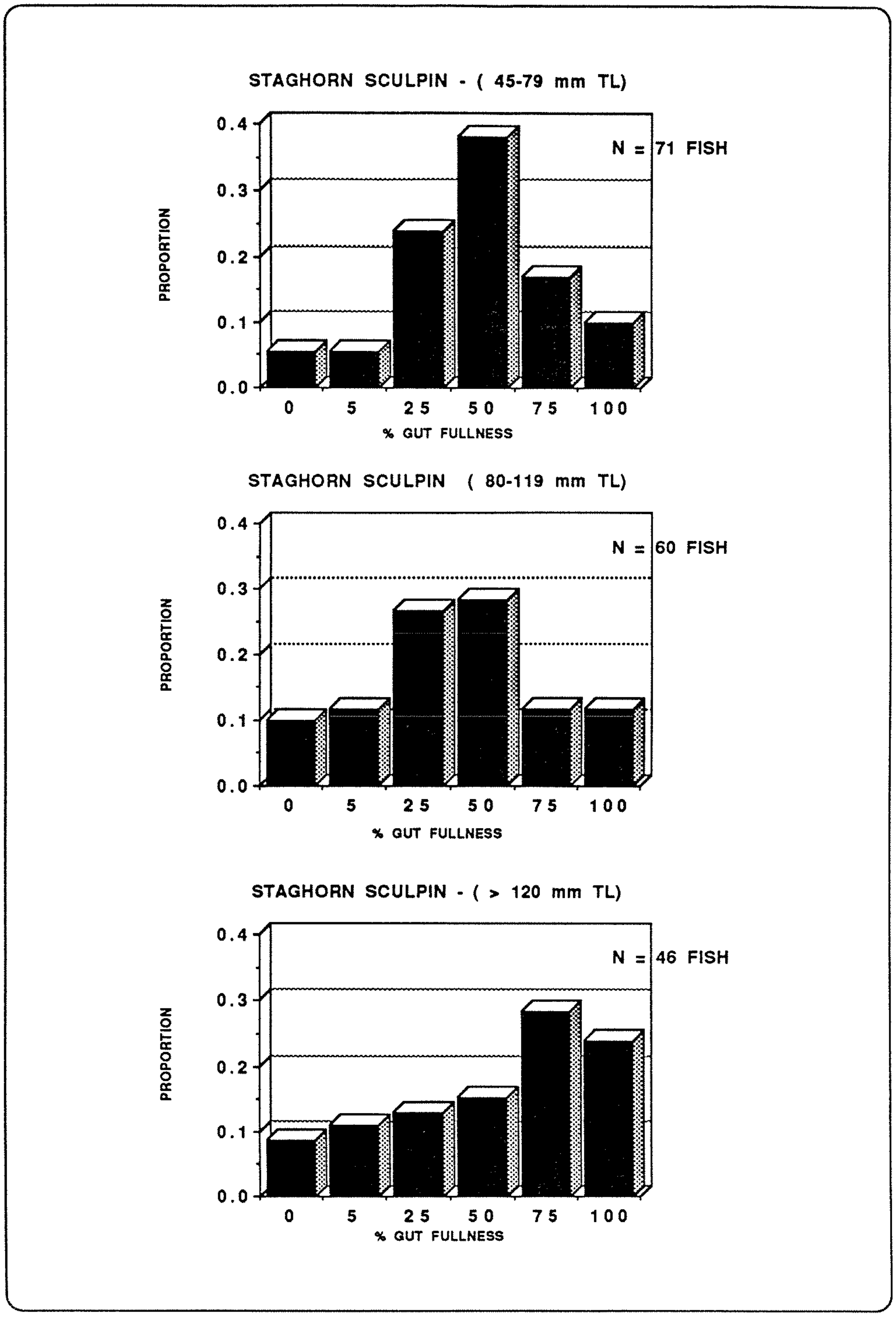


Figure 12. Histograms showing the percent gut fullness by size groupings for staghorn sculpin caught by beach seine at March Point and Ship Harbor during the summer of 1988.

Table 11. Percent IRIs for stomach contents from three sizes of staghorn sculpin caught by beach seine at March Point and Ship Harbor during the summer of 1988.

Prey category	Sculpin size* I	II	III	All combined
Amphipod	54.3	27.6	6.5	31.5
Isopod	21.6	21.7	29	28.2
Crab	1.2	33.6	29.1	18.8
Polychaete	8.6	7.9	2.2	5.5
Mollusc	8.4	3.5	2.1	5.1
Fish	0.1	1.8	18.8	4.9
Algae, wood, rock	1	2.8	11.4	4
Shrimp	3.9	1	0.3	1.5
Crustacea parts	1	0.1	0.6	0.5

*Size I = 45-79 mm; Size II = 80-119 mm; Size III = >120 mm.

vegetative cover in cages, while some cages in the other two experiments contained approximately 50% eelgrass (*Zostera marina*) cover.

Only in the first experiment was a statistically significant reduction in crab numbers noted for the experimental cages (Table 12). However, even in this case the reduction in crab numbers inside the cages with sculpin was less than 10% as compared to the control cages.

The possible conclusions from these labor-intensive experiments were twofold: (1) staghorn sculpin are not significant predators of juvenile crab, or (2) the cage environment was too artificial and stressful to allow realistic interactions between the fish and crab. Prior observations by us in related studies in Grays Harbor (J. Armstrong, unpublished) discount the first conclusion and suggest that the cage studies adversely affected fish and/or crab behaviors. Hence, more controlled laboratory studies were conducted in 1988.

Laboratory Predator/Prey Experiments

Predator/prey size selectivity experiments. The purpose of this experiment was to determine preference by staghorn sculpin for prey sizes of *C. magister* ranging from megalopae to juvenile instars. Six fish of various sizes were allowed to feed on megalopae and 1st through 5th instar crab, or both, for 24 h following 3 days of starvation. The two smallest fish, 54- and 78-mm TL, ate only two crab megalopae each, having been offered five megalopae and five 1st and 2nd instars each. A 98-mm fish ate three megalopae, two 1st and one 2nd instars, having been offered 5 megalopae and 5 instars. A 130 mm fish ate a single 3rd instar having been offered one 3rd and four 4th instars, whereas a 160-mm fish ate none of the five 4th instars.

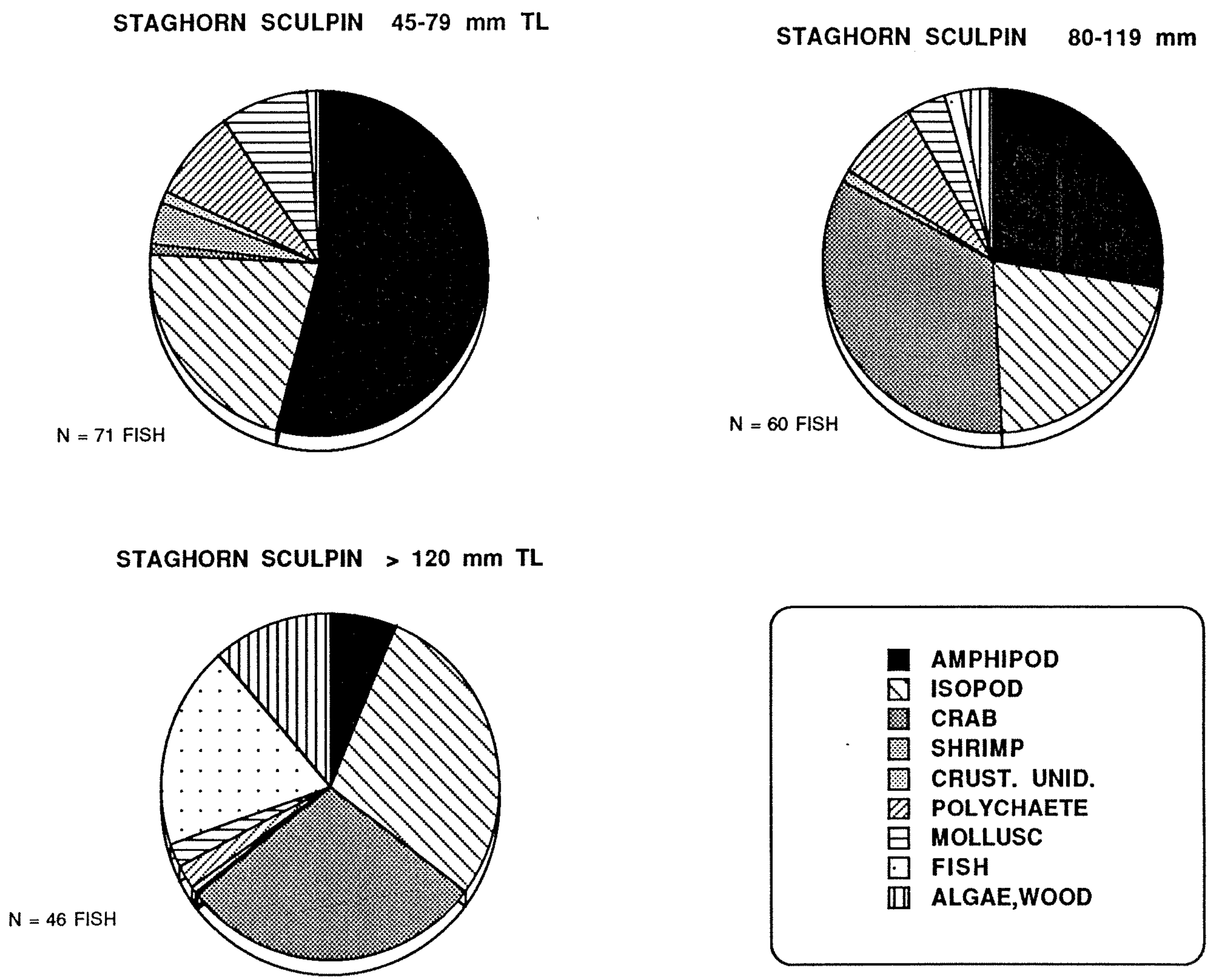


Figure 13. Average diet (as % IRIs) of three size groupings of staghorn sculpin caught by beach seine at March Point and Ship Harbor during the summer of 1988.

Table 12. Results of the predator inclusion cage experiments conducted in south Padilla Bay during the summer of 1987. Each cage had 20 crab instars and one sculpin, which was allowed to feed for 24 h.

Cage no.	Experimental or control	% eelgrass cover	Substrate	No. of uneaten crab	Average	Standard deviation
20 - 22 August 1987						
7	C	0	Sand	20		
13	C	0	Sand	17		
16	C	0	Sand	19		
18	C	0	Sand	19	18.89	1.76
10	C	0	Sand	20		
14	C	0	Sand	20		
17	C	0	Sand	20		
9	C	0	Sand	20		
6	C	0	Sand	15		
15	E	0	Sand	15		
12	E	0	Sand	16		
8	E	0	Sand	18	17.00*	1.58
4	E	0	Sand	19		
5	E	0	Sand	17		
23 - 25 August 1987						
4	C	0	Sand	19		
3	C	50	Sand	18		
5	C	50	Sand	22**		
7	C	50	Sand	20		
8	C	50	Sand	16		
9	C	50	Sand	17	18.14	1.49
10	C	50	Sand	17		
11	C	50	Sand	21**		
15	C	50	Sand	20		
16	C	50	Sand	19		
6	E	0	Sand	20		
1	E	50	Sand	20		
2	E	50	Sand	20		
12	E	50	Sand	22**	17.57	2.47
13	E	50	Sand	16		
14	E	50	Sand	15		
17	E	50	Sand	19		
18	E	50	Sand	21**		
19	E	50	Sand	14		
20	E	50	Sand	19		

Table 12—cont.

