ECOLOGY OF FISHES IN UPPER NEWPORT BAY, CALIFORNIA: SEASONAL DYNAMICS AND COMMUNITY STRUCTURE

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by

Michael H. Horn and Larry G. Allen

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ECOLOGY OF FISHES IN UPPER NEWPORT BAY, CALIFORNIA: SEASONAL DYNAMICS AND COMMUNITY STRUCTURE

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ABSTRACT

A total of 366 bimonthly (January 1978-January 1979) samples taken with six types of gear (otter trawl, gill net, bag seine, small seine, drop net, square enclosure - all with replication except the gill net) at four stations in upper Newport Bay, California yielded 51,816 fishes belonging to 46 species and weighing over 353 kg. Atherinops affinis (topsmelt) was the most abundant species accounting for 76% of total individuals. Seven species, all of low trophic levels, made up over 97% of the total catch. Mugil cephalus (striped mullet) ranked first in biomass (≈ 36% of the total) with six species accounting for more than 80% of the total biomass. The largest number of individuals (71%) was collected with the bag seine, the greatest number of species (35) was captured with the otter trawl and the largest percentage of the biomass (56%) was obtained with the gill net. Species richness, number of individuals and biomass were lowest in January (1978 or 1979) or March and highest in July (numbers, biomass) or September (species). Bimonthly diversity (H') values ranged from 0.48 to 2.17 (overall value 1.05) and tended to be inversely related to abundance levels. Species richness was greatest at Station 4 (the lowermost station) and least at Station 1 (the uppermost station). Numbers of individuals and biomass peaked at Station 2 and reached lowest levels at Station 1.

Length-frequency analysis of six of the most abundant species indicated utilization of the upper bay by two or more stages in the life history of these species.

More than 92,000 eggs belonging to seven taxa and an unknown category and 426 larvae from 20 taxa were collected with a 0.5 m net mounted on an epibenthic sled during the same bimonthly periods and at the same stations as the juvenile/adult samples. Most of the eggs were collected at Station 2 in May with the numbers overwhelmingly dominated by those of Anchoa compressa (deepbody anchovy) (99.7% of total numbers). The most abundant larva was that of Clevelandia ios (arrow goby). Nearly 60% of the total larval catch was made up of members of the family Gobiidae. Larval taxa and individuals were fewest in January (1978). The number of taxa was highest in March, September and January (1979) whereas larval numbers peaked in May. The number of taxa and of individual larvae varied only slightly among the four stations.

Asymptotic species accumulation curves indicated adequate sampling of juvenile/adult fishes. Cluster analysis produced eight species groups of resident and periodic species that variously utilize the three main habitats (channel, inshore, pannes) in the upper bay. Species richness and abundance were positively correlated with both

temperature and salinity. Temperature, salinity and depth of capture were frequently correlated with individual species abundances and were used in combination to partially explain the spatial utilization of species and species groups.

The upper bay fish community is important and worthy of preservation for at least three reasons: 1) it contains species assemblages not duplicated in any other coastal environment; 2) it contains life history stages of a variety of coastal fish species; and 3) it contains large populations of small, low-trophic level species and juveniles of other species which serve as forage for larger, predatory species that are frequently of economic importance. Members of the fish community respond noticeably to altered environmental conditions such as the heavy rainfall (and accompanying low salinity and high turbidity) that occurred during the early months of 1978. The short and long term, as yet often unpredictable, fluctuations in the populations emphasize the need for periodic monitoring and for the development of a mathematical model of the fish community if it is to be thoroughly understood and properly managed.

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ACKNOWLEDGMENTS

Two people deserve special recognition for their assistance in bringing this study to completion. The first is Kathryn Heath who ably assisted in all aspects of the field and laboratory work and helped compile the data. The second is Wayne White who enthusiastically joined in a large portion of the field work and identified the eggs and larvae. We are particularly grateful to both of them.

We thank Jeffrey Jones for his consistent and valuable participation in the field and for helping design and build some of the sampling gear.

A number of other people were important in helping carry out the rather demanding three days of sampling each bimonthly period. Marie Harvey provided particularly reliable assistance as did Russell Bellmer and Jack Fancher. Gary Devian, Frank Edmands, Terry Edwards, Peter Haaker, Dennis Hagner, Paul Kramsky, Linda Sims, Vic Tanny, Jr., Carol Usui, Brian White and Craig Wingert were also able assistants on various occasions.

We appreciate the cooperation of the area offices of the U. S. Fish and Wildlife Service and the U. S. Army Corps of Engineers for allowing Wayne White and Jack Fancher (both of USFWS) and Russell Bellmer (USACE) to participate in this study.

Dennis Hagner diligently transferred the data to computer cards, tirelessly checked the arithmetic and assiduously prepared several of the illustrations. Clyde

Henry gave needed aid on computer techniques, and Marie Harvey provided vital assistance in preparing the illustrations.

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INTRODUCTION

Newport Bay is one of the major bay-estuarine environments in California. Its upper portion (upper Newport Bay) is one of the least altered estuarine habitats in the state and one recognized (Bane, 1978; Frey, Klein and Spruill, 1970) as a spawning or nursery area for certain coastal fish species and as a year-round or seasonal habitat for other fishes. A total of 78 species has been recorded (Allen, 1976) from the bay as a whole.

Studies of Newport Bay fishes are relatively few in number and have included a species list (Frey, Klein and Spruill, 1970), a general descriptive account (Bane, 1978), or have focused on the biology of individual species (Fronk, 1979; Bane and Robinson, 1970) or on the population ecology of the fauna based on sampling juveniles and adults (Posejpal, 1979; Allen, 1976) or the eggs and larvae (White, 1977). The jointly executed 18-month surveys by Allen (1976) and White (1977) are the most comprehensive investigations to date.

The present study was undertaken as one of the biological studies sponsored by the California Department of Fish and Game to provide baseline information for the management of the Upper Newport Bay Ecological Reserve. The purposes of the project were to 1) assess the seasonal abundance and diversity of upper bay fish populations, 2) to determine the degree of utilization of upper bay habitats by the life history stages (eggs, larvae, juveniles, adults) of various fish species, and 3) to analyze the structure of the fish community and its faunal components that co-occur at given periods during the year. A variety of sampling methods were used over short time intervals each study period to accomplish these purposes. The comparative effectiveness of the inshore sampling methods and the trophic relationships of the upper bay fish species are the subjects of separate papers (Horn and Allen, in prep.; Horn, Allen and Hagner, in prep., respectively).

MATERIALS AND METHODS

Station Locations

Four relatively equally-spaced station locations (Figure 1) were selected with the basic criterion being that each be adjacent to a natural marsh island or marsh area. The stations are situated as follows: 1) the uppermost location, in the ski zone basin and narrows region; 2) adjacent to the middle marsh island, opposite Big Canyon and Vaughn's launch ramp; 3) adjacent to Shellmaker island; and 4) the lowermost location, adjacent to Bayside Peninsula. Station 4 is not in the ecological reserve but was included in the study to provide more complete coverage of the upper bay environment that is generally considered to be the area above the Pacific Coast highway bridge (Figure 1).

Sampling Procedures

Each station was divided into 10 equal-area sites and one site was randomly selected for occupation each sampling

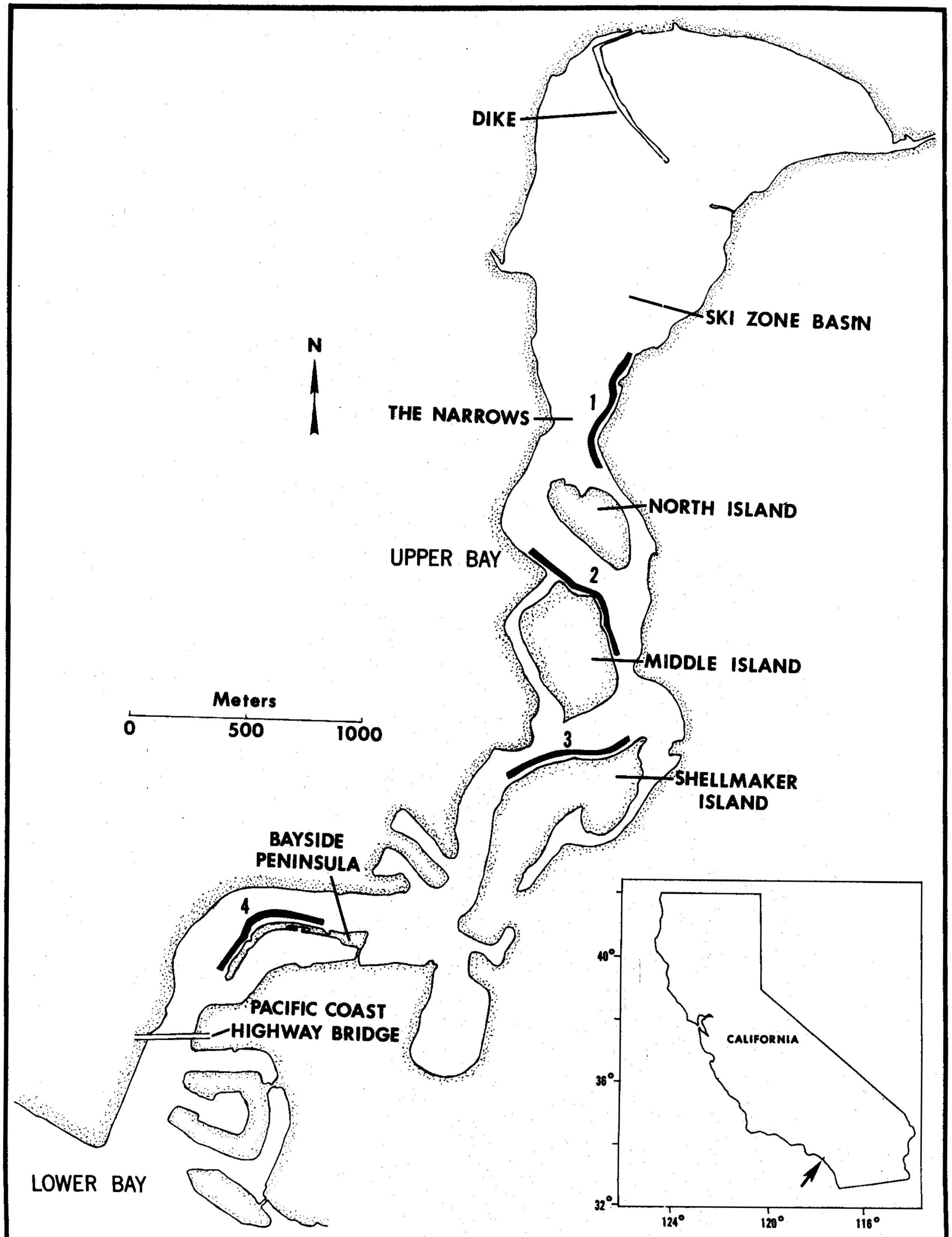


Figure 1. Map of upper Newport Bay, California, with the location of the four sampling stations.

period. Sampling was conducted bimonthly (January 1978-January 1979) at each station and within ± 3 hrs of daytime, neap high tide to minimize tidal level effects. Three days were required to carry out the sampling at the four stations; Station 4 was occupied on the first day, Stations 1 and 2 on the second day and Station 3 on the third day of each three-day period.

At each station, seven types of sampling methods were used:

1) A 0.5 m Hensen plankton net of 0.505 mm nitex mesh mounted on an epibenthic sled was used to collect eggs and larvae at a depth 40 cm above the bottom. Two tows of 5 min duration were made from a Boston whaler against the prevailing current at each station each sampling period. Two flowmeters, one mounted in the mouth of the net and one on the frame of the sled, were used to estimate the volume of water filtered by the net in comparison to the volume of water flowing by the sled. [Volume rates were not significantly different for the two flow meters (paired t-test, $P<0.5$)].

2) An otter trawl with a 3.8 m headrope, 4.1 m wings of 2.0 cm mesh, a 2.6 m codend with 0.8 cm mesh in the liner and 0.3 x 0.5 m doors was towed with 30 m polypropylene bridles behind the Boston whaler to collect bottom-associated juvenile and adult fishes in the channel areas of each station. Two tows, each of 5 min duration, were made against the prevailing current at each station each sampling period. Mean area sampled by each haul was 1127 m^2.

3) A 45.6 x 2.4 m monofilament gill net was set parallel to the shore in 2-3 m of water once at each station each sampling period to capture juvenile and adult fishes in the water column of the channel and deeper inshore areas. The net was composed of 6 panels of variable mesh with two panels of 1.3 - 2.5 cm mesh, two panels of 2.5 - 5.1 cm mesh and two panels of 6.4 - 7.6 cm mesh. Mean duration of each set was 2.8 hrs (range 1.8 - 4.8 hrs).

4) A 15.2 x 1.8 m seine (herein referred to as bag seine) fitted with a 1.8 x 1.8 x 1.8 m bag was used to collect inshore juvenile and adult fishes. Mesh size was 0.6 cm in the wings and 0.3 cm in the bag. Hauls (2 each station each sampling period) were made by setting the seine parallel to and 15 m from shore in approximately 1-2 m of water and pulling the seine to shore with polypropylene lines attached to 1.8 m dowels on each end of the seine. Each haul sampled an area of 220 m^2.

5) A 4.6 x 1.2 m seine (herein referred to as small seine) with 0.3 cm mesh was also used to collect inshore juvenile and adult fishes. The seine was pulled parallel to shore for a distance of 10 m at a position 2 m from the water line (at a depth to 1 m) and then pivoted on the nearshore dowel and brought to shore. Two hauls along the shore and one in the panne (marsh pool or channel) were made at each station each sampling period. [Exceptions to the sampling routine occurred at Station 4: no panne collection in January (1978), two additional panne samples in March

and one additional panne sample each in May and January (1979).] Each haul sampled an area of 62.4 m^2.

6) A 2.45 x 2.45 x 1.00 m drop net with 0.3 cm mesh was used to collect inshore juvenile and adult fishes at depths of approximately 0.5 - 1.5 m. The bottom of the net was weighted by 12 m of 0.5 cm chain and twenty 2.5 cm metal pursing rings. The net was mounted on each upper corner of a 5 x 5 x 1 m aluminum frame by release pins attached to 0.3 cm diam nylon lines 15 m in length. Two 19 liter plastic buckets were fastened to each lower corner of the frame to provide flotation. The frame and suspended net were floated into position and left undisturbed for 10 min before releasing the net. The net was dropped by pulling the release pins and pursed after a 5 sec delay by pulling the 0.6 cm diam nylon line threaded through the metal rings. Two drops were made at each station each sampling period. Each drop sampled an area of 6.0 m^2.

7) Small enclosures of two types were used in conjunction with an anesthetic (quinaldine mixed 1:5 with isopropyl alcohol) to sample inshore juvenile and adult fishes. The first type of enclosure was a 1.0 m diam cylinder 0.8 m in height formed from a 0.6 mm thick polyethylene sheet. This device sampled an area of 0.8 m^2 and used only in January 1978. A 1.0 x 1.0 x 1.0 m square enclosure was used during subsequent sampling periods and constructed of heavy duck material fastened to a frame of 2.5 cm diam PVC pipe. The enclosure was set at three

randomly chosen positions at each station each sampling period in a depth range of 0.5 - 1.0 m. The bottom of the enclosure was firmly settled into the upper few cm of substrate. The quinaldine mixture was added and the enclosed water column and substrate thoroughly searched for 10 min with a 1.0 mm mesh long-handled dipnet. This device (herein referred to as square enclosure) sampled an area of 1.0 m^2. The January 1978 catch with the first type of enclosure was included in the square enclosure totals. (The exception to the 3 sample per station routine occurred in January 1978, at Station 4 when only two samples were taken.

Methods 5, 6 and 7 were designed and utilized with the expectation that they would be effective in capturing fishes of the family Gobiidae. The enclosure-anesthetic method was expected to be particularly suitable for collecting these small, burrow-inhabiting fishes.

Plankton samples were fixed in 5% buffered formalin soon after collection for transport to the laboratory.

Standard lengths (mm SL) and weights (g) of juvenile/ adult fishes were recorded in the field for the entire catch or aliquots of the catch in cases of very large samples. The fishes were either fixed in 10% buffered formalin or frozen on dry ice for return to the laboratory. Digestive tracts of larger (>150 mm SL) fishes were injected via the anus with 10% buffered formalin to preserve dietary items.

Data or samples were taken for seven physical parameters at each station each sampling period. The seven abiotic factors were: 1) temperature (Figure 2); 2) salinity (Figure 3); 3) dissolved oxygen (Figure 4); 4) secchi reading (Figure 5); 5) sediment particle size (Figure 6); 6) depth (Figure 7); and 7) distance into the upper bay from Pacific Coast highway bridge (Figure 8).

Temperature (with bucket thermometer), salinity (with refractometer) and water samples for dissolved oxygen (with Van Dorn bottle) were obtained at three depths (surface, mid-depth, bottom) in the channel, at an inshore location ($\simeq$ 0.5 m) and in the panne at each station. Water samples for dissolved oxygen determination were fixed with 1 ml each of manganese sulfate solution and alkaline iodide solution then stored in 300 ml glass-stoppered bottles for subsequent laboratory analysis.

Depth readings for water transparency were obtained with a secchi disc at channel, inshore and panne locations. Bottom depth was recorded for the channel location (position of water sample) and the panne (maximum depth). Depths at all inshore locations were $\leq$ 1 m. Sediment samples for particle size determination were taken at channel and inshore locations with a hand corer or other device. Distance of each sampling site (within a station) from the highway bridge was estimated from distances measured on U. S. Coast and Geodetic Survey chart 5108 of Newport Bay.

Laboratory Procedures

All formalin-fixed juvenile/adult fishes were transferred to 40% isopropyl alcohol for preservation either

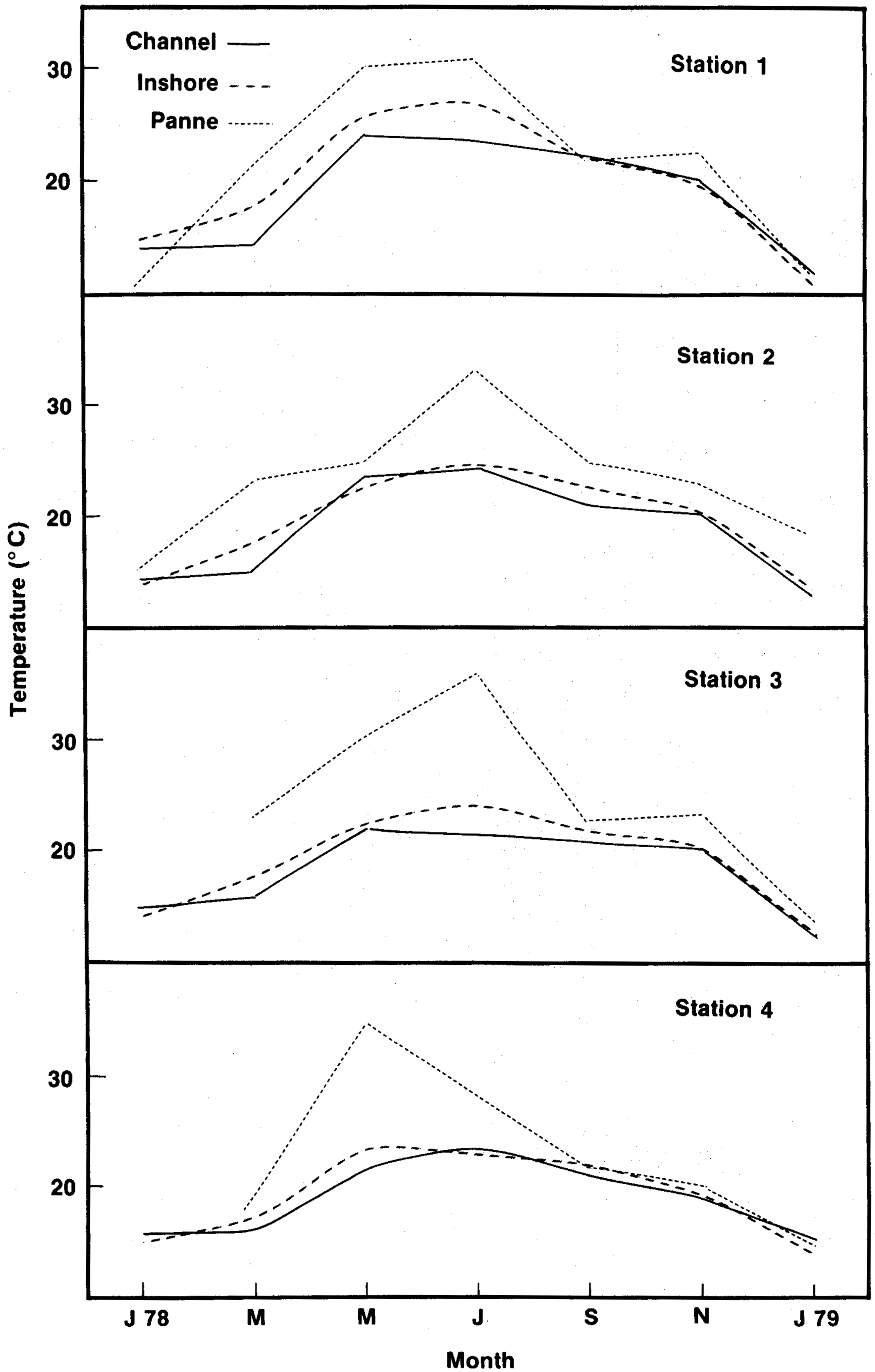


Figure 2. Bimonthly variation (January 1978-January 1979) in temperature (°C) for three locations (channel, inshore, panne) at each of four stations in upper Newport Bay. Channel values are means of surface, mid-depth and bottom readings.

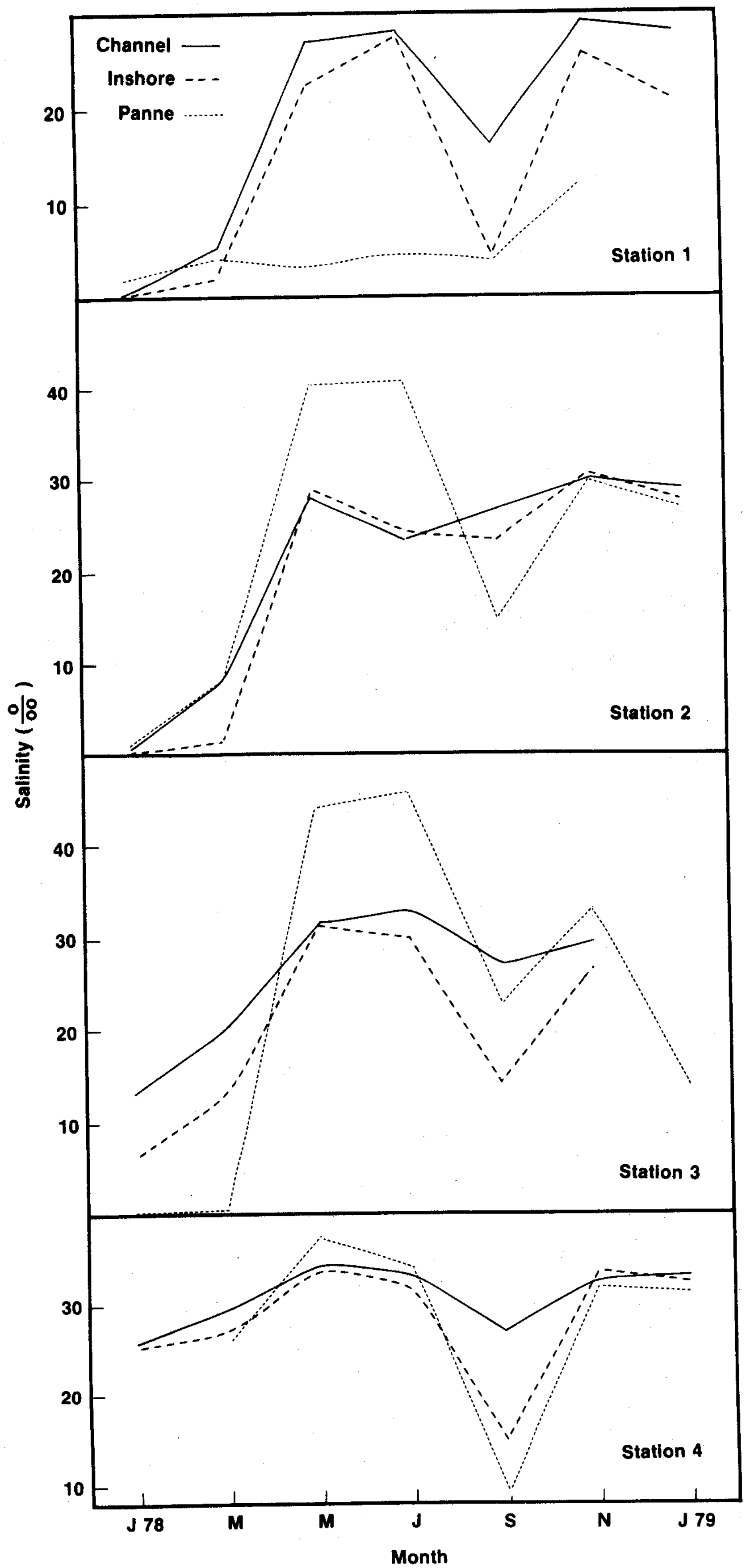


Figure 3. Bimonthly variation (January 1978-January 1979) in salinity (0/00) for three locations (channel, inshore, panne) at each of four stations in upper Newport Bay. Channel values are means of surface, mid-depth and bottom readings.

