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Annual, Seasonal, and Diel Composition of Larval and Juvenile Fishes Collected by Dip-net in Clam Bay, Puget Sound, Washington, from 1985 to 1995

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ABSTRACT

Larval and juvenile fishes were collected in dip-nets on an irregular basis, typically from late winter through early summer (1985-95), from a pier in Clam Bay, Puget Sound, Washington. The sampling site is located at an interface of rocky intertidal, mud flat, and deeper (20-100 m) subtidal marine habitats. Sampling was conducted during daylight or at night with the aid of floodlights. A total of 2,505 larval and juvenile fishes, consisting of at least 65 species representing 24 families, was collected. The family Cottidae was represented by the greatest number of taxa (14) followed by Stichaeidae (8) and Pleuronectidae (8). Overall, annual, seasonal, monthly, and diel species compositions of the ichthyoplankton assemblage were determined using presence/absence data by compiling lists of unique species, frequently occurring taxa, and recurrent group analysis. The number of taxa included in an assemblage differed among the analyses but similarities in species composition were found. The number of taxa present and composition of the ichthyoplankton assemblage changed seasonally, annually, and over diel periods. Taxonomic diversity was greatest during spring months and distinct daytime and nighttime assemblages were identified. The greatest number of taxa was collected in 1988 and 1995 and the least in 1991.

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INTRODUCTION

Puget Sound is a large, temperate fjord located in northwestern Washington State (Fig. 1). Clam Bay is located on the western shore of central Puget Sound in Kitsap County, Washington (47° 34' 15" N, 122 °32' 30" W), 5.5 km east of the city of Bremerton. Over 225 fish species from 68 families of fishes are known to occur in Puget Sound (Palsson 1993). Despite the ecological and economic importance of the Puget Sound ecosystem, few published reports on the distribution, ecology, species composition, or taxonomy of larval fishes exist for the area. Most of the limited information available resides in environmental impact and contract reports, masters theses, and doctoral dissertations (Table 1). Of these studies, only Waldron (1972) is based on an ichthyoplankton survey that occupied stations located throughout Puget Sound. At the station closest to Clam Bay, *Merluccius productus* and larval fishes in the families Pleuronectidae, Gadidae, Scorpaenidae, Cottidae, and Liparidae were collected. Other studies including those of Kendall (1966), Blackburn (1973), Bollens et al. (1992), and Roni and Weitkamp (1996) incorporated collections of ichthyoplankton or juvenile and adult fishes at specific monitoring sites within Puget Sound. Several studies have targeted specific fishes of economic value such as *Clupea pallasi* and *Gadus macrocephalus* (Trumble et al. 1977, Karp and Miller 1977, Miller et al. 1977). In some studies, not all larval fishes collected were routinely identified (Dan Penttila, WDFW pers. commun. Oct. 1995).

Our sampling in Clam Bay was originally intended to collect undescribed early life history stages of Puget Sound fishes. After several years of sampling, we realized that we had a valuable record of the species composition, annual, seasonal, and diel structure of the Clam Bay ichthyoplankton community. In this study, we describe the species composition of the Clam Bay ichthyoplankton assemblage during an 11- year period and report on annual, seasonal, and diel changes in its components. Trends in sea surface temperature are examined and evaluated.

METHODS

Study Site

Clam Bay occupies a relatively small, tidally influenced basin of approximately 750 m^2 (Fig. 2). Water depths range from 0.3 to13.0 m at mean high water. Several different types of substrate are present within or immediately adjacent to Clam Bay that provide diverse habitats for marine life. The area near the mouth of Beaver Creek, extending north to the pier and east to several floating fish pens, is a mudflat that is often exposed at low tides in shallow areas near the beach (Fig. 2). North of the pier, the substrate composition grades rapidly from gravel to cobble and boulders off the rocky headland, Middle Point, where tidepool habitat is also present. Additional rocky intertidal and subtidal habitat is present along the beach adjacent to the floating fish pens continuing farther east to Orchard Point. Immediately offshore from Middle Point and Clam Bay, water depths increase rapidly to 30 m in the adjacent deep channel, Rich Passage. Much of the shoreline surrounding Clam Bay is forested consisting mostly of *Pseudotsuga menziesii* (Douglas fir), *Thuja plicata* (western red cedar), and *Tsuga heterophylla* (western hemlock).

The pier, which served as our sampling platform, is approximately 180 m long and depth at the end is about 15 m at extreme high water. Located near Beaver Creek, the pier and attached floating fish pens are used for research by the Northwest Fisheries Science Center's (NWFSC), Manchester Field Station. Commercially operated floating net pen facilities used for salmon culture are also present in the bay. Most of the land and shoreline north of the pier is within the boundaries of Manchester State Park. Rich Passage is a major shipping and transportation lane serving the Port of Bremerton. A large refueling pier, operated by the U.S. Navy, is located immediately south of Clam Bay near the town of Manchester.

Data Collection

Sampling was conducted using dip-nets during the months of January-July, 1985-95 (Table 2). Sampling was accomplished on an opportunistic basis. During 1995, sampling was conducted on at least one day and night for each month from January through June. Sampling effort was not standardized (e.g., duration of sampling, number of collectors, number of collections per month or year) but an attempt was made to collect representatives of all species present on each sampling date. Most sampling was conducted on incoming tides.

Fish larvae were collected with dip-nets constructed from a 25.5 by 17.0 cm rectangular-shaped, plastic coated wire frame with a 10 cm deep bag of 333μ mesh suspended from it. The frame was connected to a handle of 1.5 m length made of 2.5 cm outside diameter PVC pipe. Most juvenile fish were collected with a dip-net consisting of a 21.0 by 15.0 cm rectangular-shaped, plastic-coated wire frame with a 18.0 cm deep bag of 1.0 mm mesh connected to a 90 cm handle. Occasionally, juvenile fish were captured with the dip nets constructed for fish larvae. On night collections from 1989 to 1993, a 100 W spotlight was attached to the pier to illuminate the surface waters adjacent to the floating dock below. In 1994 and 1995, a 500 W halogen outdoor lamp was attached to the pier and a 250 W model was attached to the floating dock. The sampling platform was a floating dock with several attached net pens that were elevated approximately 50 cm above the surface of the water.

Larval and juvenile fishes were first spotted and then actively pursued and captured with the dip-nets. Upon capture, larval and juvenile fish were placed in a jar containing 1.0 g/l solution of MS-222 in seawater until anesthetized and then transferred to a 3.5% buffered formalin solution for preservation. All fish collected were then taken to the Alaska Fisheries Science Center (AFSC) ichthyoplankton laboratory for identification, enumeration, and measurement (standard length: mm SL). Taxonomic information from Matarese et al. (1989), Busby (1998), and Orr and Matarese, AFSC (in press) were used to make identifications.

Analytical Methods

<u>Data Sources</u>

Only presence-absence data were used in this study. A list of taxa collected during all sampling dates was compiled. To study annual, seasonal, and diel differences in species composition, this data set was divided into four subsets: combined (winter and spring) for the years 1993-95, winter (January-March) for the years 1991-95, spring (April-June) for the years

1987-90 and 1993-95, and diel for the years 1992-95 (Table 2). Dividing the data in this manner gave us the most complete and comparable data sets for analysis.

Sea surface temperature data was collected on most sampling dates in 1989 and all sampling dates from 1990 to 1995. Data for other dates were collected and provided by NWFSC staff of the Manchester Field Station. Tide direction, heights, and geographic correction factors were found in the annual tide tables for Puget Sound (NOAA, 1985-95).

Data Analysis

Not all analytical methods were performed on each data set but methods were selected for their appropriateness in each case. Descriptions of each analysis used are presented below:

Lists of unique taxa - - The overall list of taxa was sorted to identify taxa that occurred only in winter, spring, daytime, or nighttime collections. These lists of "unique taxa" were used to determine the absolute components in these respective assemblages.

Lists of frequently occurring taxa - - The most frequently occurring taxa were compiled in lists for winter, spring, daytime, and nighttime collections. These taxa represent the common or consistent members of the Clam Bay ichthyoplankton assemblage.

Monthly and yearly species richness - - The number of species collected during each month (species richness) was determined from the overall data set (all years combined) to examine seasonal differences. This was also done for each individual year to examine interannual differences.

Recurrent group analysis - - Recurrent group analysis (Fager 1957, Moser et al. 1987) was used to group species using affinity indices based on presence/absence data. The affinity index used was as follows:

$$I_{ab} = \frac{N_j}{\sqrt{N_a N_b}} - \frac{1}{2\sqrt{N_b}},$$

where N_j is the number of joint occurrences, N_a is the number of occurrences of taxon a, the less common taxon, and N_b is the number of occurrences of taxon b, the more common taxon. The second term in the equation is simply a correction factor which adjusts for sample size. This analysis groups data according to a specified minimum affinity level. The computer program REGROUP was used to perform the analyses (Moser et al. 1987). An analysis was done for the combined data set as well as for each individual year and the winter, spring, day, and night data sets using an affinity level of 0.4. Other taxa were considered "affiliate" if they met or exceeded the affinity level with one or more but not all members of the recurrent group.

Spawning periods and growth trends - - Length range (minimum and maximum) of each taxon collected was measured on each sampling date. The length range data for the 13 most frequently occurring taxa over the entire study period were pooled and plotted by month to estimate approximate spawning periods and observe generalized growth trends.

Sea surface temperature - - Winter and spring (January-June) sea surface temperatures measured at the pier over the entire study were pooled. Analysis of variance (ANOVA) was used to test for differences between months and years.

RESULTS

A total of 2,505 larval and juvenile fishes consisting of at least 65 species representing 24 families, including one unidentified, was collected (Table 3). The actual number of species was probably greater because taxonomic knowledge of larval stages of the family Osmeridae and the genera *Sebastes*, *Liparis,* and *Pholis* is incomplete, and these taxa were probably represented by more than one species. The family Cottidae was represented by the greatest number of taxa (14), followed by the families Stichaeidae and Pleuronectidae (8 each).

Combined Ichthyoplankton Assemblage

Recurrent Groups

Analysis of the combined winter and spring 1993-95 data identified eight recurrent groups (Table 2 and Fig. 3). One or more taxa within four of the groups had affinity with one or more taxa outside the group. The largest group (10 taxa) is dominated by fishes in the family Cottidae (*Leptocottus armatus, Clinocottus acuticeps, Oligocottus maculosus, Artedius harringtoni,* and *Scorpaenichthys marmoratus)*. Two additional scorpaeniform taxa; *Sebastes* spp. (family Scorpaenidae) and *Podothecus acipenserinus* (family Agonidae) are also members of this recurrent group. The remainder of the group is comprised of one taxon each in the families Bathymasteridae (*Ronquilis jordani*), Stichaeidae (*Anoplarchus* spp.), and Pleuronectidae (*Psettichthys melanostictus*). The next two largest recurrent groups are comprised of four taxa each. Two gadids (*Gadus macrocephalus* and *Theragra chalcogramma*) and two pleuronectids (*Lepidopsetta* cf. *bilineata*, and *Lyopsetta exilis*) comprise the first group and the second is comprised entirely of pleuronectids (*Isopsetta isolepis*, *Platichthys stellatus*, *Parophrys vetulus*, and *Lepidopsetta bilineata*). The remaining groups are comprised of two or three taxa and are represented by one taxon each in the families Osmeridae, Gadidae, Hexagrammidae, Cottidae, Hemitripteridae, Liparidae, Stichaeidae, Pholidae, Anarhichadidae, Ptilichthyidae, and Ammodytidae.

Seasonal Ichthyoplankton Assemblages

Some seasonal components of the ichthyoplankton community were identified in the recurrent group analysis of the combined winter and spring data (Fig. 3). The group comprised of *Chirolophis decoratus* and *Anarrhichthys ocellatus* represents a winter assemblage. Two groups comprised the late winter - early spring transitional assemblage (*Ammodytes hexapterus* and *Liparis* spp.; *Apodichthys flavidus*, *Hexagrammos stelleri*, and *H. decagrammus*). The taxa in the remaining three groups were uniquely spring members of the assemblage, with the exception of *Leptocottus armatus*, *Scorpaenichthys marmoratus*, and *Artedius fenestralis* which occurred in both winter and spring but were only affiliates with spring taxa in this analysis.

Unique Taxa

Only three taxa (*Anarrhichthys ocellatus*, *Chirolophis decoratus*, and *Chirolophis* spp.) were unique to winter samples while 31 taxa were unique to spring, the majority of which belonged to the families Cottidae and Pleuronectidae (Table 3). There were 31 other taxa that occurred in both winter and spring samples.

Frequently Occurring Taxa

Examination of the 1991-95 winter data revealed a group of eight frequently occurring taxa (≥ 4 occurrences) with *Hexagrammos stelleri* having occurred on the greatest number of sampling dates and being the only taxon present in all sampling years (Tables 2 and 4A). *Apodichthys flavidus*, *Ammodytes hexapterus*, *Liparis* spp., and *Ophiodon elongatus* were absent in one year and *Hexagrammos decagrammus* and *Psychrolutes sigalutes* were absent in three years. Of the taxa considered to have occurred frequently in winter collections, *Apodichthys flavidus*, *Ammodytes hexapterus, Chirolophis nugator* and *Liparis* spp. also occurred frequently in early spring and are all part of the late winter-early spring transitional assemblage.

Twenty taxa were considered to have occurred frequently (≥ 10 occurrences) upon examination of the 1987-90, 1993-95 spring data with *Liparis* spp. being present on the greatest number of sampling dates (Tables 2 and 4B). *Liparis* spp., *Psettichthys melanostictus*, *Clinocottus acuticeps*, and *Platichthys stellatus* were the only taxa present in all years of sampling. Nine taxa were absent in one year and seven were absent in more than one year.

Recurrent Groups

Recurrent group analysis of the winter data identified four groups (Fig. 4). There were two or more taxa within two of the groups that had affinities with one or more affiliate taxa outside the recurrent group. Although each taxon had several occurrences in the spring, the group comprised of *Liparis* spp., *Ammodytes hexapterus*, and *Chirolophis nugator* represented a winter assemblage because none of these taxa appeared in any spring recurrent groups (Fig. 5). *Apodichthys flavidus* was also absent from spring recurrent groups. The affiliate taxon *Anarrhichthys ocellatus* occurred exclusively in the winter. All but one occurrence of *Psychrolutes sigalutes* was during winter. Although *Hexagrammos stelleri* occurred mostly in the winter, it and the remaining taxa were components of a late winter-early spring transitional assemblage or belonged to both the winter and spring ichthyoplankton communities.