Cage no.	Experimental or control	% eelgrass cover	Substrate	No. of uneaten crab	Average	Standard deviation
3 - 5 September 1987						
1	C	0	Sand	21**		
3	C	0	Sand	19		
8	C	0	Sand	18	18.75	0.96
15	C	0	Sand	18		
19	C	0	Sand	20		
2	E	0	Sand	19		
7	E	0	Sand	20		
13	E	0	Sand	18	18.60	0.89
14	E	0	Sand	18		
16	E	0	Sand	18		
10	C	50	Sand	18		
11	C	50	Sand	18		
12	C	50	Sand	17	16.80	1.64
17	C	50	Sand	17		
20	C	50	Sand	14		
4	E	50	Sand	18		
5	E	50	Sand	18		
6	E	50	Sand	14	17.00	1.73
9	E	50	Sand	17		
18	E	50	Sand	18		

*Significant difference at $p \leq 0.05$.
**More crab were recovered than originally stocked in the cages. Either the initial counts were inaccurate or immigration occurred, or both.

The largest fish, 263 mm, ate the largest prey, one 5th instar crab (37-mm CW) and also ate three of the five 4th and 5th instars offered.

These results suggest that fish less than 80 mm TL would predominately eat megalopae and be less able to feed on Dungeness instars. At about 90-100 mm, sculpin are able to feed on 1st and 2nd crab instars (5-11 mm CW) in addition to eating megalopae. As sculpin grow, they switch to increasingly larger crab instars, even up to 5th instar, which is generally about the size attained by Dungeness crab during their first summer of growth in Puget Sound.

Fish predation on megalopae. This experiment was designed to determine the rate at which small staghorn sculpin (70- to 90-mm TL) consume *C. magister* megalopae. Five sculpin were individually presented with 20 megalopae for 24 h following starvation for 3 days. Results of the mean number of megalopae consumed during the 24-h period are summarized in Table 13 and Figure 14. Sculpin ate about 7 of the 20 megalopae (~35%) within the first half hour. Larger fish (80-90 mm) ate ~50% of the available megalopae within the first 2 h, and by 6 h all fish had consumed 50-75% of the megalopae. By 12 h, the larger fish had eaten 90%, while the smaller fish (70-79 mm) had eaten only 60% of the megalopae. For this experiment, a mean cumulative number of 17.4 of 20 megalopae (87%) was eaten in 24 h.

Examination of the stomach contents revealed that fish can digest Dungeness crab megalopae to an indistinguishable slurry of exoskeleton within 12 h. The rate of predation on megalopae by staghorn sculpin is probably sculpin size-dependent and may be megalopae density-dependent. In addition, predation rates on megalopae are probably affected by the availability of other prey species. These aspects of the predator-prey relationship could be investigated by testing fish/megalopae interactions in the presence of other prey species.

Fish predation on juvenile crab. The next experiment measured staghorn sculpin predation of 1st and 2nd instar Dungeness crab in order to estimate the daily mean predation rate on crab instars by staghorn sculpin.

Six fish were offered fifteen 1st and five 2nd instars over a 24-h period following 3 days of starvation. Fish tested ranged in size from 88- to 102-mm TL with wet weights of 6.4 to 11.6 g. Total crabs consumed per 24 h ranged from 0.65 to 1.15 g wet weight with a mean of 0.80 ± 0.19 (SD) g. Fish consumed approximately 10% of their wet body weight per day as crab (mean = 9.6%, range = 6.5 - 12.5%). The mean cumulative number of instars consumed over time is summarized in Table 14 and Figure 15. The results show that small- to medium-sized fish are able to consume a large proportion of the small instars available (50%, 60% and 75% within 1, 6 and 24 h, respectively) in a laboratory setting. The mean daily ration of early crab instars was determined to be 15 instars per day for this sculpin size.

The number of crab instars still discernable from the total number of instars consumed within 24 hours was calculated for each of the six fish. The average percentage of crab not fully digested (i.e., still discernable as a crab) at the end of the test was 36 ± 16%. Most of the instars were ingested within the first 6 h, but only 36% could be identified 18 h later, thus highlighting the importance of capturing and fixing fish as soon as possible after collection to provide the best analysis of their diets. The rate at which juvenile instars were consumed is similar to the rate at which megalopae were consumed (the equations describing the two curves in Figures 14 and 15 are essentially the same).

Table 13. Mean number of Dungeness crab megalopae eaten by staghorn sculpin in a laboratory feeding experiment.

Elapsed time (hours)	Mean (± SD) cumulative number of megalopae eaten	Range
0.5	6.6 ± 2.3	5 - 10
1	8.0 ± 2.3	6 - 11
2	9.8 ± 3.3	6 - 15
3	10.4 ± 3.2	7 - 15
4	10.8 ± 2.9	8 - 15
6	13.8 ± 3.5	10 - 17
8	15.0 ± 4.1	10 - 18
12	15.8 ± 4.0	11 - 20
24	17.4 ± 3.1	12 - 20

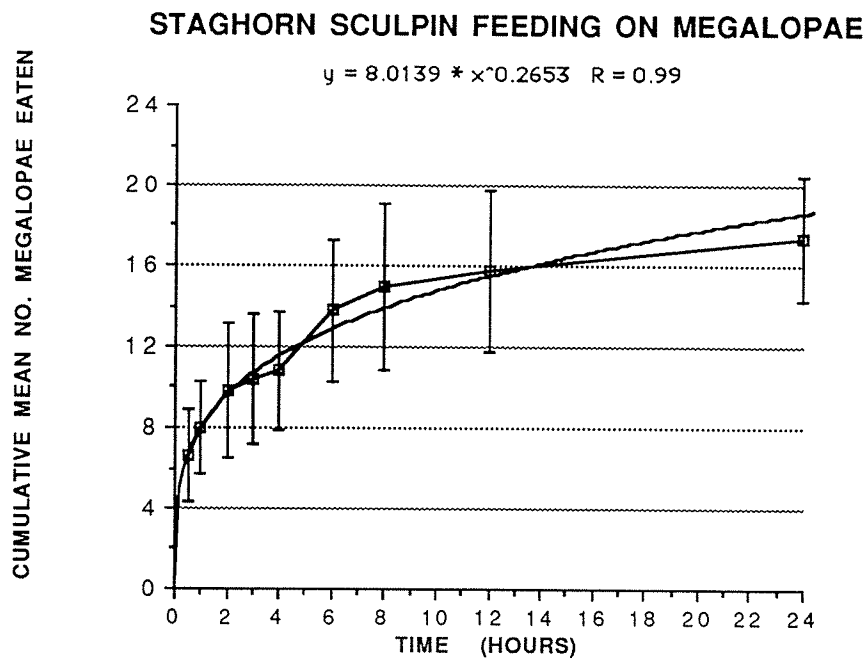


Figure 14. Graph of the cumulative mean number of Dungeness crab megalopae eaten by staghorn sculpin in a 24 h laboratory feeding experiment. Each of five fish was presented with 20 megalopae at T_0 following 72 h of starvation.

Table 14. Mean number of juvenile Dungeness crab instars eaten by staghorn sculpin in a laboratory feeding experiment.

Elapsed time (hours)	Mean (± SD) cumulative number of crab instars eaten	Range
0.5	5.0 ± 5.5	0 - 13
1	10.0 ± 4.1	5 - 16
2	10.5 ± 3.8	6 - 16
3	11.0 ± 3.3	7 - 16
4	11.5 ± 3.1	7 - 16
6	12.5 ± 2.5	10 - 16
8	12.8 ± 2.5	10 - 16
12	13.5 ± 2.5	11 - 17
24	15.0 ± 1.7	13 - 17

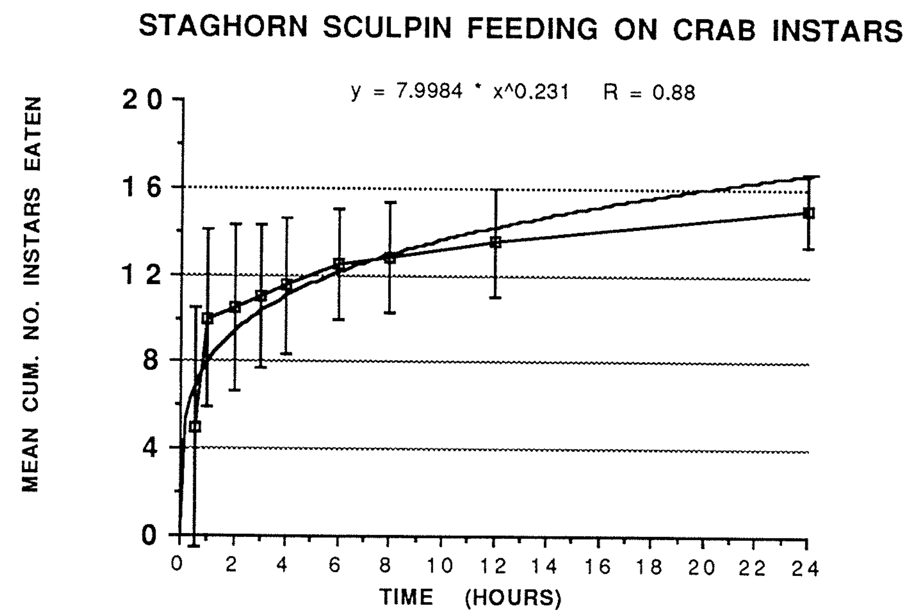


Figure 15. Graph of the cumulative mean number of juvenile Dungeness crab instars consumed in a 24 h laboratory feeding experiment. Each of six fish was presented with 20 juvenile crab at T_0 following 72 h of starvation.

The ratio of 1st to 2nd instars offered to the fish was 3:1. In all cases, sculpin predated the 1st instars more heavily than the 2nd instars, with a mean consumption of approximately six 1st instars to one 2nd instar. Thus, this size range of fish appeared to select for the smaller instars.