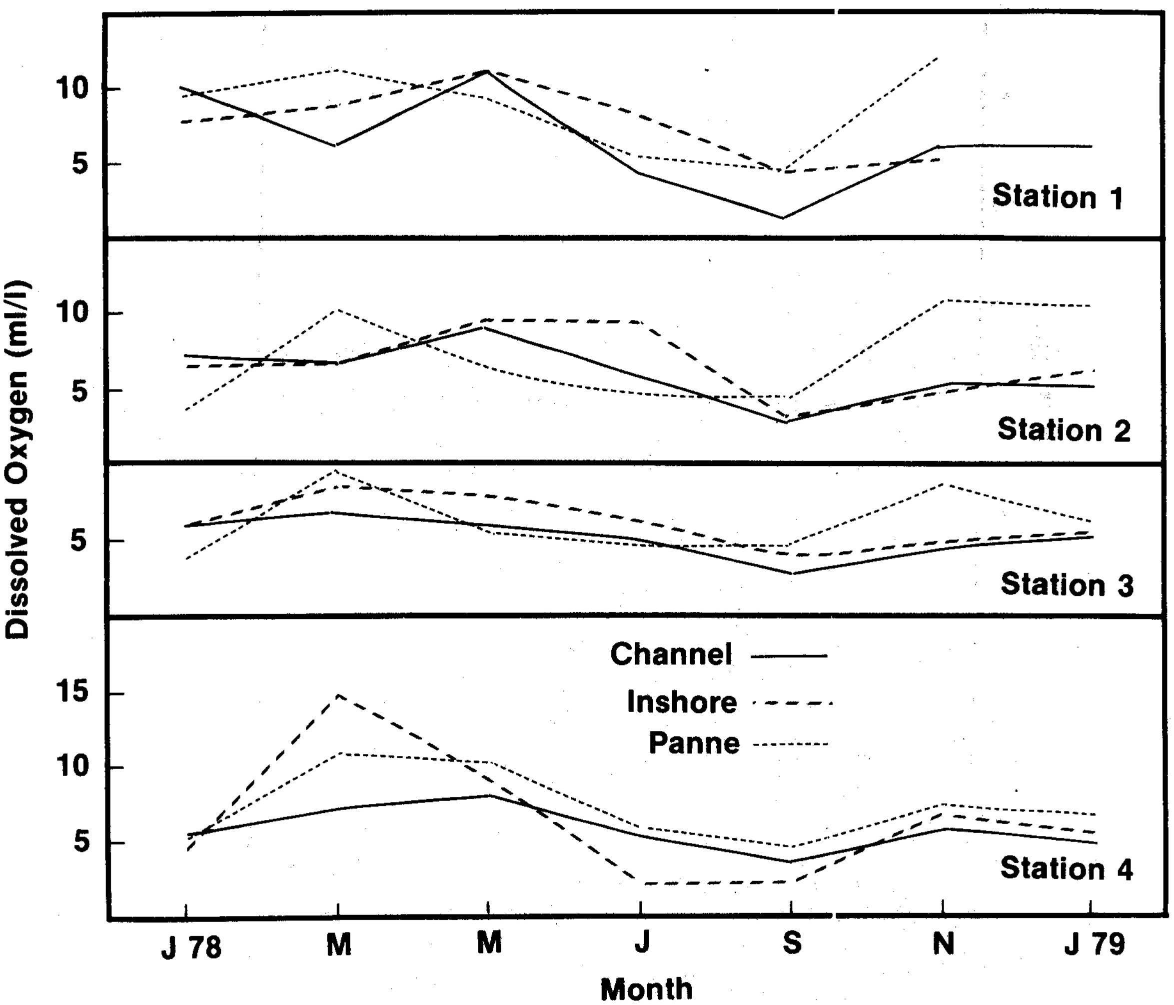


Figure 4. Bimonthly variation (January 1978-January 1979) in dissolved oxygen (ml/l) for three locations (channel, inshore, panne) at each of four stations in upper Newport Bay. Channel values are means of surface, mid-depth and bottom readings.

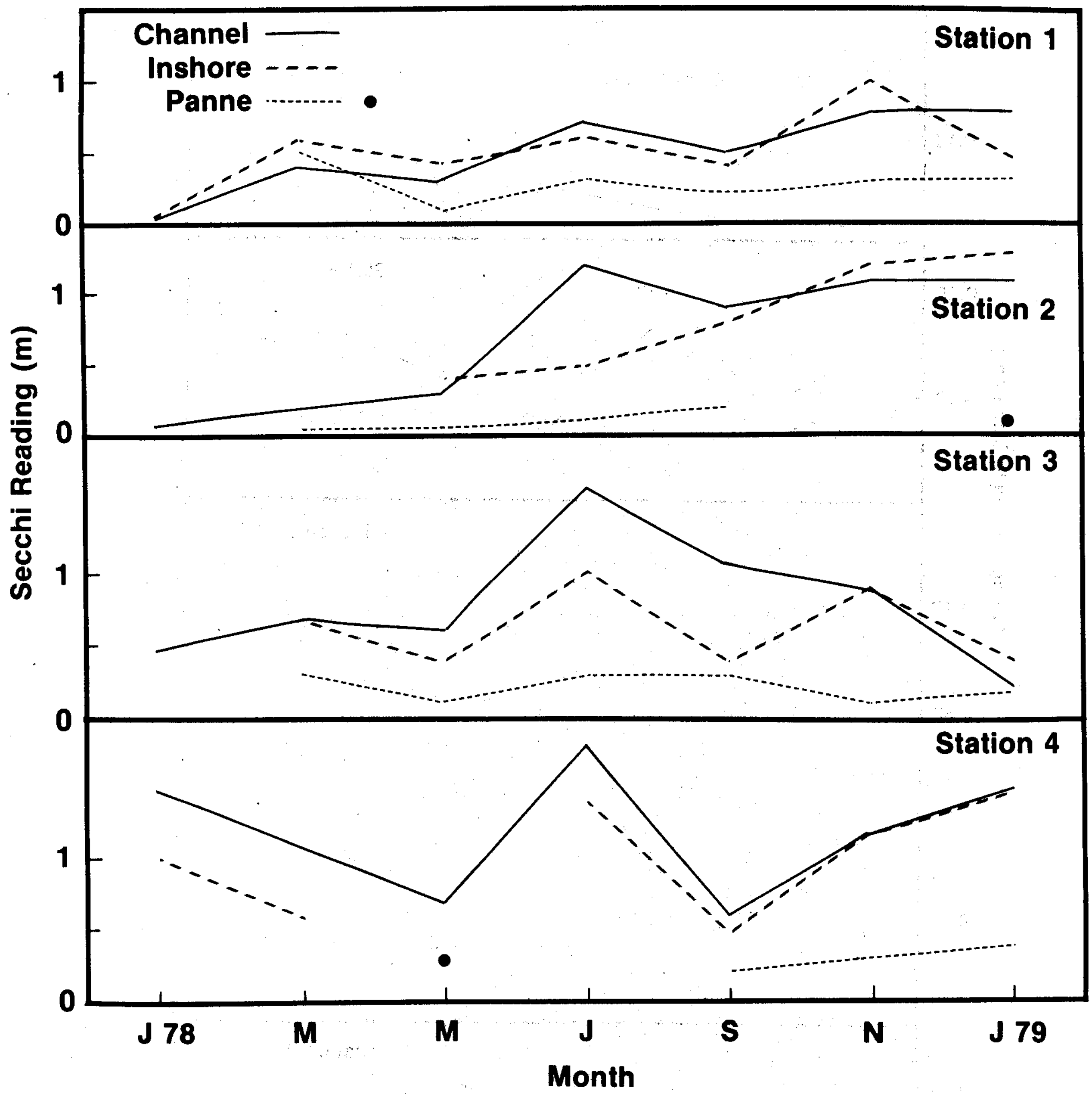


Figure 5. Bimonthly variation (January 1978–January 1979) in secchi readings (m) for three locations (channel, inshore, panne) at each of four stations in upper Newport Bay.

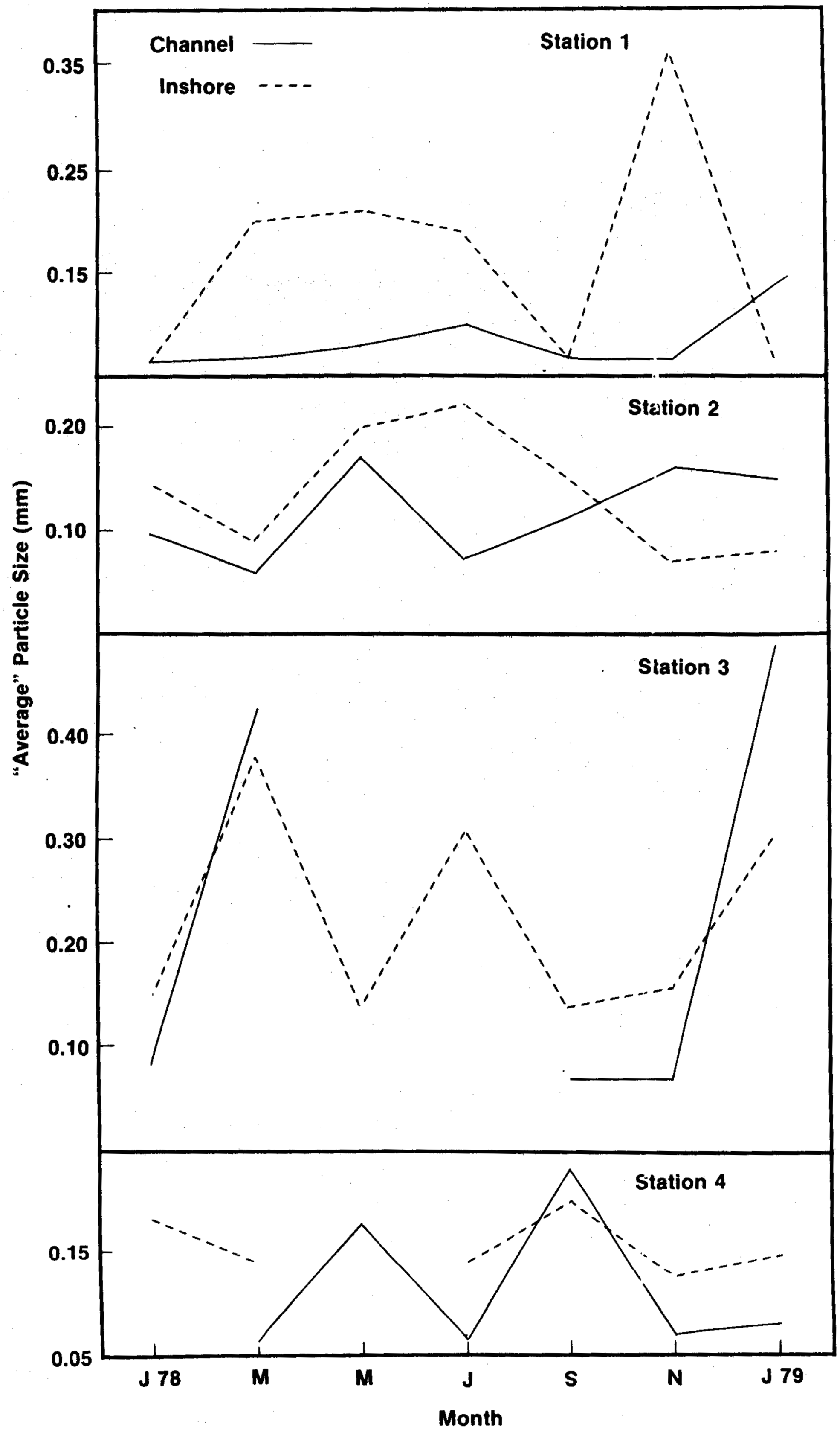


Figure 6. Bimonthly variation (January 1978-January 1979) in "average" particle size of sediment (mm) for two locations (channel, inshore) at each of four stations in upper Newport Bay.

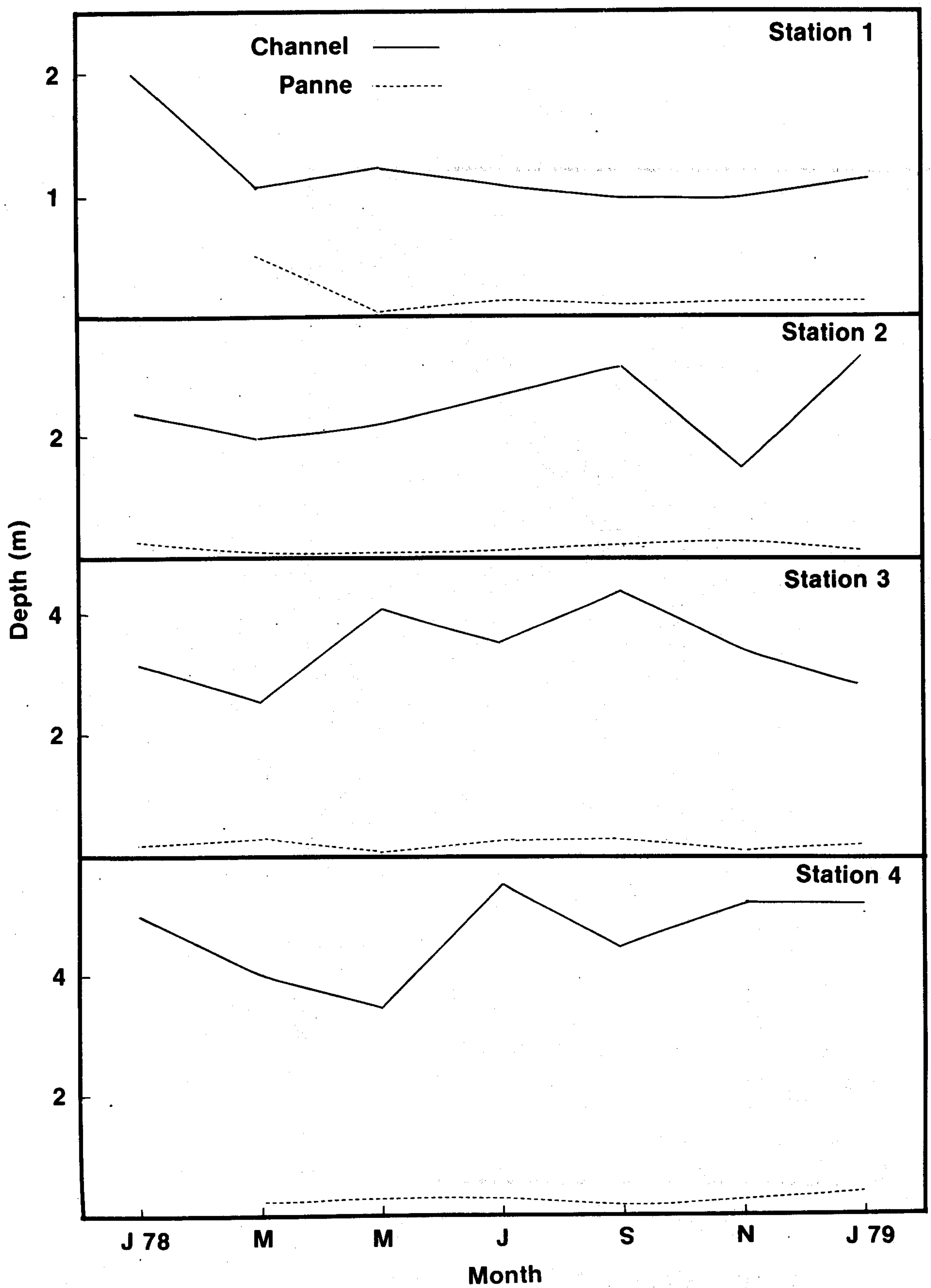


Figure 7. Bimonthly variation (January 1978-January 1979) in depth (m) for two locations (channel, panne) at each of four stations in upper Newport Bay.

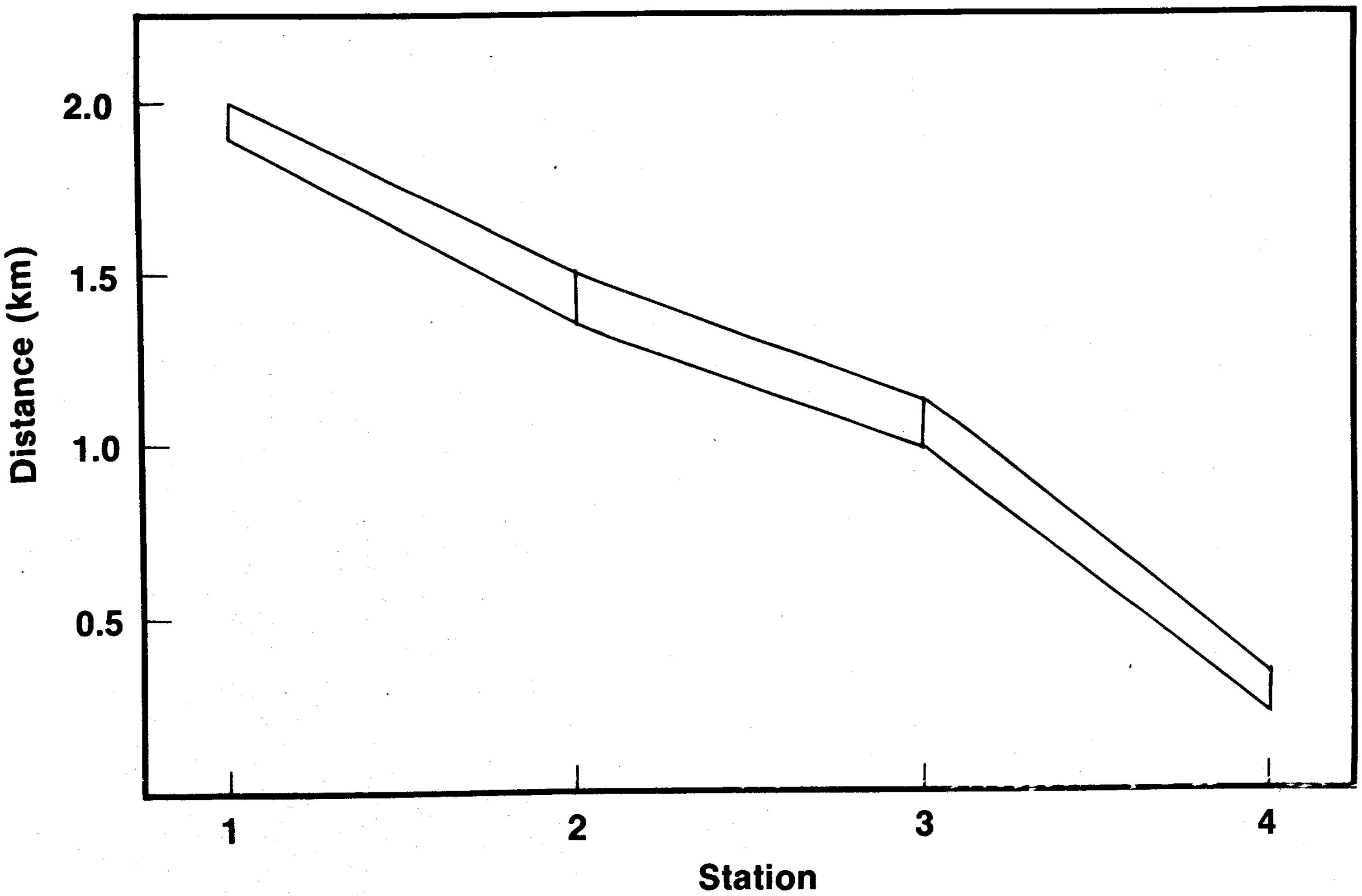


Figure 8. Distance (km) into upper Newport Bay from Pacific Coast highway bridge of the four sampling stations. Vertical line indicates range of distances among sites at each station.

as vouchers or as specimens for subsequent gut content analysis. Frozen specimens were thawed for dry weight and ash-free dry weight determination in a related study (Allen, 1980) on fish production in the upper bay. Small specimens (<10 g wet weight) were re-weighed in the laboratory to check field weights and insure accuracy.

Eggs and larvae were sorted from the plankton samples, identified to the lowest possible taxonomic level and enumerated by taxon. Sorted specimens were maintained in 5% buffered formalin.

Dissolved oxygen concentrations (ml/l) of the water samples were determined using the modified Winkler titration method described by Strickland and Parsons (1968).

Sediment samples were dried in a 30°C oven for 48 hrs then weighed to the nearest 0.1 g. Each sample was then sieved through a screen series of 1.0, 0.25, 0.125 and 0.067 mm meshes. This series of sieve sizes yielded particle categories equivalent to shell fragments and pebble, coarse-medium sand, fine sand, very fine sand and silt-clay, respectively (Inman, 1952). The last fraction passed through the sieve series. Each fraction, except silt-clay, was weighed, dried in a 30°C oven for 48 hrs and weighed again to the nearest 0.01 g. The silt-clay fraction was determined as the difference between the original weight and the sum of the first four fractions. The weight of the particles of each fraction was then expressed as a proportion (range 0--1) of the original weight. "Average" particle size of each sediment sample was estimated by multiplying the proportion of each fraction times the median particle size for the range and summing the products.

Data Analysis

A classification program (cluster analysis) from the Ecological Analysis Package developed by R. W. Smith was used at the University of Southern California Computer Center to determine species associations based on sample abundances and flexible sorting in the analysis. The Bray-Curtis index of dissimilarity (Clifford and Stephenson, 1975) was utilized and allowed quantitative clustering without assuming normality in the sampled populations. This index is a measure of the degree of "un-likeness" or "non-affinity" between all pairs in a series of samples and is calculated as follows:

$$D = \frac{\sum_{i=1}^{n} \left| X_{1_j} - X_{2_j} \right|}{\sum_{i=1}^{n} (X_{1_j} + X_{2_j})}$$

where, D = dissimilarity between a pair of species, summed for all samples;

n = number of samples

X_{1_j} = abundance in sample j of species 1

X_{2_j} = abundance in sample j of species 2

An index value of 0.0 indicates that a pair of species always occurred together in equal numbers while increasingly large values indicate greater dissimilarity in occurrence and abundance. Square-root transformation of species abundances was used to counter the tendency of the index to overemphasize dominant species.

Correlations of individual species abundances with single abiotic factors were produced on a multiple regression program in the Ecological Analysis Package.

The Shannon-Wiener information function, $H' = -\sum_{i=1}^{s} P_i \log P_i$ where P_i is the proportion of individuals in the _ith_ species, was used (with $\log_e$) as a measure of diversity as in previous studies of fish communities (e.g., Dahlberg and Odum, 1970).

RESULTS

Juvenile/Adult Populations

Total Catch and Catch by Method

A total of 51,816 fishes belonging to 46 species and weighing 353,051 g was captured in 366 samples taken with six different methods during seven bimonthly periods (January 1978 - January 1979) in upper Newport Bay (Table 1). _Atherinops affinis_ (topsmelt) was the most abundant species comprising more than 76% of the total catch. Seven species accounted for over 97% of the total individuals collected. _Mugil cephalus_ (striped mullet) constituted nearly 36% of the total biomass followed by _A. affinis_ with almost 24%. Six species made up more than 80% of the total biomass.

The bag seine was the principal inshore sampling device in terms of magnitude of catch (Table 2). A

Table 1. Number of individuals and biomass of juvenile/adult fish species collected by all methods at four stations in upper Newport Bay during seven bimonthly periods (January 1978 - January 1979).