There were eight recurrent groups identified in the analysis of the spring data (Fig. 5). One or more taxa within four of the recurrent groups had affinity with at least one or more taxa outside of the group. Unique spring components of the assemblage were identified in four of the recurrent groups. The other four contain taxa that were also determined to be members of recurrent groups in the winter analysis (*Leptocottus armatus*, *Hexagrammos decagrammus*, *H. stelleri*, *Ophiodon elongatus*, *and S. marmoratus*). The group containing Osmeridae, *Ronquilis* *jordani, Ptilichthys goodei, Artedius fenestralis*, and *Microgadus proximus* represented a late spring assemblage by having nearly all occurrences in late May or June.

Monthly Species Richness

This analysis showed seasonal trends in species richness during the months sampling was conducted over all years in the study combined. The greatest number of taxa were collected in May and the least in August (Fig. 6).

Interannual Comparisons

Annual Species Richness

The greatest number of species was collected in 1988 and 1995 and the fewest in 1991 (Fig. 7). A period of reduced species richness occurred from 1990 to 1994. Several taxa were absent or became notably less common in samples collected after 1988-90 including *Theragra chalcogramma, Hexagrammos decagrammus, Nautichthys oculofasciatus, Artedius lateralis*, and *Clinocottus embryum*. The year with the fewest number of species to occur on 10% or more of the sampling dates was 1991 and the greatest was 1988 (Fig. 7). The greatest number of cottid species occurred in 1987 and the greatest numbers of pleuronectids in 1987, 1988, and 1995. The species of pleuronectids present, however, were not identical in each year.

Recurrent Groups

Recurrent group analysis of winter data from each individual year 1991-95 revealed from one to three groups comprised of two to six taxa (Figs. 8A-E). The fewest recurrent groups and taxa within groups were present in 1991 and the most in 1992. *Hexagrammos stelleri* was present in a group every year. *Ammodytes hexapterus* was a member of a group in all years with the exception of 1991 and *Apodichthys flavidus* was in all groups except 1993. Taxa that occurred in winter recurrent groups in three of the five years include *Chirolophis nugator* (1992-94) and *Ophiodon elongatus* (1991, 1992, and 1995). *Apodichthys flavidus* and *H. stelleri* were members of the same group in three years (1991, 1992, and 1995). *Xiphister* spp. was present in a winter group in 1992 and 1994. *Oncorhynchus gorbuscha* was a member of a winter recurrent group in 1994 and was an affiliate taxon in 1995. Since *O. gorbuscha* is not present in any spring recurrent groups, it is clearly a member of the winter ichthyoplankton assemblage, as is *Xiphister* spp.

There were 1-10 groups comprised of 2-15 taxa identified in each recurrent group analysis of spring data from individual years 1987-90 and 1993-95 (Figs. 9A-G). The fewest recurrent groups were present in 1993 and the most in 1988. *Ammodytes hexapterus* was present in a recurrent group in all years with the exceptions of 1987 and 1995. In 1988 and 1989, *Ammodytes hexapterus* and *Apodichthys flavidus* were in the same groups. *Sebastes* spp. was a component of a recurrent group in all years with the exception of 1993 and 1994. Pleuronectids (e.g., *Lyopsetta exilis, Hippoglossoides elassodon, Parophrys vetulus, Lepidopsetta bilineata, Isopsetta isolepis, Platichthys stellatus*, and *Psettichthys melanostictus*) were present in recurrent groups in four out of seven years (1987-89 and 1995). In several cases, three or more pleuronectids occurred in the same recurrent group (Figs. 9A, B, G).

Three members of the family Gadidae (*Gadus macrocephalus, Microgadus proximus*, and *Theragra chalcogramma*) were found in recurrent groups from 1987 to1989 and 1995. *Gadus* *macrocephalus* was a member of a recurrent group and an affiliate of two other taxa in another group in 1988. *Microgadus proximus* and *T. chalcogramma* were in the same recurrent group in 1987 and 1988 and in different groups in 1989. *Microgadus proximus* was the only gadid present in recurrent groups in 1995.

Diel Comparisons

Unique taxa

Of the 65 taxa identified in this study, only three (*Psychrolutes sigalutes*, *Anarrhichthys ocellatus*, and *Xiphister* spp.) were unique to night samples while 35 were collected only during daylight (Table 3).

Frequently Occurring Taxa

Examination of data from day collections revealed a group of 13 frequently occurring taxa ($\geq$3 occurrences) with *Hexagrammos stelleri* having occurred on the greatest number of sampling dates (Tables 2 and 5A). *Psettichthys melanostictus*, *Liparis* spp., *Clinocottus acuticeps*, and *Platichthys stellatus* occurred in all sampling years. *Hexagrammos stelleri* and *Ammodytes hexapterus* were absent in one year and *Microgadus proximus*, *Sebastes* spp., *Parophrys vetulus*, *Pholis* spp., *Leptocottus armatus*, *Anoplarchus* spp., and *Apodichthys flavidus* were absent in more than one year. *Hexagrammos stelleri*, *Liparis* spp. , *Ammodytes hexapterus*, and *Apodichthys flavidus* also occurred frequently at night.

A group of seven frequently occurring taxa ($\geq$3 occurrences) was identified upon examination of data from night collections (Tables 2 and 5B). *Ammodytes hexapterus* occurred on the greatest number of sampling dates. *Ammodytes hexapterus*, *Liparis* spp., *Chirolophis nugator,* and *H. stelleri* were present in all years. The remaining three taxa were absent in one or more years. Although *A. hexapterus* was also collected during the daytime, it was collected more frequently at night (binomial test of proportions P=0.017).

Recurrent Groups

Recurrent group analysis of daytime data revealed six groups (Fig. 10). One of these groups is comprised of the same ten taxa as the largest group in the combined winter-spring assemblage from 1993 to 1995 (Fig. 3). Half of the members of this assemblage were members of the family Cottidae. The affiliate taxa were also identical with the exception of *H. stelleri* in the daytime assemblage. There were five additional groups ranging in size from two to five taxa. One group of four taxa (*Gadus macrocephalus*, *Theragra chalcogramma*, *Lepidopsetta* cf. *bilineata*, and *Lyopsetta exilis*) and one of three taxa (Osmeridae, *Microgadus proximus*, and *Ptilichthys goodei*) were also present in the combined winter and spring assemblage. The group containing four pleuronectids (*Isopsetta isolepis*, *Lepidopsetta bilineata*, *Parophrys vetulus*, and *Platichthys stellatus*) was nearly identical to another group in the combined winter and spring analysis with the exception of *Liparis* spp.

In contrast, the nighttime recurrent groups showed little resemblance to any of those from the combined winter and spring 1993-95 analysis (Fig. 11). One species, *Leptocottus armatus*, was included in the assemblages of both analyses. *Psychrolutes sigalutes* was the only member of the nighttime recurrent group that was also collected exclusively at night. *Anarrhichthys* *ocellatus* was also only collected at night but is not present in any of these recurrent groups. The group containing *Anarrhichthys ocellatus* and *Chirolophis decoratus* that was found in the combined winter and spring recurrent group analysis (Fig. 3) is the only definite night component of the assemblage.

Spawning Times and Growth Trends

Although analysis of spawning times and growth trends were not objectives of this study, the length range (minimum and maximum) of each taxon was measured on each collection date. The length range data for the 13 most frequently occurring taxa over the entire study period were pooled and plotted to estimate approximate spawning periods and observe generalized growth trends (Fig. 12). *Clinocottus acuticeps*, *Leptocottus armatus*, *Apodichthys flavidus*, and *Liparis* spp. were winter spawners whose larvae increased in size progressively throughout the spring. *Liparis* spp., however, appeared to continue spawning into the spring as the minimum size declined and maximum size increased from March to April. *Anoplarchus* spp. and *Ammodytes hexapterus* spawned in the late winter and early spring. *Hexagrammos stelleri* and *Scorpaenichthys marmoratus* spawned throughout the winter and spring. *Microgadus proximus*, *Sebastes* spp., *Parophrys vetulus*, *Platichthys stellatus*, and *Psettichthys melanostictus* spawned in the spring and their larvae steadily increased in size.

Other Biological Observations

During the 11- year period, numerous other aquatic organisms were observed or collected from the pier. An advanced stage encrusting community of organisms is present on the pier pilings. The intertidal zone is characterized by an abundance of *Balanus* spp. (barnacles), *Mytilus edulis* (blue mussels), Polychaeta (family Sabellidae, featherduster worms), and *Pugettia gracilis* (graceful kelp crabs). The subtidal zone is dominated by large *Metridium senile* (plumose anemones). Some larger crabs, mostly *Pugettia producta* (northern kelp crabs) and *Oregonia gracilis* (graceful decorator crabs), are also present. Schools of *Loligo opalescens* (opalescent inshore squid) and *Gonatus fabricii* (boreoatlantic armhook squid) were sometimes observed in late winter. Adult fish observed or collected by hook and line include Osmeridae, *Clupea pallasi, Oncorhynchus* spp., *Aulorhynchus flavidus*, *Gasterosteus aculeatus*, Embiotocidae, *Sebastes* spp., *Ophiodon elongatus, Scorpaenichthys marmoratus*, *Liparis* spp., *Pholis laeta*, *P. ornata*, and *Platichthys stellatus*. Aquatic mammals including *Phoca vitulina* (harbor seal), *Zalophus californianus* (California sea lion), and *Lutra canadensis* (river otter) were observed in Clam Bay during our study.

Sea Surface Temperature

Sea surface temperature measured at the pier ranged from 7.0° to 13.5 °C over the entire study. Analysis of pooled winter and spring (January-June) sea surface temperature data revealed that temperatures were significantly higher in 1992 than in all other years from 1987 to 1995

(ANOVA $P \leq 0.001$) (Fig. 13). Significantly higher temperatures were recorded in the individual months of February (ANOVA $P \leq 0.001$) and March (ANOVA $P \leq 0.001$) 1992 (Fig. 14).

DISCUSSION

Although this study was not quantitative in nature, it provides a detailed description of the taxonomic composition of the ichthyoplankton community in Clam Bay during the winter and spring months. Because our sampling site on a pier was located in close proximity to several varieties of marine habitats, the larval fishes collected there closely represent the diversity of ichthyoplankton fauna of the Puget Sound ecosystem. More taxa of larval and juvenile fishes were collected in this study than in any other previously conducted in Puget Sound (Kendall 1966, Waldron 1972, Blackburn 1973, Bollens et al. 1992, Roni and Wheitkamp 1996). We collected at least 65 taxa in Clam Bay, while the second largest number of taxa reported was 49 collected in Dabob Bay (Bollens et al. 1992).

Clam Bay has an ichthyoplankton community with distinct assemblages for winter, spring and day and night. In general terms, the Clam Bay ichthyoplankton fauna is dominated by a diverse assemblage of cottids and their relatives (Rhamphocottidae, Psychrolutidae, and Hemitripteridae) that displays changing taxonomic composition on annual, seasonal, and diel time scales. Larval fishes in the families Gadidae, Scorpaenidae, Liparidae, Ammodytidae, Stichaeidae, and Pleuronectidae are other common members of the Clam Bay ichthyoplankton community. Taxa such as *Hexagrammos decagrammus, H. stelleri, Ophiodon elongatus, Leptocottus armatus, Scorpaenichthys marmoratus, Liparis* spp., *Apodichthys flavidus,* and *Ammodytes hexapterus* are nearly always present throughout the winter, spring and day, night.

Some notable trends in the occurrence of particular species were found after compiling lists of unique taxa. *Anarrhichthys ocellatus* was collected only at night in the winter. Late larval and early juvenile *Psychrolutes sigalutes* also occurred only at night, mostly in the winter (only one early spring occurrence). *Sebastes* spp., *Podothecus acipenserinus*, and six species of pleuronectids were collected only in spring during the day. It is also interesting to note that cottids, gadids, and pleuronectids usually shared recurrent groups with taxa of their own families.

Recurrent group analysis provided the best opportunity to examine annual variations in species composition of the ichthyoplankton community using presence-absence data and could be applied to all temporal scales considered in this study. It is also the most ecologically meaningful since it evaluates the co-occurrence of species and thus can potentially indicate biological and ecological interactions. The daytime assemblage was well defined by recurrent group analysis as three groups matched the combined winter and spring assemblage exactly and another group with four species of pleuronectids matched with all but one taxon (Figs. 3 and 10). This, however, is not entirely unexpected because daytime is a large component within the combined winter and spring data.

The taxa of larval fish collected in this study are representative of the adult ichthyofauna inhabiting the diverse marine habitats of Clam Bay surrounding the pier. Species such as *A. hexapterus*, nearshore pleuronectids (e.g., *Isopsetta isolepis*, *Parophrys vetulus*, and *Platichthys stellatus*), and *Trichodon trichodon* inhabit the tidal mudflat and areas with sand/mud substrate located immediately south of the pier. Many species of cottids and their relatives (Rhamphocottidae and Hemitripteridae), scorpaenids, and some stichaeids are characteristic of the intertidal and subtidal zones of rocky headlands such as Middle Point immediately north of the pier. Adults of several taxa including hexagrammids (*Ophiodon elongatus* and *Hexagrammos* spp.), a cottid (*S. marmoratus*), liparids (*Liparis* spp.), and pholids (*A. flavidus*, *Pholis laeta*, and *P. ornata*) were observed or collected near the pier, its support pilings, or attached vegetation during the study.

All of the taxa collected in 1967 by Waldron (1972) at Station 2, his closest station to our study site, were collected during our study in Clam Bay with the exception of *Merluccius productus*. It should be noted that 14 species representing 11 families reported in the study of Bollens et al. (1992) in Dabob Bay were not present in collections from Clam Bay (Table 6A). The sampling procedures and gear used (1 m^2 Tucker Trawl with 500μm mesh net) by Bollens et al. (1992) facilitated collection of larvae of deep-water fishes including *Stenobrachius leucopsaurus* (Myctophidae), *M. productus* (Merlucciidae), *Brosmophysis marginata* (Bythitidae), and *Nectoliparis pelagicus* (Liparidae). Other taxa collected by Bollens et al. (1992), that were not present in Clam Bay, may have been present because of temporal differences in sampling between our studies. These include *Engraulis mordax* (Engraulidae); primarily collected in early summer and *Mallotus villosus* (Osmeridae); collected in fall. It is not clear why planktonic larvae of some nearshore fishes of the families Stichaeidae, Gobiidae, Bothidae, and Pleuronectidae were collected in Dabob Bay but not in Clam Bay.