Gut evacuation rate experiment. Two tests were conducted to determine how rapidly staghorn sculpin are able to digest a crab meal. In the first test, 30 smaller sculpin (85-110 mm TL) were fed eleven 1st and 2nd instars for 3 h following a 3-day starvation period. Fish were then sacrificed in random groups of three at various intervals up to 48 h and the degree of meal digestion determined. Quantitatively, the percent digestion was calculated based on wet weight of the gut contents divided by the wet weight of the crab meal consumed. Results (Table 15) showed that this size of sculpin consumed four to seven instars in the 3-h period. A 85- to 95-mm subgroup consumed a mean of 4.9 crab instars while a 100- to 110-mm subgroup ate 5.8 instars (a single sculpin out of the 30 test fish failed to feed and was thus deleted from the test). The amount of crab consumed averaged about 6% of the sculpin's wet body weight. The rate at which the crab meals were digested followed a second order polynomial relationship as shown in Figure 16. There was a great deal of variability in the average percent digestion during the first three sampling periods, although by 18 h after feeding, crab were digested to about 50% of the original wet weight. A 75% reduction in the meal weights was measured 21 to 27 h after eating, and by 48 h, meals had been reduced by 90% of their original weights. Qualitatively, crab instars were becoming indiscernible at 18 h, and by 21 h the number of individual crab in the original meal could not have been determined if not individually counted prior to ingestion. Figure 16 illustrates the negative exponential relationship between time and mean stomach fullness.

The second test investigated predator size as related to digestion rate. Eighteen larger staghorn sculpin (124-180 mm TL) were fed 14 2nd to 4th juveniles for 3 h and sacrificed at various intervals up to 72 h. The total number of crab eaten ranged from 1 to 7 with a mean of 4 ± 1.5 instars. The results of this test (Table 15) showed that:

a. During the first 24 h after consuming crab, 57% of the meal was digested (Fig. 17) and stomach fullness was reduced to 30% of the gut capacity (Fig. 17). For very small crab meals (1 or 2 small crab), the gut contents were not recognizable as being crab at this time.

b. By 36 h, stomach fullness declined to 10-15% of capacity and the meal was 90% digested. At this point, the gut contents were generally undistinguishable and only pairs of eyestalks indicated a crab meal.

c. At 72 h, only 5% of the original volume (3% by weight) of the meal remained, and the gut was considered empty and evacuation complete.

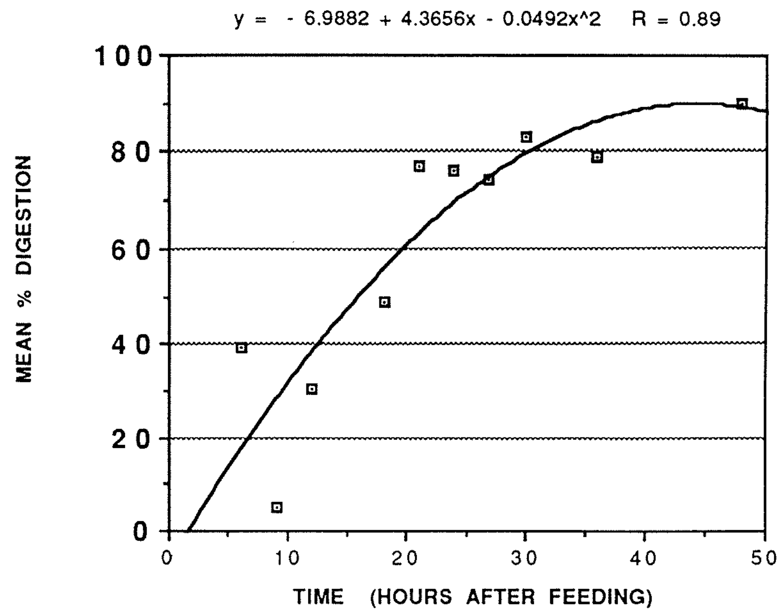
Table 15. Results of two laboratory experiments to determine the rates at which juvenile Dungeness crab are digested by staghorn sculpin.

Time after feeding	Mean % gut fullness*	Mean % digestion**	Mean no. crabs eaten	Mean wet wt. crab meal
Gut evacuation test #1				
6	60	39	4.3	0.48
9	78	5	6.3	0.72
12	50	30	5.3	0.42
18	43	49	5.3	0.44
21	25	77	5.7	0.76
24	25	76	5.7	1.00
27	22	74	4.5	0.55
30	20	83	4.7	0.52
36	11	79	4.7	0.48
48	5	90	6.0	0.68
Gut evacuation test #2				
6	83	45.2	5.0	3.56
12	***	***	***	***
24	30	57.1	2.7	1.27
36	11	89.1	3.3	1.66
48	15	87.9	4.0	2.29
72	5	96.9	5.7	4.47

*Qualitative estimate based on visual assessment "scale; empty gut = 0%, maximum fullness = 100%."
**Quantitative calculation based on stomach content wet weight/estimated crab meal wet weight.
***"Insufficient data: 2 of 3 fish did not eat, thus data point deleted."

NOTE: Means are for three fish per time period sampled in each experiment.

The percent digestion (as calculated by wet weight of the gut contents/wet weight of the estimated crab meal) versus time followed a second order polynomial relationship with a high degree of correlation (R = 0.95) (Fig. 17). Mean percent gut fullness versus time after feeding was a negative exponential relationship (Fig. 17), also with a high degree of correlation (R = 0.96). In both cases the y-intercept should be forced through 0% or 100% at time zero. Because of the experimental design, the mean wet weight of the crab meals varied quite a bit within sacrifice times. Better results may have been achieved with more standardization of the meal sizes and more replicates per time period.



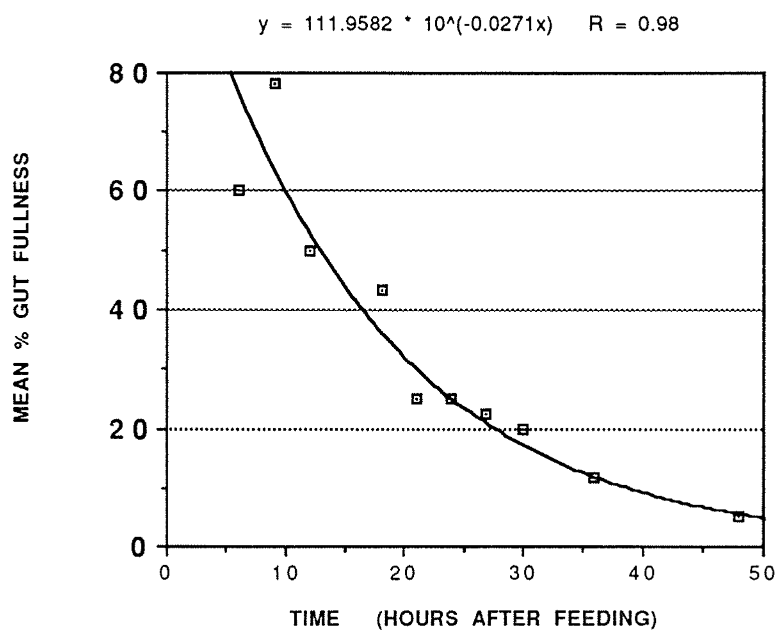


Figure 16. Mean percent gut fullness and percent digestion through time of staghorn sculpin stomachs following ingestion of of juvenile Dungeness crab instars in the laboratory (Test 1).

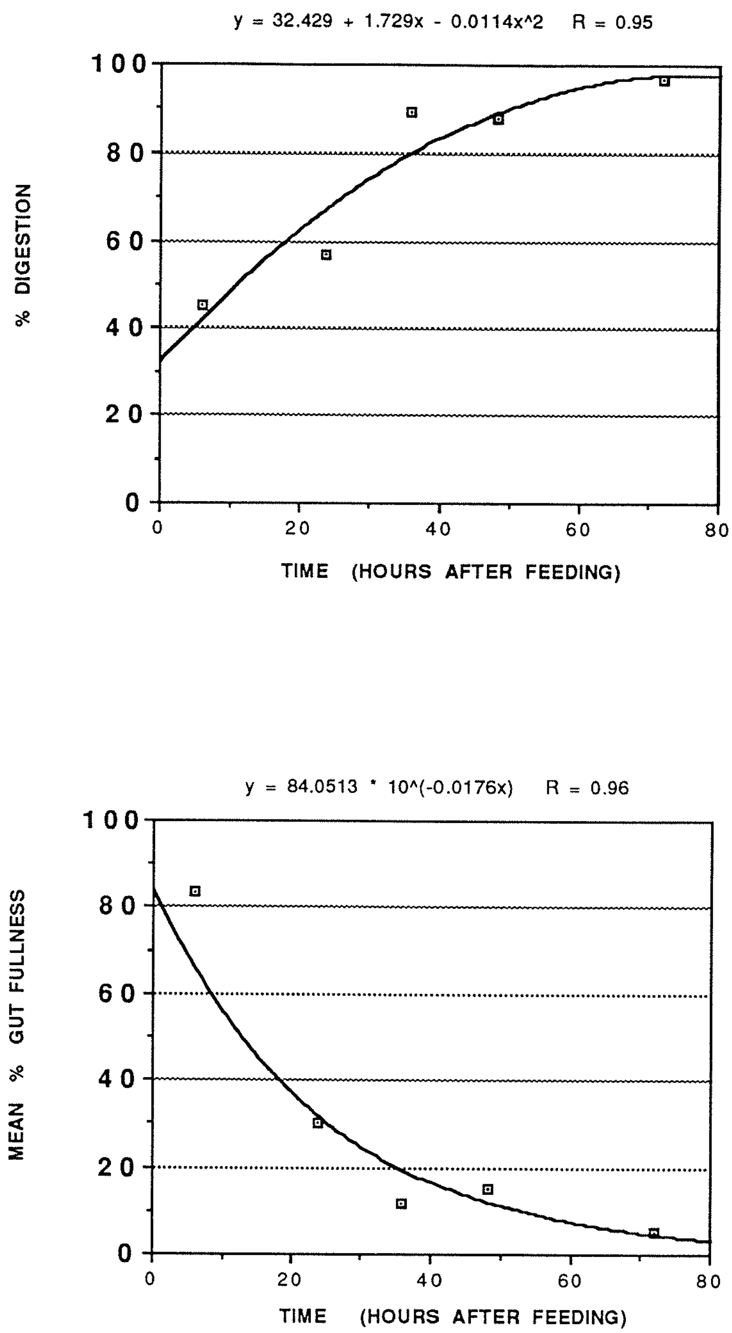


Figure 17. Mean percent gut fullness and percent digestion through time of staghorn sculpin stomachs following ingestion of of juvenile Dungeness crab in the laboratory (Test 2).

DISCUSSION

MARINE FISH

Forty species of marine fish were caught in the beam trawl samples and one additional species (spiny dogfish) was caught in the trammel net sets. Of these 41 fish species, 12 species not previously identified from Padilla Bay were recorded. However, none of the new species were unusual for this type of Puget Sound ecosystem. These faunal additions now bring the number of fish species identified in Padilla Bay to a total of 69 species (WDOE 1984).