Species	JANUARY 1978 No.	Biomass (g)	MARCH No.	Biomass (g)	MAY No.	Biomass (g)	JULY No.	Biomass (g)	SEPTEMBER No.	Biomass (g)
Atherinops affinis	345	2,595.5	85	2,166.0	433	4,305.3	26,099	25,613.9	7,201	21,206.5
Fundulus parvipinnis	382	337.2	184	127.4	36	96.2	758	854.8	1,707	2,323.0
Gambusia affinis	46	10.3	9	3.2	56	7.1	573	342.9	1,029	399.4
Anchoa compressa	39	275.9	96	428.4	989	14,663.4	270	2,472.2	63	1,022.1
Anchoa delicatissima	11	11.5	80	97.8	18	50.2	6	20.1	1,129	4,709.7
Clevelandia ios	57	24.7	85	14.9	163	31.8	496	110.8	159	44.0
Cymatogaster aggregata	98	1,879.0	66	1,745.0	304	1,301.2	68	193.0	130	1,393.1
Engraulis mordax							84	92.4	179	333.6
Umbrina roncador					13	2,181.0	33	4,163.0	119	15,996.0
Gillichthys mirabilis	12	2.4	14	3.5	20	40.1	62	251.3	2	30.3
Mugil cephalus	47	3,670.0	16	20,556.5	18	24,340.0	29	41,946.0		
Hypsopsetta guttulata	10	1,735.0	1	185.0	23	3,678.8	35	4,536.0	14	2,220.0
Embiotoca jacksoni	17	2,920.0	10	1,350.0	27	4,972.0	4	916.0	22	572.5
Ilypnus gilberti					40	7.8	39	9.7	3	0.9
Paralichthys californicus	4	425.0	1	80.0	2	45.2	12	757.4	11	565.0
Quietula ycauda	1	1.0			5	1.7	41	19.1	6	2.5
Morone saxatilis	15	9,354.0	9	3,002.0	7	2,520.0	4	1,264.0		
Lepomis cyanellus									31	49.3
Leuresthes tenuis							3	0.3	22	14.4
Paralabrax maculatofasciatus	2	750.0			3	635.0	8	2,092.0	4	815.0
Seriphus politus	1	2.0	2	6.0	2	260.0	5	423.0	3	49.0
Syngnathus auliscus					5	4.6	5	4.3	2	1.5
Phanerodon furcatus	2	398.0	5	535.0	2	514.0				
Urolophus halleri			1	260.0	5	1,580.0	2	1,086.0	1	315.0
Paralabrax nebulifer	3	127.0			1	46.0			4	480.0
Mustelus californicus							6	863.0	1	205.0
Ictalurus melas			7	882.0						
Lepomis macrochirus	2	735.0	3	1,315.0						
Damalichthys vacca	3	14.5	2	4.1						
Leptocottus armatus			1	1.0	3	5.2			1	8.0
Syngnathus leptorhynchus									4	6.9
Girella nigricans							1	0.4	1	10.5
Genyonemus lineatus	1	5.0							1	40.0
Acanthogobius flavimanus					2	4.1	1	12.0		
Pleuronichthys ritteri					2	329.0				
Symphurus atricauda	1	15.0	1	22.0			1	8.0		
Menticirrhus undulatus					2	2,240.0				
Peprilus simillimus									1	18.9
Anisotremus davidsoni					2	195.0				
Porichthys myriaster									1	0.5
Cynoscion nobilis							1	6.6		
Sphyraena argentea										
Polydactylus approximans										
Myliobatis californica					1	570.0				
Albula vulpes									1	115.0
Heterostichus rostratus									1	15.0
TOTALS	977	25,288.0	678	32,784.8	2,184	64,024.7	28,646	88,058.2	11,853	52,962.6
No. of Species	22		21		28		27		31	
H'	1.95	2.01	2.17	1.46	1.77	2.00	0.48	1.59	1.34	1.76

Table 1. (Continued)

Species	NOVEMBER No.	NOVEMBER Biomass (g)	JANUARY 1979 No.	JANUARY 1979 Biomass (g)	TOTALS No.	TOTALS % of Total	TOTALS Biomass (g)	TOTALS % of Total
Atherinops affinis	2,977	17,729.6	2,333	10,144.2	39,473	76.2	83,761.0	23.7
Fundulus parvipinnis	1,367	768.4	67	29.1	4,501	8.7	4,536.1	1.3
Gambusia affinis	149	15.2			1,862	3.6	778.1	0.2
Anchoa compressa	8	102.0			1,465	2.8	18,964.0	5.4
Anchoa delicatissima	7	24.0	4	12.0	1,255	2.4	4,925.3	1.4
Clevelandia ios	145	31.7	11	2.5	1,116	2.1	260.4	0.1
Cymatogaster aggregata	70	470.6	182	3,145.4	918	1.8	10,127.3	2.9
Engraulis mordax	3	6.0	7	15.0	273	0.5	447.0	0.1
Umbrina roncador	2	272.0			167	0.3	22,612.0	6.4
Gillichthys mirabilis	38	668.5	6	0.3	154	0.3	996.4	0.3
Mugil cephalus	3	5,582.5	28	29,455.5	141	0.3	125,550.5	35.6
Hypsopsetta guttulata	20	3,271.9	15	1,859.2	118	0.2	17,485.9	5.0
Embiotoca jacksoni	7	1,608.0	6	1,462.0	93	0.2	13,800.5	3.9
Ilypnus gilberti	1	0.1			83	0.2	18.5	<0.1
Paralichthys californicus	12	1,691.0	21	6,250.0	63	0.1	9,813.6	2.8
Quietula ycauda	1	0.1			54	0.1	24.4	<0.1
Morone saxatilis			1	498.0	36	0.1	16,638.0	4.7
Lepomis cyanellus					31	0.1	49.3	<0.1
Leuresthes tenuis	1	1.0	2	3.9	28	0.1	19.6	<0.1
Paralabrax maculatofasciatus	3	406.0			20	<0.1	4,698.0	1.3
Seriphus politus	1	2.0	2	4.0	16	<0.1	746.0	0.2
Syngnathus auliscus					12	<0.1	10.4	<0.1
Phanerodon furcatus	1	144.0			10	<0.1	1,591.0	0.4
Urolophus halleri	1	56.0			9	<0.1	3,241.0	0.9
Paralabrax nebulifer					9	<0.1	709.0	0.2
Mustelus californicus					7	<0.1	1,068.0	0.3
Ictalurus melas					7	<0.1	882.0	0.3
Lepomis macrochirus			1	205.0	6	<0.1	2,255.0	0.6
Damalichthys vacca					5	<0.1	18.6	<0.1
Leptocottus armata					5	<0.1	14.2	<0.1
Syngnathus leptorhynchus			1	0.3	5	<0.1	7.2	<0.1
Girella nigricans	3	1,724.0			5	<0.1	1,734.9	0.5
Genyonemus lineatus			2	212.0	4	<0.1	257.0	0.1
Acanthogobius flavimanus					3	<0.1	16.1	<0.1
Pleuronichthys ritteri	1	150.0			3	<0.1	479.0	0.1
Symphurus atricauda					3	<0.1	45.0	<0.1
Menticirrhus undulatus	1	912.0			3	<0.1	3,152.0	0.9
Peprilus simillimus			2	13.0	3	<0.1	31.9	<0.1
Anisotremus davidsoni					2	<0.1	195.0	0.1
Porichthys myriaster	1	0.1			2	<0.1	0.6	<0.1
Cynoscion nobilis					1	<0.1	6.6	<0.1
Sphyraena argentea	1	4.2			1	<0.1	4.2	<0.1
Polydactylus approximans	1	380.0			1	<0.1	380.0	0.1
Myliobatis californica					1	<0.1	570.0	0.2
Albula vulpes					1	<0.1	115.0	<0.1
Heterostichus rostratus					1	<0.1	15.0	<0.1
TOTALS	4,787	36,020.9	2,691	53,311.4	51,816		353.050.6	
No. Species	27		18		46			
H'	1.05	1.81	0.62	1.38	1.02		2.15	

majority of the individuals (70.7%) and nearly one-fourth (24.1%) of the biomass for the entire study was collected with this method. Atherinops affinis was by far the most abundant of the 27 species captured with the bag seine.

In terms of total catch, the small seine was second in importance among inshore methods (Table 3). This device accounted for 12.7% of total numbers and 1.1% of total biomass for the study. Atherinops affinis again dominated the samples which contained a total of 19 species; however, the dominance of A. affinis was less than in the bag seine collections. The small seine was the only method used to sample the pannes (Table 4). Fundulus parvipinnis (California killifish) and Gambusia affinis (mosquitofish) were the most abundant of the eight species collected in the panne habitat.

The two other inshore sampling devices, drop net (Table 5) and square enclosure (Table 6), contributed relatively small amounts (less than 1% each of numbers and biomass) to the total catch. Although Atherinops affinis was the most abundant species obtained by each method, gobies were captured in relatively high densities by both devices.

The two methods used to sample the channel habitat, otter trawl and gill net, collected a small percentage of the total individuals but large proportions of the total biomass indicating that, in general, larger fishes were captured with these devices. The otter trawl accounted for

Table 2. Number of individuals, density and biomass of juvenile/adult fish species collected bimonthly (January 1978-January 1979) by bag seine in upper Newport Bay.

SPECIES	Number	% of Total	Density (No./m^2)	Biomass (g)	% of Total
Atherinops affinis	33,247	90.8	2.699	70,157.8	82.6
Anchoa delicatissima	1,155	3.2	0.094	4,728.7	5.6
Fundulus parvipinnis	851	2.3	0.069	2,292.2	2.7
Anchoa compressa	392	1.1	0.032	5,311.0	6.3
Cymatogaster aggregata	367	1.0	0.030	1,058.5	1.2
Engraulis mordax	260	0.7	0.021	423.0	0.5
Clevelandia ios	172	0.5	0.014	47.8	0.1
Gambusia affinis	77	0.2	0.006	33.0	<0.1
Leuresthes tenuis	25	0.1	0.002	17.1	<0.1
Mugil cephalus	24	0.1	0.002	565.4	0.7
Lepomis cyanellus	20	0.1	0.002	29.6	<0.1
Gillichthys mirabilis	11	<0.1	0.001	70.6	0.1
Hypsopsetta guttulata	7	<0.1	0.001	19.5	<0.1
Syngnathus auliscus	5	<0.1	<0.001	4.3	<0.1
Syngnathus leptorhynchus	3	<0.1	<0.001	5.2	<0.1
Lepomis macrochirus	3	<0.1	<0.001	11.1	<0.1
Paralichthys californicus	3	<0.1	<0.001	5.4	<0.1
Ilypnus gilberti	2	<0.1	<0.001	0.4	<0.1
Quietula ycauda	2	<0.1	<0.001	1.3	<0.1
Acanthogobius flavimanus	1	<0.1	<0.001	49.0	0.1
Mustelus californicus	1	<0.1	<0.001	58.0	0.1
Seriphus politus	1	<0.1	<0.001	1.0	<0.1
Peprilus simillimus	1	<0.1	<0.001	15.9	<0.1
Porichthys myriaster	1	<0.1	<0.001	0.1	<0.1
Cynoscion nobilis	1	<0.1	<0.001	6.6	<0.1
Leptocottus armatus	1	<0.1	<0.001	1.1	<0.1
Sphyraena argentea	1	<0.1	<0.001	4.2	<0.1
TOTALS	36,634		2.974	84,920.7	

TOTAL SPECIES = 27

Table 3. Number of individuals, density and biomass of juvenile/adult fish species collected bimonthly (January 1978-January 1979) by small seine in upper Newport Bay.

SPECIES	Number	% of Total	Density (No./m^2)	Biomass (g)	% of Total
Atherinops affinis	5,108	77.5	1.462	2,357.0	62.0
Clevelandia ios	747	11.3	0.214	168.5	4.4
Fundulus parvipinnis	455	6.9	0.130	959.4	25.2
Gambusia affinis	101	1.5	0.029	38.8	1.0
Anchoa compressa	38	0.6	0.011	80.4	2.1
Gillichthys mirabilis	34	0.5	0.010	106.2	2.8
Ilypnus gilberti	27	0.4	0.008	6.2	0.2
Quietula ycauda	23	0.3	0.007	12.9	0.3
Anchoa delicatissima	21	0.3	0.006	12.5	0.3
Lepomis cyanellus	11	0.2	0.003	19.7	0.5
Hypsopsetta guttulata	10	0.2	0.003	13.5	0.4
Mugil cephalus	7	0.1	0.002	2.7	0.1
Syngnathus leptorhynchus	2	<0.1	0.001	2.0	0.1
Syngnathus auliscus	2	<0.1	0.001	1.6	<0.1
Lepomis macrochirus	1	<0.1	<0.001	1.1	<0.1
Leptocottus armatus	1	<0.1	<0.001	0.7	<0.1
Girella nigricans	1	<0.1	<0.001	0.4	<0.1
Paralichthys californicus	1	<0.1	<0.001	0.2	<0.1
Acanthogobius flavimanus	1	<0.1	<0.001	0.1	<0.1
TOTALS	6,591		1.886	3,801.9	
TOTAL SPECIES = 19					

Table 4. Number of individuals, density and biomass of juvenile/ adult fish species collected bimonthly (January 1978-January 1979) by small seine in the pannes (Stations 1-4 combined) in upper Newport Bay.

SPECIES	Number	% of Total	Density (No./m^2)	Biomass (g)	% of Total
Fundulus parvipinnis	3,061	56.1	1.533	1201.1	38.9
Gambusia affinis	1,685	30.9	0.844	704.7	22.8
Atherinops affinis	508	9.3	0.254	937.3	30.3
Clevelandia ios	114	2.1	0.057	23.0	0.7
Gillichthys mirabilis	61	1.1	0.031	151.6	4.9
Mugil cephalus	21	0.4	0.011	68.2	2.2
Syngnathus leptorhynchus	5	0.1	0.003	1.5	<0.1
Quietula ycauda	3	0.1	0.002	1.2	<0.1
TOTALS	5,458		2.733	3088.6	
TOTAL SPECIES = 8					

Table 5. Number of individuals, density and biomass of juvenile/adult fish species collected bimonthly (January 1978-January 1979) by drop net in upper Newport Bay.

SPECIES	Number	% of Total	Density (No./m^2)	Biomass (g)	% of Total
Atherinops affinis	319	72.2	0.949	654.7	77.2
Ilypnus gilberti	34	7.7	0.101	8.9	1.0
Clevelandia ios	28	6.3	0.083	8.5	1.0
Quietula ycauda	21	4.8	0.063	7.1	0.8
Cymatogaster aggregata	14	3.2	0.042	22.9	2.7
Anchoa compressa	8	1.8	0.024	87.9	10.4
Gillichthys mirabilis	5	1.1	0.015	2.7	0.3
Fundulus parvipinnis	4	0.9	0.012	25.3	3.0
Anchoa delicatissima	2	0.5	0.006	9.8	1.2
Leptocottus armatus	2	0.5	0.006	4.5	0.5
Leuresthes tenuis	2	0.5	0.006	1.1	0.1
Hypsopsetta guttulata	1	0.2	0.003	2.9	0.3
Girella nigricans	1	0.2	0.003	10.5	1.2
Syngnathus auliscus	1	0.2	0.003	1.0	0.1
TOTALS	442		1.315	847.8	

TOTAL SPECIES = 14

Table 6. Number of individuals, density and biomass of juvenile/adult fish species collected bimonthly (January 1978-January 1979) by square enclosure in upper Newport Bay.

SPECIES	Number	% of Total	Density (No./m^2)	Biomass (g)	% of Total
Atherinops affinis	79	53.4	0.952	118.7	78.9
Clevelandia ios	44	29.7	0.530	9.1	6.1
Ilypnus gilberti	16	10.8	0.193	1.9	1.3
Fundulus parvipinnis	4	2.7	0.048	20.1	13.4
Gillichthys mirabilis	4	2.7	0.048	0.5	0.3
Quietula ycauda	1	0.7	0.012	0.1	0.1
TOTALS	148		1.783	150.4	
TOTAL SPECIES = 6					

only 2.1% of total numbers but over one-fifth (20.4% of the biomass (Table 7). Trawl totals were dominated numerically by Cymatogaster aggregata (shiner surfperch) and in biomass by Embiotoca jacksoni (black surfperch) and Hypsopsetta guttulata (diamond turbot). A larger number of species (35) was collected by otter trawl than any of the other methods. The gill net accounted for only 3.1% of total numbers but over one-half (55.6%) of the total biomass (Table 8). Of the 22 species captured by gill net, Anchoa compressa (deepbody anchovy) was caught in greatest abundance whereas Mugil cephalus constituted the largest biomass.

All species collected (including those only in egg or larval stage) are listed by scientific name, common name and family in the Appendix.

Seasonal Abundance and Diversity

Marked changes in abundance and diversity parameters occurred during the 13-month study period. For the upper bay as a whole (Table 1; Figure 9), species richness (number of species) generally increased from January 1978 (22 species) to a maximum in September (31), then declined to the lowest value (18) in January 1979. Diversity H' for numbers was lowest in July (0.48) and highest in March (2.17) and for biomass lowest in January 1979 (1.38) and highest in January 1978 (2.01). The number of individuals increased dramatically from a low in March (678) to a peak in July (28,646) primarily as a result of the population increase of Atherinops affinis. Biomass showed a similar pattern ranging from a

Table 7. Number of individuals, density and biomass of juvenile/ adult fish species collected bimonthly (January 1978-January 1979) by otter trawl in upper Newport Bay.

SPECIES	Number	% of Total	Density (No./m^2)	Biomass (g)	% of Total
Cymatogaster aggregata	519	46.9	0.048	9,711.4	13.5
Embiotoca jacksoni	92	8.3	0.009	18,698.0	26.0
Hypsopsetta guttulata	92	8.3	0.009	15,803.0	22.0
Anchoa compressa	89	8.0	0.008	684.4	1.0
Anchoa delicatissima	77	7.0	0.007	174.3	0.2
Paralichthys californicus	57	5.1	0.005	9,705.0	13.5
Atherinops affinis	36	3.3	0.003	327.7	0.5
Umbrina roncador	23	2.1	0.002	1,955.0	2.7
Paralabrax maculatofasciatus	15	1.4	0.001	4,016.0	5.6
Seriphus politus	15	1.4	0.001	22.8	<0.1
Morone saxatilis	15	1.4	0.001	3,205.0	4.4
Paralabrax nebulifer	11	1.0	0.001	824.0	1.1
Engraulis mordax	11	1.0	0.001	23.0	<0.1
Urolophus halleri	7	0.6	0.001	2,415.0	3.4
Ictalurus melas	7	0.6	0.001	882.0	1.2
Syngnathus auliscus	4	0.4	<0.001	3.5	<0.1
Quietula ycauda	4	0.4	<0.001	1.8	<0.1
Ilypnus gilberti	4	0.4	<0.001	1.4	<0.1
Girella nigricans	3	0.3	<0.001	1,724.0	2.4
Phanerodon furcatus	3	0.3	<0.001	639.0	0.9
Pleuronichthys ritteri	3	0.3	<0.001	479.0	0.7
Symphurus atricauda	3	0.3	<0.001	117.0	0.2
Anisotremus davidsoni	2	0.2	<0.001	195.0	0.3
Genyonemus lineatus	2	0.2	<0.001	45.0	0.1
Fundulus parvipinnis	2	0.2	<0.001	32.0	<0.1
Gillichthys mirabilis	2	0.2	<0.001	18.3	<0.1
Peprilus simillimus	2	0.2	<0.001	13.0	<0.1
Mugil cephalus	1	0.1	<0.001	410.0	0.6
Albula vulpes	1	0.1	<0.001	115.0	0.2
Heterostichus rostratus	1	0.1	<0.001	15.0	<0.1
Leptocottus armatus	1	0.1	<0.001	8.0	<0.1
Lepomis macrochirus	1	0.1	<0.001	6.4	<0.1
Porichthys myriaster	1	0.1	<0.001	0.5	<0.1
Leuresthes tenuis	1	0.1	<0.001	0.4	<0.1
Clevelandia ios	1	0.1	<0.001	0.1	<0.1
TOTALS	1,108		0.103	72,271.0	
TOTAL SPECIES = 35					

Table 8. Number of individuals, catch rate and biomass of juvenile/adult fish species collected bimonthly (January 1978-January 1979) by gill net in upper Newport Bay.

SPECIES	Number	% of Total	Catch Rate (No./hr)	Biomass (g)	% of Total
Anchoa compressa	928	58.2	11.73	12,515	6.4
Atherinops affinis	355	22.3	4.49	9,696	4.9
Umbrina roncador	144	9.0	1.82	20,657	10.5
Mugil cephalus	88	5.5	1.11	124,535	63.5
Morone saxatilis	21	1.3	0.27	13,433	6.8
Damalichthys vacca	10	0.6	0.13	2,629	1.3
Hypsopsetta guttulata	8	0.5	0.10	4,137	2.1
Mustelus californicus	6	0.4	0.08	1,010	0.5
Cymatogaster aggregata	6	0.4	0.08	183	0.1
Paralabrax maculatofasciatus	5	0.3	0.06	682	0.3
Phanerodon furcatus	4	0.3	0.05	617	0.3
Menticirrhus undulatus	3	0.2	0.04	3,152	1.6
Urolophus halleri	3	0.2	0.04	834	0.4
Seriphus politus	3	0.2	0.04	352	0.2
Geyonemus lineatus	2	0.1	0.03	212	0.1
Paralichthys californicus	2	0.1	0.03	58	<0.1
Myliobatis californica	1	0.1	0.01	570	0.3
Polydactylus approximans	1	0.1	0.01	380	0.2
Embiotoca jacksoni	1	0.1	0.01	255	0.1
Paralabrax nebulifer	1	0.1	0.01	220	0.1
Acanthogobius flavimanus	1	0.1	0.01	12	<0.1
Engraulis mordax	1	0.1	0.01	1	<0.1
TOTALS	1,594		20.15	196,140	

TOTAL SPECIES = 22

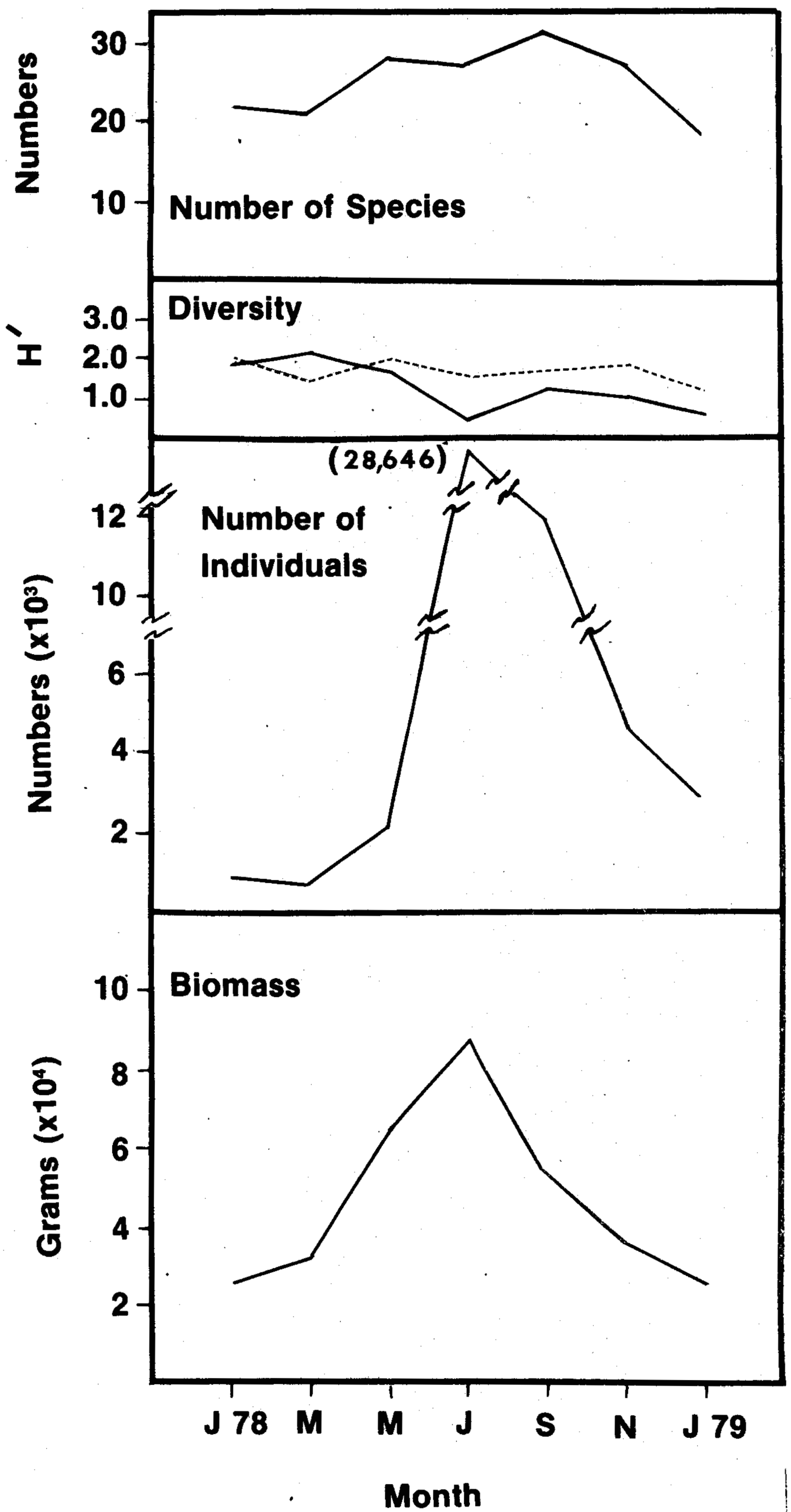


Figure 9. Bimonthly variation (January 1978-January 1979) in number of species, diversity H' (numbers = solid line, biomass = broken line), number of individuals and biomass (g) of juvenile/adult fishes collected by all methods for Stations 1-4 combine in upper Newport Bay.

low in January 1978 (25,359 g) to a maximum in July (88,058 g). For both numbers and biomass, values steeply declined from July to the end of the study period.