Roni and Weitkamp (1996) reported the presence of 14 taxa representing 8 families of juvenile and adult fishes in collections at the nearby U.S. Navy fuel pier that were not collected in our study (Table 6B). Since the focus of their study was juvenile *Oncorhynchus* spp., most of these taxa are members of the family Salmonidae. Adults of other taxa reported by Roni and Weitkamp (1996) including *Aulorhynchus flavidus*, *Syngnathus griseolineatus*, and embiotocids were observed regularly near the pier in Clam Bay but larvae or juveniles were not collected. One similarity between the two studies is that both collected *Microgadus proximus* frequently.

It is unclear how much exogenous ichthyoplankton is transported into Clam Bay by currents from the deeper waters of Rich Passage. The presence of very few deep-water taxa in our collections suggests that very little influx of ichthyoplankton occurs despite the presence of sometimes vigorous tidal circulation (Collias and Benttinnen 1967). Larvae and juveniles of some deep-water taxa are known to undergo vertical migrations toward the surface in darkness (Nielson and Perry 1990) and may have been collected at night if a significant amount of water from Rich Passage was moving into Clam Bay. In general, water in Clam Bay and Rich Passage flows in the same direction (to the northeast or southeast), but during tidal changes, a back eddy causes a reversal of flow in the bay (Collias and Benttinnen 1967). Some deeper water species that were probably transported into Clam Bay from Rich Passage include gadids (*Gadus macrocephalus* and *Theragra chalcogramma*), psychrolutids (*Dasycottus setiger* and *Malacocottus kincadii*), and a pleuronectid (*Hippoglossoides elassodon*). Even though larvae of a few deep-water species were collected, they occurred rarely or infrequently in our samples. This indicates low-level or infrequent plankton transport from Rich Passage into Clam Bay and suggests that most of the ichthyoplankton was present as a result of adults spawning within the bay.

There was a reduction in the overall number of taxa present in Clam Bay from 1990 to 1994 (Fig. 7). This may be partially a result of above-normal ocean temperatures that occurred in the north Pacific during the moderate El Niño of 1991-93 (Bailey et al. 1995, Lynn et al. 1995, Murphree and Reynolds 1995). However, it must also be noted that sampling effort was lower in these years and may have resulted in the observed reduction in species richness. In addition to a notable decline in the diversity of cottids and related taxa, larvae of a former recreationally important gadid in Puget Sound (*T. chalcogramma*) were notably absent throughout most of this period. It is also worth noting that the adult populations of all economically important gadoid fishes in Puget Sound (*G. macrocephlalus*, *T. chalcogramma*, and *M. productus*) have declined dramatically in abundance over the last decade (Palsson et al. 1997). The diversity of pleuronectid larvae was also reduced during these years. In addition to variations in ocean temperature, the taxonomic composition and diversity of the ichthyoplankton assemblage in Clam Bay is probably influenced by changes in salinity caused by freshwater input from Beaver Creek. During our study, salinity, dissolved oxygen concentration, and water clarity (Secchi depth) measurements were periodically recorded but not frequently enough to establish statistical correlations with observed changes in the taxonomic composition of the ichthyoplankton community. Salinity ranged from 24.0 to 37.7 ppt, dissolved oxygen from 6.3 to 9.9 ppm, and water clarity ranged from 3.2 to 8.7 m (NWFSC, Conservation Biology Division, unpubl. data).

Since the length data collected for each taxon were ranges, we could not calculate means, medians, standard errors, or use statistical inference to determine anything about growth rates. However, it is apparent that some taxa did increase in size throughout the spring and others had young larvae present from January through June (Fig. 12). These data are interesting because they do show seasonal trends, but they should be used with caution since each range is based on different numbers of larvae that were not collected randomly or with equal sampling effort, and in some cases, they may be based on only one or two fish. Also, since data from all years were pooled, any year effect is lost.

The aquatic ecosystem of Puget Sound, and its biological resources, including the ichthyoplankton community, are suffering damaging effects resulting from human activities (West 1997, PSWQAT 1998). Water pollution and habitat modification are the primary anthropogenic factors negatively influencing health and survival of larval and juvenile fishes (West 1997, PSWQAT 1998). Fishing, El Niños, and increases in marine mammal populations are among the many factors potentially contributing to the decline of numerous Puget Sound fish populations (West 1997). Despite some of these major problems facing the Puget Sound ecosystem, there is very little environmental research or long-term monitoring being conducted, especially ichthyoplankton sampling. The Washington Department of Fish and Wildlife (WDFW) conducted bottom trawl surveys in 1987, 1989, 1991, and 1995 to estimate the abundance of adult groundfishes (Palsson et al. 1997). Since very little baseline data exist on the taxonomic composition and abundance of the ichthyoplankton fauna of Puget Sound, a full scale oceanographic and biological monitoring program that includes ichthyoplankton surveys should be initiated. The establishment of several monitoring stations throughout Puget Sound that would be occupied one or more times per year would be useful for detecting changes in the physical and biological features of Puget Sound and assessing ecosystem health.

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CITATIONS

Bailey, K. M., S. A. Macklin, R. K. Reid, R. D. Brodeur, W. J. Ingraham, J. F. Piatt, M. Shima, R. C. Francis, P. J. Anderson, T. C. Royer, A. B. Hollowed, D. A. Somerton, and W.S. Wooster. 1995. ENSO events in the northern Gulf of Alaska, and effects on selected marine fisheries. CalCOFI Rep. 36:78-96.

Blackburn, J. E. 1973. A survey of the abundance, distribution, and factors affecting distribution of ichthyoplankton in Skagit Bay. M.S. thesis, Univ. Washington, Seattle, WA., 136 p.

Bollens, S. M., B. W. Frost, H. R. Schwaninger, C. S. Davis, K. J. Way, and M. C. Landsteiner. 1992. Seasonal plankton cycles in a temperature fjord and comments on the match-mismatch hypothesis. J. Plankton Res. 14:1279-1305.

Busby, M. S. 1998. Guide to the identification of larval and early juvenile poachers (Scorpaeniformes: Agonidae) from the northeastern Pacific Ocean and Bering Sea. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 137, 88 p.

Collias E. E., and T. H. Benttinen. 1967. A study of water circulation in Clam Bay, WA. U.S. Public Health Service, Division of Buildings and Facilities, Design and Construction Branch. 202 Willste Bldg. Silver Spring, MD. No. D-874043-7. 13 p.

English, T. 1961. An inquiry into distributions of planktonic fish eggs in a restricted area of Puget Sound. Ph.D. diss., Univ. Washington, Seattle, WA, 227 p.

Fager, E. W. 1957. Determination and analysis of recurrent groups. Ecology 38: 586-595.

Garrison, K. J., and B. S. Miller. 1982. Review of the early life history of Puget Sound fishes. FRI-UW-8216, Fish. Res. Inst., Univ. Washington, Seattle, WA, 729 p.

Giorgi, A. E. 1981. The environmental biology of the embryos, egg masses, and nesting sites of the lingcod, *Ophiodon elongatus*. Proc. Rep. 81-06, Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98115-0070, 107 p.

Hickman, C. P., Jr. 1959. The larval development of the sand sole (*Psettichthys melanostictus*). Wash. Dept. Fish. Fish. Res. Pap. 2:38-47.

Karp, W. A., and B. S. Miller. 1977. Pacific cod (*Gadus macrocephalus*) studies in Port Townsend Bay, Washington. FRI-UW-7723, Fish. Res. Inst., Univ. Washington, Seattle, WA 98195, 42 p.

Kendall, A. W., Jr. 1966. Sampling juvenile fishes on some sandy beaches of Puget Sound, Washington. M.S. thesis, Univ. Washington, Seattle, 77 p.

Lynn, R. J., F. B. Schwing, and T. L. Hayward. 1995. The effect of the 1991-1993 ENSO on the California Current System. CalCOFI Rep. 36:57-71.

Matarese, A. C., A. W. Kendall Jr., D. M. Blood, and B. M. Vinter. 1989. Laboratory guide to early life history stages of Northeast Pacific fishes. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 80, 652 p.

Miller, B. S. 1969. Life history observations on normal and tumor-bearing flathead sole in East Sound, Orcas Island (Washington). Ph.D. diss., Univ. Washington, Seattle, WA, 131 p.

Miller, B. S, W. A. Karp, and G. E. Walters. 1978. Pacific cod (*Gadus macrocephalus*) studies in Port Townsend Bay, Washington. Two-year Prog. Rep. FRI-UW-8608, Fish. Res. Inst., Univ. Wash., Seattle, WA 98195, 69 p.

Moser, H.G., P.E. Smith, and L.E. Eber. 1987. Larval fish assemblages in the California Current region, 1954-1960, a period of dynamic environmental change. CalCOFI Rep. 28:97-127.

Murphree, T., and C. Reynolds. 1995. El Niño and La Niña effects on the northeast Pacific: The 1991-1993 and 1988-1989 events. CalCOFI Rep. 36:45-56.

Nielsen, J. D., and R. I. Perry. 1990. Diel vertical migration of marine fishes: an obligate or facultive process? Adv. Mar. Biol. 26:115-168.

National Oceanic and Atmospheric Administration 1985-1995. Tide tables: High and low water predictions, west coast of North and South America including the Hawaiian Islands. U.S. Dep. Commer., NOAA, Natl. Ocean Service.

Orr, J. W., and A. C. Matarese. (In press). Revision of the genus *Lepidopsetta* Gill, 1862, (Teleostei: Pleuronectidae) based on adult and larval morphology, with a description of a new species.

Palsson, W. A. 1993. Fishes found in the marine waters of Washington State. Wash. Dept. Fish. and Wildl., Mar. Fish. Prog. Progress Rep. 26 p. Available from the author at Washington Deptartment of Fisheries and Wildlife 16018 Mill Creek Blvd. Mill Creek, WA 98012-1296.

Palsson, W. A. , J. C. Hoeman, G. G. Bargmann, and D. E. Day. 1997. 1995 Status of Puget Sound bottom fish stocks (revised). Wash. Dept. Fish Wildl. Fish Manag. Prog., Mar. Res. Div. Rep. No. MRD97-03. 98 p.

Puget Sound Water Quality Action Team (PSWQAT). 1998. 1998 Puget Sound Update: Report of the Puget Sound Ambient Monitoring Program. Puget Sound Water Quality Action Team. Olympia, Washington. 96 p.

Roni, P., and L. A. Weitkamp. 1996. Environmental monitoring of the Manchester Naval Pier replacement, Puget Sound, Washington, 1991-1994. Contract Rep. N62474-91-MP-00758. Coastal Zone and Estuarine Studies Div., Northwest Fish. Sci. Cent., 2725 Montlake Blvd. E, Seattle, WA 98112, 76 p.

Sommani, P. 1969. Growth and development of sand sole postlarvae (*Psettichthys melanostictus*). M. S. thesis, Univ. Washington, Seattle, 60 p.

Stahl-Johnson, K. L. 1985. Descriptive characteristics of reared *Sebastes caurinus* and *S. auriculatus* larvae. *In* A. W. Kendall, Jr., and J. B. Marliave (editors), Description of early life history stages of selected fishes: From the 3rd international symposium on early life history of fishes and 8th annual larval fish conference. Can. Tech. Rep. Fish. Aquat. Sci. 1359:65-76.

Trumble, R., D. Penttila, D. Day, P. McAllister, J. Boettner, R. Adair, and P. Wares. 1977. Results of herring spawning grounds surveys in Puget Sound, 1975 and 1976. Wash. Dept. Fish. Prog. Rep. 21, 28 p.

Waldron, K. D. 1972. Fish larvae collected from the northeastern Pacific Ocean and Puget Sound during April and May 1967. U.S. Dep. Commer., NOAA Tech. Rep., NMFS SSRF-663. 16 p.

West, J. E. 1997. Protection and restoration of marine life in the inland waters of Washington state. Puget Sound/Georgia Basin Environmental Report Series: Number 6. Puget Sound Water Quality Action Team. Olympia, Washington. 144 p.

Table 1. Summary of early life history (ELH) studies and ichthyoplankton surveys conducted in Puget Sound, Washington, 1966-1996.

Investigator(s)	Year	Research Focus	Results
English	1966	pleuronectid eggs/circulation patterns	distribution of three pleuronectids
Kendall	1966	juvenile fish/gear performance	species composition and abundance
Miller	1969	*Hippoglossoides elassodon*	data on early life history
Sommani	1969	*Psettichthys melanostictus*	data on growth and development
Waldron	1972	1967 survey (15 stations)	14 families collected
Blackburn	1973	Skagit Bay survey	43+ taxa in 14 families
Trumble et al.	1977	*Clupea pallasi*	locations of spawning grounds
Karp and Miller	1977	*Gadus macrocephalus*	spawning, life history, and ecology
Miller et al.	1978	*Gadus macrocephalus*	spawning, life history, and ecology
WDF&W*	1970s	*C. pallasi,* Osmeridae, *Ammodytes hexapterus*	distribution and abundance of select species
Giorgi	1981	*Ophiodon elongatus*	biology of spawning sites, embryos
Garrison and Miller	1982	ELH of Puget Sound fishes	general taxonomic information on 175 spp.
Stahl-Johnson	1985	*Sebastes auriculatus, S. caurinus*	descriptions of reared larvae
Bollens et al.	1992	Dabob Bay seasonal plankton cycles	49 taxa in 19 families collected
Roni and Weitkamp	1996	juvenile fish monitoring	40 species in 13 families collected

* Washington Department of Fish and Wildlife

Table 2. Distribution of sampling dates at Manchester Field Station Pier, Clam Bay, Washington, 1985-95 by month and year. Shaded and outlined areas indicate data sets used in analyses: A. Winter, Spring, and combined (Winter and Spring); B. Day; C. Night. Numbers in cells are the numbers of sampling dates in each year/month combination.

A.

Winter
Spring
Winter/Spring

MONTH	YEAR 1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Jan										1	2	3
Feb							1*	2	1		3	7
March					1		1	2	2	1	3	10
April			1	7	12	1	1			2	4*	28
May	1	1	4	5	11	3		1	3	3	3	35
June			4	2	9	3				1	3*	22
July			2		1		1		1			5
Aug						2*						2
Total	1	1	11	14	34	9	4	5	7	8	18	

B. Day

MONTH	YEAR 1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Jan											1	1
Feb							1	1			1	3
March					1		1			1	2	5
April			1	7	12	1				1	3*	25
May	1	1	4	5	10	3		1	3	2	2	32
June			4	2	9	3				1	2*	21
July			2		1		1		1			5
Aug						1						1
Total	1	1	11	14	33	8	3	2	4	5	11	

C. Night

MONTH	YEAR 1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Jan										1	1	2
Feb								1	1		2	4
March								2	2		1	5
April							1			1	1	3
May					1					1	1	3
June											1	1
July												0
Aug						1						1
Total	0	0	0	0	1	1	1	3	3	3	7	

* No larvae collected on one sampling date.