Fish Predation on Crab

One of the primary objectives of this study was to assess the degree of fish predation on megalopae and juvenile stages of Dungeness crab. Of the six most common fish capable of feeding on Dungeness crab, staghorn sculpin proved to be the foremost crab predator (beam trawl % IRI for crab = 14%), with Dungeness crab accounting for roughly 1-3% of the total IRI values for fish caught by beam trawl and beach seine. A total of 55 0+ Dungeness crab were found in 414 staghorn sculpin stomachs for a frequency of occurrence of 0.133 crab/sculpin. The average estimated density of staghorn sculpin from the beam trawl catches for July through October (the period of time when juvenile Dungeness crab are most abundant) was about 70 fish/ha. Thus, at any one point in time, the per hectare consumption of Dungeness crab could be estimated to be about 9 crab/ha. Assuming a meal digestion rate of about 48 h (from the laboratory gut evacuation experiments), then the total consumption of crab over a 4-month summer period would approximate 560 crab/ha.

Considering that the summer 1987 and 1988 intertidal crab densities of the 1st to 4th instars averaged about 10 crab/m^2 in eelgrass areas (Fig. 5), the total number of crab/ha would be about 100,000. Thus, the estimated consumption of crab by staghorn sculpin would only be about 0.6% of the total crab population for these 2 years. Presently, we do not know the efficiency of the beam trawl for sculpin, but observations during beach seining suggest that the densities of sculpin may be many times higher than 70 fish/ha in intertidal areas. A typical beach seine haul at March Point caught 10-20 sculpin and covered perhaps 200 m^2. Hence, sculpin densities in this case must have exceeded 500 fish/ha. Thus, more realistic estimates of staghorn sculpin predation on Dungeness crab may be about 5% of the summer crab population. This speculation about higher sculpin densities is supported by the work of Thom et al. (1989), who found average staghorn sculpin densities of about 1,500/ha in Drayton Harbor, Washington (biweekly beach seine sampling, March-October 1988).

Few studies in Puget Sound have investigated either staghorn sculpin diets or predation by any fish species on Dungeness crab. The only study to look at staghorn sculpin feeding was conducted as a student project by Pantalone (1985), who analyzed the stomach contents of 45 staghorn sculpin collected on one day in April 1985 from a high intertidal slough in Padilla Bay. He found that the sculpin diets included 10% crab by number. However, these crab were not identified to species.

In areas outside of Puget Sound, others have documented pelagic fish (especially salmon) predation on megalopae off the coasts of California, Oregon and Washington and in the coastal estuaries (Reilly 1983; Merkel 1957; Heg and Van Hyning 1951; Silliman 1941). Others have noted significant predation on *C. magister* megalopae and juvenile instars by demersal fish, including copper rockfish (*Sebastes caurinus*) in Humboldt Bay, California (Prince and Gotshall 1976) and by a variety of fishes in the San Francisco area (Reilly 1983). In the latter study, Reilly found that the highest predation on juvenile Dungeness crab was by green and white sturgeon (*Acipenser* spp.), starry flounder (*Platichthys stellatus*) and rock sole (*Lepidopsetta bilineata*). Reilly found that staghorn sculpin averaged <1 crab/stomach during 5 years of sampling. This number is substantially less than for the other species named above (e.g., 12-53 crab/stomach for other fish species during the 1977 sampling). Reilly also found highly variable degrees of predation on Dungeness crab. This was due, in large part, to between-year differences in crab settlement and secondarily due to apparent localized aggregations ("clumping") of newly settled post-larvae. There is little doubt that this same highly variable pattern of crab predation by sculpin would be evident for Padilla Bay if this study were to span a multitude of years.

DUNGENESS CRAB

Dungeness crab populations in Padilla Bay have been sampled by the University of Washington since 1985 using beam trawls, crab pots, diver transects and intertidal surveys. The beam trawl and intertidal survey data form the most complete and and continuous database for this species in Padilla Bay and are summarized in this report. Figure 4 shows that the highest beam trawl catches (and, hence, the highest estimated densities) of crab have been in the subtidal channels, which are plentiful in Padilla Bay. The reasons for the relatively high crab abundances in the channels are at least twofold: (1) 1- to 2-year-old crab concentrate in the shallow subtidal channels following emigration from eelgrass beds where Dungeness crab generally settle and grow for the first year. These subadult crab spend their second year in these channels prior to migrating to deeper waters in their third year; and 2) young crab (0- to 1-year-olds) residing in eelgrass beds may be poorly sampled by trawl gear. A similar study in Lummi Bay (Dinnel et al. 1987) showed that the beam trawl was sometimes <1% efficient in catching 0- to 1-year-old crab.

Intertidal samples collected from March Point and South Padilla Bay confirmed that newly settled crab in their first year are poorly sampled by trawl gear. Ignoring big, temporary peaks in abundance of newly metamorphosed 1st instar crab, Figure 5 shows that typical intertidal crab densities are 2-5 crab/m^2 following the initial post-settlement high mortality period. Assuming a conservative average intertidal density of 2 crab/m^2, then the density of intertidal crab would be equal to about 20,000 crab/ha. The overall estimated density of crab from the beam trawl sampling in the eelgrass strata was approximately 175 crab/ha. Thus, our trawl data from Padilla Bay appears to underestimate intertidal (and probably shallow subtidal) juvenile crab densities by roughly 100-fold. In contrast, the crab density estimates for the subtidal channel stratum are probably fairly close to the actual densities. This particular beam trawl design (Gunderson and Ellis 1986) greatly facilitates sampling of crab in sandy substrates, which are found in the Padilla Bay channels. In addition, comparative diver transect surveys, conducted side-by-side with trawling in a previous Padilla Bay study (Dinnel et al. 1987), showed that there was little difference in the overall calculated densities between the two sample methods.

In addition to baseline and habitat-related information for Dungeness crab, we anticipate that these data will provide essential information for relating early settlement rates and survival to eventual yearclass success as measured by the commercial and sport fishery catches for this species. However, it will be several years hence before these relationships are known, since the 1985 settlers are only now entering the fishery.

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APPENDICES

Appendix Table 1. Catches and estimated densities (fish/ha) of marine fish caught by beam trawl in Padilla Bay during June 1987.

INTERTIDAL EELGRASS

Fish Species	Jun-87 IE Sta 12	#/ha	Jun-87 IE Sta 13	#/ha	Jun-87 IE Sta 15	#/ha	TOTAL NUMBER	TOTAL #/ha
saddleback gunnel	1	22.9	15	407.6	11	341.6	27	239.6
staghorn sculpin			6	163.0	16	496.9	22	195.2
crescent gunnel			11	298.9	5	155.3	16	142.0
shiner perch			4	108.7	6	186.3	10	88.7
snake prickleback	1	22.9	2	54.3	3	93.2	6	53.2
silverspotted sculpin			3	81.5	2	62.1	5	44.4
three-spined stickleback			1	27.2	3	93.2	4	35.5
English sole					3	93.2	3	26.6
buffalo sculpin			1	27.2			1	8.9
tubesnout			1	27.2			1	8.9
sturgeon poacher			1	27.2			1	8.9
bay pipefish					1	31.1	1	8.9
tubenose poacher					1	31.1	1	8.9
sharpnose sculpin					1	31.1	1	8.9
Total	2	45.8	45	1222.8	52	1614.9	99	878.4

AVERAGE FISH/HECTARE = 878.0 **SPECIES DIVERSITY =** 2.05
SPECIES RICHNESS = 14

SUBTIDAL EELGRASS

Fish Species	Jun-87 SE Sta 6	#/ha	Jun-87 SE Sta 8	#/ha	Jun-87 SE Sta 11	#/ha	TOTAL NUMBER	TOTAL #/ha
saddleback gunnel	24	802.7	3	90.0	9	244.6	36	359.8
silverspotted sculpin	1	33.4	5	149.9	10	271.7	16	159.9
tubesnout	1	33.4			13	353.3	14	139.9
shiner perch	4	133.8	8	239.9			12	119.9
three-spined stickleback			3	90.0	6	163.0	9	90.0
crescent gunnel	4	133.8			4	108.7	8	80.0
tadpole sculpin			4	119.9	4	108.7	8	80.0
snake prickleback	3	100.3			1	27.2	4	40.0
great sculpin	3	100.3					3	30.0
English sole					1	27.2	1	10.0
whitespotted greenling					1	27.2	1	10.0
tubenose poacher			1	30.0			1	10.0
ribbon snailfish			1	30.0			1	10.0
starry flounder	1	33.4					1	10.0
Total	41	1371.2	25	749.6	49	1331.5	115	1149.4

AVERAGE FISH/HECTARE = 1149.0 **SPECIES DIVERSITY =** 2.12
SPECIES RICHNESS = 14

SUBTIDAL CHANNEL

Fish Species	Jun-87 SC Sta 9	#/ha	Jun-87 SC Sta 14	#/ha	Jun-87 SC Sta 16	#/ha	TOTAL NUMBER	TOTAL #/ha
English sole	57	563.2	25	255.8	31	385.1	113	404.4
snake prickleback	11	108.7	17	173.9	43	534.2	71	254.1
staghorn sculpin	6	59.3	38	388.7	9	111.8	53	189.7
buffalo sculpin	2	19.8	34	347.8			36	128.8
whitespotted greenling			9	92.1	9	111.8	18	64.4
speckled sanddab	5	49.4	4	40.9	2	24.8	11	39.4
sturgeon poacher	1	9.9	8	81.8	1	12.4	10	35.8
ribbed sculpin	3	29.6	3	30.7			6	21.5
Pacific sandlance					4	49.7	4	14.3
great sculpin	2	19.8	1	10.2			3	10.7
silverspotted sculpin	1	9.9	1	10.2			2	7.2
chinook salmon					2	24.8	2	7.2
padded sculpin	1	9.9	1	10.2			2	7.2
sand sole	1	9.9			1	12.4	2	7.2
saddleback gunnel					1	12.4	1	3.6
tadpole sculpin	1	9.9					1	3.6
bay pipefish			1	10.2			1	3.6
big skate					1	12.4	1	3.6
chum salmon					1	12.4	1	3.6
Total	91	899.2	142	1452.7	105	1304.3	338	1209.5

AVERAGE FISH/HECTARE = 1209.5 **SPECIES DIVERSITY =** 1.97
SPECIES RICHNESS = 19

ALL SUBSTRATES COMBINED

Fish Species	TOTAL NUMBER	TOTAL #/ha
English sole	117	237.7
snake prickleback	81	164.6
staghorn sculpin	75	152.4
saddleback gunnel	64	130.0
buffalo sculpin	37	75.2
crescent gunnel	24	48.8
silverspotted sculpin	23	46.7
shiner perch	22	44.7
whitespotted greenling	19	38.6
tubesnout	15	30.5
three-spined stickleback	13	26.4
speckled sanddab	11	22.3
sturgeon poacher	11	22.3
tadpole sculpin	9	18.3
great sculpin	6	12.2
ribbed sculpin	6	12.2
Pacific sandlance	4	8.1
bay pipefish	2	4.1
chinook salmon	2	4.1
padded sculpin	2	4.1
sand sole	2	4.1
tubenose poacher	2	4.1
big skate	1	2.0
chum salmon	1	2.0
ribbon snailfish	1	2.0
sharpnose sculpin	1	2.0
starry flounder	1	2.0
Total	552	1121.5

ALL STATIONS

SPECIES DIVERSITY = 2.5

SPECIES RICHNESS = 27.0

AVERAGE FISH/HECTARE = 1121.0

Appendix Table 1. Continued. Catches and estimated densities (fish/ha) of marine fish caught by beam trawl in Padilla Bay during July 1987.