In general, abundance and diversity patterns for the entire upper bay reflected those of individual stations but with some important differences. At Station 1 (Figure 10), diversity H' (for numbers) was lowest in January 1979 and highest in May and, biomass, after declining to a very low level in September, increased to a secondary peak in January 1979 when numbers were relatively low. At Station 2 (Figure 11), biomass decreased to a relatively low level in November, then increased by more than two-fold in January 1979. At Station 3 (Figure 12), the number of individuals peaked in May following a low in March and, biomass, after peaking in January 1978, gradually declined to its lowest level in January 1979. Station 4 (Figure 13) showed the greatest deviation of all the stations from the basic pattern. Species richness at this station had two peaks, one in May and a second in September with low values in January 1978 and July and the lowest in January 1979. Biomass, unlike number of indviduals which reflected the overall upper bay pattern, reached its lowest value in July and the highest in September with a secondary peak in March.

In most cases at all stations, diversity H' was inversely related to number of individuals.

Overall abundance and diversity values as a function of distance into the upper bay (Figure 14) revealed that

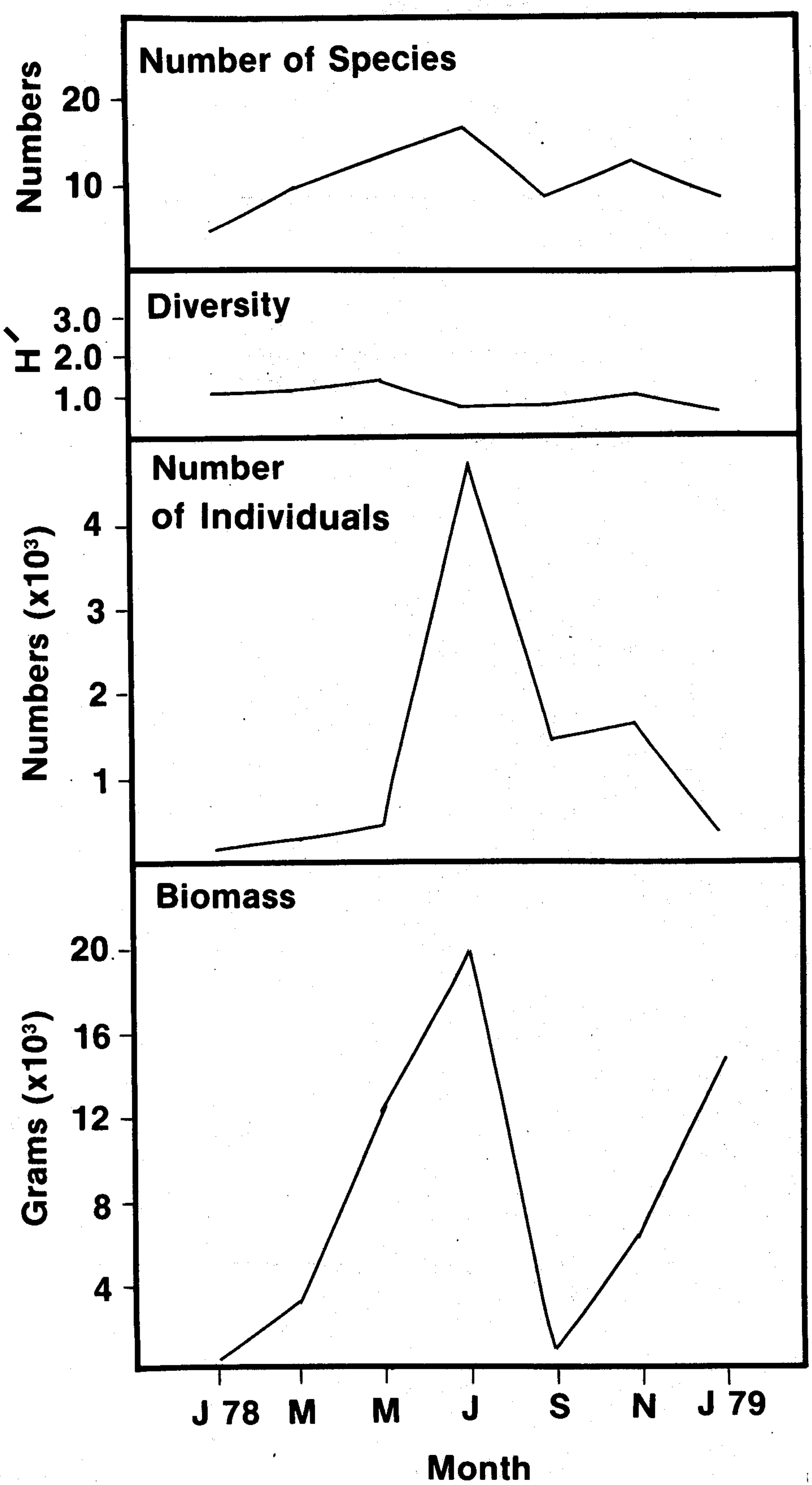


Figure 10. Bimonthly variation (January 1978-January 1979) in number of species, diversity H' (for numbers), number of individuals and biomass (g) of juvenile/adult fishes collected by all methods at Station 1 in upper Newport Bay.

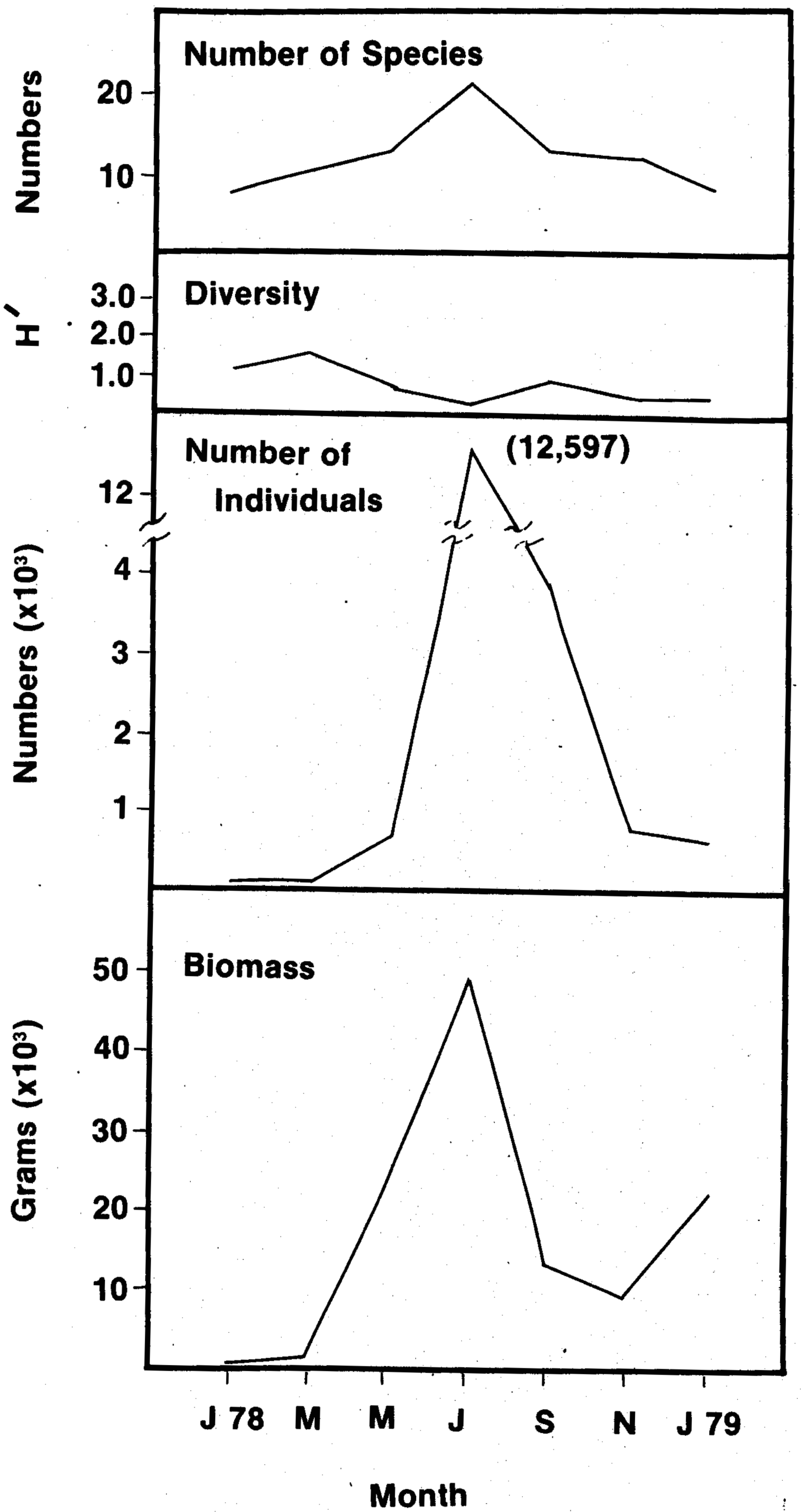


Figure 11. Bimonthly variation (January 1978-January 1979) in number of species, diversity H' (for numbers), number of individuals and biomass (g) of juvenile/adult fishes collected by all methods at Station 2 in upper Newport Bay.

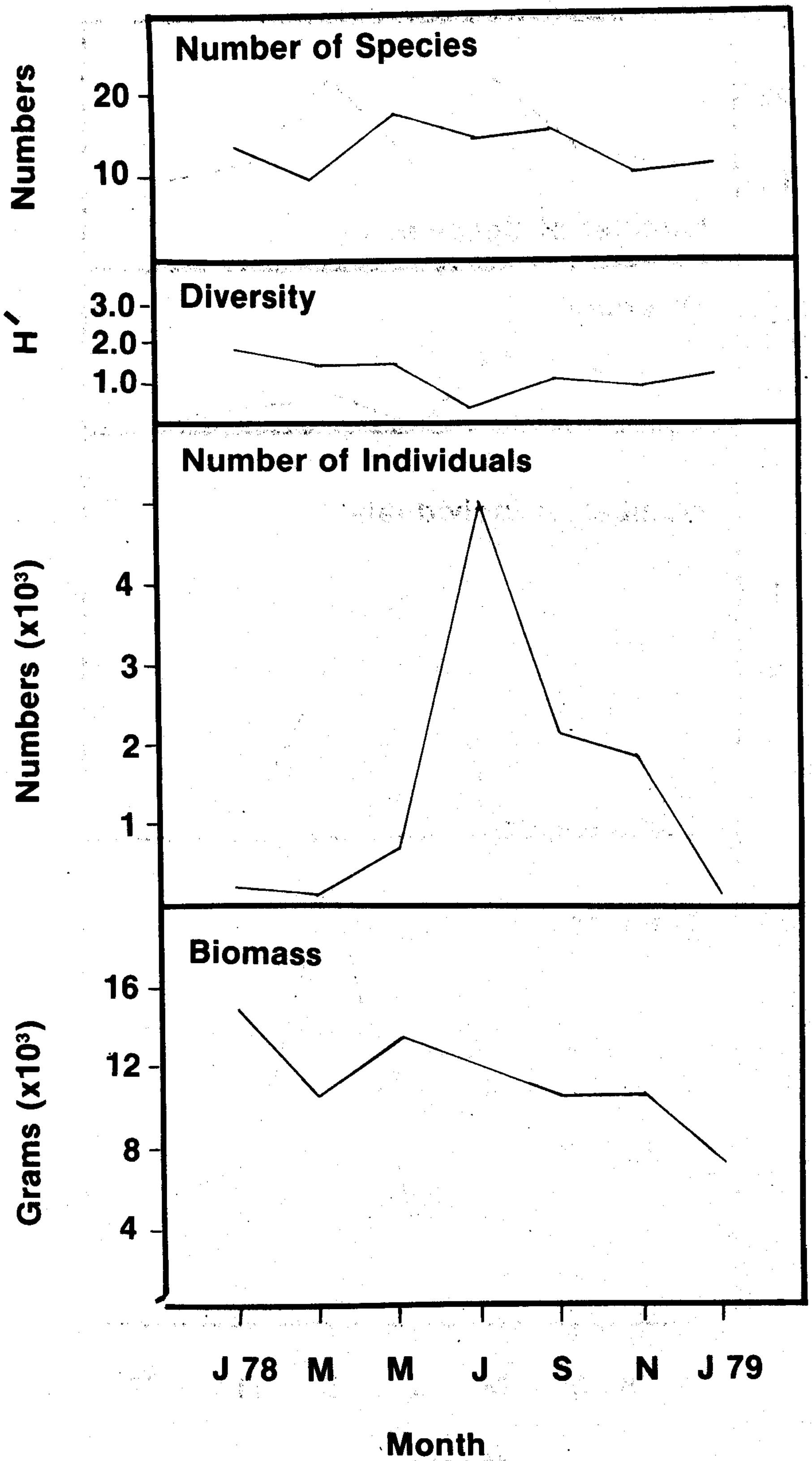


Figure 12. Bimonthly variation (January 1978-January 1979) in number of species, diversity H' (for numbers), number of individuals and biomass (g) of juvenile/adult fishes collected by all methods at Station 3 in upper Newport Bay.

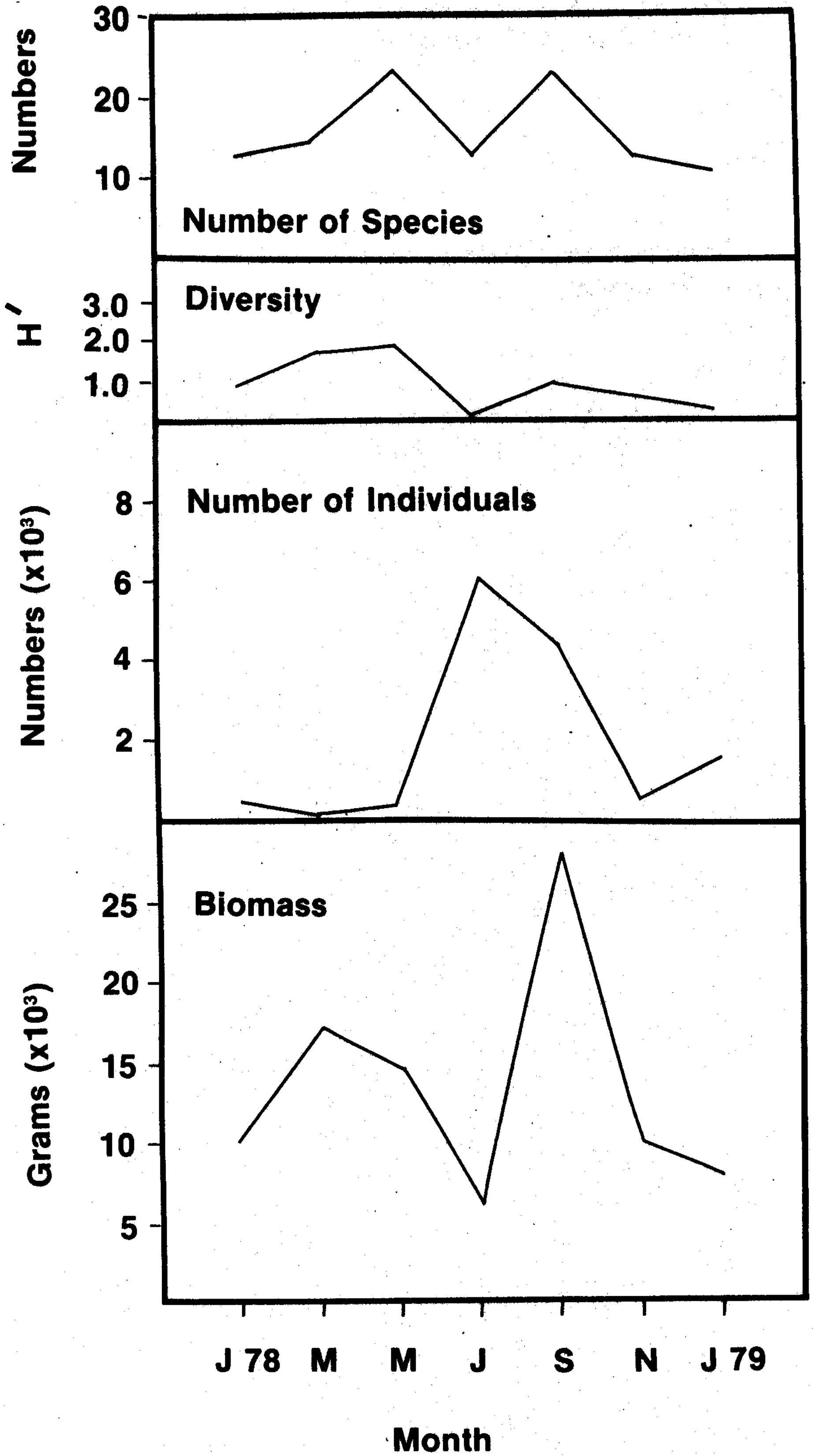


Figure 13. Bimonthly variation (January 1978-January 1979) in number of species, diversity H' (for numbers), number of individuals and biomass (g) of juvenile/adult fishes collected by all methods at Station 4 in upper Newport Bay.

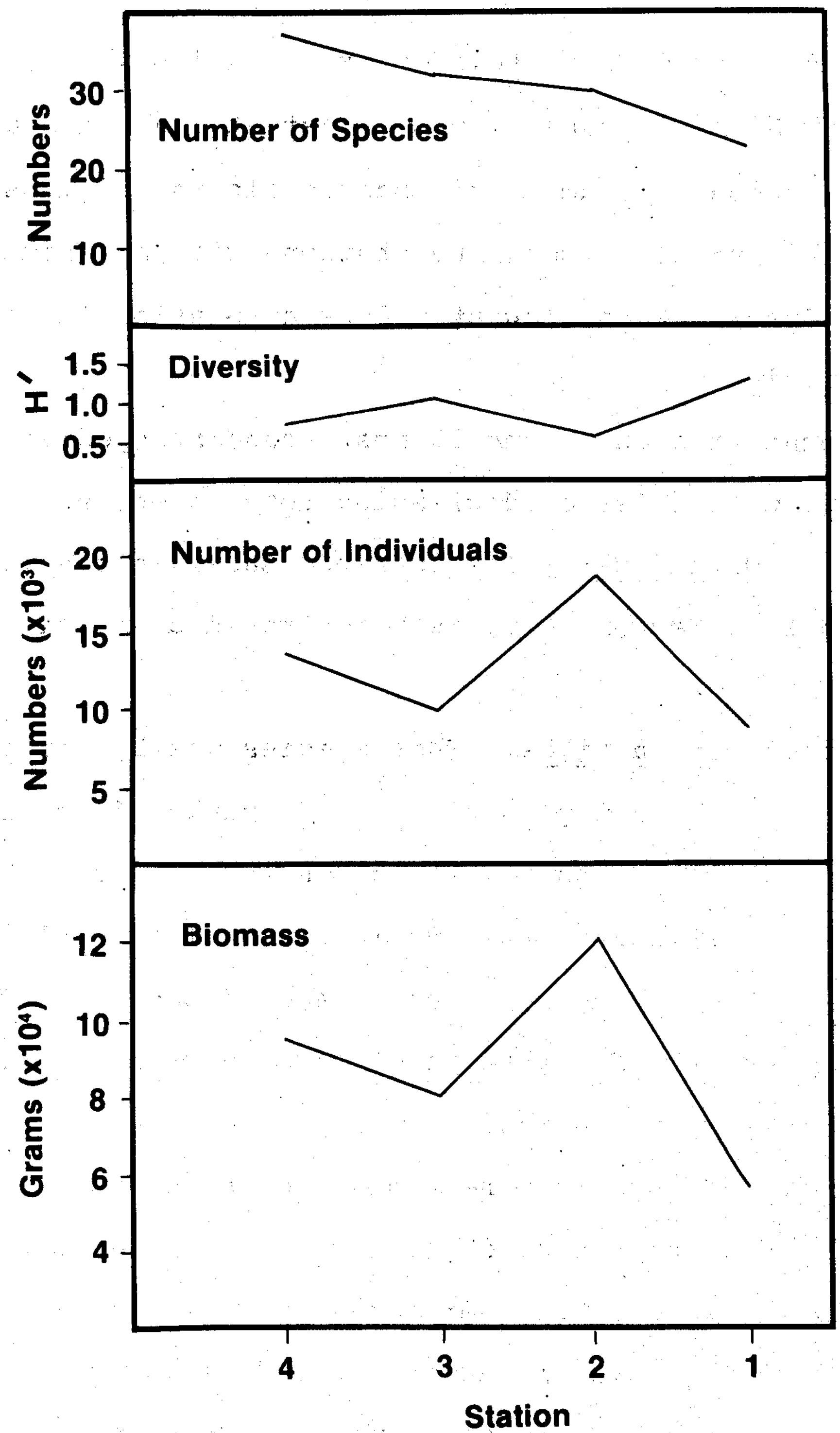


Figure 14. Variation with increasing distance into upper Newport Bay (Station 4 ⟶ Station 1) in number of species, diversity H' (for numbers), number of individuals and biomass (g) of juvenile/adult fishes collected by all methods over seven bimonthly periods (January 1978–January 1979).

species richness gradually declined from Station 4 to Station 1. Diversity H' (for numbers) was lowest at Station 2 and highest at Station 1. Number of individuals and biomass showed similar patterns among the stations with a maximum for both at Station 2 and lowest values at Station 1.

Principal Species

An account of each of the 11 most abundant species is presented below in order of decreasing total numbers. Information on *Morone saxatilis* (striped bass), a species transplanted into Newport Bay, is also provided in this section.

1) *Atherinops affinis*. This species was by far the most abundant in the study (Table 1). It ranked first in the catch of all four inshore methods as well as seventh in the otter trawl samples and second in the gill net collections (Tables 2, 3, 5-8). The great abundance of fishes in July was primarily due to the presence of large numbers of *A. affinis*, especially juveniles.

Atherinops affinis occurred in a wide size range (10-175 mm SL) during the study (Figure 15). In January 1978, a broad range of sizes were present followed in March by a much narrower range of larger individuals only. Length frequencies were strongly bimodal in May and moderately so in July. Size classes were loosely clustered around intermediate lengths in September. This pattern continued into November accompanied by an increase in mean fish size. Length frequencies in January 1979 were

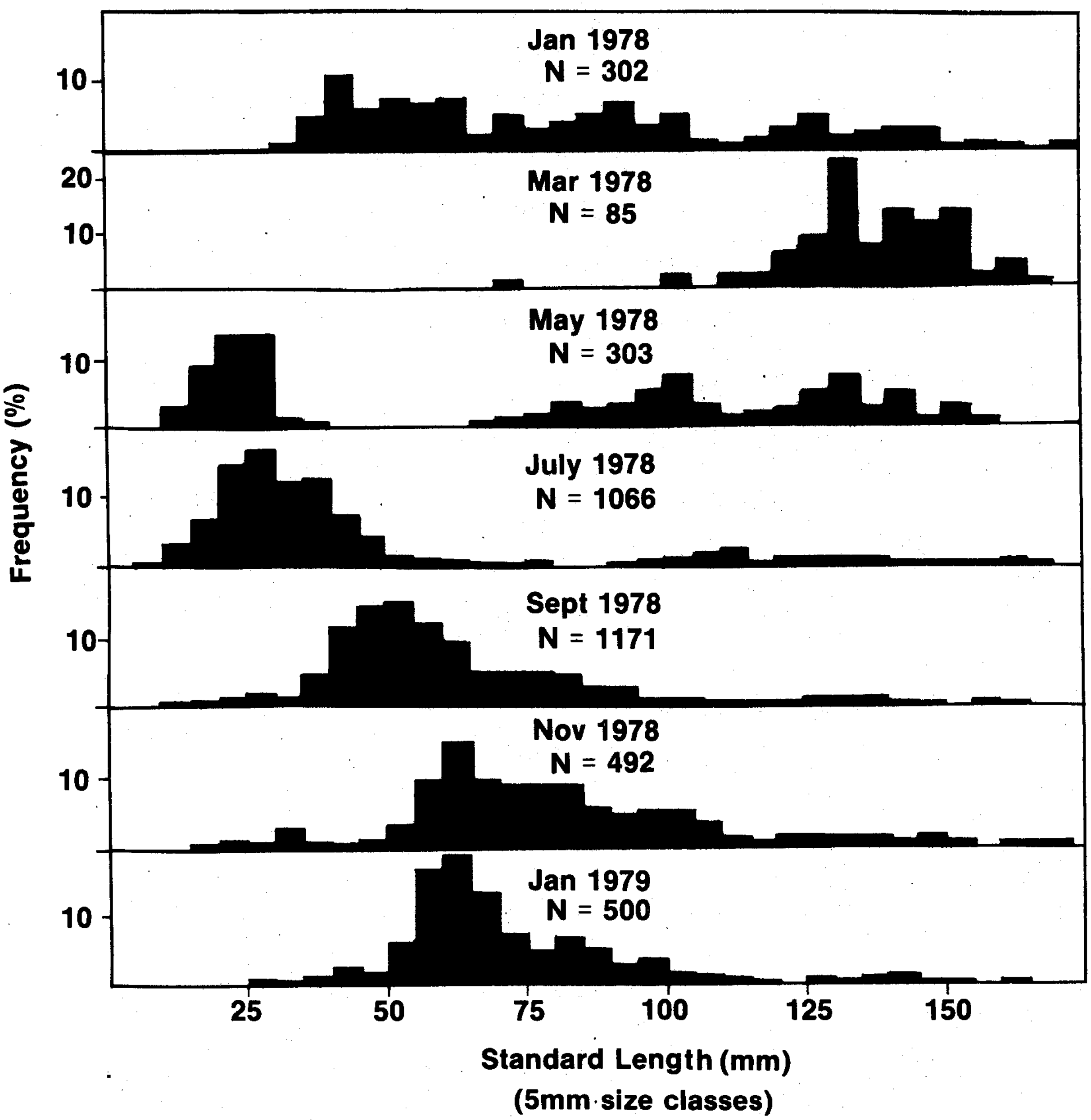


Figure 15. Bimonthly (January 1978-January 1979) length-frequency histograms of Atherinops affinis from upper Newport Bay. N = sample size.

similar to those in November.