Table 3. List of larval and juvenile fish taxa collected by dip-net at Manchester Field Station Pier, Clam Bay, Washington, 1985-95 and primary times of occurrence. W-Winter, S-Spring; D-day, N-night.

Scientific name	Common name	Season	Day/Night
	unidentified	S	D
Clupeidae			
Clupea pallasi	Pacific herring	WS	DN
Osmeridae	smelts	WS	DN
Salmonidae			
Oncorhynchus gorbuscha	pink salmon	WS	DN
Gadidae		S	DN
Gadus macrocephalus	Pacific cod	S	D
Microgadus proximus	Pacific tomcod	WS	DN
Theragra chalcogramma	walleye pollock	WS	DN
Gasterosteidae			
Gasterosteus aculeatus	threespine stickleback	WS	DN
Scorpaenidae			
Sebastes spp.	rockfishes	WS	D
Hexagrammidae			
Hexagrammos decagrammus	kelp greenling	WS	DN
Hexagrammos stelleri	whitespotted greenling	WS	DN
Ophiodon elongatus	lingcod	WS	DN
Rhamphocottidae			
Rhamphocottus richardsoni	grunt sculpin	S	DN
Cottidae			
Artedius fenestralis	padded sculpin	WS	DN
A. harringtoni	scalyhead sculpin	S	D
A. lateralis	smoothhead sculpin	S	D
Chitonotus pugetensis	roughback sculpin	S	D
Clinocottus acuticeps	sharpnose sculpin	WS	DN
C. embryum	calico sculpin	S	D
Enophrys bison	buffalo sculpin	S	D
Hemilepidotus hemilepidotus	red Irish lord	WS	DN
Leptocottus armatus	Pacific staghorn sculpin	WS	DN
Myoxocephalus polyacanthacephalus	great sculpin	WS	DN
Oligocottus maculosus	tidepool sculpin	S	D
Ruscarius meanyi	Puget Sound sculpin	S	DN
Scorpaenichthys marmoratus	cabezon	WS	DN
Synchirus gilli	manacled sculpin	WS	D
Psychrolutidae			
Dasycottus setiger	spinyhead sculpin	S	D
Malacocottus kincadi	blackfin sculpin	S	D
Psychrolutes paradoxus	tadpole sculpin	S	DN
Psychrolutes sigalutes	soft sculpin	WS	N
Hemitripteridae			
Blepsias cirrhosus	silverspotted sculpin	S	D
Nautichthys oculofasciatus	sailfin sculpin	WS	D

Scientific name	Common name	Season	Day/Night
Agonidae			
Agonopsis vulsa	northern spearnose poacher	S	D
Odontopyxis trispinosa	pygmy poacher	S	D
Podothecus acipenserinus	sturgeon poacher	S	D
Cyclopteridae			
Eumicrotremus orbis	Pacific spiny lumpsucker	WS	DN
Liparidae			
Liparis spp.	unidentified snailfish	WS	DN
Liparis pulchellus	showy snailfish	WS	DN
Bathymasteridae			
Ronquilus jordani	northern ronquil	S	DN
Stichaeidae			
Anoplarchus spp.	unidentified cockscomb		
Anoplarchus purpurescens	high cockscomb	S	D
Chirolophis spp.	unidentified warbonnet	W	DN
Chirolophis decoratus	decorated warbonnet	W	DN
Chirolophis nugator	mosshead warbonnet	WS	DN
Lumpenus sagitta	snake prickleback	WS	DN
Phytichthys chirus	ribbon prickleback	S	D
Xiphister spp.	unidentified prickleback	WS	N
Cryptacanthodidae			
Cryptacanthodes aleutensis	dwarf wrymouth	WS	DN
C. gigantea	giant wrymouth	WS	DN
Pholidae			
Apodichthys flavidus	penpoint gunnel	WS	DN
Pholis spp.	unidentified gunnel	WS	DN
Pholis ornata	saddleback gunnel	S	DN
Anarhichadidae			
Anarrhichthys ocellatus	wolf-eel	W	N
Trichodontidae			
Trichodon trichodon	Pacific sandfish	S	D
Ptilichthyidae			
Ptilichthys goodei	quillfish	WS	DN
Ammodytidae			
Ammodytes hexapterus	Pacific sandlance	WS	DN
Pleuronectidae			
Hippoglossoides elassodon	flathead sole	S	D
Isopsetta isolepis	butter sole	S	D
Lepidopsetta bilineata	southern rocksole	WS	D
Lepidopsetta cf. *bilineata*	northern rocksole	WS	D
Lyopsetta exilis	slender sole	S	D
Parophrys vetulus	English sole	S	D
Platichthys stellatus	starry flounder	S	D
Psettichthys melanostictus	sand sole	S	D

Table 4. Lists of frequently occurring larval and juvenile fish taxa from winter and spring dip-net samples collected at Manchester Field Station Pier, Clam Bay, Washington, 1987-95. Numbers in cells are numbers of sampling dates on which the taxon was collected. A. Winter, based on four or more occurrences; B. Spring, based on ten or more occurrences. -indicates samples not used in study.

	Year									
Taxon	87	88	89	90	91	92	93	94	95	Total
A. Winter										
Hexagrammos stelleri	-	-	-	-	1	3	1	1	8	14
Apodichthys flavidus	-	-	-	-	2	4	0	1	5	12
Ophiodon elongatus	-	-	-	-	2	3	0	1	4	10
Ammodytes hexapterus	-	-	-	-	1	3	1	0	3	8
Liparis spp.	-	-	-	-	1	4	2	0	1	8
H. decagrammus	-	-	-	-	0	2	0	0	4	6
Psychrolutes sigalutes	-	-	-	-	3	3	0	0	3	6
Chirolophis nugator	-	-	-	-	0	1	1	1	1	4
B. Spring										
Liparis spp.	2	4	9	2	-	-	2	2	4	25
Anoplarchus spp.	1	8	8	2	-	-	2	0	3	24
Parophrys vetulus	5	9	6	1	-	-	0	1	2	24
Microgadus proximus	2	6	6	2	-	-	1	0	6	23
Psettichthys melanostictus	2	6	2	6	-	-	2	1	3	22
Ammodytes hexapterus	0	6	6	2	-	-	2	2	3	21
Clinocottus acuticeps	1	6	7	1	-	-	2	1	3	21
Leptocottus armatus	3	7	6	0	-	-	2	1	2	21
Sebastes spp.	3	5	4	2	-	-	4	0	1	19
Scorpaenichthys marmoratus	2	8	3	1	-	-	2	0	1	17
Pholis spp.	0	4	6	0	-	-	1	1	4	16
Artedius harringtoni	5	5	2	0	-	-	2	0	1	15
Oligocottus maculosus	1	3	6	0	-	-	2	0	2	14
Platichthys stellatus	1	5	3	1	-	-	1	1	2	14
Apodichthys flavidus	0	4	6	0	-	-	0	1	1	12
Artedius fenestralis	3	3	2	1	-	-	1	0	2	12
Chirolophis nugator	0	4	2	3	-	-	0	2	0	11
Nautichthys oculofasciatus	2	4	4	1	-	-	0	0	1	12
Ronquilis jordani	2	3	1	0	-	-	2	0	2	10
Isopsetta isolepis	1	3	0	1	-	-	1	2	2	10

Table 5. Lists of frequently occurring larval and juvenile fish taxa from day and night dip-net samples collected at Manchester Field Station Pier, Clam Bay, Washington, 1992-95. Numbers in cells are numbers of sampling dates on which the taxon was collected. A. Day, based on three or more occurrences; B. Night, based on three or more occurrences.

	Year				
Taxon	92	93	94	95	Total
A. Day					
Hexagrammos stelleri	1	2	0	5	8
Psettichthys melanostictus	1	2	1	3	7
Liparis spp.	2	1	1	2	6
Clinocottus acuticeps	1	2	1	2	6
Anoplarchus spp.	1	2	0	2	5
Apodichthys flavidus	2	0	0	3	5
Leptocottus armatus	0	2	1	2	5
Microgadus proximus	1	1	0	3	5
Platichthys stellatus	1	1	1	2	5
Parophrys vetulus	1	0	1	2	4
Pholis spp.	0	1	1	2	4
Sebastes spp.	0	4	0	0	4
Ammodytes hexapterus	1	1	0	1	3
B. Night					
Ammodytes hexapterus	3	1	2	5	11
Liparis spp.	3	2	1	3	9
Hexagrammos stelleri	2	1	1	4	8
Apodichthys flavidus	3	0	1	3	7
Ophiodon elongatus	3	0	1	3	7
Psychrolutes sigalutes	3	0	0	3	6
Chirolophis nugator	1	1	1	1	4

Table 6. List of larval and juvenile fish taxa collected in other studies that were absent in dip-net collections at Manchester Field Station Pier, Clam Bay, Washington, 1985-95. A. Bollens et al. (1992); B. Roni and Weitkamp (1996).

A	B
Engraulidae	**Rajidae**
Engraulis mordax	*Raja binoculata*
Osmeridae	**Salmonidae**
Mallotus villosus	*Onchorhynchus clarkii*
Myctophidae	*O. keta*
Stenobrachius leucopsaurus	*O. kisutch*
Merlucciidae	*O. mykiss*
Merluccius productus	*O. tshawytscha*
Bythitidae	**Gasterosteidae**
Brosmophysis marginata	*Aulorhynchus flavidus*
Hexagrammidae	**Merlucciidae**
Oxylebius pictus	*Merluccius productus*
Cottidae	**Syngnathidae**
Radulinus asperellus	*Syngnathus griseolineatus*
Liparidae	**Embiotocidae**
Nectoliparis pelagicus	*Cymatogaster aggregata*
Stichaeidae	*Embiotoca lateralis*
Plectobranchus evides	*Rhacochilus vacca*
Poroclinus rothrocki	**Bothidae**
Gobiidae	*Citharichthys stigmaeus*
Clevelandia ios	**Pleuronectidae**
Coryphopterus nicholsi	*Pleuronichthys coenosus*
Lepidogobius lepidus	
Bothidae	
Citharichthys spp.	
Pleuronectidae	
Pleuronichthys coenosus	

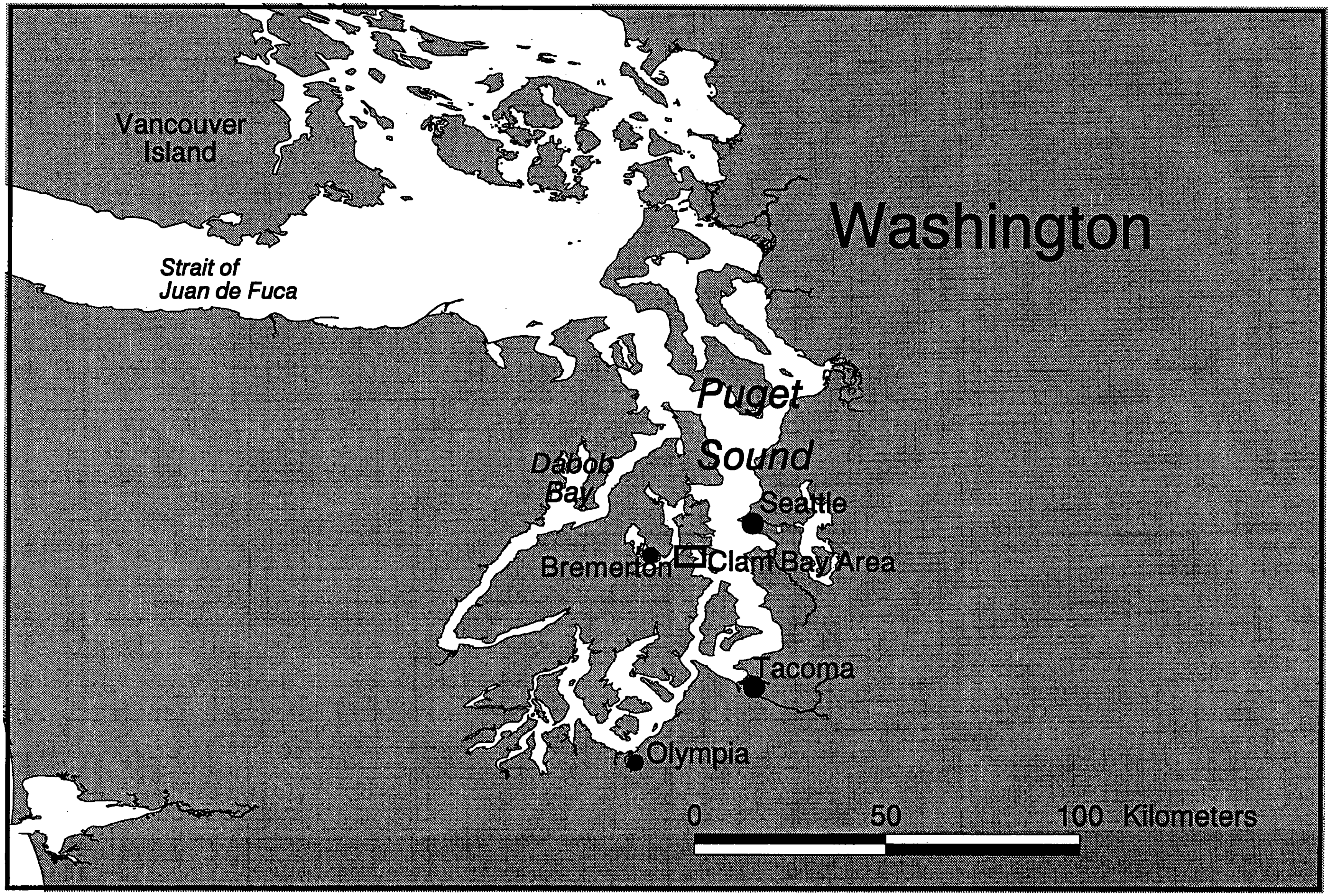


Figure 1. Northwest region of Washington State, U.S.A., showing Puget Sound and adjacent inland marine waters. Square in center encloses the Clam Bay Area (47° 34' 15" N, 122° 32' 30" W).