INTERTIDAL EELGRASS

Fish Species	Jul-87 IE Sta 12	#/ha	Jul-87 IE Sta 13	#/ha	Jul-87 IE Sta 15	#/ha	TOTAL NUMBER	TOTAL #/ha
three-spined stickleback	37	919.3	54	1173.9	20	644.1	111	946.292
shiner perch	46	1142.9	32	695.7	3	96.6	81	690.537
saddleback gunnel	20	496.9	9	195.7	7	225.4	36	306.905
silverspotted sculpin	23	571.4					23	196.078
snake prickleback			13	282.6			13	110.827
staghorn sculpin	2	49.7	3	65.2	5	161.0	10	85.251
crescent gunnel			2	43.5	4	128.8	6	51.151
bay pipefish	3	74.5	1	21.7			4	34.101
tubesnout	1	24.8					1	8.525
padded sculpin			1	21.7			1	8.525
penpoint gunnel					1	32.2	1	8.525
starry flounder			1	21.7			1	8.525
Total	132	3279.5	116	2521.7	40	1288.2	288	2455.243

AVERAGE FISH/HECTARE = 2455.0 **SPECIES DIVERSITY =** 1.66
SPECIES RICHNESS = 12

SUBTIDAL EELGRASS

Fish Species	Jul-87 SE Sta 6	#/ha	Jul-87 SE Sta 8	#/ha	Jul-87 SE Sta 11	#/ha	TOTAL NUMBER	TOTAL #/ha
shiner perch	49	1291.2	64	2529.6	26	753.6	139	1421.995
saddleback gunnel	42	1106.7	11	434.8	5	144.9	58	593.350
three-spined stickleback	20	527.0	8	316.2	23	666.7	51	521.739
tubesnout	11	289.9			33	956.5	44	450.128
snake prickleback	23	606.1					23	235.294
crescent gunnel	12	316.2	8	316.2			20	204.604
silverspotted sculpin	6	158.1			11	318.8	17	173.913
penpoint gunnel	8	210.8	1	39.5	6	173.9	15	153.453
staghorn sculpin	2	52.7	1	39.5	5	144.9	8	81.841
tadpole sculpin			7	276.7			7	71.611
padded sculpin	1	26.4	5	197.6			6	61.381
pile perch	2	52.7	4	158.1			6	61.381
great sculpin			1	39.5	2	58.0	3	30.691
rock sole	1	26.4					1	10.230
Pacific tomcod					1	29.0	1	10.230
bay pipefish	1	26.4					1	10.230
cabezon					1	29.0	1	10.230
plainfin midshipman	1	26.4					1	10.230
Total	179	4716.7	110	4347.8	113	3275.4	402	4112.532

AVERAGE FISH/HECTARE = 4112.5 **SPECIES DIVERSITY =** 2.11
SPECIES RICHNESS = 18

SUBTIDAL CHANNEL

Fish Species	Jul-87 SC Sta 9	#/ha	Jul-87 SC Sta 14	#/ha	Jul-87 SC Sta 16	#/ha	TOTAL NUMBER	TOTAL #/ha
English sole	33	358.7	64	927.5	10	108.7	107	422.925
snake prickleback	11	119.6	25	362.3	4	43.5	40	158.103
shiner perch	1	10.9	1	14.5	26	282.6	28	110.672
staghorn sculpin	7	76.1	11	159.4	3	32.6	21	83.004
sand sole	14	152.2	5	72.5			19	75.099
sturgeon poacher	9	97.8	1	14.5	1	10.9	11	43.478
buffalo sculpin	3	32.6	3	43.5	4	43.5	10	39.526
padded sculpin			1	14.5	8	87.0	9	35.573
rock sole	3	32.6	3	43.5			6	23.715
whitespotted greenling					6	65.2	6	23.715
Pacific tomcod	2	21.7	3	43.5			5	19.763
speckled sanddab	4	43.5	1	14.5			5	19.763
three-spined stickleback	1	10.9			2	21.7	3	11.858
Pacific sandlance			3	43.5			3	11.858
saddleback gunnel	1	10.9			1	10.9	2	7.905
crescent gunnel					1	10.9	1	3.953
pile perch					1	10.9	1	3.953
great sculpin					1	10.9	1	3.953
big skate					1	10.9	1	3.953
Pacific spiny lumpsucker	1	10.9					1	3.953
Total	90	978.3	121	1753.6	69	750.0	280	1106.719

AVERAGE FISH/HECTARE = 1106.7 **SPECIES DIVERSITY =** 2.15
SPECIES RICHNESS = 20

ALL STATIONS COMBINED

Fish Species	TOTAL NUMBER	TOTAL #/ha
shiner perch	248	529.9
three-spined stickleback	165	352.5
English sole	107	228.6
saddleback gunnel	96	205.1
snake prickleback	76	162.4
tubesnout	45	96.1
silverspotted sculpin	40	85.5
staghorn sculpin	39	83.3
crescent gunnel	27	57.7
sand sole	19	40.6
padded sculpin	16	34.2
penpoint gunnel	16	34.2
sturgeon poacher	11	23.5
buffalo sculpin	10	21.4
pile perch	7	15.0
rock sole	7	15.0
tadpole sculpin	7	15.0
Pacific tomcod	6	12.8
whitespotted greenling	6	12.8
bay pipefish	5	10.7
speckled sanddab	5	10.7
great sculpin	4	8.5
Pacific sandlance	3	6.4
big skate	1	2.1
cabezon	1	2.1
Pacific spiny lumpsucke	1	2.1
plainfin midshipman	1	2.1
starry flounder	1	2.1
Total	970	2072.4

ALL STATIONS

SPECIES DIVERSITY = 2.43

SPECIES RICHNESS = 28

AVERAGE FISH/HECTARE = 2072.0

Appendix Table 1. Continued. Catches and estimated densities (fish/ha) of marine fish caught by beam trawl in Padilla Bay during August 1987.

INTERTIDAL EELGRASS

Fish Species	Aug-87 IE Sta 12	#/ha	Aug-87 IE Sta 13	#/ha	Aug-87 IE Sta 15	#/ha	TOTAL NUMBER	TOTAL #/ha
shiner perch	43	934.8	13	269.2	15	434.8	71	551.2
three-spined sticklebacl	19	413.0			24	695.7	43	333.9
saddleback gunnel	6	130.4	1	20.7	15	434.8	22	170.8
bay pipefish	7	152.2	7	144.9	3	87.0	17	132.0
silverspotted sculpin	10	217.4	1	20.7	1	29.0	12	93.2
crescent gunnel	3	65.2	1	20.7	4	115.9	8	62.1
staghorn sculpin			1	20.7	5	144.9	6	46.6
padded sculpin			3	62.1			3	23.3
penpoint gunnel	1	21.7	2	41.4			3	23.3
great sculpin	1	21.7	2	41.4			3	23.3
English sole			2	41.4			2	15.5
snake prickleback			2	41.4			2	15.5
buffalo sculpin			2	41.4			2	15.5
tubesnout			1	20.7			1	7.8
Pacific tomcod			1	20.7			1	7.8
sharpnose sculpin	1	21.7					1	7.8
sturgeon poacher			1	20.7			1	7.8
tubenose poacher			1	20.7			1	7.8
Total	91	1978.3	41	848.9	67	1942.0	199	1545.0

AVERAGE FISH/HECTARE = 1545.0 SPECIES DIVERSITY = 2.02
SPECIES RICHNESS = 18

SUBTIDAL EELGRASS

Fish Species	Aug-87 SE Sta 6	#/ha	Aug-87 SE Sta 8	#/ha	Aug-87 SE Sta 11	#/ha	TOTAL NUMBER	TOTAL #/ha
shiner perch	18	579.7	29	900.6	13	314.0	60	573.3
three-spined stickleback	2	64.4	5	155.3	24	579.7	31	296.2
saddleback gunnel	11	354.3	4	124.2	4	96.6	19	181.6
tubesnout	9	289.9			1	24.2	10	95.6
bay pipefish			3	93.2	5	120.8	8	76.4
silverspotted sculpin	1	32.2	3	93.2	3	72.5	7	66.9
crescent gunnel	3	96.6	1	31.1			4	38.2
sharpnose sculpin					4	96.6	4	38.2
penpoint gunnel	3	96.6					3	28.7
whitespotted greenling	1	32.2	1	31.1	1	24.2	3	28.7
snake prickleback	2	64.4					2	19.1
plainfin midshipman	2	64.4					2	19.1
English sole					1	24.2	1	9.6
tadpole sculpin					1	24.2	1	9.6
staghorn sculpin	1	32.2					1	9.6
striped perch			1	31.1			1	9.6
marbeled snailfish	1	32.2					1	9.6
Total	54	1739.1	47	1459.6	57	1376.8	158	1509.8

AVERAGE FISH/HECTARE = 1510.0 SPECIES DIVERSITY = 2.01
SPECIES RICHNESS = 17

SUBTIDAL CHANNEL

Fish Species	Aug-87 SC Sta 9	#/ha	Aug-87 SC Sta 14	#/ha	Aug-87 SC Sta 16	#/ha	TOTAL NUMBER	TOTAL #/ha
English sole	16	231.9	53	921.7	9	87.0	78	339.1
tadpole sculpin	35	507.2					35	152.2
padded sculpin	22	318.8			6	58.0	28	121.7
tubesnout	14	202.9			10	96.6	24	104.3
Pacific sandlance			20	347.8			20	87.0
crescent gunnel	3	43.5			16	154.6	19	82.6
snake prickleback			9	156.5	10	96.6	19	82.6
silverspotted sculpin	2	29.0			14	135.3	16	69.6
shiner perch					15	144.9	15	65.2
staghorn sculpin	3	43.5	10	173.9	2	19.3	15	65.2
Pacific tomcod	5	72.5	2	34.8			7	30.4
whitespotted greenling	2	29.0			3	29.0	5	21.7
bay pipefish					4	38.6	4	17.4
saddleback gunnel	1	14.5			2	19.3	3	13.0
penpoint gunnel	1	14.5			2	19.3	3	13.0
great sculpin					2	19.3	2	8.7
striped perch					2	19.3	2	8.7
sand sole	2	29.0					2	8.7
sturgeon poacher	1	14.5					1	4.3
rock sole			1	17.4			1	4.3
Total	107	1550.7	95	1652.2	97	937.2	299	1300.0

AVERAGE FISH/HECTARE = 1300.0 SPECIES DIVERSITY = 2.46
SPECIES RICHNESS = 20

ALL STATIONS COMBINED

Fish Species	Total	#/ha
shiner perch	146	315.0
English sole	81	174.8
three-spined stickleback	74	159.7
saddleback gunnel	44	94.9
tadpole sculpin	36	77.7
silverspotted sculpin	35	75.5
tubesnout	35	75.5
crescent gunnel	31	66.9
padded sculpin	31	66.9
bay pipefish	29	62.6
snake prickleback	23	49.6
staghorn sculpin	22	47.5
Pacific sandlance	20	43.2
penpoint gunnel	9	19.4
Pacific tomcod	8	17.3
whitespotted greenling	8	17.3
great sculpin	5	10.8
sharpnose sculpin	5	10.8
striped perch	3	6.5
buffalo sculpin	2	4.3
plainfin midshipman	2	4.3
sand sole	2	4.3
sturgeon poacher	2	4.3
marbeled snailfish	1	2.2
rock sole	1	2.2
tubenose poacher	1	2.2
Total	656	1415.5

ALL STATIONS

SPECIES DIVERSITY = 2.6

SPECIES RICHNESS = 26.0

AVERAGE FISH/HECTARE = 1415.0

Appendix Table 1. Continued. Catches and estimated densities (fish/ha) of marine fish caught by beam trawl in Padilla Bay during Sept. 1987.