2) Fundulus parvipinnis. This species was the second most abundant fish in the study comprising 8.7% of the individuals but only 1.3% of the biomass (Table 1). It was collected almost exclusively in inshore areas and pannes of Stations 1-3 and ranked first in the total panne samples (Table 4). Abundance of F. parvipinnis was greatest in September followed in order by November and July.

Fundulus parvipinnis occurred in a broad size range (15-100 mm SL) during the study period (Figure 16). In January (1978) and March, length frequencies were strongly unimodal around the 25 mm interval. Small fish (15-20 mm SL) as well as a wide size range of larger individuals were present in May. A broad range of sizes was also found in July but a pronounced peak occurred at 20 mm SL. Length frequencies in September were mostly clustered around 50 mm SL. Although no distinct peaks were present in November, most individuals were in the 20-50 mm SL range. The January catch consisted mostly of small fish (20-30 mm SL).

3) Gambusia affinis. This species was the third most abundant fish in the study constituting 3.6% of the individuals and 0.2% of the biomass (Table 1). It occurred exclusively at inshore and panne locations, mainly in the panne at Station 1. In small seine inshore collections (Table 3), G. affinis ranked fourth in abundance and, in the panne samples (Table 4), second in total numbers and third in biomass. It was most abundant in September and July and

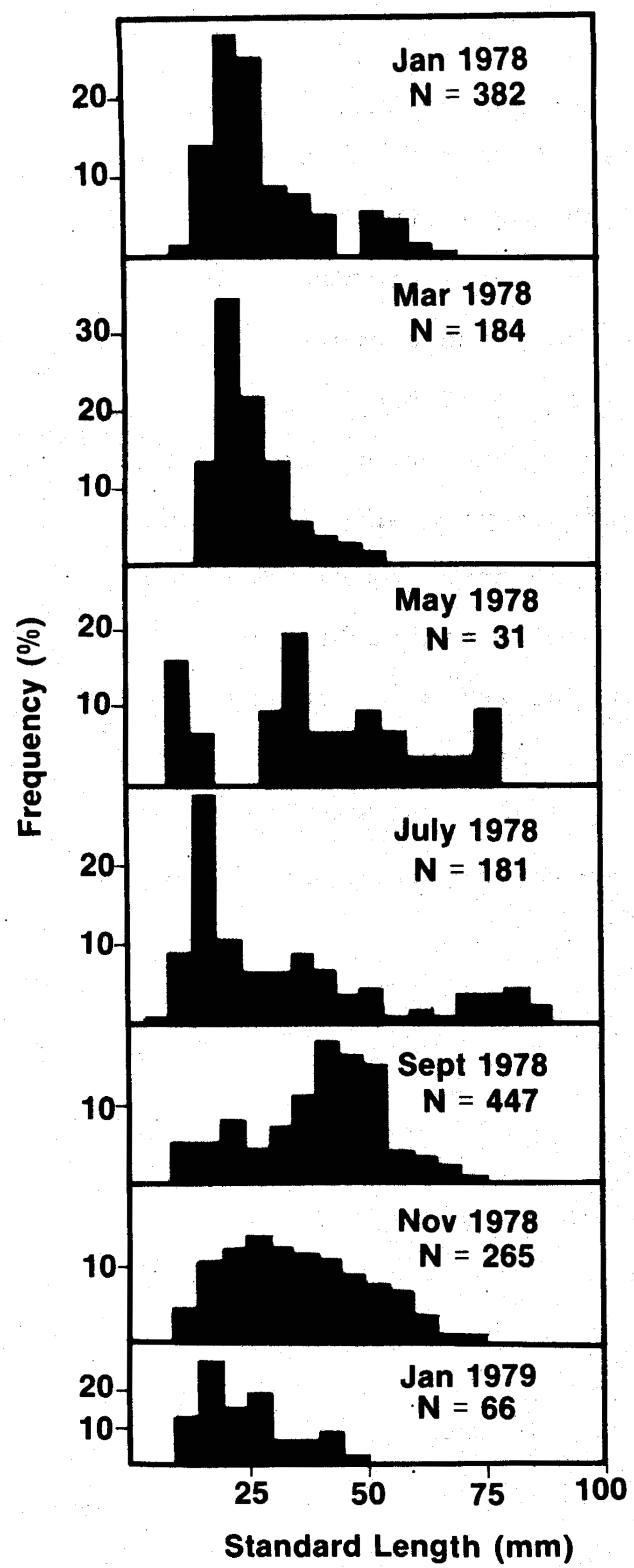


Figure 16. Bimonthly (January 1978-January 1979) length-frequency histograms of Fundulus parvipinnis from upper Newport Bay. N = sample size.

at Station 1. None was collected at Station 4.

4) Anchoa compressa. This engraulid was the fourth most abundant fish in the study making up 2.8% of total numbers and 5.4% of total biomass (Table 1). It was taken in both channel and inshore areas. The fish ranked fourth in the bag seine catch (Table 2), fifth in the small seine (Table 3), fourth in the otter trawl (Table 7) and first in the gill net collections (Table 8). Anchoa compressa was most abundant in the upper bay in May, at Station 2. Few individuals were collected at Station 4.

Length frequencies for A. compressa (Figure 17) were strongly bimodal in January (1978), March and May, slightly bimodal in July and unimodal with increasingly narrower size ranges in September and November. None was collected in January 1979.

5) Anchoa delicatissima (slough anchovy). This second engraulid species was fifth in total individuals comprising 2.4% of numbers and 1.4% of biomass (Table 1). It also was collected in both channel and inshore areas. The fish ranked second in the bag seine catches (Table 2), ninth in the small seine (Table 3) and fifth in the otter trawl samples (Table 7). It reached greatest abundance in September at Station 4.

6) Clevelandia ios (arrow goby). This species was sixth in total numbers accounting for 2.1% of individuals and 0.1% of total biomass (Table 1). It was captured almost exclusively in inshore and panne habitats. This species ranked seventh in bag seine samples (Table 2), second in

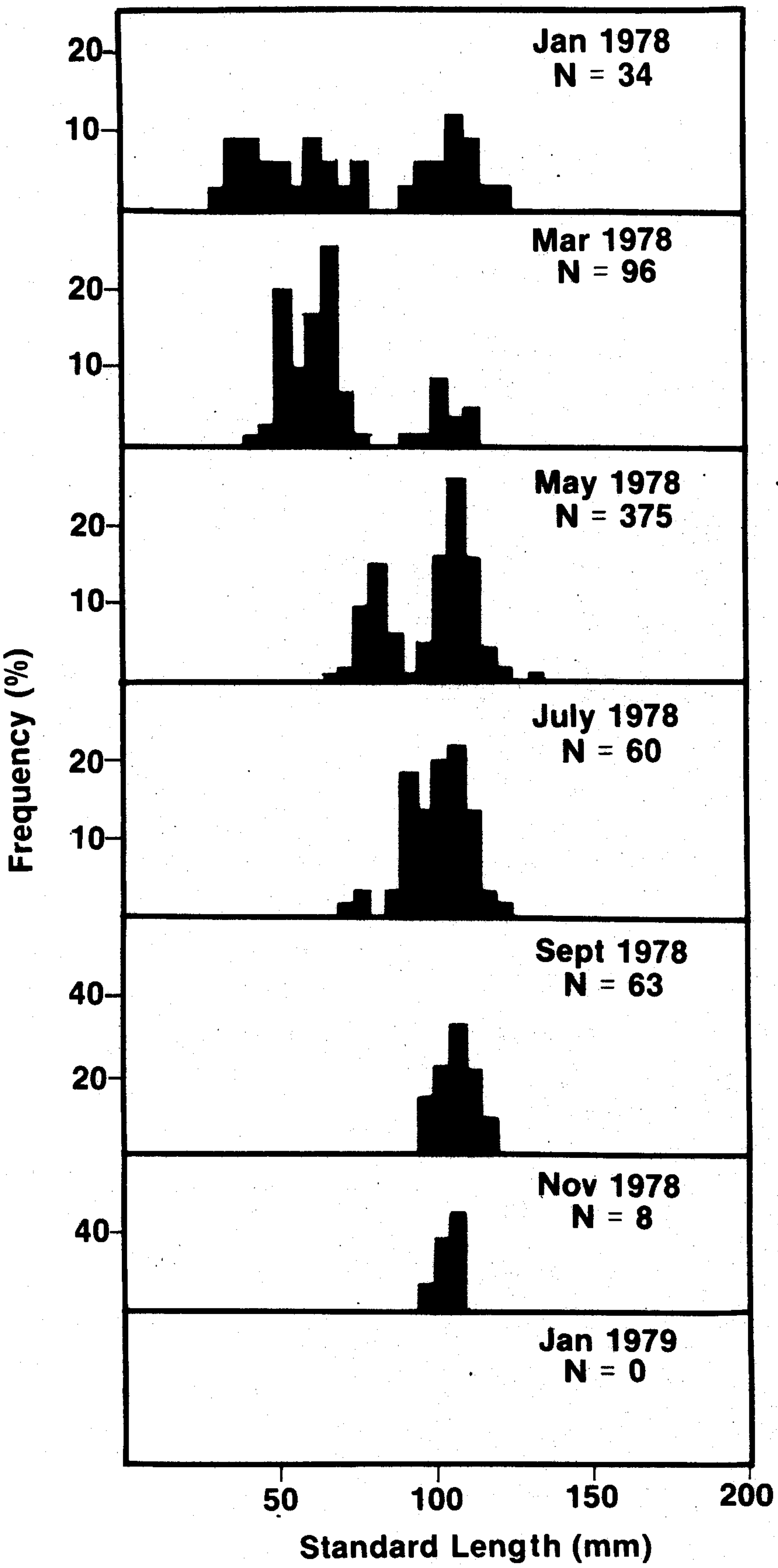


Figure 17. Bimonthly (January 1978-January 1979) length-frequency histograms of Anchoa compressa from upper Newport Bay. N = sample size.

small seine (inshore) samples (Table 3), third in drop net samples (Table 5), second in the square enclosure (Table 6) and fourth in panne collections (Table 4). It was taken in greatest numbers at Stations 2 and 3, with the peak of abundance occurring in July.

Length frequencies for C. ios (Figure 18) ranged from strongly unimodal to moderately bimodal in the size span of 15 to 60 mm SL. Size classes clustered around a peak of 40 mm SL in January 1978, 25-30 mm in March, 30 mm in July, and 30-35 mm in September and November. Bimodal trends were evident in May and January 1979.

7) Cymatogaster aggregata. This embiotocid was seventh in total numbers comprising 1.8% of the individuals and 2.9% of the biomass (Table 1). It was collected at both channel and inshore locations. This species ranked fifth in the bag seine (Table 2), fifth in the drop net (Table 5), first in the otter trawl (Table 7) and ninth in the gill net samples (Table 8). It was taken primarily at Stations 3 and 4 and in greatest numbers in May and in second highest numbers in September.

Length frequencies for C. aggregata (Figure 19) shifted markedly over the study period. In January (1978) and May the samples were composed almost totally of larger (75-140 mm SL) individuals whereas in May strongly bimodal size classes were present. The abundant, smaller sized fish clustered around 40 mm SL (25-55 mm range) and the larger fish ranged in size from 85 to 125 mm. Beginning in July, the samples

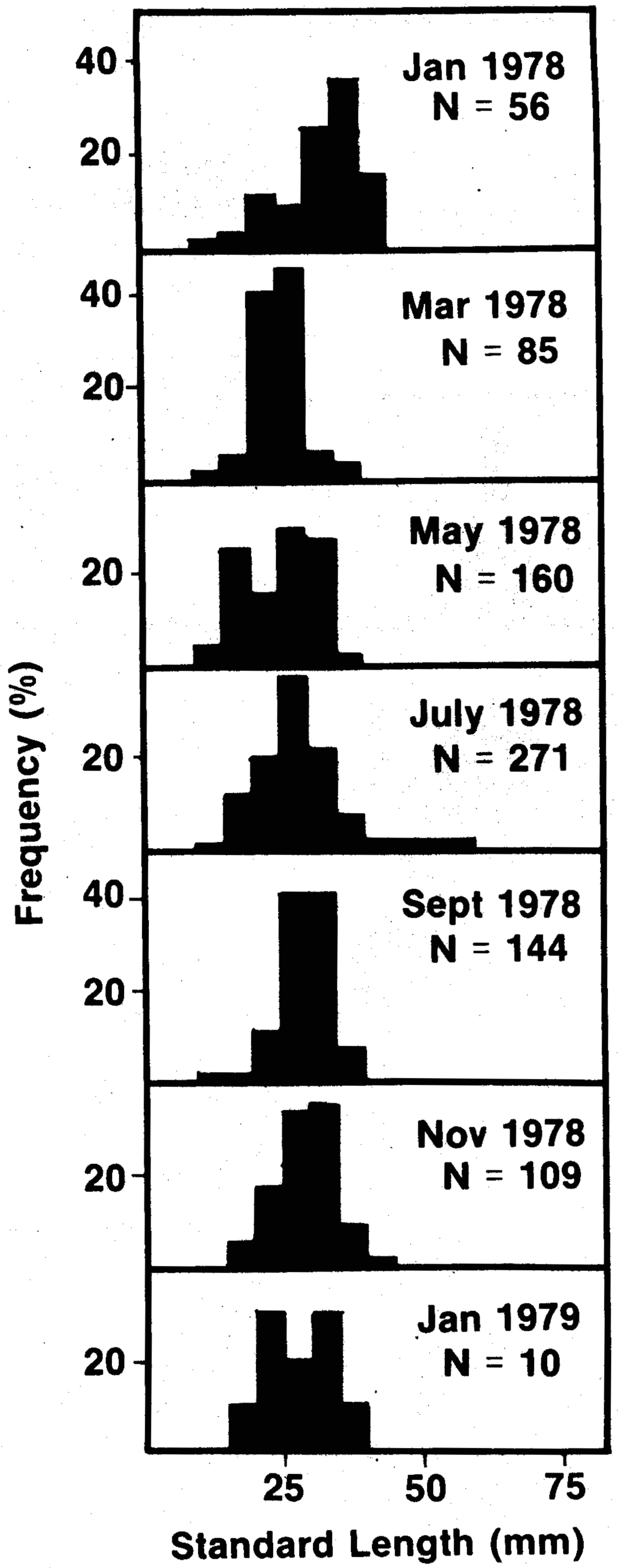


Figure 18. Bimonthly length-frequency histograms of *Clevelandia ios* from upper Newport Bay. N = sample size.

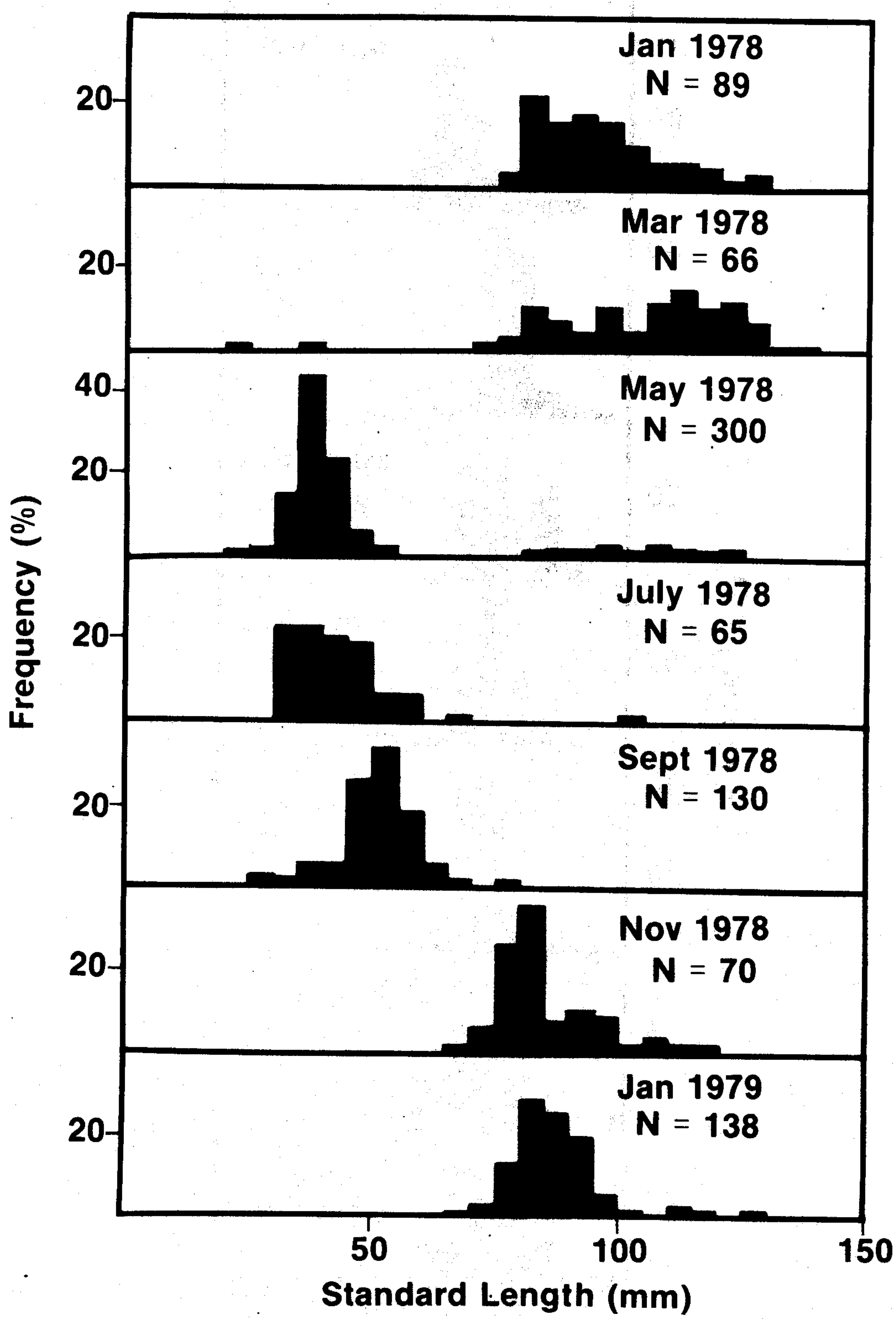


Figure 19. Bimonthly (January 1978-January 1979) length-frequency histograms of Cymatogaster aggregata from upper Newport Bay. N = sample size.

consisted of primarily small individuals which increased in size through January 1979.

8) Engraulis mordax (northern anchovy). This third engraulid was eighth in total numbers accounting for 0.5% of the individuals and 0.1% of the biomass (Table 1). The fish was collected in both channel and inshore areas with most specimens being captured in the bag seine (Table 2) and a small number in the otter trawl (Table 7). It was taken almost entirely at Stations 2 and 4 and mainly during July and September. None was collected in January (1978), March or May.

9) Umbrina roncador (yellowfin croaker). This species was ninth in total numbers accounting for 0.3% of the individuals and 6.4% of the biomass (Table 1). It was captured only in the channel and ranked eighth in otter trawl samples (Table 7) and third in gill net collections (Table 8). The fish was taken at all stations but mainly at Stations 2-4, and primarily in July and September.

10) Gillichthys mirabilis (longjaw mudsucker). This goby ranked tenth in total numbers comprising 0.3% of the individuals and 0.3% of the biomass (Table 1). It was caught almost exclusively inshore and in the pannes. This species ranked twelfth in the bag seine (Table 2), sixth in the small seine (Table 3), seventh in the drop net (Table 5) and fifth in the square enclosure samples (Table 6). Two specimens were taken in the otter trawl (Table 7). The fish was the fifth most abundant species collected in the pannes

(Table 4). Most specimens were captured at Stations 1-3, mainly in July.

11) Mugil cephalus. This species was eleventh in total numbers comprising 0.3% of the individuals; however, it ranked first in biomass accounting for 35.6% of the weight of the total catch (Table 1). Small juveniles were caught inshore and in the pannes whereas the larger individuals were taken in the channel. The fish ranked tenth in the bag seine (Table 2), twelfth in the small seine (Table 3) and sixth in the panne collections (Table 4). In the gill net samples (Table 8), M. cephalus ranked fourth in numbers but was by far the most important contributor to total biomass. One specimen was collected in the otter trawl (Table 7).

Length classes for M. cephalus (Figure 20) were widely separated and generally trimodal in January (1978) and March indicating the presence of very small, intermediate and larger-sized individuals. Fish size became progressively larger through November followed in January 1979 by the occurrence again of very small juveniles as well as large individuals.

12) Morone saxatilis. Individuals of this species were planted in upper Newport Bay by the California Department of Fish and Game in April of each year from 1974 through 1977. Approximately 10,000 - 14,000 individuals ranging in size from 100 to 150 mm SL were released each year.

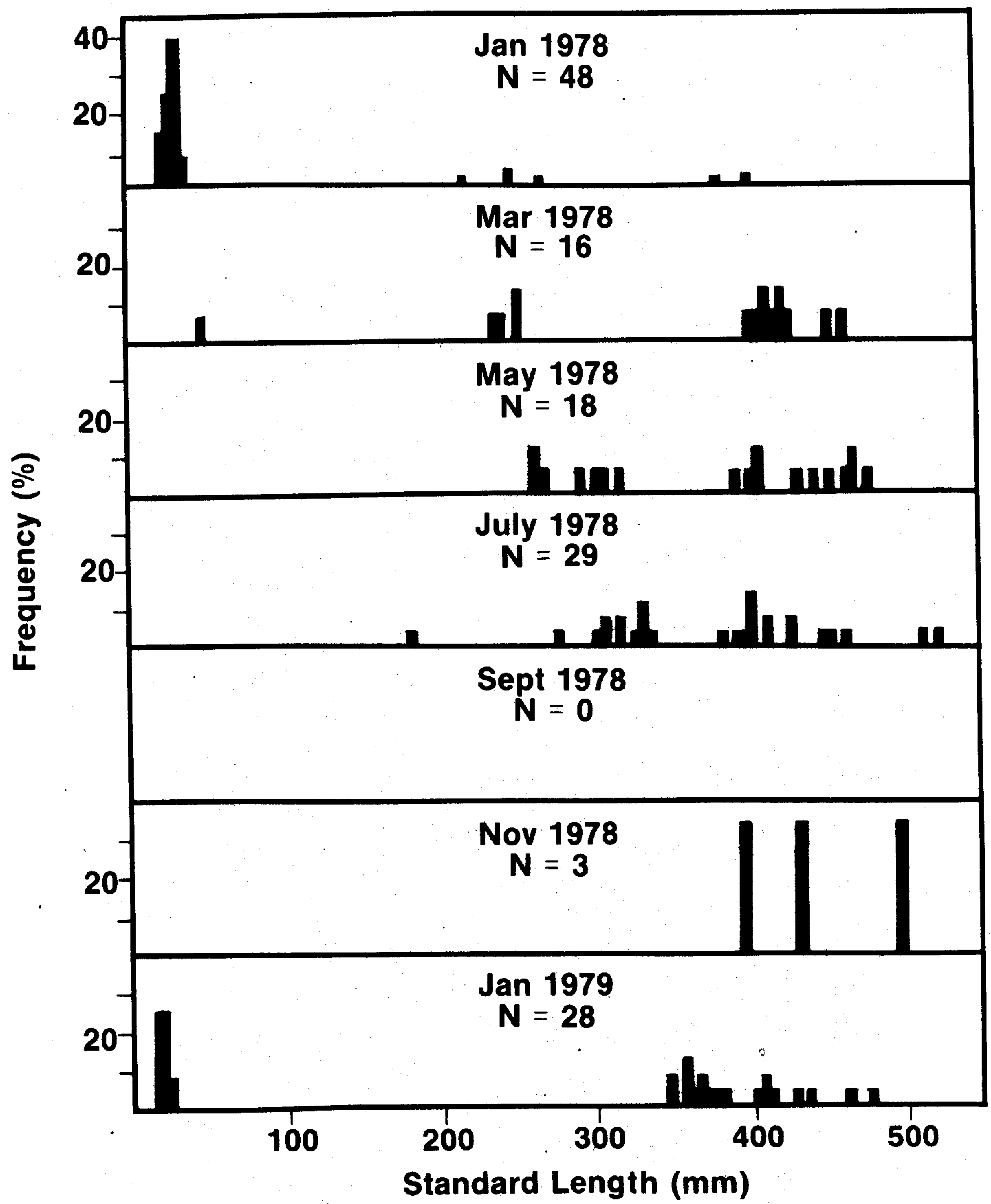


Figure 20. Bimonthly (January 1978-January 1979) length-frequency histograms of Mugil cephalus from upper Newport Bay. N = sample size.