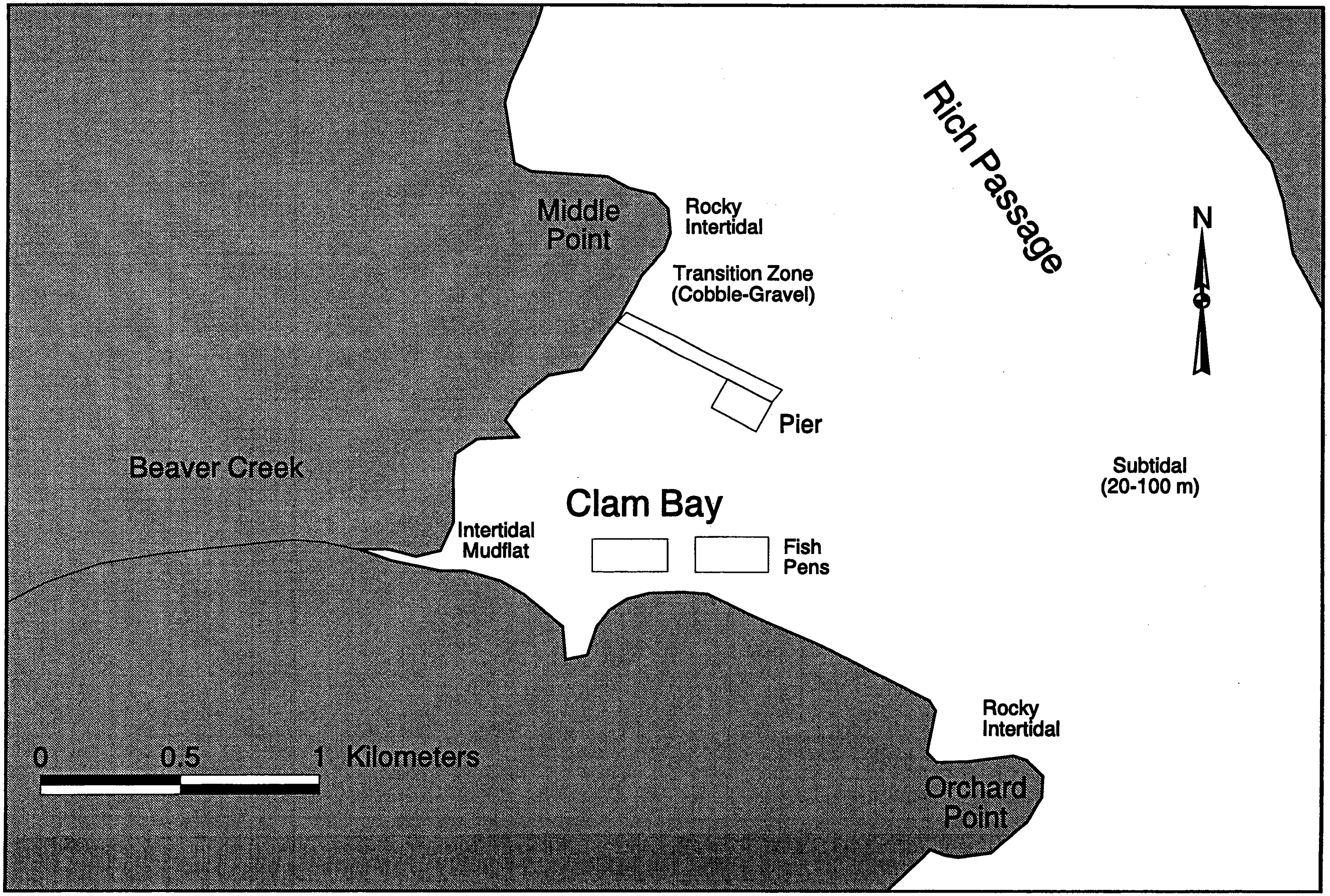


Figure 2. Clam Bay, Washington, showing location of the Manchester Field Station Pier and marine habitat types.

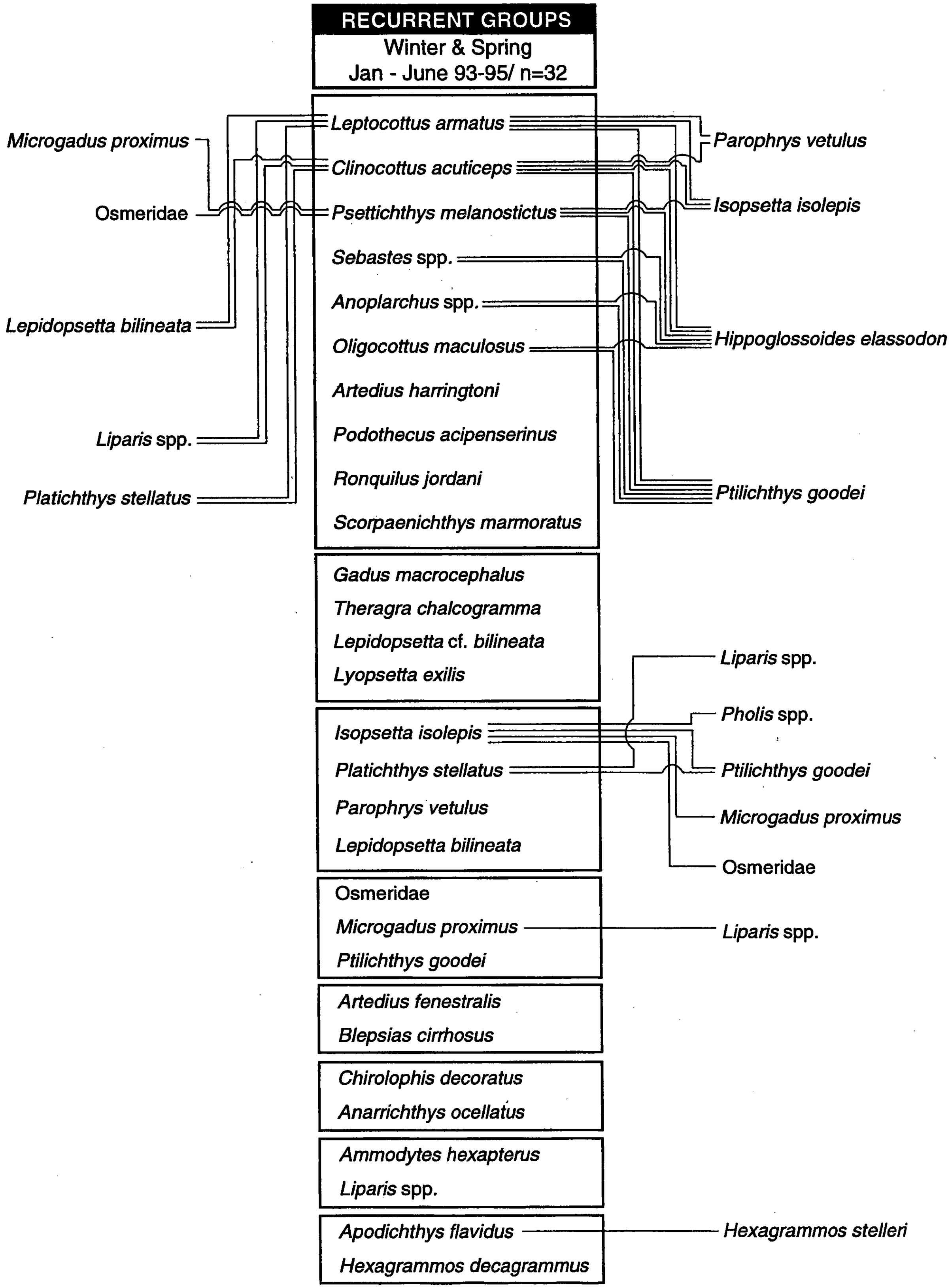


Figure 3. Recurrent groups and affiliate taxa of larval and juvenile fish taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: winter and spring 1993-95.

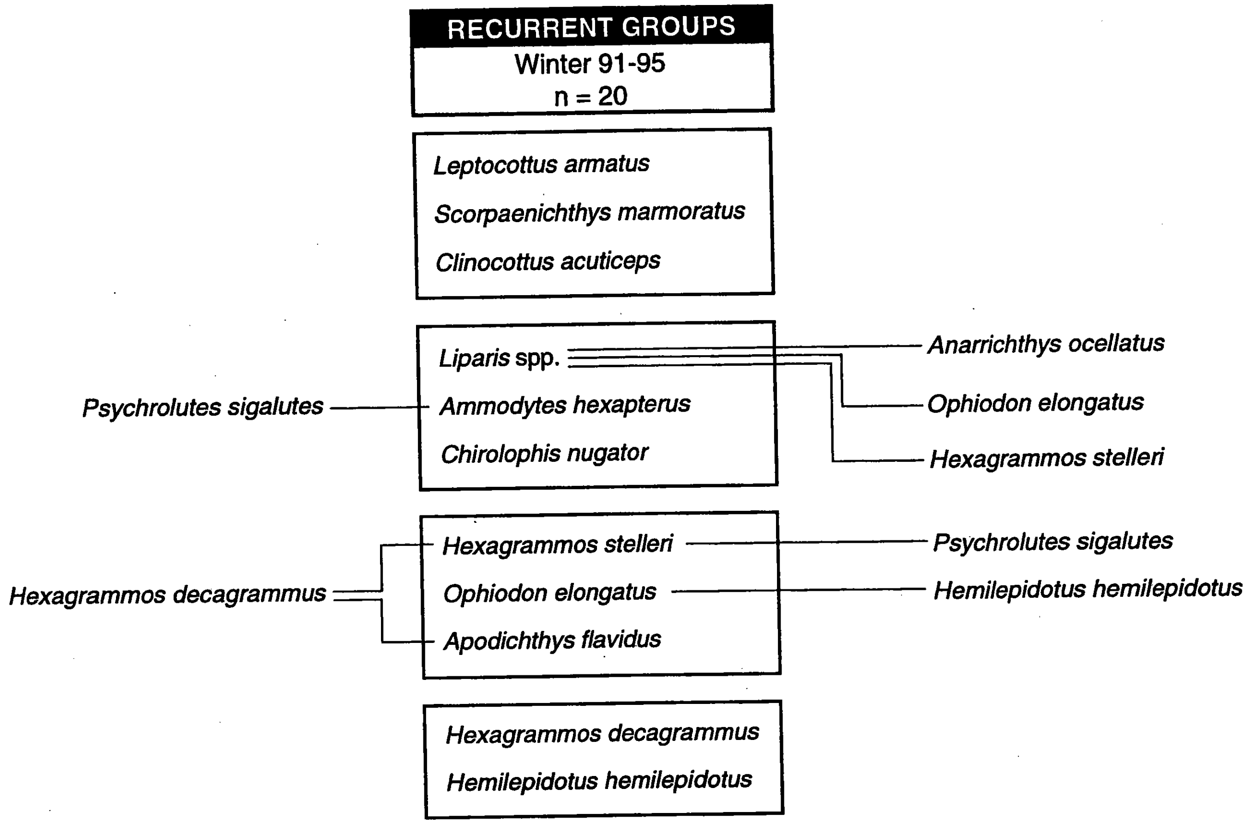


Figure 4. Recurrent groups and affiliate taxa of larval and juvenile fish taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: winter 1991-95.

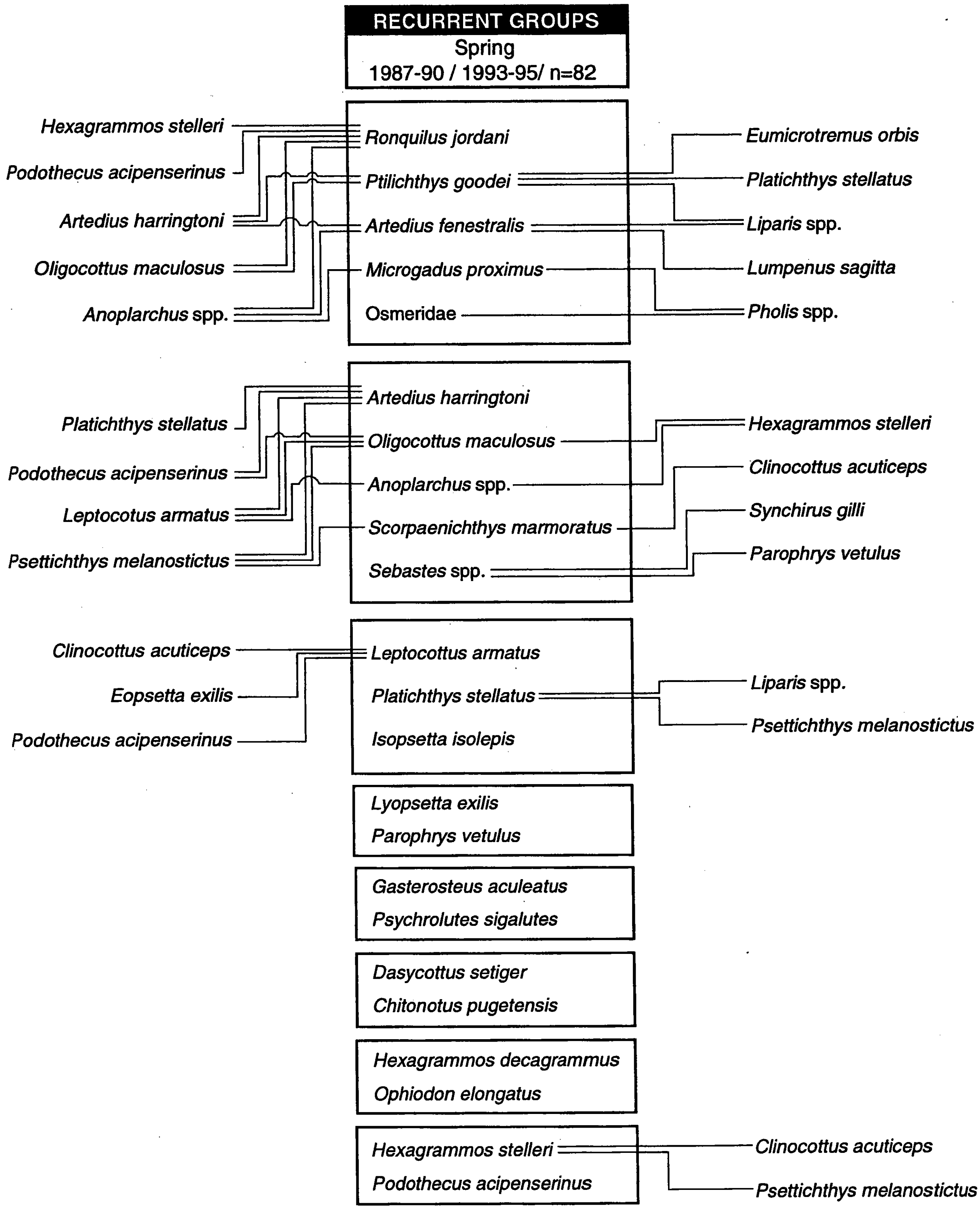


Figure 5. Recurrent groups and affiliate taxa of larval and juvenile fish taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: spring 1987-90, 1993-95.