INTERTIDAL EELGRASS

Fish Species	Sep-87 IE Sta 12	#/ha	Sep-87 IE Sta 13	#/ha	Sep-87 IE Sta 15	#/ha	TOTAL NUMBER	TOTAL #/ha
shiner perch	2	62.1	1	29.0	22	382.6	25	201.3
bay pipefish	1	31.1	10	289.9			11	88.6
three-spined stickleback	6	186.3	4	115.9	1	17.4	11	88.6
tubesnout			10	289.9			10	80.5
saddleback gunnel			1	29.0	4	69.6	5	40.3
sharpnose sculpin	3	93.2			2	34.8	5	40.3
silverspotted sculpin	4	124.2					4	32.2
crescent gunnel					4	69.6	4	32.2
staghorn sculpin	1	31.1			2	34.8	3	24.2
penpoint gunnel			2	58.0			2	16.1
English sole					1	17.4	1	8.1
buffalo sculpin			1	29.0			1	8.1
sturgeon poacher			1	29.0			1	8.1
whitespotted greenling			1	29.0			1	8.1
pile perch					1	17.4	1	8.1
Total	17	528.0	31	898.6	37	643.5	85	684.4

AVERAGE FISH/HECTARE = 684.0 **SPECIES DIVERSITY =** 2.23
SPECIES RICHNESS = 15

SUBTIDAL EELGRASS

Fish Species	Sep-87 SE Sta 6	#/ha	Sep-87 SE Sta 8	#/ha	Sep-87 SE Sta 11	#/ha	TOTAL NUMBER	TOTAL #/ha
shiner perch	9	301.0	17	492.8	12	434.8	38	413.0
silverspotted sculpin	9	301.0	10	289.9	4	144.9	23	250.0
crescent gunnel	5	167.2	13	376.8			18	195.7
bay pipefish	5	167.2	3	87.0	9	326.1	17	184.8
saddleback gunnel	4	133.8	5	144.9	2	72.5	11	119.6
staghorn sculpin	2	66.9	7	202.9	1	36.2	10	108.7
great sculpin	2	66.9	6	173.9	1	36.2	9	97.8
padded sculpin			6	173.9	1	36.2	7	76.1
penpoint gunnel			2	58.0	5	181.2	7	76.1
tadpole sculpin			1	29.0	5	181.2	6	65.2
whitespotted greenling	3	100.3	2	58.0			5	54.3
three-spined stickleback	1	33.4			1	36.2	2	21.7
tubesnout	1	33.4					1	10.9
grunt sculpin	1	33.4					1	10.9
Pacific spiny lumpsucker					1	36.2	1	10.9
ribbon snailfish			1	29.0			1	10.9
tubenose poacher			1	29.0			1	10.9
Total	42	1404.7	74	2144.9	42	1521.7	158	1717.4

AVERAGE FISH/HECTARE = 1717.0 **SPECIES DIVERSITY =** 2.36
SPECIES RICHNESS = 17

SUBTIDAL CHANNEL

Fish Species	Sep-87 SC Sta 9	#/ha	Sep-87 SC Sta 14	#/ha	Sep-87 SC Sta 16	#/ha	TOTAL NUMBER	TOTAL #/ha
English sole	18	164.8	13	133.0	1	8.9	32	100.1
buffalo sculpin					30	266.2	30	93.8
Pacific sandlance	4	36.6	5	51.2			9	28.2
sturgeon poacher	7	64.1					7	21.9
padded sculpin					5	44.4	5	15.6
bay pipefish					4	35.5	4	12.5
saddleback gunnel			2	20.5	2	17.7	4	12.5
tubesnout	2	18.3					2	6.3
Pacific tomcod	2	18.3					2	6.3
staghorn sculpin	1	9.2					1	3.1
great sculpin					1	8.9	1	3.1
sand sole	1	9.2					1	3.1
speckled sanddab	1	9.2					1	3.1
starry flounder			1	10.2			1	3.1
Total	36	329.5	21	214.8	43	381.5	100	312.8

AVERAGE FISH/HECTARE = 313.0 **SPECIES DIVERSITY =** 1.92
SPECIES RICHNESS = 14

ALL STATIONS COMBINED

Fish Species	Total	#/ha
shiner perch	63	117.6
English sole	33	61.6
bay pipefish	32	59.7
buffalo sculpin	31	57.8
silverspotted sculpin	27	50.4
crescent gunnel	22	41.1
saddleback gunnel	20	37.3
staghorn sculpin	14	26.1
three-spined stickleback	13	24.3
tubesnout	13	24.3
padded sculpin	12	22.4
great sculpin	10	18.7
Pacific sandlance	9	16.8
penpoint gunnel	9	16.8
sturgeon poacher	8	14.9
tadpole sculpin	6	11.2
whitespotted greenling	6	11.2
sharpnose sculpin	5	9.3
Pacific tomcod	2	3.7
grunt sculpin	1	1.9
Pacific spiny lumpsucker	1	1.9
pile perch	1	1.9
ribbon snailfish	1	1.9
sand sole	1	1.9
speckled sanddab	1	1.9
starry flounder	1	1.9
tubenose poacher	1	1.9
Total	343	640.0

ALL STATIONS

SPECIES DIVERSITY = 2.8

SPECIES RICHNESS = 27.0

AVERAGE FISH/HECTARE = 640.0

Appendix Table 1. Continued. Catches and estimated densities (fish/ha) of marine fish caught by beam trawl in Padilla Bay during Oct. 1987.

INTERTIDAL EELGRASS

Fish Species	Oct-87 IE Sta 12	#/ha	Oct-87 IE Sta 13	#/ha	Oct-87 IE Sta 15	#/ha	TOTAL NUMBER	TOTAL #/ha
bay pipefish	4	138.0	8	271.7	2	54.3	14	147.0
shiner perch	4	138.0			9	244.6	13	136.5
sharpnose sculpin	1	34.5	1	34.0	5	135.9	7	73.5
silverspotted sculpin	4	138.0	1	34.0			5	52.5
padded sculpin	1	34.5	3	101.9			4	42.0
staghorn sculpin	3	103.5			1	27.2	4	42.0
tubesnout	1	34.5	3	101.9			4	42.0
crescent gunnel			1	34.0	1	27.2	2	21.0
penpoint gunnel	1	34.5	1	34.0			2	21.0
buffalo sculpin			1	34.0			1	10.5
great sculpin			1	34.0			1	10.5
rock greenling	1	34.5					1	10.5
starry flounder			1	34.0			1	10.5
whitespotted greenling			1	34.0			1	10.5
Total	20	690.1	22	747.3	18	489.1	60	630.1

AVERAGE FISH/HECTARE = 630.0 **SPECIES DIVERSITY = 2.24**
SPECIES RICHNESS = 14

SUBTIDAL EELGRASS

Fish Species	Oct-87 SE Sta 6	#/ha	Oct-87 SE Sta 8	#/ha	Oct-87 SE Sta 11	#/ha	TOTAL NUMBER	TOTAL #/ha
tadpole sculpin					45	815.2	45	408.5
silverspotted sculpin	20	621.1	3	131.8			23	208.8
bay pipefish	4	124.2	7	307.4	5	90.6	16	145.2
padded sculpin			8	351.3	6	108.7	14	127.1
shiner perch			14	614.8			14	127.1
staghorn sculpin	8	248.4	5	219.6			13	118.0
penpoint gunnel	3	93.2	1	43.9			4	36.3
saddleback gunnel	2	62.1	2	87.8			4	36.3
crescent gunnel	2	62.1					2	18.2
great sculpin	2	62.1					2	18.2
ribbon snailfish	2	62.1					2	18.2
snake prickleback	2	62.1					2	18.2
buffalo sculpin					1	18.1	1	9.1
Pacific spiny lumpsucker					1	18.1	1	9.1
tubenose poacher					1	18.1	1	9.1
Total	45	1397.5	40	1756.7	59	1068.8	144	1307.1

AVERAGE FISH/HECTARE = 1307.0 **SPECIES DIVERSITY = 2.11**
SPECIES RICHNESS = 15

SUBTIDAL CHANNEL

Fish Species	Oct-87 SC Sta 9	#/ha	Oct-87 SC Sta 14	#/ha	Oct-87 SC Sta 16	#/ha	TOTAL NUMBER	TOTAL #/ha
English sole	8	103.8	2	21.7			10	40.4
buffalo sculpin	3	38.9	1	10.9	3	38.4	7	28.3
sturgeon poacher	4	51.9	1	10.9			5	20.2
tadpole sculpin	5	64.9					5	20.2
saddleback gunnel			1	10.9	3	38.4	4	16.2
bay pipefish	2	26.0			1	12.8	3	12.1
butter sole	3	38.9					3	12.1
padded sculpin	2	26.0			1	12.8	3	12.1
tubenose poacher					2	25.6	2	8.1
tubesnout	2	26.0					2	8.1
plainfin midshipman	1	13.0					1	4.0
rock sole	1	13.0					1	4.0
sand sole	1	13.0					1	4.0
starry flounder			1	10.9			1	4.0
Total	32	415.3	6	65.2	10	127.9	48	194.1

AVERAGE FISH/HECTARE = 194.0 **SPECIES DIVERSITY = 2.39**
SPECIES RICHNESS = 14

ALL STATIONS COMBINED

Fish Species	Total	#/ha
tadpole sculpin	50	110.5
bay pipefish	33	72.9
silverspotted sculpin	28	61.9
shiner perch	27	59.7
padded sculpin	21	46.4
staghorn sculpin	17	37.6
English sole	10	22.1
buffalo sculpin	9	19.9
saddleback gunnel	8	17.7
sharpnose sculpin	7	15.5
penpoint gunnel	6	13.3
tubesnout	6	13.3
sturgeon poacher	5	11.0
crescent gunnel	4	8.8
butter sole	3	6.6
great sculpin	3	6.6
tubenose poacher	3	6.6
ribbon snailfish	2	4.4
snake prickleback	2	4.4
starry flounder	2	4.4
Pacific spiny lumpsucker	1	2.2
plainfin midshipman	1	2.2
rock greenling	1	2.2
rock sole	1	2.2
sand sole	1	2.2
whitespotted greenling	1	2.2
Total	252	556.7

ALL STATIONS

SPECIES DIVERSITY = 2.6

SPECIES RICHNESS = 26.0

AVERAGE FISH/HECTARE = 556.7

Appendix Table 1. Continued. Catches and estimated densities (fish/ha) of marine fish caught by beam trawl in Padilla Bay during Jan. 1988.