In the present study, a total of 36 *M. saxatilis* weighing 16,638 g were collected. The species ranked seventeenth in total numbers, accounting for 0.1% of the individuals, and sixth in biomass, contributing 4.7% to the total weight of the samples (Table 1). Fifteen specimens in a size range of 135-265 mm SL were collected in the otter trawl (Table 7) while 21 larger individuals ranging in size from 240 to 460 mm SL were captured in the gill net (Table 8). Most (83%) of the specimens were obtained at Stations 2 and 3; 31 of the 36 individuals were collected during the first three sampling periods (January-May 1978). The fins of a high proportion (>50%) of specimens were infested with cymothoid isopod parasites.

Egg and Larval Populations

A total of 92,085 eggs was collected in the 56 plankton tows taken in upper Newport Bay during the seven bimonthly periods (Table 9). These eggs belonged to seven taxa and an unknown category. Eggs of *Anchoa compressa* overwhelmingly dominated the catch making up 99.7% of the total numbers. The unknown category ranked second accounting for 0.2% of all eggs collected. The number of egg taxa peaked in March and declined thereafter whereas the overwhelming majority (98.9%) of individual eggs were collected in May due to the great abundance of *A. compressa* eggs (Table 9; Figure 21). Egg numbers peaked in May at Stations 1-3 (Figures 22-24) and were greatest in September and January (1978) at Station 4

Table 9. Number and density of egg and larval taxa collected in plankton tows at four stations in upper Newport Bay during seven bimonthly periods (January 1978-January 1979).

TAXA	JANUARY 1978 No.	% of Total	No./m³	MARCH No.	% of Total	No./m³	MAY No.	% of Total	No./m³	JULY No.	% of Total	No./m³
EGGS												
Anchoa compressa							91,765	99.97	261.439	9	64.3	0.023
Unknown eggs	52	73.2	0.146	20	36.4	0.042	4	<0.1	0.011	2	14.3	0.005
Sciaenid				28	50.9	0.059	1	<0.1	0.002	3	21.4	0.008
Pleuronichthys ritteri	18	25.3	0.051	4	7.3	0.008						
Anchoa delicatissima							16	<0.1	0.046			
Engraulis mordax				3	5.5	0.006	2	<0.1	0.006			
Atherinops affinis							2	<0.1	0.006			
Pleuronichthys coenosus	1	1.4	0.003									
TOTALS	71		0.199	55		0.115	91,790		261.510	14		0.036

TAXA	SEPTEMBER No.	% of Total	No./m³	NOVEMBER No.	% of Total	No./m³	JANUARY 1979 No.	% of Total	No./m³	TOTALS No.	% of Total	No./m³
EGGS												
Anchoa compressa										91,774	99.7	30.114
Unknown eggs	122	97.6	0.273	2	100.0	0.004	26	92.9	0.044	228	0.2	0.075
Sciaenid										32	<0.1	0.011
Pleuronichthys ritteri	2	1.6	0.005				2	7.1	0.003	26	<0.1	0.009
Anchoa delicatissima										16	<0.1	0.005
Engraulis mordax										5	<0.1	0.002
Atherinops affinis										2	<0.1	0.001
Pleuronichthys coenosus	1	0.8	0.002							2	<0.1	0.001
TOTALS	125		0.280	2		0.004	28		0.048	92,085		30.216

TAXA	JANUARY 1978 No.	% of Total	No./m³	MARCH No.	% of Total	No./m³	MAY No.	% of Total	No./m³	JULY No.	% of Total	No./m³
LARVAE												
Clevelandia ios	13	72.2	0.037	4	5.7	0.008	13	11.5	0.037	8	36.4	0.021
Anchoa spp.							79	69.9	0.225			
Gobiid				3	4.3	0.006				3	13.6	0.008
Engraulis mordax	2	11.1	0.006	33	47.1	0.069						
Ilypnus gilberti							10	8.9	0.029	7	31.8	0.018
Quietula ycauda							6	5.3	0.017	1	4.5	0.003
Sciaenid	1	5.6	0.003	16	22.9	0.034						
Gillichthys mirabilis	1	5.6	0.003	2	2.9	0.004						
Genyonemus lineatus				10	14.3	0.021						
Syngnathus auliscus												
Atherinops affinis				1	1.4	0.002	4	3.5	0.011			
Syngnathus leptorhynchus							1	0.9	0.003			
Syngnathus sp.										1	4.5	0.003
Anchoa delicatissima										1	4.5	0.003
Heterostichus rostratus												
Gibbonsia sp.												
Hypsoblennius jenkinsi										1	4.5	0.003
Sebastes sp.				1	1.4	0.002						
Cottid												
Pleuronichthys ritteri	1	5.6	0.003									
TOTALS	18		0.051	70		0.147	113		0.322	22		0.057

TAXA	SEPTEMBER No.	% of Total	No./m³	NOVEMBER No.	% of Total	No./m³	JANUARY 1979 No.	% of Total	No./m³	TOTALS No.	% of Total	No./m³
LARVAE												
Clevelandia ios	33	41.8	0.074	29	40.3	0.065	14	26.9	0.024	114	26.8	0.037
Anchoa spp.										79	18.5	0.026
Gobiid	11	13.9	0.025	20	27.8	0.045	14	26.9	0.024	51	12.0	0.017
Engraulis mordax	1	1.3	0.002	1	1.4	0.002	4	7.7	0.007	41	9.6	0.013
Ilypnus gilberti	12	15.2	0.027	4	5.6	0.009				37	8.7	0.012
Quietula ycauda	9	11.4	0.020	18	25.0	0.040	4	7.7	0.007	34	8.0	0.011
Sciaenid										17	4.0	0.006
Gillichthys mirabilis	1	1.3	0.002				11	21.2	0.019	15	3.5	0.005
Genyonemus lineatus							3	5.8	0.005	13	3.1	0.004
Syngnathus auliscus	9	11.4	0.020							9	2.1	0.003
Atherinops affinis										5	1.2	0.002
Syngnathus leptorhynchus	1	1.3	0.002							2	0.5	0.001
Syngnathus sp.	1	1.3	0.002							2	0.5	0.001
Anchoa delicatissima										1	0.2	<0.001
Heterostichus rostratus							1	1.9	0.002	1	0.2	<0.001
Gibbonsia sp.	1	1.3	0.002							1	0.2	<0.001
Hypsoblennius jenkinsi										1	0.2	<0.001
Sebastes sp.										1	0.2	<0.001
Cottid							1	1.9	0.002	1	0.2	<0.001
Pleuronichthys ritteri										1	0.2	<0.001
TOTALS	79		0.177	72		0.162	52		0.089	426		0.140

(Figure 25). The number of egg taxa was highest at Stations 3 and 4 and the number of individual eggs by far the greatest at Station 2 (91.2% of total), again, due to the large numbers of A. compressa eggs (Figure 26).

A total of 426 larvae from 20 taxa was captured in the same plankton tows (Table 9). Larvae of Clevelandia ios were the most abundant comprising almost 27% of the total individuals. Anchoa spp. and Gobiid ranked second and third accounting for 18.5% and 12.0% of the larvae, respectively. More than one-half (59%) of the catch was made up of members of the family Gobiidae. The number of larval taxa was lowest in January (1978) and highest in March, September and January (1979) whereas the fewest individuals were collected in January (1978) and July and the largest numbers in May (Table 9; Figure 21). Larval numbers were highest at Station 1 (Figure 22) and Station 3 (Figure 24) in May, at Station 2 in September (Figure 23) and at Station 4 in March (Figure 25). Richness of larval taxa was greatest at Station 1 and the number of individuals greatest at Stations 3 and 4 although between-station differences, especially for numbers, were relatively small (Figure 26).

Community Structure

Cumulative Species Curves

In order to estimate the adequacy of sampling the range of juvenile/adult species in the upper bay, cumulative curves of species numbers were plotted as a function of the cumulative number of sample sets taken each month of the

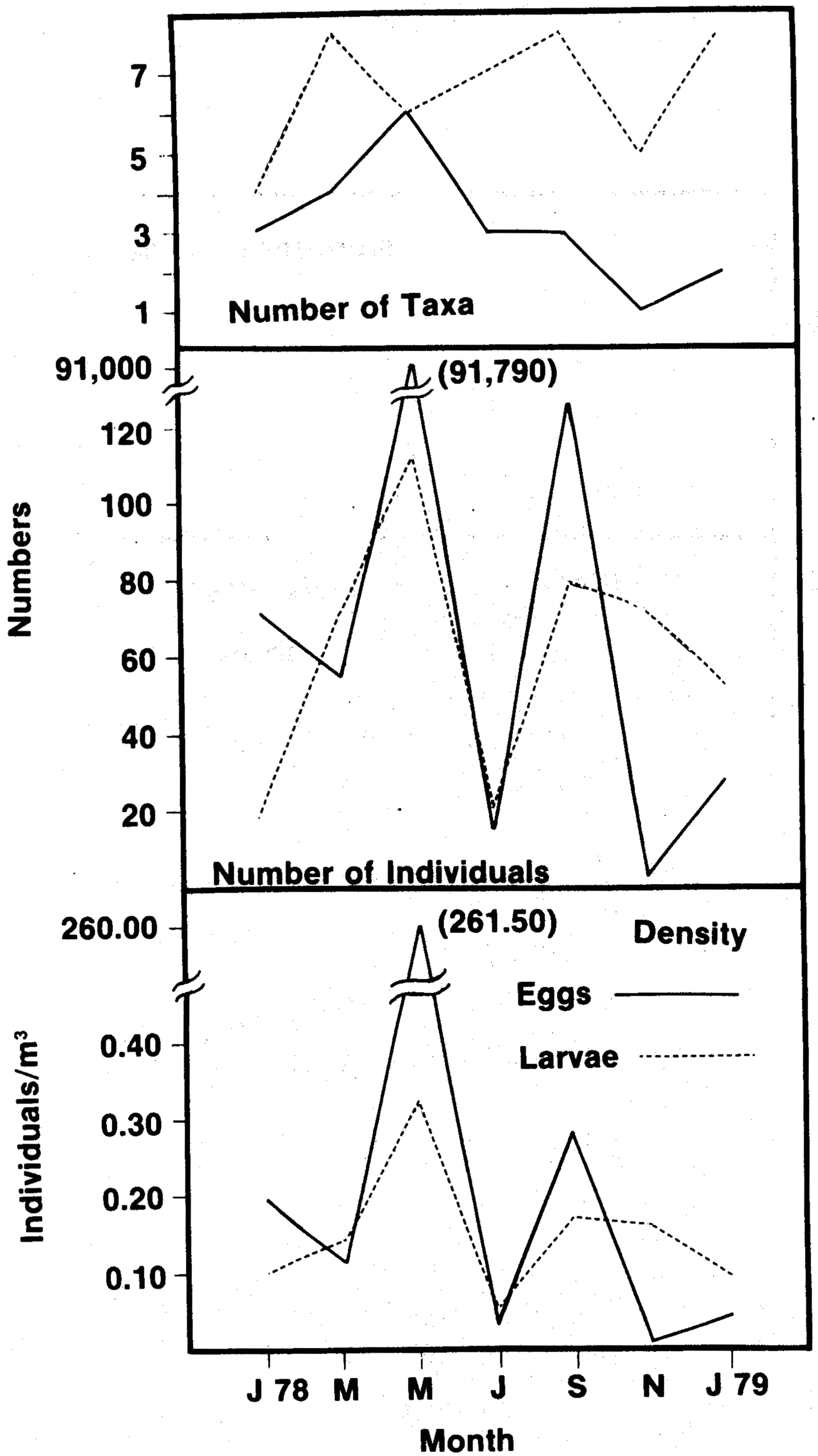


Figure 21. Bimonthly variation (January 1978-January 1979) in number of taxa, number of individuals and density of fish eggs and larvae collected at Stations 1-4 combined in upper Newport Bay.

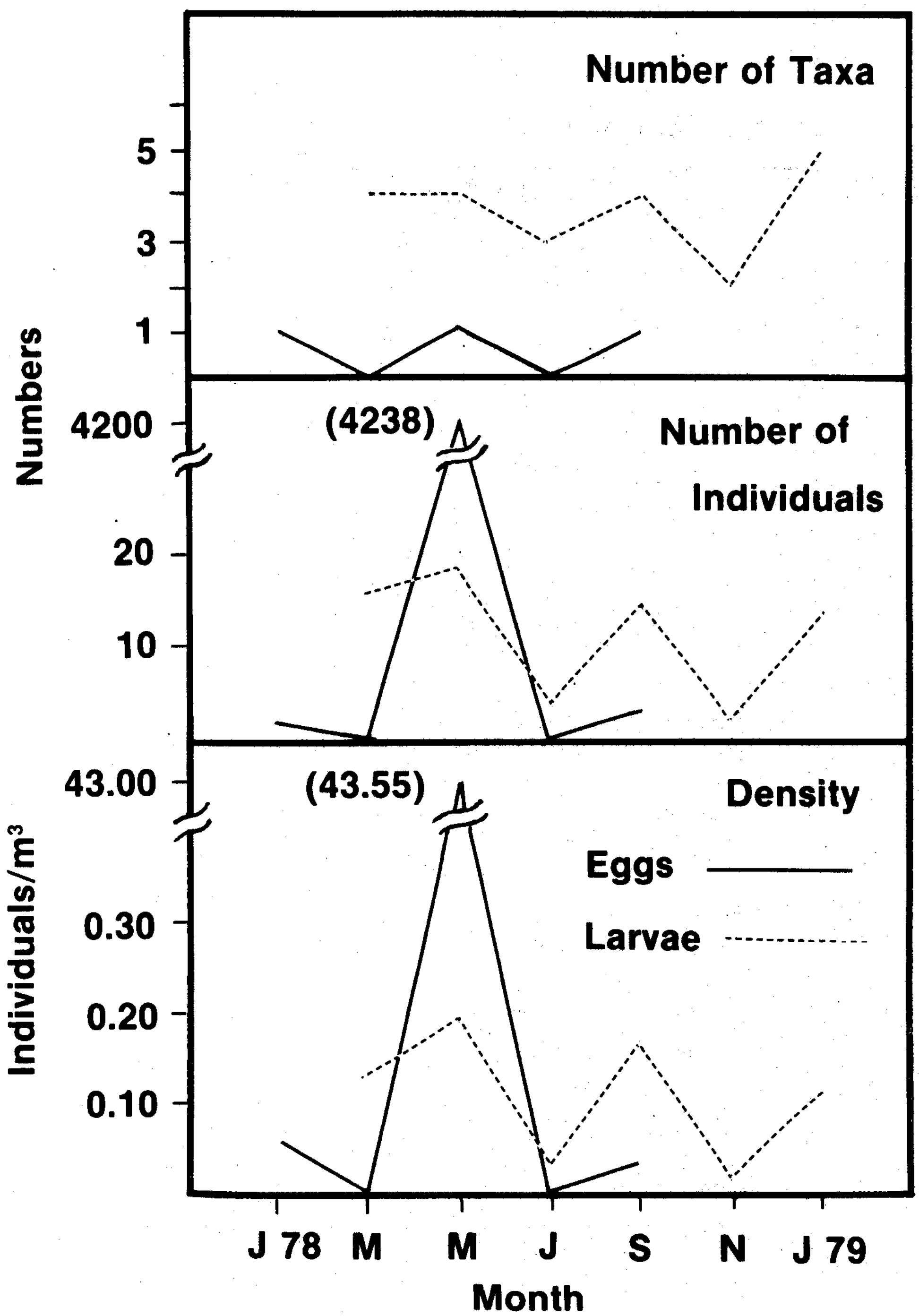


Figure 22. Bimonthly variation (January 1978–January 1979) in number of taxa, number of individuals and density of fish eggs and larvae collected at Station 1 in upper Newport Bay.

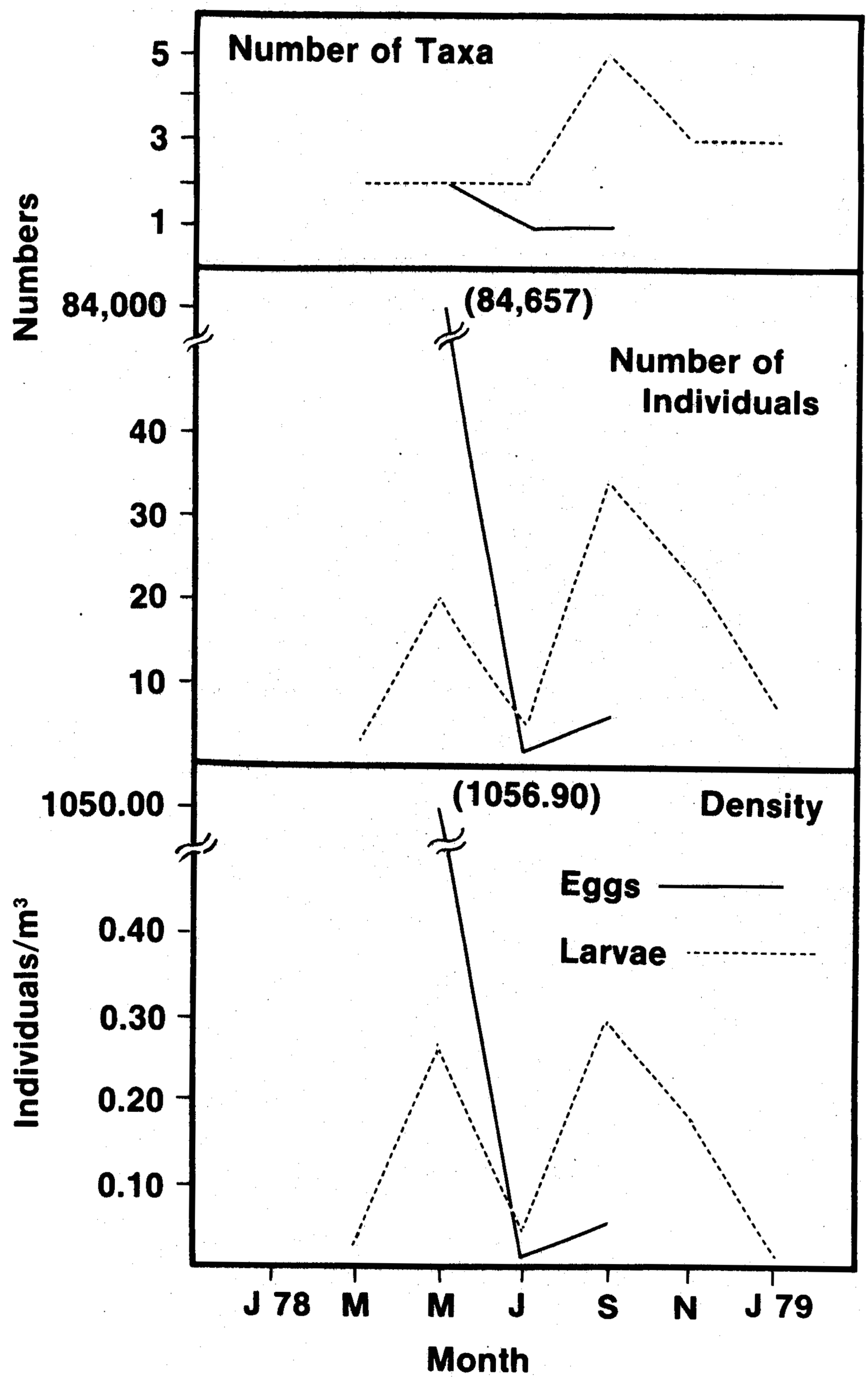


Figure 23. Bimonthly variation (January 1978--January 1979) in number of taxa, number of individuals and density of fish eggs and larvae collected at Station 2 in upper Newport Bay.

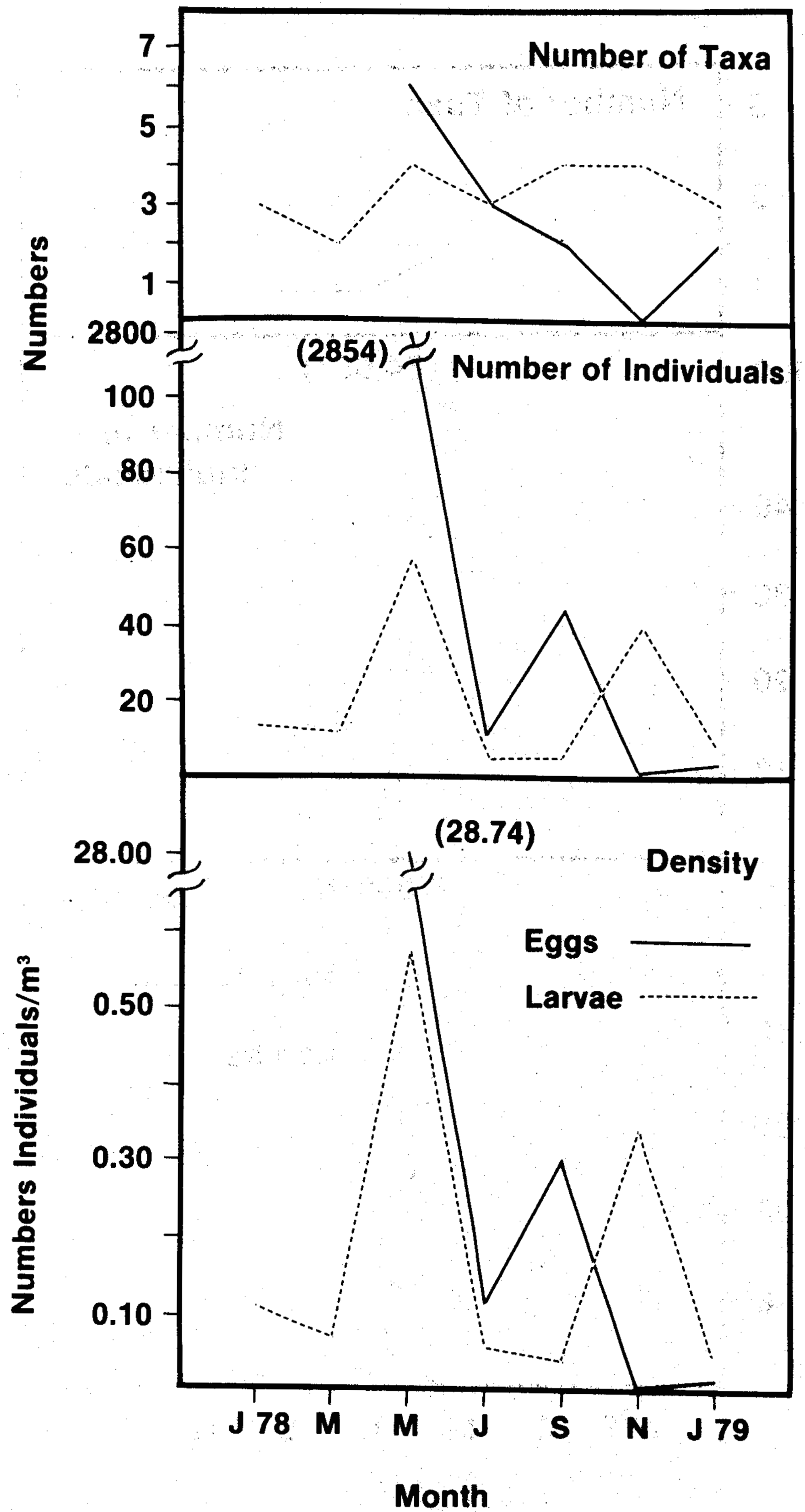


Figure 24. Bimonthly variation (January 1978-January 1979) in number of taxa, number of individuals and density of fish eggs and larvae collected at Station 3 in upper Newport Bay.