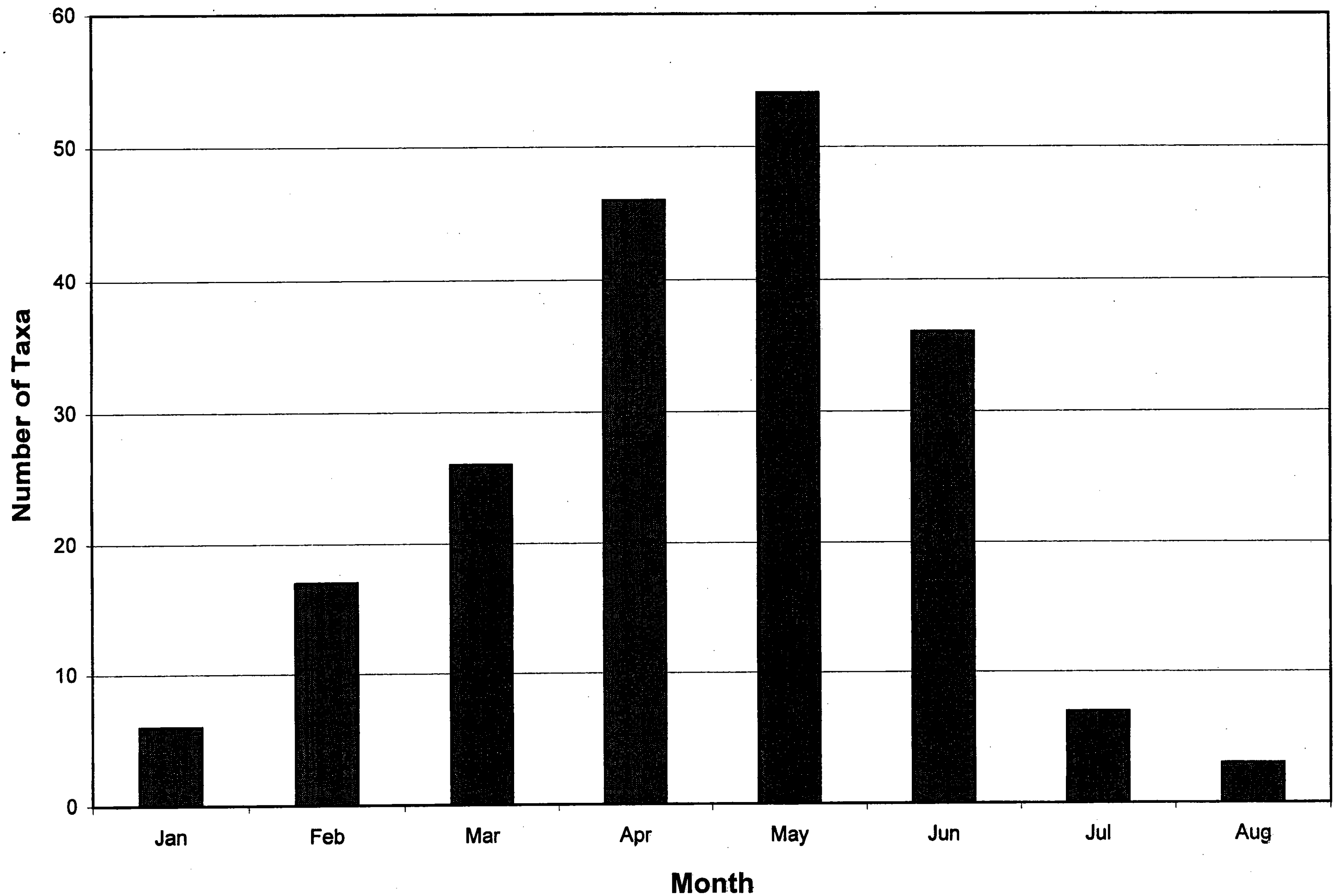


Figure 6. Number of taxa collected monthly by dip-net at the Manchester Field Station Pier, Clam Bay, Washington for the entire study period 1985-95.

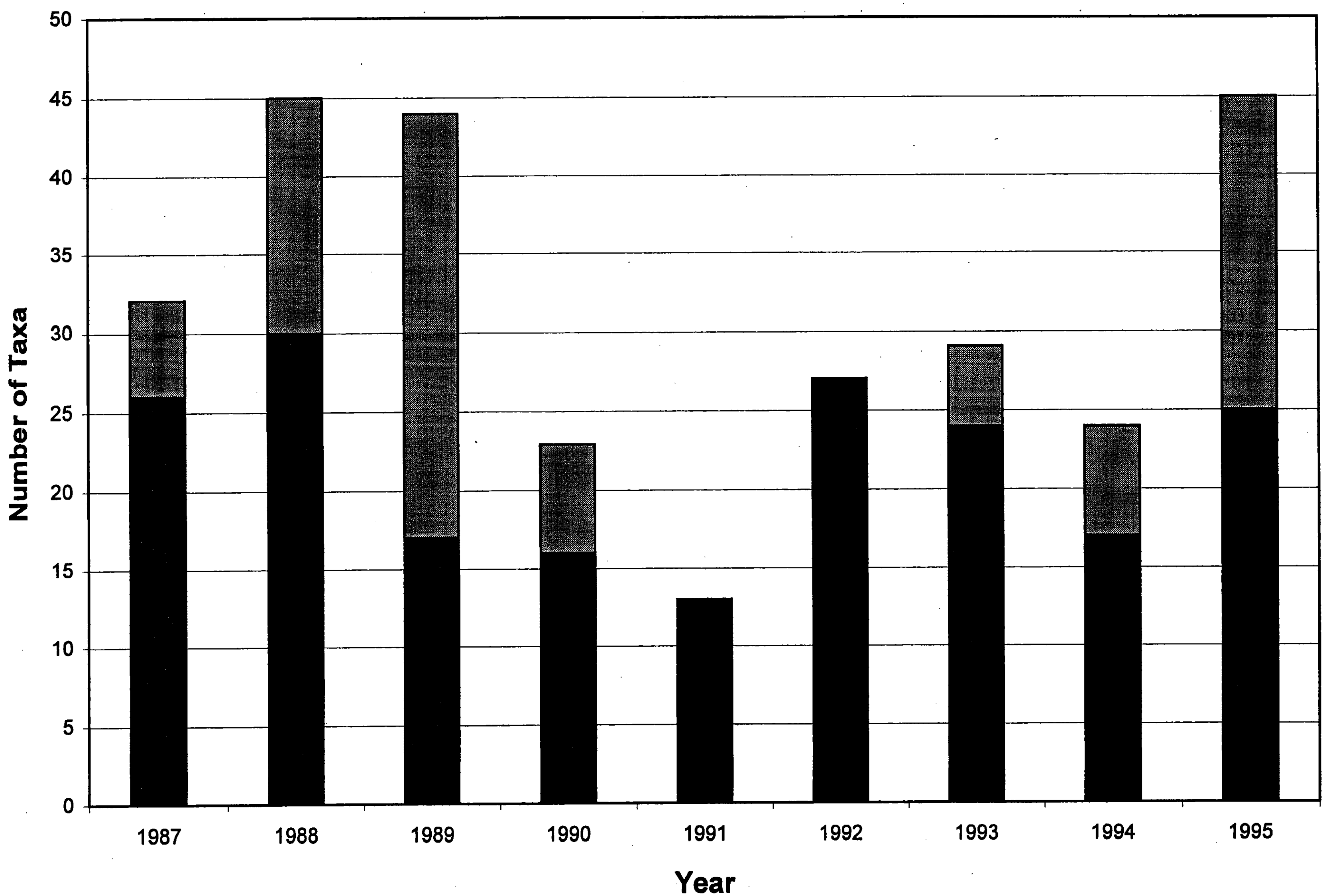


Figure 7. Number of taxa collected yearly from 1987-95 by dip-net at the Manchester Field Station Pier, Clam Bay, Washington. Darkly shaded area indicates number of taxa collected on 10 percent or more of the sampling dates in that year.

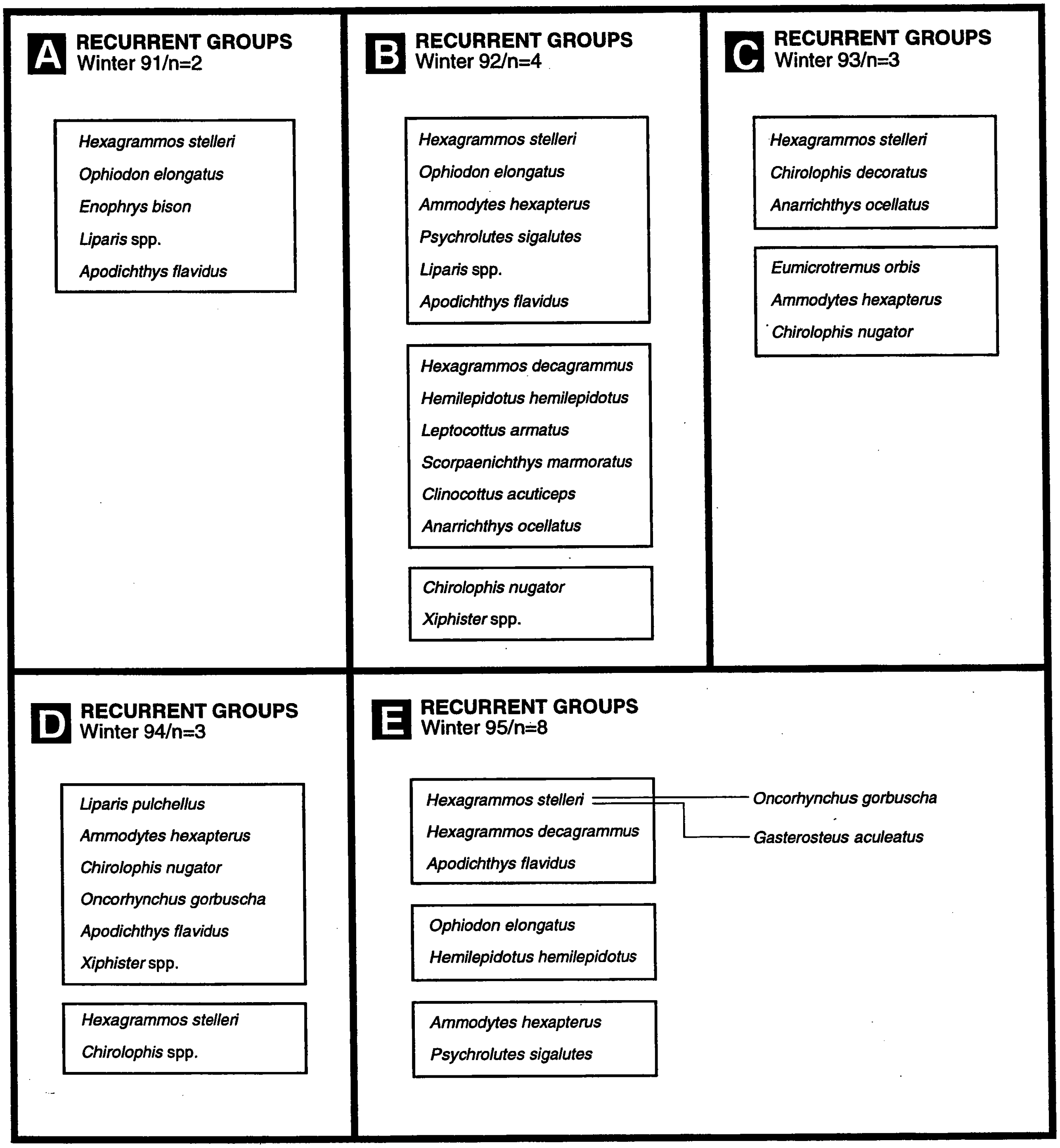
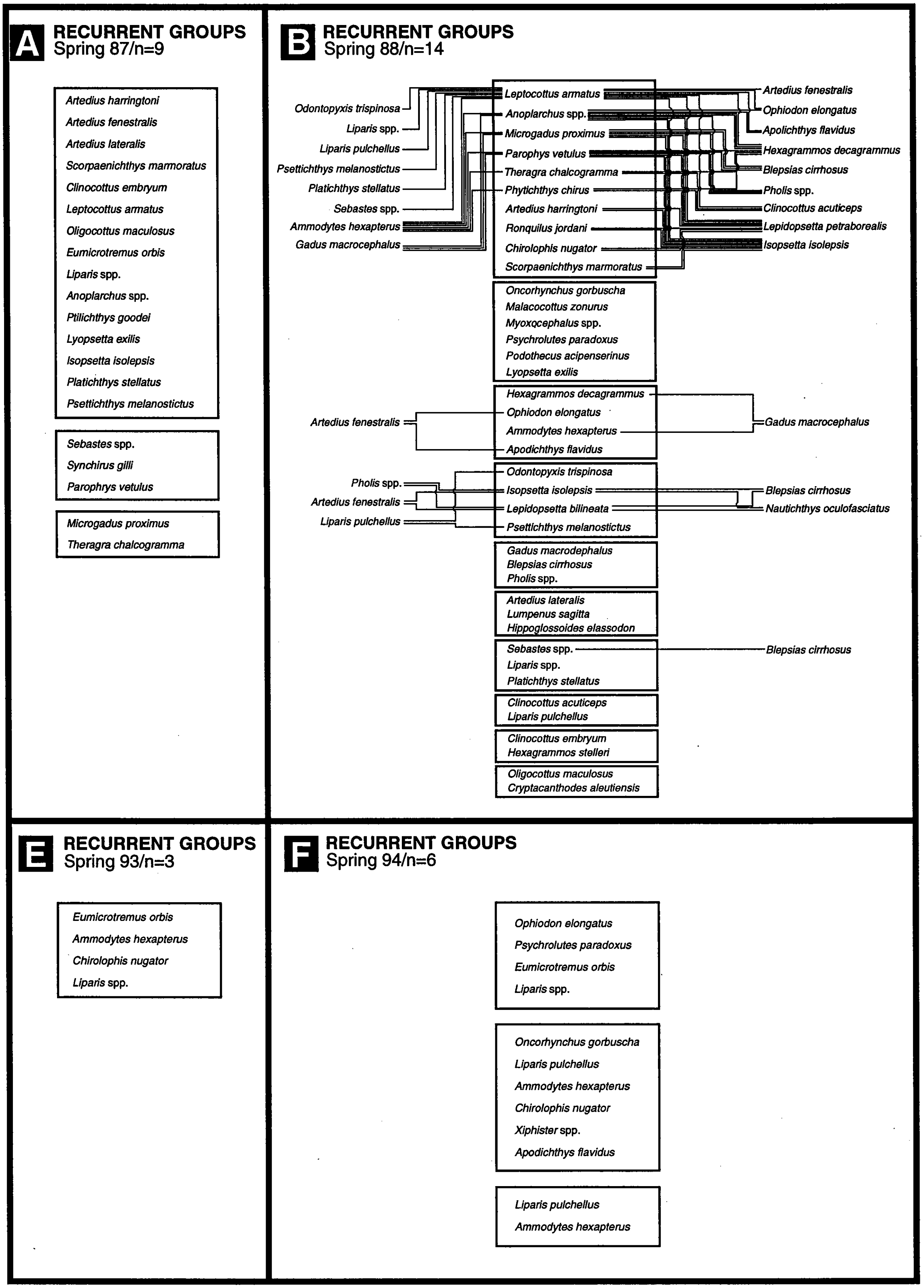
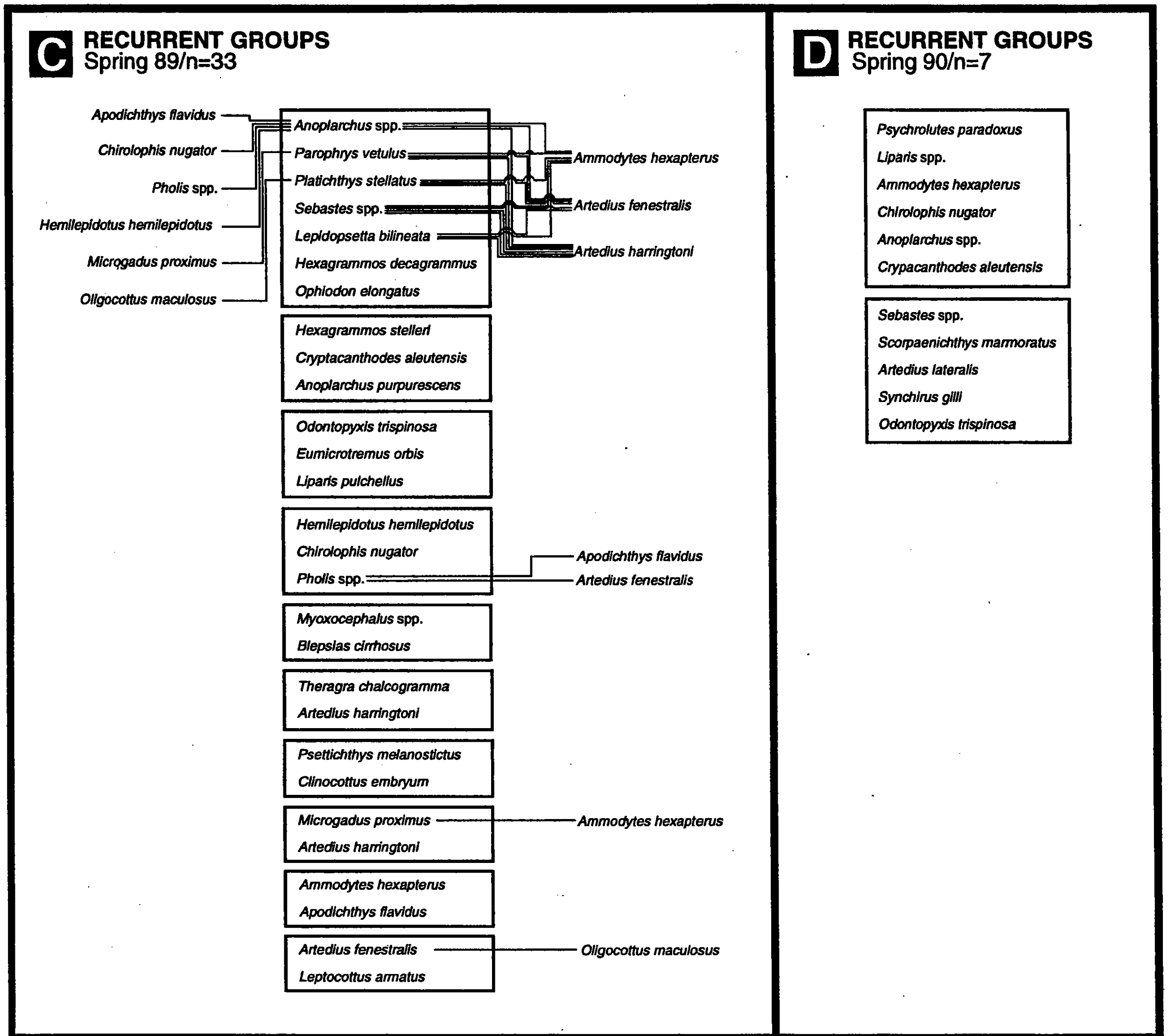