INTERTIDAL EELGRASS

Fish Species	Jan-88 IE Sta 12	#/ha	Jan-88 IE Sta 13	#/ha	Jan-88 IE Sta 15	#/ha	TOTAL NUMBER	TOTAL #/ha
bay pipefish			2	33.4	1	19.8	3	19.9
sharpnose sculpin			2	33.4			2	13.3
buffalo sculpin	1	24.8					1	6.6
starry flounder					1	19.8	1	6.6
tubesnout			1	16.7			1	6.6
Total	1	24.8	5	83.6	2	39.5	8	53.1

AVERAGE FISH/HECTARE = 53.1 **SPECIES DIVERSITY = 1.49**

SPECIES RICHNESS = 5

SUBTIDAL EELGRASS

Fish Species	Jan-88 SE Sta 6	#/ha	Jan-88 SE Sta 8	#/ha	Jan-88 SE Sta 11	#/ha	TOTAL NUMBER	TOTAL #/ha
bay pipefish	11	239.1	1	27.2	5	120.8	17	136.9
silverspotted sculpin	1	21.7			2	48.3	3	24.2
buffalo sculpin	1	21.7					1	8.1
saddleback gunnel					1	24.2	1	8.1
staghorn sculpin			1	27.2			1	8.1
starry flounder					1	24.2	1	8.1
sturgeon poacher	1	21.7					1	8.1
Total	14	304.3	2	54.3	9	217.4	25	201.3

AVERAGE FISH/HECTARE = 201.3 **SPECIES DIVERSITY = 1.16**

SPECIES RICHNESS = 7

SUBTIDAL CHANNEL

Fish Species	Jan-88 SC Sta 9	#/ha	Jan-88 SC Sta 14	#/ha	Jan-88 SC Sta 16	#/ha	TOTAL NUMBER	TOTAL #/ha
buffalo sculpin	1	9.7	6	102.3	6	74.5	13	53.6
English sole	3	29.0			5	62.1	8	33.0
bay pipefish	2	19.3	2	34.1	2	24.8	6	24.7
Pacific sandlance			4	68.2			4	16.5
starry flounder					2	24.8	2	8.2
sturgeon poacher	1	9.7	1	17.1			2	8.2
tubenose poacher	1	9.7			1	12.4	2	8.2
great sculpin					1	12.4	1	4.1
showy snailfish	1	9.7					1	4.1
snake prickleback	1	9.7					1	4.1
speckled sanddab	1	9.7					1	4.1
staghorn sculpin	1	9.7					1	4.1
Total	12	115.9	13	221.7	17	211.2	42	173.1

AVERAGE FISH/HECTARE = 173.1 **SPECIES DIVERSITY = 2.06**

SPECIES RICHNESS = 12

ALL STATIONS COMBINED

Fish Species	Total	#/ha
bay pipefish	26	50.2
buffalo sculpin	15	29.0
English sole	8	15.5
Pacific sandlance	4	7.7
starry flounder	4	7.7
silverspotted sculpin	3	5.8
sturgeon poacher	3	5.8
sharpnose sculpin	2	3.9
staghorn sculpin	2	3.9
tubenose poacher	2	3.9
great sculpin	1	1.9
saddleback gunnel	1	1.9
showy snailfish	1	1.9
snake prickleback	1	1.9
speckled sanddab	1	1.9
tubesnout	1	1.9
Total	75	144.9

ALL STATIONS

SPECIES DIVERSITY = 2.1

SPECIES RICHNESS = 16.0

AVERAGE FISH/HECTARE = 144.9

Appendix Table 1. Continued. Catches and estimated densities (fish/ha) of marine fish caught by beam trawl in Padilla Bay during April 1988.

INTERTIDAL EELGRASS

Fish Species	Apr-88 IE Sta 12	#/ha	Apr-88 IE Sta 13	#/ha	Apr-88 IE Sta 15	#/ha	TOTAL NUMBER	TOTAL #/ha
three-spined stickleback	6	87.0	8	165.6			14	82.8
English sole					5	96.6	5	29.6
tubesnout			3	62.1			3	17.7
bay pipefish	3	43.5					3	17.7
saddleback gunnel	1	14.5	1	20.7			2	11.8
staghorn sculpin					1	19.3	1	5.9
silverspotted sculpin	1	14.5					1	5.9
starry flounder			1	20.7			1	5.9
Total	12	173.9	13	269.2	6	115.9	31	183.4

AVERGE FISH/HECTARE = 183.4   SPECIES DIVERSITY = 1.61

SPECIES RICHNESS = 8

SUBTIDAL EELGRASS

Fish Species	Apr-88 SE Sta 6	#/ha	Apr-88 SE Sta 8	#/ha	Apr-88 SE Sta 11	#/ha	TOTAL NUMBER	TOTAL #/ha
three-spined stickleback	2	48.3			5	114.4	7	53.4
tubesnout			2	43.5	2	45.8	4	30.5
English sole			3	65.2			3	22.9
bay pipefish	2	48.3					2	15.3
saddleback gunnel	1	24.2					1	7.6
whitespotted greenling					1	22.9	1	7.6
sturgeon poacher					1	22.9	1	7.6
Total	5	120.8	5	108.7	9	205.9	19	144.9

AVERGE FISH/HECTARE = 144.9   SPECIES DIVERSITY = 1.69

SPECIES RICHNESS = 7

SUBTIDAL CHANNEL

Fish Species	Apr-88 SC Sta 9	#/ha	Apr-88 SC Sta 14	#/ha	Apr-88 SC Sta 16	#/ha	TOTAL NUMBER	TOTAL #/ha
Pacific sandlance			8	148.0			8	41.7
staghorn sculpin	6	72.5					6	31.2
tadpole sculpin	2	24.2	1	18.5	3	54.3	6	31.2
English sole	2	24.2	1	18.5	1	18.1	4	20.8
speckled sanddab	2	24.2					2	10.4
snake prickleback					1	18.1	1	5.2
saddleback gunnel			1	18.5			1	5.2
buffalo sculpin	1	12.1					1	5.2
Total	13	157.0	11	203.5	5	90.6	29	151.0

AVERGE FISH/HECTARE = 151.0   SPECIES DIVERSITY = 1.81

SPECIES RICHNESS = 8

ALL STATIONS COMBINED

Fish Species	Total	#/ha
three-spined stickleback	21	42.7
English sole	12	24.4
Pacific sandlance	8	16.3
staghorn sculpin	7	14.2
tubesnout	7	14.2
tadpole sculpin	6	12.2
bay pipefish	5	10.2
saddleback gunnel	4	8.1
speckled sanddab	2	4.1
snake prickleback	1	2.0
buffalo sculpin	1	2.0
silverspotted sculpin	1	2.0
whitespotted greenling	1	2.0
sturgeon poacher	1	2.0
starry flounder	1	2.0
Total	78	158.5

ALL STATIONS

SPECIES DIVERSITY = 2.3

SPECIES RICHNESS = 15.0

AVERGE FISH/HECTARE = 158.5

Appendix Table 2. Summary of staghorn sculpin stomach content IRIs by stratum for fish caught by beam trawl in Padilla Bay.

BEAM TRAWL IRI'S CALCULATED BY GROUP

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
INTERTIDAL EELGRASS								
AMPHIPOD								
Anisogammarus puget.	33	0.648						
Amphitoe sp.	1	0.035						
Caprella sp.	111	0.311						
Corophium sp.	46	0.132						
Metacaprella sp.	1	0.004						
Photis sp.	10	0.018						
Phoxocephalidae	10	0.018						
Pontogenia sp.	2	0.005						
Unidentified	3	0.024						
TOTAL	217	1.195	29	33.4877	3.0502	65.909	2408.2	29.56
CRAB								
Cancer magister	1	10.35						
Cancer gracilis	1	0.004						
Telmessus	3	0.011						
Pinnixa	35	5.505						
Unidentified	0	0						
TOTAL	40	15.87	19	6.17284	40.507	43.182	2015.7	24.75
SHRIMP								
Crangon sp.	8	0.942						
Heptacarpus brevirostus	0	0						
H. clarki	0	0						
H. stichensis	0	0						
Pandalus danae	0	0						
Unidentified	1	0.002						
TOTAL	9	0.944	8	1.38889	2.4095	18.182	69.062	0.848
MOLLUSC								
Bivalve	3	0.039						
Clam siphon	21	0.042						
Gastropod	0	0						
Unidentified	0	0						
TOTAL	24	0.081	8	3.7037	0.2067	18.182	71.099	0.873
ISOPOD								
Gnor. oregonensis	8	0.247						
Idotea resecata	22	7.454						
Synidotea sp.	9	0.365						
TOTAL	39	8.066	18	6.01852	20.588	40.909	1088.5	13.36

Appendix Table 2—cont.

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
POLYCHAETE								
Nerieid	10	0.251						
Terebellid	0	0						
Unidentified	14	4.513						
TOTAL	24	4.764	15	3.7037	12.16	34.091	540.8	6.639
FISH								
Enophrys bison	0	0						
G. aculeatus	4	0.28						
Leptocottus armatus	1	2.85						
Pholid	0	0						
Fish eggs	0	0						
Unidentified	3	0.342						
TOTAL	8	3.472	6	1.23457	8.8621	13.636	137.68	1.69
OTHER								
Cumacean	2	0.007	2	0.30864	0.0179	4.5455	1.4841	0.018
Mysid	2	0.046	2	0.30864	0.1174	4.5455	1.9366	0.024
Ostracod	3	0.004	3	0.46296	0.0102	6.8182	3.2262	0.04
Tanaid	271	0.297	16	41.821	0.7581	36.364	1548.3	19.01
Algae, wood, rock, etc.	9	4.432	9	1.38889	11.312	20.455	259.8	3.189
GRAND TOTAL	648	39.178	44	100	100		8145.8	100

SUBTIDAL EELGRASS

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
AMPHIPOD								
Anisogammarus puget.	8	0.178						
Amphitoe sp.	0	0						
Caprella sp.	7	0.11						
Corophium sp.	2	0.004						
Metacaprella sp.	2	0.082						
Photis sp.	62	0.179						
Phoxocephalidae	0	0						
Pontogenia sp.	0	0						
Unidentified	0	0						
TOTAL	81	0.553	10	27.4576	1.1966	32.258	924.33	12.18
CRAB								
Cancer magister	0	0						
Cancer gracilis	1	10.55						
Telmessus	0	0						
Pinnixa	35	4.067						
Unidentified	1	0.005						
TOTAL	37	14.622	16	12.5424	31.64	51.613	2280.4	30.05

Appendix Table 2—cont.