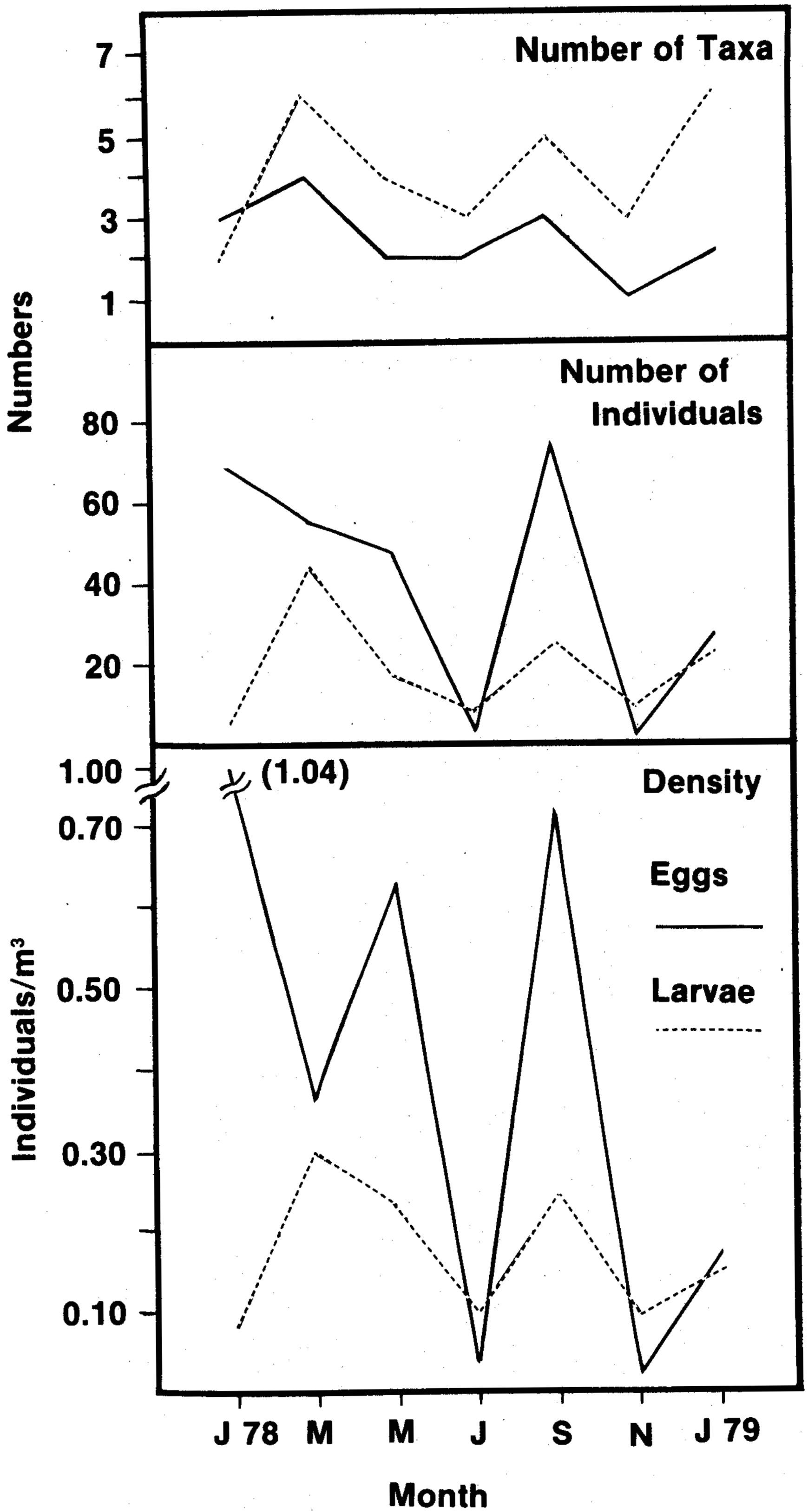


Figure 25. Bimonthly variation (January 1978–January 1979) in number of taxa, number of individuals and density of fish eggs and larvae collected at Station 4 in upper Newport Bay.

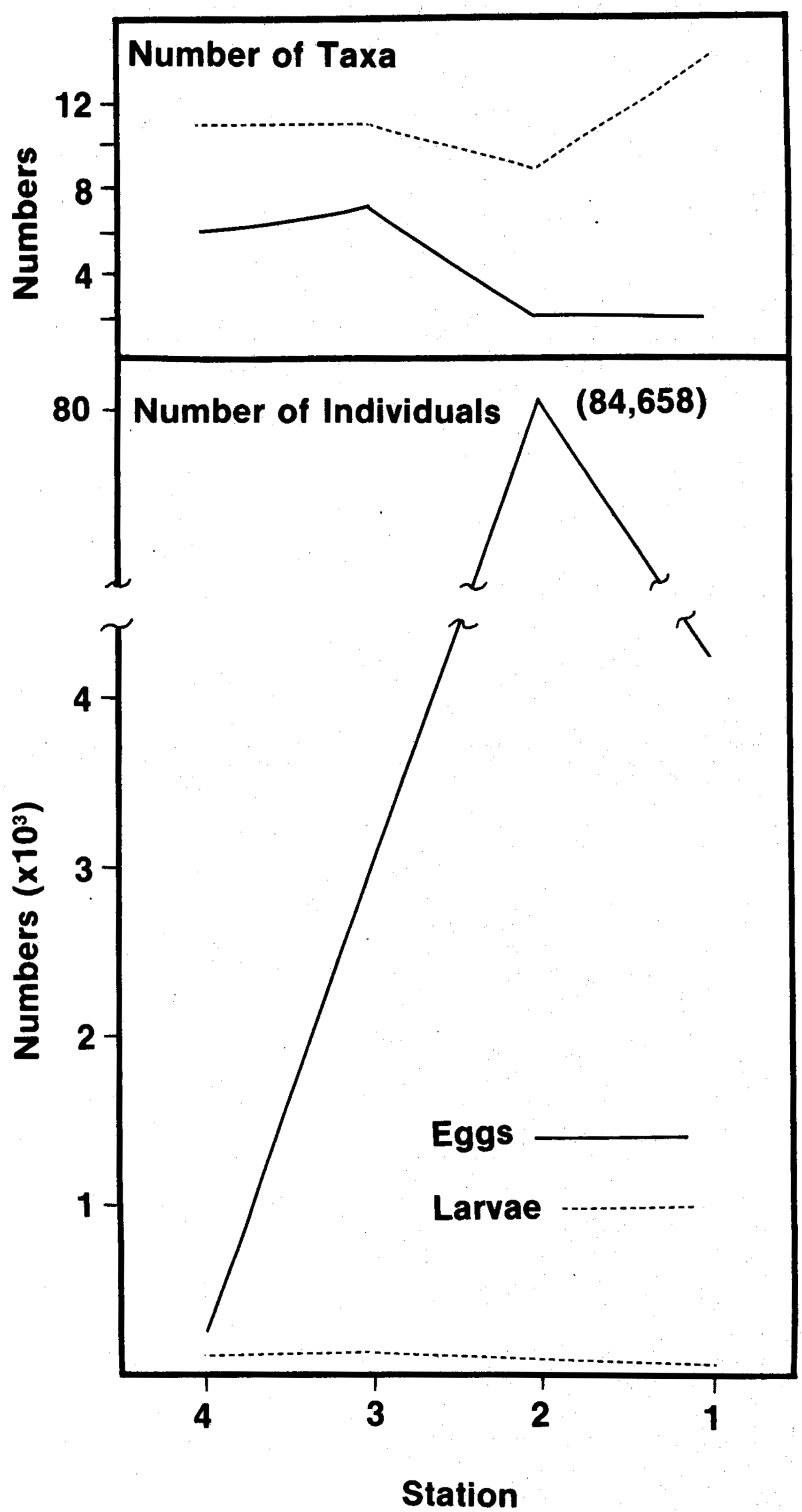


Figure 26. Variation with increasing distance into upper Newport Bay (Station 4 → Station 1) in number of taxa and number of individuals of fish eggs and larvae collected over seven bimonthly periods (January 1978–January 1979).

study period (Figure 27). Each of the three monthly curves were generated from species collected in sample sets each composed of randomly selected samples from each of the six sampling methods. Samples from all four stations formed the sample pool for each method. In most cases (17 of the 21 curves), $\geq$ 80% of the species were obtained with 55% of the samples. Curves for May, July and September rose sharply whereas those for the other four months more gradually reached asymptotic levels.

Species Associations

Clustering of juvenile/adult species based on abundance in each sample produced eight distinct species groups (Figure 28). The largest dichotomy ($\simeq$ 148% distance) was between eight species (1-2 individuals each) taken mainly by otter trawl and gill net (Group VIII) and the rest of the species. The next largest dichotomy ($\simeq$ 130% distance) was between species groups I-IV and groups V-VII. The former groups consisted largely of inshore/panne species collected by seines, drop net and square enclosure whereas the latter groups were primarily composed of channel-inhabiting species captured by otter trawl and gill net.

Group I was made up primarily of resident, inshore species. *Fundulus parvipinnis* and *Gambusia affinis*, the components of Subgroup A, are high intertidal and panne-dwelling species. *Clevelandia ios* and *Gillichthys mirabilis*, the two gobiids comprising Subgroup B, are burrow-inhabiting fishes of the shallows and pannes.

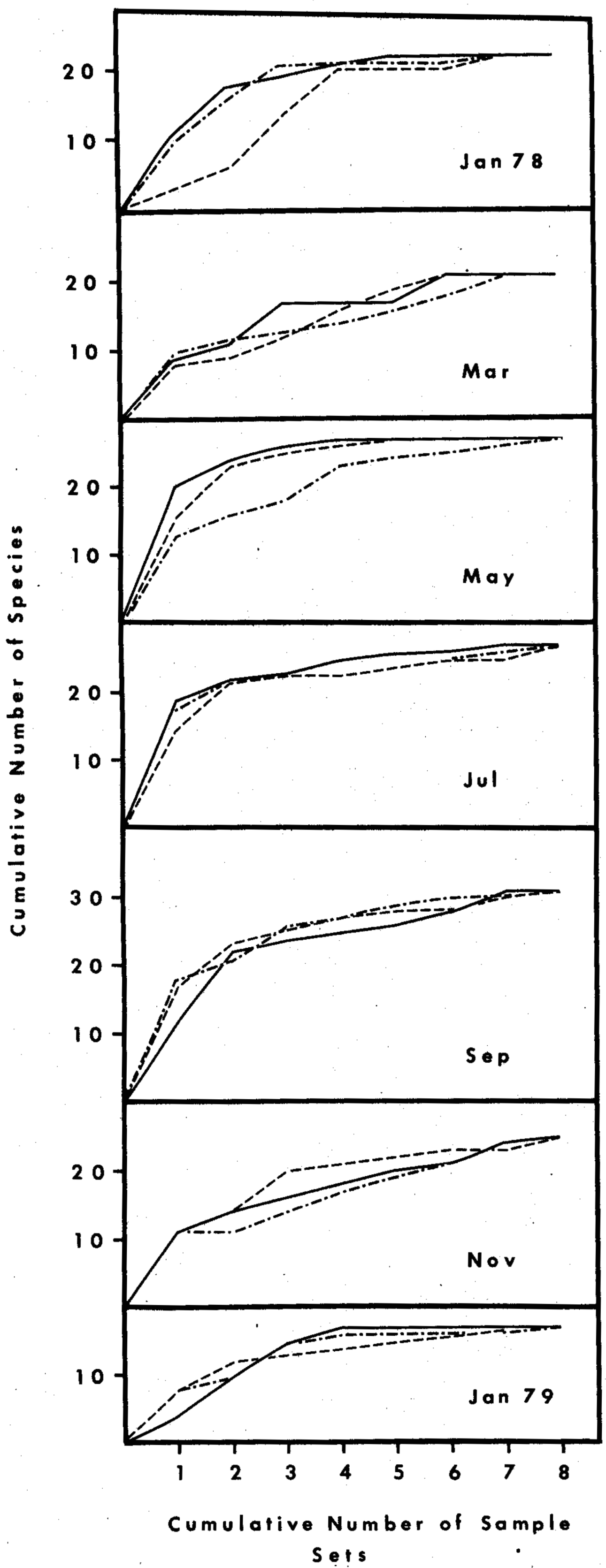


Figure 27. Cumulative number of juvenile/adult fish species as a function of cumulative sample sets taken each month of the study period (January 1978-January 1979) in upper Newport Bay. Each of the three monthly curves were generated from species collected in sample sets each composed of randomly selected samples from each of the six sampling methods. Samples from all four stations formed the sample pool for each method.

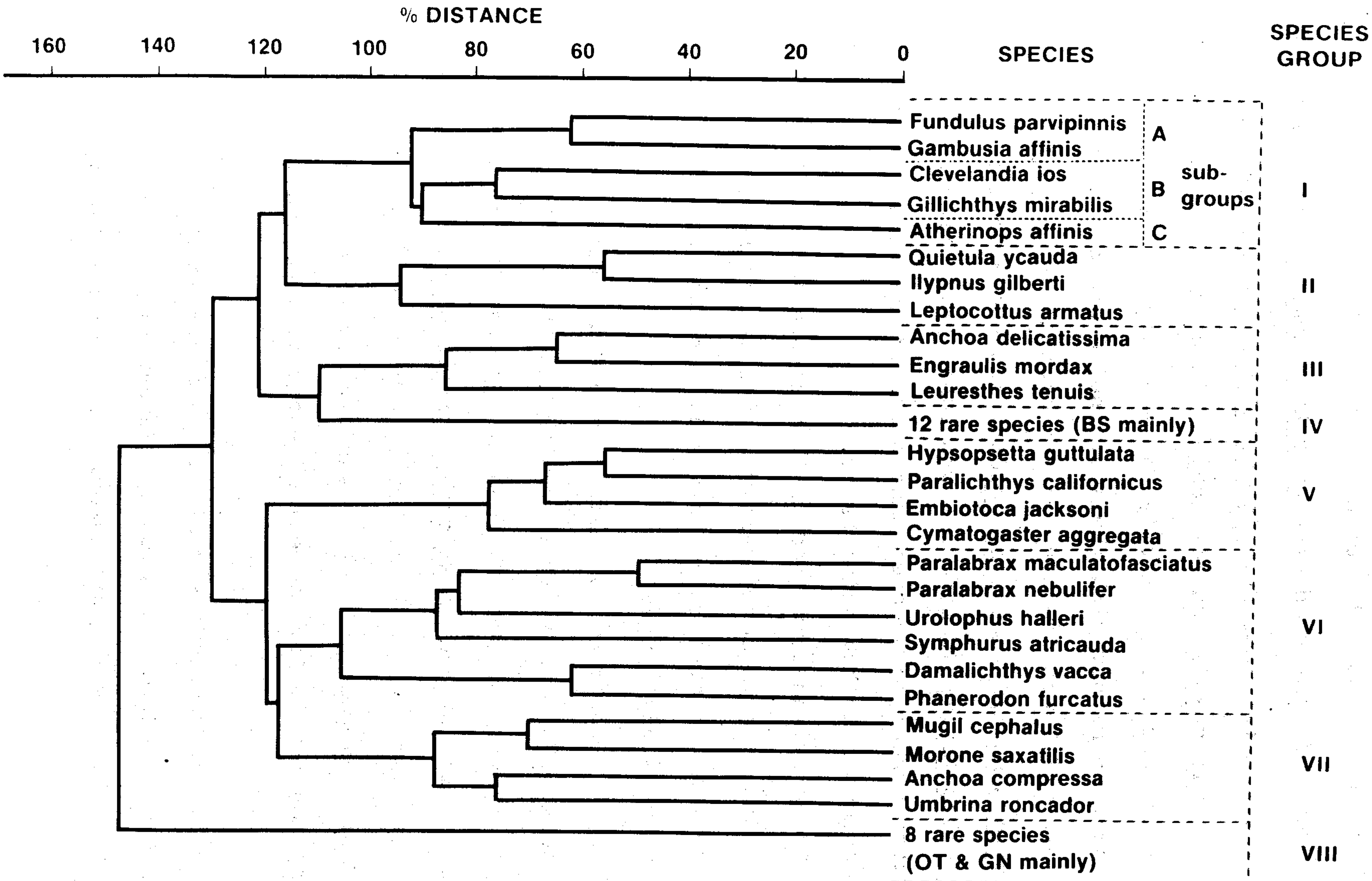


Figure 28. Dendrogram of the clustering of juvenile/adult fish species based on abundance in samples taken by all methods at Stations 1-4 combined in upper Newport Bay. Eight species groups (Roman numerals) are recognized according to the Bray-Curtis index of dissimilarity (% distance). A, B, and C are subgroups of Species Group I. BS = bag seine, OT = otter trawl, GN = gill net.

Atherinops affinis, the sole constituent of Subgroup C, is an abundant, schooling species.

Group II consisted of Leptocottus armatus (staghorn sculpin) and two gobiids, Ilypnus gilberti (cheekspot goby) and Quietula ycauda (shadow goby). These are benthic fishes that were seasonal (primarily May and July) in occurrence and captured mainly with the small seine and drop net.

Group III was composed of two engraulids, Anchoa delicatissima and Engraulis mordax, and one atherinid, Leuresthes tenuis (California grunion). All three are midwater schooling species that occurred primarily in July and September in bag seine hauls.

Group IV was comprised of 12 rare species (< 10 individuals each) caught mainly in the bag seine (as well as a few in the otter trawl and gill net) at various times during the study period.

Group V consisted of four resident demersal species that occupied the channel as adults and the shallower areas as juveniles. The two flatfishes, Hypsopsetta guttulata (diamond turbot) and Paralichthys californicus (California halibut), and the two surfperches, Cymatogaster aggregata and Embiotoca jacksoni (black surfperch), were present during most of the study period especially at Stations 3 and 4.

Group VI was composed of six channel-dwelling species that were captured periodically (January-July) in the gill net and otter trawl. The association included two serranid basses, *Paralabrax maculatofasciatus* (spotted sand bass) and *P. nebulifer* (barred sand bass), two embiotocids, *Damalichthys vacca* (pile surfperch) and *Phanerodon furcatus* (white surfperch), a flatfish, *Symphurus atricauda* (California tonguefish), and a dasyatid, *Urolophus halleri* (round stingray).

Group VII was made up of midwater, channel species that were captured seasonally in the gill net. *Mugil cephalus* and *Morone saxatilis* were taken mainly from January (1978) to May although some were collected in other months. The other two species were abundant somewhat later in the year, *Anchoa compressa* primarily in May and July, *Umbrina roncador* in July and September.

Members of the species groups identified in the dendrogram (Figure 28) are illustrated in diagrams (Figures 29-31) depicting fishes in the three principal upper bay habitats (channel, inshore, panne) during three different segments (January-March 1978, May-September 1978 and November 1978-January 1979) of the study period. During January and March 1978 (Figure 29), months characterized by heavy rainfall, a halocline existed in the water column; *Atherinops affinis* occurred beneath the halocline and was caught only at Station 4. Freshwater species such as *Gambusia affinis*, *Ictalurus melas* (black bullhead) and *Lepomis macrochirus* (bluegill) were present at inshore locations. Large *Mugil cephalus* occurred in the channel and small ones in the pannes. During May, July and September (Figure 30), increased water temperatures and higher salinities (with loss of the halocline) was accompanied by an increased number of species and a high abundance of certain species, especially Atherinops affinis. The green algal mats (primarily composed of Chaetomorpha linum, Enteromorpha sp. and Ulva lobata) that developed along the shore were concentrating areas for a large number of fishes, especially juveniles. Several species, e.g., Atherinops affinis, Anchoa compressa and Cymatogaster aggregata, occurred both inshore and in the channel; the juveniles were usually in the shallows. In November 1978 and January 1979 (Figure 31), the algal mats had disappeared, fish numbers had declined and three species, Atherinops affinis, Cymatogaster aggregata and Mugil cephalus, were present in both inshore and channel areas.

Relationship of Abiotic Factors to Fish Distribution and Abundance

Correlations calculated for total catch parameters vs. temperature, salinity and dissolved oxygen produced the following significant ($p < .05$) relationships: 1) Total number of species and number of individuals ($\log_{10}$) were positively correlated with water temperature. 2) Total number of species and biomass ($\log_{10}$) were positively correlated with salinity. 3) Total number of individuals ($\log_{10}$) was negatively correlated with dissolved oxygen levels.

Correlations of each of the seven abiotic factors with the number of individuals of the principal species

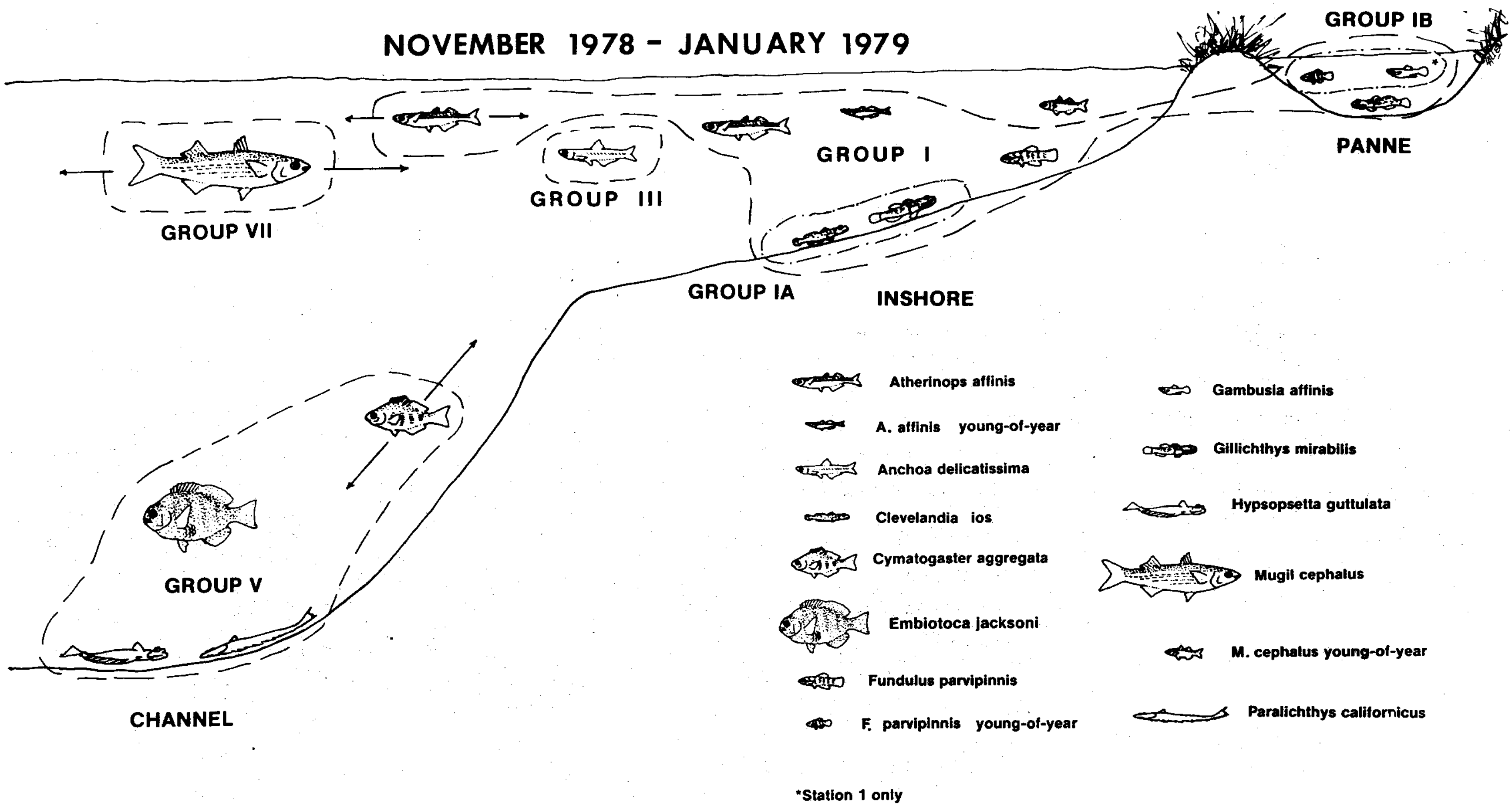


Figure 29. Illustration of the principal juvenile/adult fish species present in three habitats (channel, inshore, panne) of upper Newport Bay during January and March 1978. Inclusion of species limited to those with ≥ 4 individuals in the samples. Dashed lines enclose species groups derived from dendrogram of Figure 28. Arrows indicate inshore-offshore occurrence.

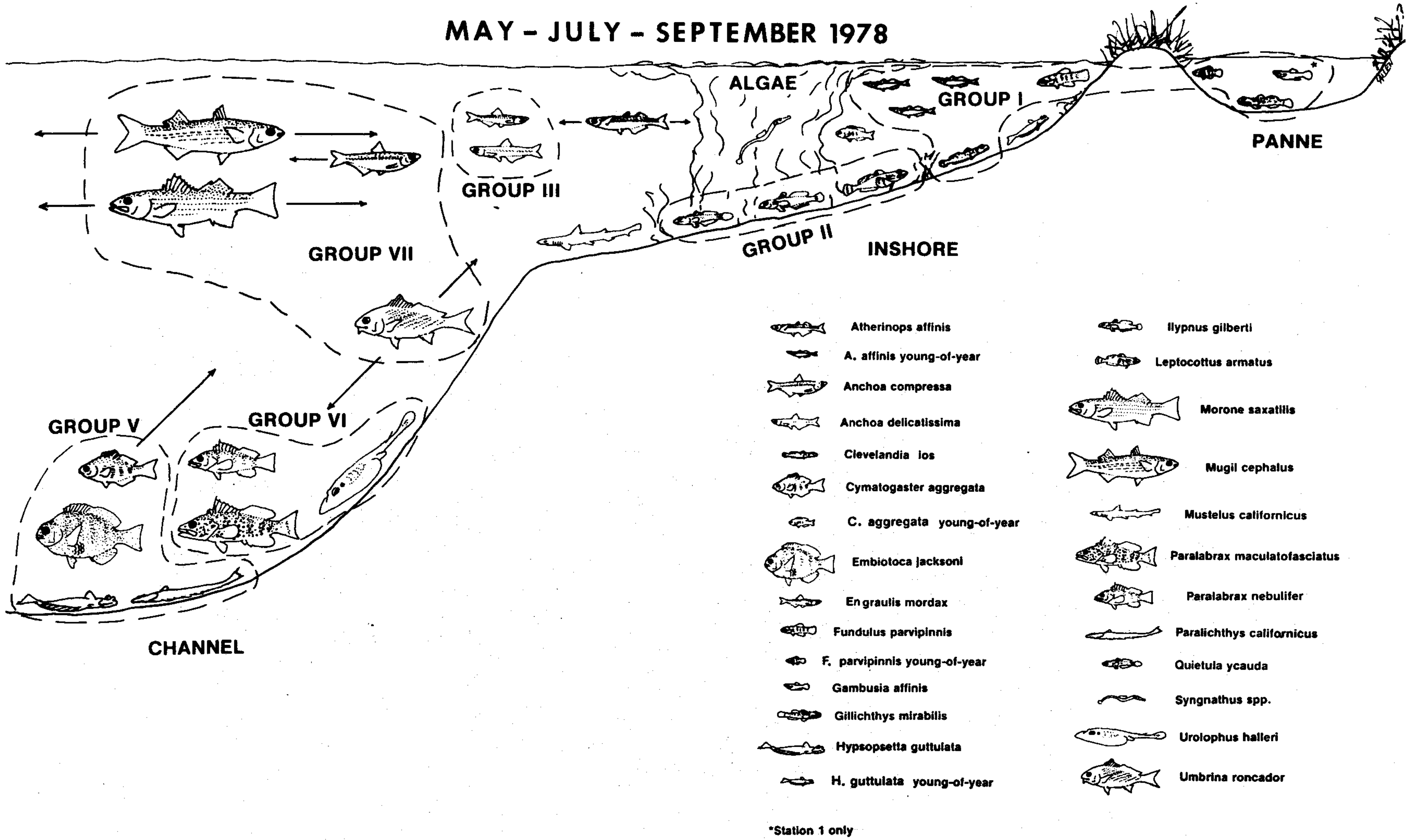


Figure 30. Illustration of the principal juvenile/adult fish species present in three habitats (channel, inshore, panne) of upper Newport Bay during May, July and September 1978. Wavy vertical lines in the inshore habitat represent green algal mat. Other information as in Figure 29.