Figure 8. Recurrent groups and affiliate taxa of larval and juvenile fish taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: A. winter 1991; B. winter 1992; C. winter 1993; D. winter 1994; E. winter 1995.


A RECURRENT GROUPS
Spring 87/n=9
Artedius harringtoni
Artedius fenestralis
Artedius lateralis
Scorpaenichthys marmoratus
Clinocottus embryum
Leptocottus armatus
Oligocottus maculosus
Eumicrotremus orbis
Liparis spp.
Anoplarchus spp.
Ptilichthys goodei
Lyopsetta exilis
Isopsetta isolepsis
Platichthys stellatus
Psettichthys melanostictus
Sebastes spp.
Synchirus gilli
Parophrys vetulus
Microgadus proximus
Theragra chalcogramma
B RECURRENT GROUPS
Spring 88/n=14
Odontopyxis trispinosa
Liparis spp.
Liparis pulchellus
Psettichthys melanostictus
Platichthys stellatus
Sebastes spp.
Ammodytes hexapterus
Gadus macrocephalus
Leptocottus armatus
Anoplarchus spp.
Microgadus proximus
Parophrys vetulus
Theragra chalcogramma
Phytichthys chirus
Artedius harringtoni
Ronquilus jordani
Chirolophis nugator
Scorpaenichthys marmoratus
Artedius fenestralis
Ophiodon elongatus
Apolichthys flavidus
Hexagrammos decagrammus
Blepsias cirrhosus
Pholis spp.
Clinocottus acuticeps
Lepidopsetta petraborealis
Isopsetta isolepsis
Oncorhynchus gorbuscha
Malacocottus zonurus
Myoxocephalus spp.
Psychrolutes paradoxus
Podothecus acipenserinus
Lyopsetta exilis
Artedius fenestralis
Hexagrammos decagrammus
Ophiodon elongatus
Ammodytes hexapterus
Apodichthys flavidus
Gadus macrocephalus
Pholis spp.
Artedius fenestralis
Liparis pulchellus
Odontopyxis trispinosa
Isopsetta isolepsis
Lepidopsetta bilineata
Psettichthys melanostictus
Blepsias cirrhosus
Nautichthys oculofasciatus
Gadus macrodephalus
Blepsias cirrhosus
Pholis spp.
Artedius lateralis
Lumpenus sagitta
Hippoglossoides elassodon
Sebastes spp.
Liparis spp.
Platichthys stellatus
Blepsias cirrhosus
Clinocottus acuticeps
Liparis pulchellus
Clinocottus embryum
Hexagrammos stelleri
Oligocottus maculosus
Cryptacanthodes aleutiensis
E RECURRENT GROUPS
Spring 93/n=3
Eumicrotremus orbis
Ammodytes hexapterus
Chirolophis nugator
Liparis spp.
F RECURRENT GROUPS
Spring 94/n=6
Ophiodon elongatus
Psychrolutes paradoxus
Eumicrotremus orbis
Liparis spp.
Oncorhynchus gorbuscha
Liparis pulchellus
Ammodytes hexapterus
Chirolophis nugator
Xiphister spp.
Apodichthys flavidus
Liparis pulchellus
Ammodytes hexapterus



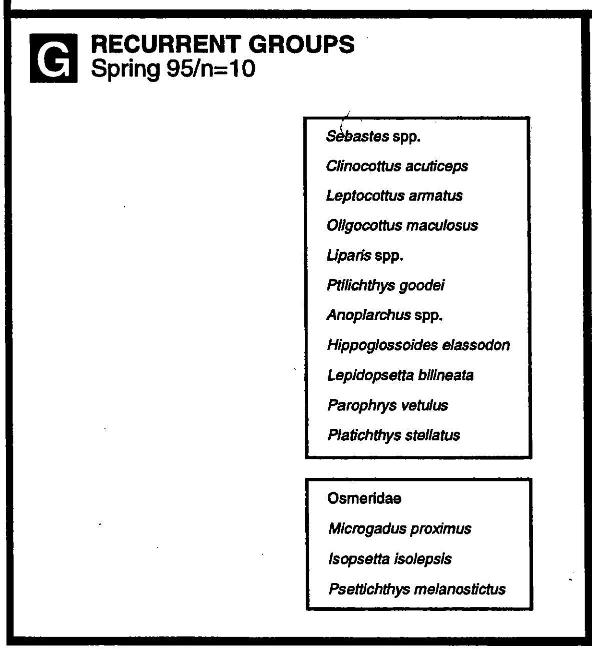


Figure 9. Recurrent groups and affiliate taxa of larval and juvenile fish taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: A. spring 1987; B. spring 1988; C. spring 1989; D. spring 1990; E. spring 1993; F. spring 1994; G. spring 1995.

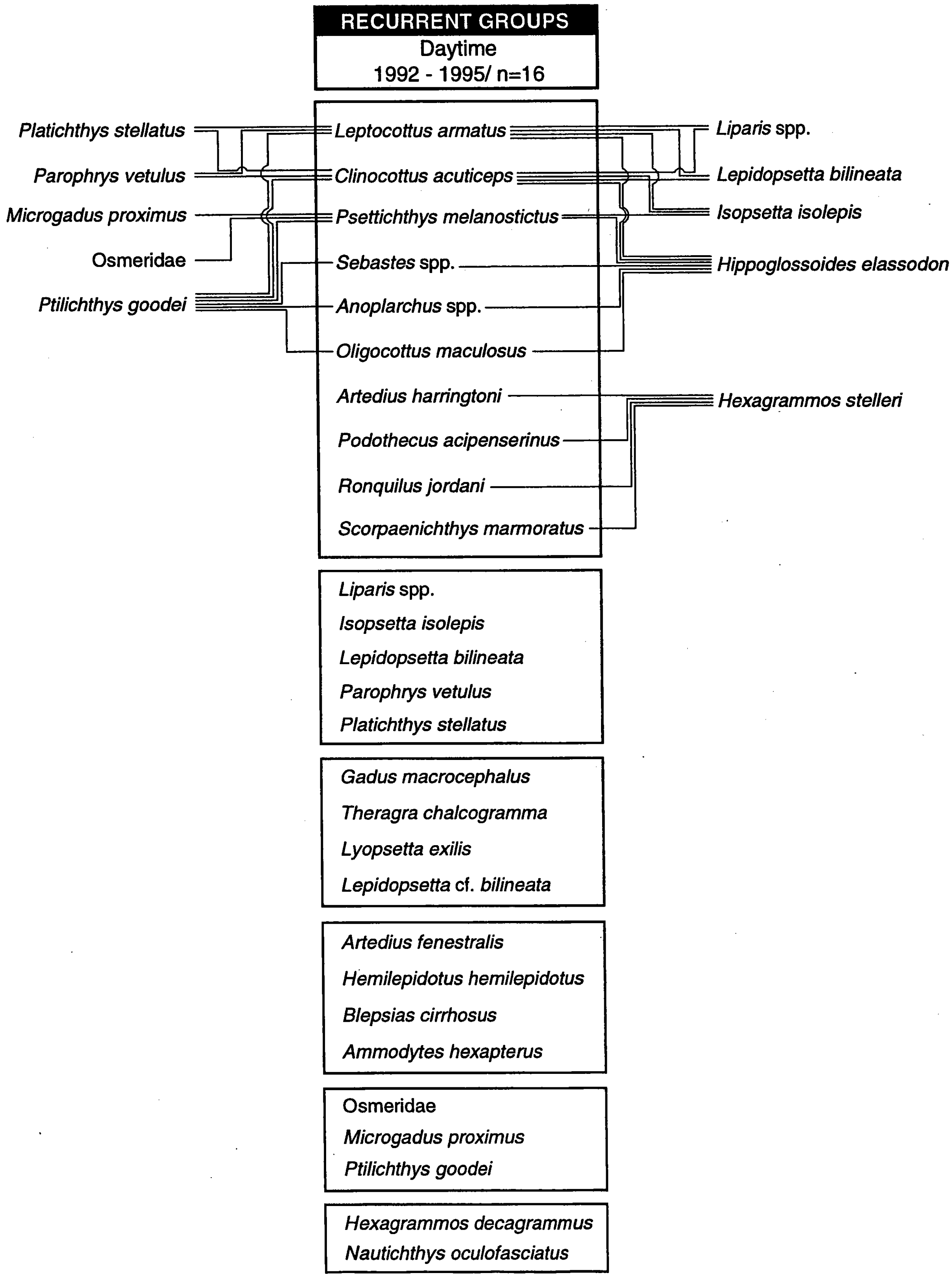


Figure 10. Recurrent groups and affiliate taxa of larval and juvenile fish taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: daytime 1992-95.