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
SHRIMP								
Crangon sp.	4	2.176						
Heptacarpus brevirostus	2	0.88						
H. clarki	2	0.28						
H. stichensis	1	0.37						
Pandalus danae	5	4.48						
Unidentified	1	0.77						
TOTAL	15	8.956	10	5.08475	19.379	32.258	789.17	10.4
MOLLUSC								
Bivalve	0	0						
Clam siphon	4	0.02						
Gastropod	96	4.501						
Unidentified	0	0						
TOTAL	100	4.521	8	33.8983	9.7827	25.806	1127.3	14.86
ISOPOD								
Gnor. oregonensis	13	1.364						
Idotea resecata	14	8.26						
Synidotea sp.	16	1.499						
TOTAL	43	11.123	17	14.5763	24.068	54.839	2119.2	27.93
POLYCHAETE								
Nerieid	3	0.403						
Terebellid	3	3.925						
Unidentified	5	0.295						
TOTAL	11	4.623	6	3.72881	10.003	19.355	265.79	3.503
FISH								
Enophrys bison	0	0						
G. aculeatus	0	0						
Leptocottus armatus	0	0						
Pholid	1	0.431						
Fish eggs	0	0						
Unidentified	0	0						
TOTAL	1	0.431	1	0.33898	0.9326	3.2258	4.1019	0.054
OTHER								
Cumacean	0	0	0	0	0	0	0	0
Mysid	1	0.004	1	0.33898	0.0087	3.2258	1.1214	0.015
Ostracod	0	0	0	0	0	0	0	0
Tanaid	1	0.004	1	0.33898	0.0087	3.2258	1.1214	0.015
Algae, wood, rock, etc.	5	1.379	5	1.69492	2.9839	16.129	75.465	0.995
GRAND TOTAL	295	46.216	31	100	100		7587.9	100

Appendix Table 2—cont.

SUBTIDAL CHANNEL

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
AMPHIPOD								
Anisogammarus puget.	91	1.742						
Amphitoe sp.	0	0						
Caprella sp.	28	0.221						
Corophium sp.	36	0.117						
Metacaprella sp.	7	0.136						
Photis sp.	385	1.566						
Phoxocephalidae	9	0.05						
Pontogenia sp.	14	0.055						
Unidentified	9	0.046						
TOTAL	579	3.933	70	59.5067	5.4161	82.353	5346.6	57.32
CRAB								
Cancer magister	3	5.114						
Cancer gracilis	2	0.1						
Telmessus	0	0						
Pinnixa	32	1.832						
Unidentified	0	0						
TOTAL	37	7.046	23	3.80267	9.703	27.059	365.45	3.918
SHRIMP								
Crangon sp.	27	1.384						
Heptacarpus brevirostus	0	0						
H. clarki	0	0						
H. stichensis	0	0						
Pandalus danae	0	0						
Unidentified	3	0.019						
TOTAL	30	1.403	21	3.08325	1.9321	24.706	123.91	1.328
MOLLUSC								
Bivalve	2	0.018						
Clam siphon	5	0.02						
Gastropod	13	0.432						
Unidentified	2	0.064						
TOTAL	22	0.534	10	2.26105	0.7354	11.765	35.252	0.378
ISOPOD								
Gnor. oregonensis	69	2.871						
Idotea resecata	3	0.185						
Synidotea sp.	53	1.816						
TOTAL	125	4.872	50	12.8469	6.7092	58.824	1150.4	12.33
POLYCHAETE								
Nerieid	105	2.975						
Terebellid	2	0.152						
Unidentified	23	2.626						
TOTAL	130	5.753	48	13.3607	7.9224	56.471	1201.9	12.89

Appendix Table 2—cont.

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
FISH								
Enophrys bison	1	0.04						
G. aculeatus	0	0						
Leptocottus armatus	0	0						
Pholid	3	0.78						
Fish eggs	1	14.05						
Unidentified	1	0.155						
TOTAL	6	15.025	4	0.61665	20.691	4.7059	100.27	1.075
OTHER								
Cumacean	10	0.08	9	1.02775	0.1102	10.588	12.049	0.129
Mysid	0	0	0	0	0	0	0	0
Ostracod	1	0.003	1	0.10277	0.0041	1.1765	0.1258	0.001
Tanaid	16	0.034	11	1.6444	0.0468	12.941	21.886	0.235
Algae, wood, rock, etc.	17	33.934	17	1.74717	46.73	20	969.55	10.39
GRAND TOTAL	973	72.617		100	100		9327.3	100

ALL STRATA COMBINED

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
AMPHIPOD								
Anisogammarus puget.	132	2.604						
Amphitoe sp.	1	0.035						
Caprella sp.	146	0.642						
Corophium sp.	84	0.252						
Metacaprella sp.	10	0.222						
Photis sp.	457	1.762						
Phoxocephalidae	19	0.068						
Pontogenia sp.	16	0.06						
Unidentified	12	0.07						
TOTAL	877	5.715	109	45.7724	3.7059	68.125	3370.7	42.79
CRAB								
Cancer magister	4	15.464						
Cancer gracilis	4	10.649						
Telmessus	3	0.011						
Pinnixa	102	11.404						
Unidentified	1	0.005						
TOTAL	114	37.533	58	5.9499	24.338	36.25	1097.9	13.94

Appendix Table 2—cont.

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
SHRIMP								
Crangon sp.	39	4.502						
Heptacarpus brevirostus	2	0.88						
H. clarki	2	0.28						
H. stichensis	1	0.37						
Pandalus danae	5	4.48						
Unidentified	5	0.791						
TOTAL	54	11.303	39	2.81837	7.3294	24.375	247.35	3.14
MOLLUSC								
Bivalve	5	0.056						
Clam siphon	30	0.081						
Gastropod	109	4.933						
Unidentified	2	0.064						
TOTAL	146	5.134	26	7.62004	3.3291	16.25	177.92	2.259
ISOPOD								
Gnor. oregonensis	90	4.482						
Idotea resecata	39	15.9						
Synidotea sp.	78	3.68						
TOTAL	207	24.062	85	10.8038	15.603	53.125	1402.9	17.81
POLYCHAETE								
Nerieid	118	3.629						
Terebellid	5	4.077						
Unidentified	42	3.629						
TOTAL	165	11.335	69	8.61169	7.3501	43.125	688.35	8.738
FISH								
Enophrys bison	1	0.04						
G. aculeatus	4	0.28						
Leptocottus armatus	1	2.85						
Pholid	4	1.211						
Fish eggs	1	14.05						
Unidentified	4	0.479						
TOTAL	15	18.91	11	0.78288	12.262	6.875	89.684	1.138
OTHER								
Cumacean	12	0.087	11	0.6263	0.0564	6.875	4.6937	0.06
Mysid	3	0.05	3	0.15658	0.0324	1.875	0.3544	0.004
Ostracod	4	0.006	4	0.20877	0.0039	2.5	0.5316	0.007
Tanaid	288	0.335	28	15.0313	0.2172	17.5	266.85	3.387
Algae, wood, rock, etc.	31	39.745	31	1.61795	25.772	19.375	530.69	6.736
GRAND TOTAL	1916	154.215		100	100		7877.9	100

Appendix Table 3. Summary of staghorn sculpin stomach content IRIs for fish caught by trammel net in south Padilla Bay.

TRAMMEL NET IRI'S CALCULATED BY GROUP

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
ALL STAGHORN SCULPIN STOMACHS								
AMPHIPOD								
Anisogammarus puget.	1	0.016						
Amphitoe sp.	1	0.128						
TOTAL	2	0.144	2	5.26316	0.6763	20	118.79	1.423
CRAB								
Telmessus	1	1.14						
Pinnixa	4	0.537						
Unidentified	1	8.92						
TOTAL	6	10.597	4	15.7895	49.772	40	2622.5	31.42
SHRIMP								
Crangon sp.	2	0.397						
TOTAL	2	0.397	2	5.26316	1.8646	20	142.56	1.708
ISOPOD								
Gnor. oregonensis	9	1.277						
Idotea resecata	12	5.364						
TOTAL	21	6.641	5	55.2632	31.192	50	4322.7	51.79
POLYCHAETE								
Nerieid	1	0.513						
TOTAL	1	0.513	1	2.63158	2.4095	10	50.41	0.604
FISH								
Leptocottus armatus	1	0.487						
Pholid	3	1.789						
Unidentified	1	0.531						
TOTAL	5	2.807	4	13.1579	13.184	40	1053.7	12.62
OTHER								
Algae	1	0.192	1	2.63158	0.9018	10	35.334	0.423
GRAND TOTAL	38	21.291	10	100	100		8346	100

Appendix Table 4. Summary of staghorn sculpin stomach content IRIs for fish caught by beach seine at the intertidal station in south Padilla Bay in 1987.

1987 BEACH SEINE IRI'S CALCULATED BY GROUP

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
ALL STAGHORN SCULPIN STOMACHS								
AMPHIPOD								
Anisogammarus puget.	100	1.3						
Amphitoe sp.	39	0.877						
Aoroides sp.	7	0.012						
Caprella sp.	110	0.45						
Corophium sp.	94	0.313						
Metacaprella sp.	4	0.036						
Photis sp.	366	0.989						
Phoxocephalidae	6	0.021						
Pontogenia sp.	4	0.001						
Synchelidium sp.	155	0.262						
Unidentified	15	0.207						
TOTAL	900	4.468	60	69.7134	18.351	89.552	7886.4	59.79
CRAB								
Cancer magister	20	0.35						
Cancer gracilis	3	0.046						
Telmessus	1	0.124						
Pinnixa	76	4.42						
TOTAL	100	4.94	37	7.74593	20.29	55.224	1548.3	11.74
SHRIMP								
Crangon sp.	19	1.587						
Hyppolytid	1	0.016						
Pandalus danae	1	0.045						
Unidentified	25	0.778						
TOTAL	46	2.426	23	3.56313	9.9643	34.328	464.37	3.52
MOLLUSC								
Bivalve	1	0.018						
Gastropod	4	0.186						
TOTAL	5	0.204	5	0.3873	0.8379	7.4627	9.1432	0.069
ISOPOD								
Gnor. oregonensis	75	3.983						
Idotea resecata	15	1.02						
Idotea wosen.	1	0.165						
Synidotea sp.	50	1.448						
TOTAL	141	6.616	45	10.9218	27.174	67.164	2558.7	19.4

Appendix Table 4—cont.

	NUMBER	WEIGHT	COUNT	NUM %	GRAV %	FO %	IRI	% IRI
POLYCHAETE								
Nerieid	29	1.28						
Unidentified	17	2.498						
TOTAL	46	3.778	20	3.56313	15.517	29.851	569.57	4.318
FISH								
Cymatogaster aggregata	2	1.387						
G. aculeatus	5	0.412						
TOTAL	7	1.799	6	0.54222	7.389	8.9552	71.026	0.538
OTHER								
Cumacean	15	0.056	8	1.16189	0.23	11.94	16.62	0.126
Tanaid	31	0.06	17	2.40124	0.2464	25.373	67.18	0.509
GRAND TOTAL	1291	24.347	67	100	100		13191	100