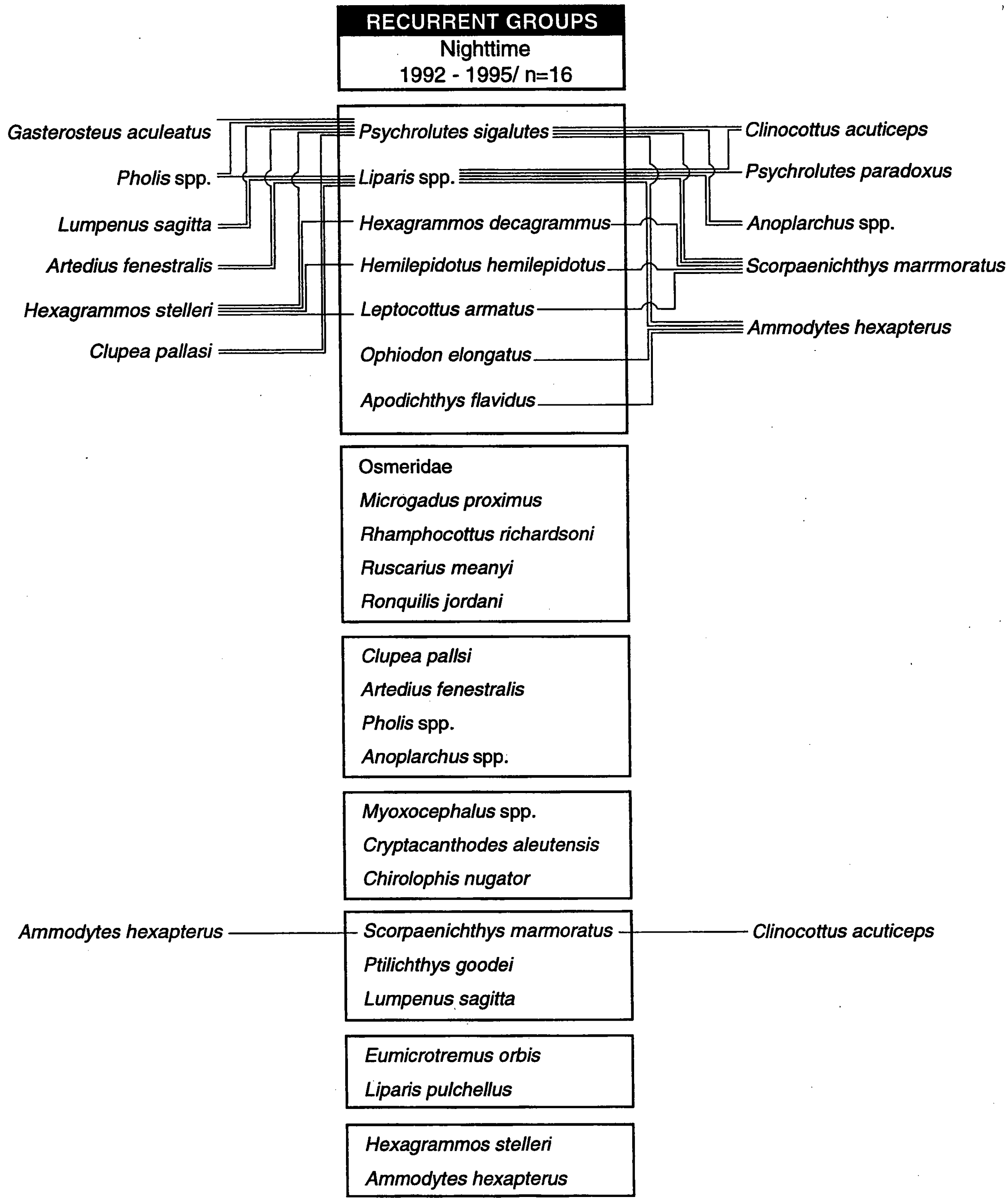
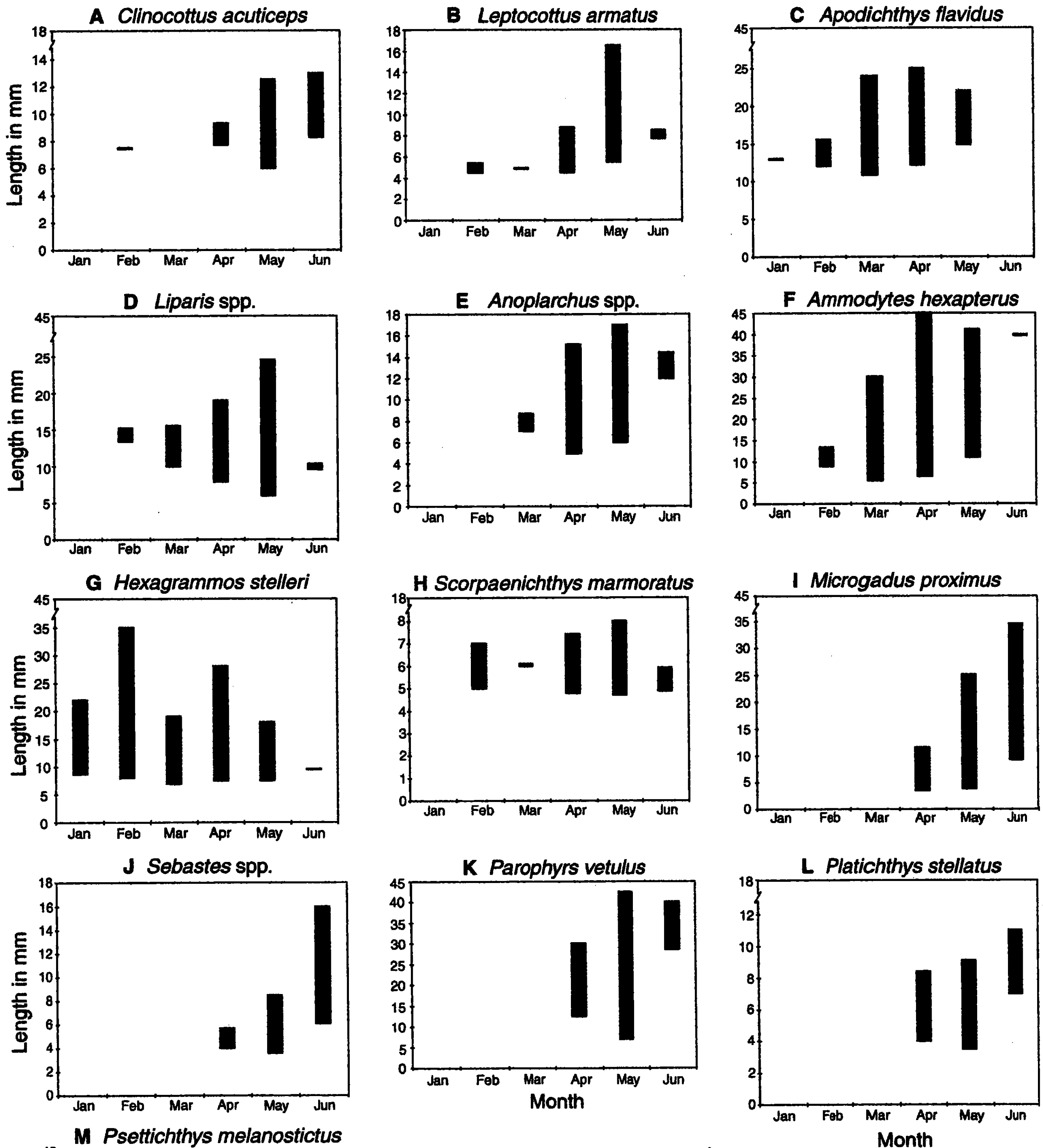


Figure 11. Recurrent groups and affiliate taxa of larval and juvenile fish taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: nighttime 1992-95.



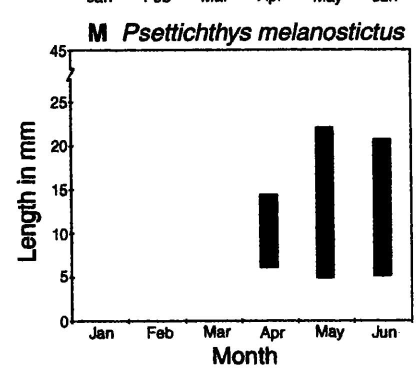


Figure 12. Monthly pooled length ranges for the 13 most frequently collected taxa collected by dip-net at the Manchester Field Station Pier, Clam Bay, Washington: All sampling dates 1985-95. A; *Clinocottus acuticeps* B; *Leptocottus armatus* C; *Apodichthys flavidus* D; *Liparis* spp. E; *Anoplarchus* spp. F; *Ammodytes hexapterus* G; *Hexagrammos stelleri* H; *Scorpaenichthys marmoratus* I; *Microgadus proximus* J; *Sebastes* spp. K; *Parophrys vetulus* L; *Platichthys stellatus* M; *Psettichthys melanostictus*.

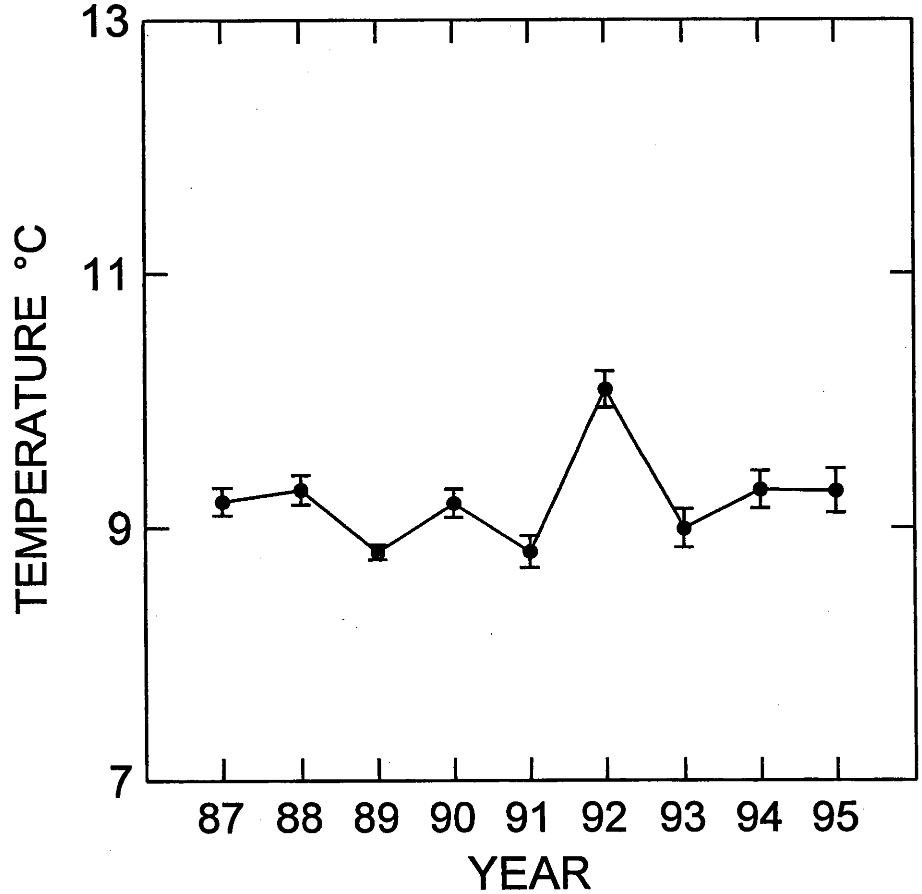


Figure 13. Annual least square mean sea surface temperatures measured at the Manchester Field Station Pier, Clam Bay, Washington: January through-June 1987-95.

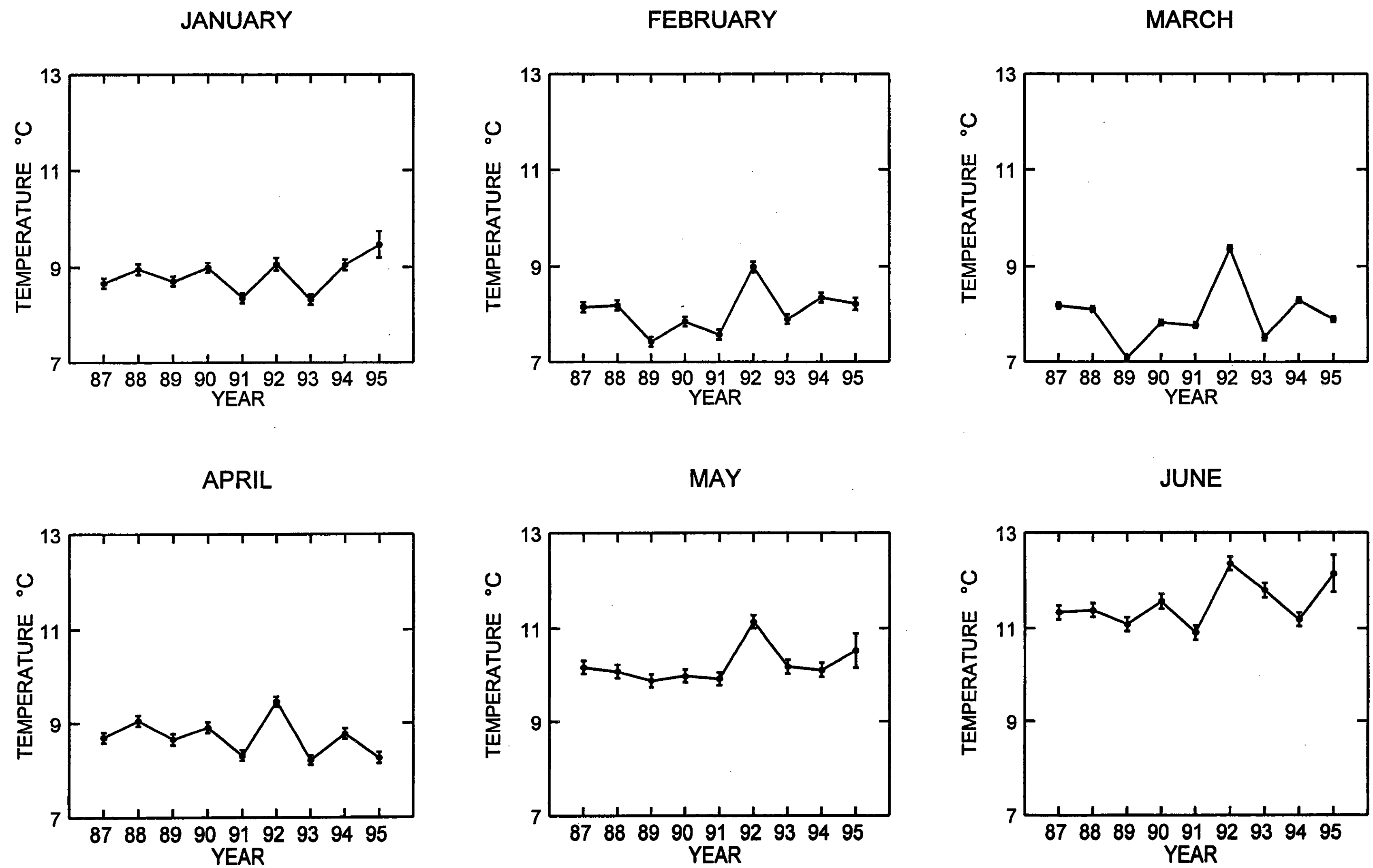


Figure 14. Monthly least square mean sea surface temperatures measured at the Manchester Field Station Pier, Clam Bay, Washington: January through-June 1987-95.

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