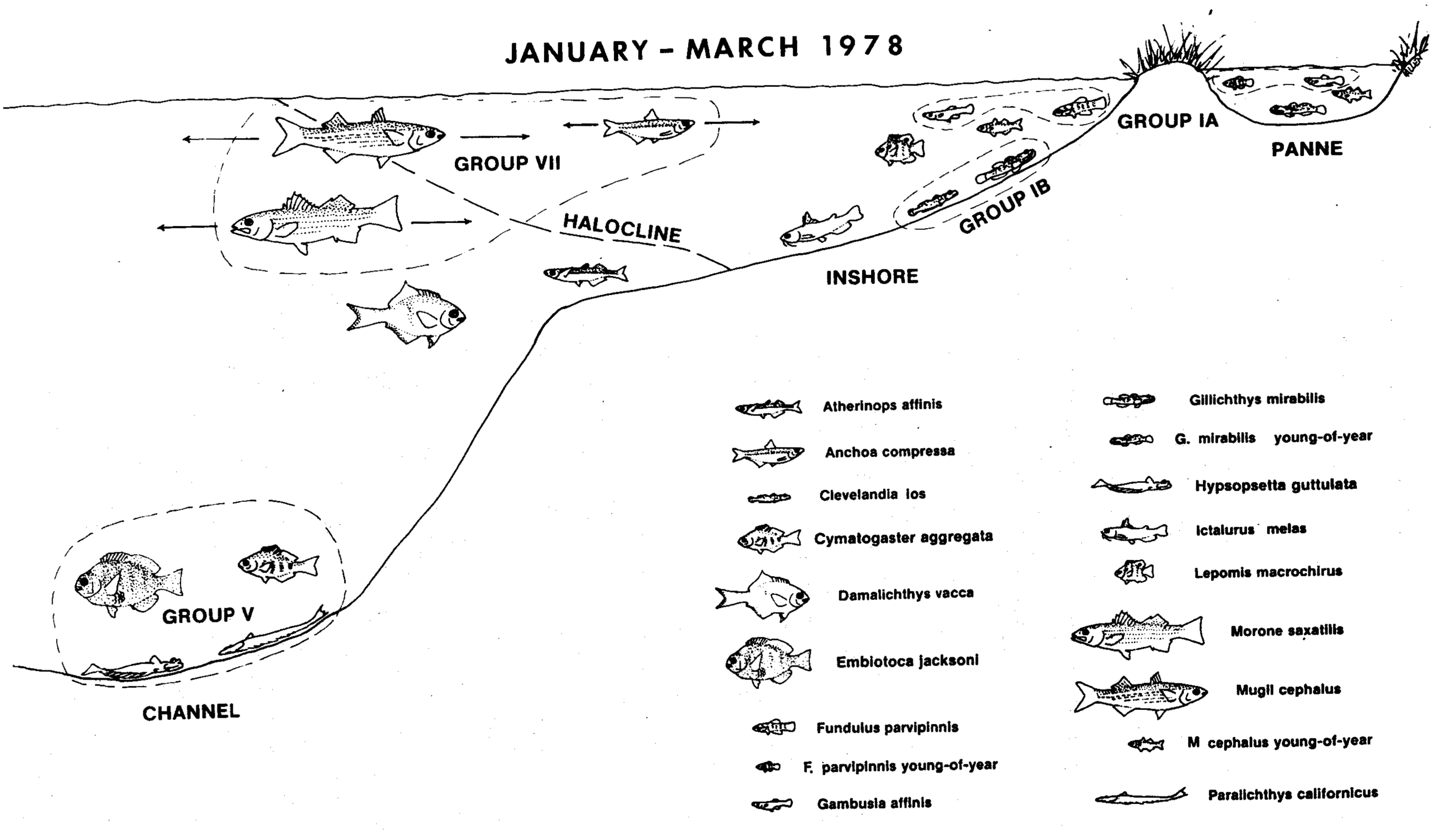


Figure 31. Illustration of the principal juvenile/adult fish species present in three habitats (channel, inshore, panne) of upper Newport Bay during November 1978 and January 1979. Other information as in Figure 29.

(those with $\geq$ 6 individuals) listed in the dendrogram (Figure 28) produced a variety of significant relationships (Table 10) that in most cases helped to explain species abundance and distribution patterns. As examples of the information contained in the ranked correlations, the following statements can be made that are consistent with general observations: 1) *Fundulus parvipinnis* occurred mainly in low salinity, shallow water in the upper reaches of the upper bay. 2) *Atherinops affinis* was most abundant in warmer waters. 3) *Paralichthys californicus* occurred primarily in deep, clear, high salinity waters. 4) *Embiotoca jacksoni* was most abundant in deep, high salinity waters in the lower portion (Station 4) of the upper bay. 5) *Mugil cephalus* was found primarily associated with fine sediment in shallow, low salinity water of high dissolved oxygen. 6) *Lepomis macrochirus* occurred in water of low salinity and low transparency. This species is not on the dendrogram but is representative of freshwater species that occurred during low salinity conditions produced by heavy rainfall early in 1978 and 1979.

Not all correlations resulted in explainable relationships. For example, the basis for the negative correlation of *Leuresthes tenuis* abundance with dissolved oxygen is unknown.

Three of the abiotic factors that most frequently produced significant correlations with species abundances

Table 10. Rank of abiotic factors significantly ($r \geq \pm 0.23$, $p < .05$) correlated with numerical abundance of 23 species ($n \geq 6$) collected during the study period (January 1978-January 1979) in upper Newport Bay (See Figures 28 and 32).

Species	Abiotic Factor (r value)
Fundulus parvipinnis	Depth of Capture (-0.28) Salinity (-0.26) Distance into Upper Bay (+0.25)
Gambusia affinis	Distance into Upper Bay (+0.31) Temperature (+0.24) Salinity (-0.24)
Clevelandia ios	Temperature (+0.34)
Gillichthys mirabilis	Distance into Upper Bay (+0.24) Dissolved Oxygen (+0.24) Temperature (+0.23)
Atherinops affinis	Temperature (+0.32)
Quietula ycauda	Temperature (+0.32)
Ilypnus gilberti	Temperature (+0.32)
Anchoa delicatissima	None Significant
Engraulis mordax	None Significant
Leuresthes tenuis	Dissolved Oxygen (-0.30)
Hypsopsetta guttulata	Salinity (+0.42) Secchi Reading (+0.41) Depth of Capture (+0.29) Distance into Upper Bay (-0.24)
Paralichthys californicus	Depth of Capture (+0.31) Secchi Reading (+0.26) Salinity (+0.23)
Embiotoca jacksoni	Depth of Capture (+0.56) Distance in Upper Bay (-0.43) Salinity (+0.26)
Cymatogaster aggregata	Distance into Upper Bay (-0.41) Depth of Capture (+0.35) Salinity (+0.26)
Paralabrax maculatofasciatus	Secchi Reading (+0.32) Depth of Capture (+0.27) Salinity (+0.26) Distance into Upper Bay (-0.23)

Table 10 (continued)

Species	Abiotic Factor (r value)
Paralabrax nebulifer	Distance into Upper Bay (-0.28) Depth of Capture (+0.23)
Urolophus halleri	Temperature (+0.23) Salinity (+0.23)
Phanerodon furcatus	Distance into Upper Bay (-0.23)
Mugil cephalus	Average Particle Size (+0.35) Salinity (-0.25) Depth of Capture (-0.23) Dissolved Oxygen (+0.23)
Morone saxatilis	Secchi Reading (-0.29)
Anchoa compressa	Temperature (+0.31) Dissolved Oxygen (+0.30)
Umbrina roncador	Temperature (+0.35)
Lepomis macrochirus	Salinity (-0.46) Secchi Reading (-0.26)

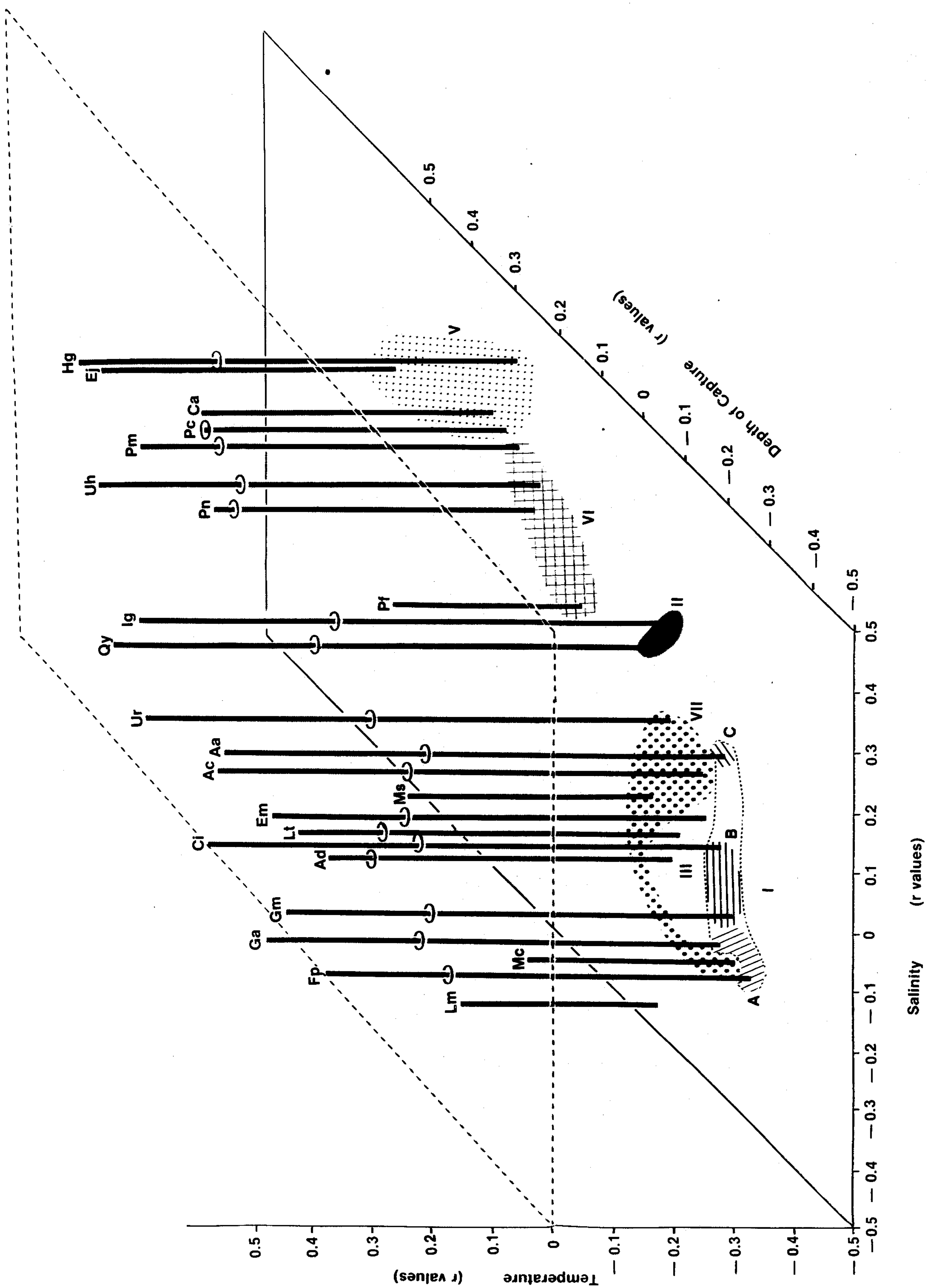
were temperature, salinity and depth of capture (Table 10). Correlations of these three variables with species abundance were treated as a continuous series of values to classify 23 species in a three-dimensional representation (Figure 32). The species in the diagram included 22 species (those with $\geq$ 6 total individuals) from the dendrogram (Figure 28) and Lepomis macrochirus.

The three-dimensional array (Figure 32) served to distinguish the species and species groups in the dendrogram (Figure 28). Group I was the shallowest group (highest negative correlation with depth of capture). Subgroups IA-C were primarily separated on the basis of salinity with A occurring in the lowest salinity and C in the highest salinity waters; subgroup B, composed of two gobies, was intermediate with Gillichthys mirabilis showing a stronger relationship to salinity than Clevelandia ios. All members of Group I were associated with warm waters.

Group II was separated from Group I on the basis of salinity and depth. The two illustrated members of Group II, Ilypnus gilberti and Quietula ycauda, occurred in slightly deeper and more saline waters. While both species were associated with warm temepratures, Ilypnus showed a stronger correlation with salinity than did Quietula.

Group III occurred in deeper water than Group I and its three members distinguished on the basis of salinity and temperature. Engraulis mordax was associated with warmer, more saline waters than the other anchovy of the group,

Figure 32. Three-dimensional representation of 23 juvenile/adult fish species classified according to correlations (r values) with depth of capture (x axis), salinity (y axis) and temperature (z axis). Correclation values for temperature are represented by the height of the species spikes. Species groups (Roman numerals and variously hatched areas) correspond to those in dendrogram of Figure 28. Aa = *Atherinops affinis*, Ac = *Anchoa compressa*, Ad = *Anchoa delicatissima*, Ca = *Cymatogaster aggregata*, Ci = *Clevelandia ios*, Ej = *Embiotoca jacksoni*, Em = *Engraulis mordax*, Fp = *Fundulus parvipinnis*, Ga = *Gambusia affinis*, Gm = *Gillichthys mirabilis*, Hg = *Hypsopsetta guttulata*, Ig = *Ilypnus gilberti*, Lm = *Lepomis macrochirus*, Lt = *Leuresthes tenuis*, Mc = *Mugil cephalus*, Ms = *Morone saxatilis*, Pc = *Paralichthys californicus*, Pf = *Phanerodon furcatus*, Pm = *Paralabrax maculatofasciatus*, Pn = *Paralabrax nebulifer*, Qy = *Quietula ycauda*, Uh = *Urolophus halleri* and Ur = *Umbrina roncador*.
(See facing page.)


Temperature (r values)
Salinity (r values)
Depth of Capture (r values)
Hg
Ej
Ca
Pc
Pm
Uh
Pn
Pf
Ig
Qy
Ur
Aa
Ac
Ms
Em
Lt
Ci
Ad
Gm
Ga
Mc
Fp
Lm
I
II
III
V
VI
VII
A
B
C

Anchoa delicatissima. *Leuresthes tenuis* displayed intermediate relationships.

Group V was clearly separated from the other groups on the basis of the three physical parameters. This set of species occurred in the deepest, highest salinity water, thus being captured primarily in the channel at the lower stations. Within-group differences were based mainly on depth and temperature . *Embiotoca jacksoni* occurred in colder, deeper water than *Hypsopsetta guttulata*. *Cymatogaster aggregata* and *Paralichthys californicus* were associated with somewhat cooler water and lower salinities than *H. guttulata*.

Group VI, located adjacent to Group V in the three-dimensional space, contained three species, *Paralabrax maculatofasciatus*, *P. nebulifer* and *Urolophus halleri*, that were positively correlated with depth and temperature. *Phanerodon furcatus*, however, was a marginal member of the group found in cooler, shallower, slightly less saline waters.

Group VII, positioned near Groups I and III, was made up of a somewhat disparate group of species. *Umbrina roncador* and *Anchoa compressa* were positively correlated with temperature and slightly associated (positively) with salinity. *Umbrina roncador* occurred in deeper water than *A. compressa*. *Morone saxatilis* was an intermediate species associated with cooler, lower salinity water. *Mugil cephalus* was the most distinct member of the group, occurring in Figure 32 near Subgroup IA. This species occurred in cooler, shallower, lower salinity conditions than other members of Group VII. The position of *M. cephalus* is largely explained by ontogenetic habitat differences. Juveniles occurred in the pannes and shallow inshore areas whereas large *M. cephalus* were found in the channel and deeper inshore areas. Thus, the dendrogram and the three-dimensional space represent for this species a composite of populations with different habitat requirements. Greater resolution between and within groups would have been realized had the juvenile and adult populations of *M. cephalus* and perhaps other species (e.g., *Atherinops affinis*, *Cymatogaster aggregata*) been clustered as separate entities.

Lepomis macrochirus showed its freshwater affinities in that it was associated with cool, shallow, low salinity waters.

DISCUSSION

Juvenile/Adult Populations

Upper Newport Bay fish populations were numerically dominated by a small number of low trophic-level species. *Atherinops affinis* functions either as a low-level carnivore (Fronk, 1969) or a herbivore (Allen, 1980) apparently depending upon levels of productivity and availability of resources. *Fundulus parvipinnis* is known (Fritz, 1975) to be mainly a low-level carnivore feeding on small crustaceans and insect larvae. The next five species in abundance are generally recognized as operants near the base of the food web. In addition, Mugil cephalus, the fish with the greatest contribution to total biomass in the study, is known (Odum, 1970) to feed on benthic diatoms and detritus. This pattern of numerical dominance by species low in the trophic structure has been demonstrated in several studies of bay-estuarine populations and reviewed by Allen and Horn (1975).

It should be understood, however, that not all upper bay species were fishes low in the trophic structure. Larger, mainly piscivorous, species included Morone saxatilis, Paralabrax maculatofasciatus, Paralabrax nebulifer and Paralichthys californicus. The last species (California halibut), for example, has been shown (Haaker, 1975) to feed with high frequency on gobies in Anaheim Bay.

Abundance parameters varied considerably from the lowermost station (4) to the uppermost station (1) in the upper bay. Diversity H' was, in general, inversely related to number of individuals and biomass. High diversity values reflected greater evenness in the population abundances (e.g., at Station 1) whereas lower values indicated increased dominance of certain species (usually Atherinops affinis) at particular stations (e.g., at Station 2). The decline in number of species with distance into the upper bay (i.e., from Station 4 to Station 1) may be explained in that Station 4 is the most distinct (in physical attributes) of the localities and receives a greater number of periodic species from the lower portion of Newport Bay.

The diversity H' values obtained (bimonthly range for numbers 0.48-2.17; overall 1.05) are similar to those calculated in several other studies of bay-estuarine fish communities. Haedrich and Haedrich (1974) obtained values of 0.33-1.03 for Mystic River estuary, Massachusetts; Stephens et al. (1974) indices of 0.65-2.08 for Los Angeles Harbor, California; and Allen and Horn (1975) 0.03-1.11 for Colorado Lagoon, Alamitos Bay, California. Allen (1976) in an otter trawl survey of Newport Bay fish populations reported H' values of 0.20 to 1.96 (overall 0.98) for the upper bay.

Seasonal fluctuations of bay-estuarine fish populations may have several causes but temperature seems frequently to be the underlying factor. The pattern of increased numbers of species and individuals with increased temperature has been reviewed by Allen and Horn (1975) and appears to have wide application among temperate bay-estuarine fishes. Seasonality as influenced by temperature change is expressed in the upper bay and similar environments by 1) periods of immigration of adult fishes for reproduction or for exploitation of high productivity during warmer months and 2) periods of high recruitment of juvenile fishes. These activities reflect the widely recognized (e.g., Haedrich and Hall, 1976) spawning-nursery ground function of bay-estuarine environments.

Length-frequency patterns of six of the principal upper bay species were a manifestation of the reproductive

activity and life history dynamics of these species and an expression of seasonality in the upper bay fish community. Evidence that the six species were utilizing the upper bay for life historical activities is as follows:
1) Atherinops affinis occurred in the size classes identified by Fronk (1969) for the Newport Bay population. The occurrence of small individuals (< 25 mm SL) from May through November indicated a protracted spawning season equal in length but later in the year than that (February-August) reported by Fronk (1969). 2) Small individuals (15 mm SL) of Fundulus parvipinnis appeared in the samples from May through January (1979) matching closely the appearance recorded by Fritz (1975) in Anaheim Bay, California. 3) Small individuals (< 50 mm SL) of Anchoa compressa were collected in January (1978) and March and large numbers of A. compressa eggs were collected in May. 4) Occurrence of small individuals (< 25 mm SL) of Clevelandia ios in all months of the study and the presence of C. ios larvae in plankton tows for all months indicated that this species spawns over long periods in the upper bay. These findings are consistent with the reports of Prasad (1959) in Elkhorn Slough, California, and Macdonald (1975) in Anaheim Bay that C. ios has a prolonged breeding season. 5) The first appearance of small individuals (25-55 mm SL) of Cymatogaster aggregata along with large (85-125 mm SL) members of the species in May followed by an absence of large fish in subsequent months is in agreement with the

pattern discovered in previous studies (Bane and Robinson, 1970; Odenweller, 1975; Allen, 1976). Both Bane and Robinson (1970) and Allen (1976) found that in Newport Bay the majority of adults migrate out of the bay after breeding in the spring leaving juveniles to utilize the area as a nursery ground. 6) The seasonal range of size classes and abundance showed that Mugil cephalus was completing portions of its life cycle in the upper bay. Small juveniles ($\leq$ 50 mm SL) occurred only in January and March 1978 and January 1979. Adults were mainly present from January through July 1978 and again in January 1979. This species is known (e.g., Major, 1978) to spawn at sea in the fall followed by a return of the prejuveniles and adults to the estuary in the winter.

Egg and Larval Populations

The extreme abundance of Anchoa compressa eggs (98.9% of all eggs collected) in May at Station 2 was largely the story of egg distribution and abundance in the upper bay during the study period. Only 16 eggs of its congener, A. delicatissima, were collected. These results are in contrast to those of White (1977) who, in sampling the upper bay ichthyoplankton with similar gear, found A. delicatissima to be the most abundant egg type, more than 5X as numerous as that of A. compressa. White also found the eggs of both species to be present for a longer period (May-September) than we did in the present study (May-July).

An explanation for these differences is not apparent other than that these two anchovies are at the northern edge of their range in Newport Bay and may undergo wide fluctuations in spawning and recruitment in response to prevailing environmental conditions. An investigation of the life histories of the two species in Newport Bay was completed (Heath, 1980) in conjunction with the present study.

Gobies dominated the list of larval taxa identified from the upper bay. Five of the eight most abundant taxa were members of the Gobiidae. White (1977) found a similar prevalence of gobies in his study of Newport Bay larvae. A recent review (W. S. White and M. H. Horn, unpub. data) has shown that members of this family dominate the ichthyoplankton of most estuaries in the eastern North Pacific.

Of the 34 adult species collected in the upper bay that could be expected to have eggs or larvae in the upper bay, only 14 such species had identifiable egg or larval stages. This discrepancy deserves further explanation. Beyond the difficulty of identifying eggs and larvae, there are the limitations of the sampling gear coupled with the life history specializations of the various species. Few eggs and larvae of *Atherinops affinis* and none of *Fundulus parvipinnis*, representing the two most abundant juvenile/ adult species, were collected. Both species lay demersal eggs which are thus not available to the net. The larvae of *F. parvipinnis* apparently (Fritz, 1975) remain largely in the pannes. The reasons for collecting only small numbers of *A. affinis* larvae under the sampling regime of the present study have been outlined by Allen and White (in press) for a previous study as follows: 1) newly hatched larvae are in an advanced state of development thus enhancing net avoidance especially with daytime sampling; 2) the larval life of the species is relatively brief (a few weeks); and 3) the larvae occur primarily near the surface above the sampling zone and also in shallow waters, often near objects (e.g., algal mats, pilings), thus outside the sampling area. Only the larvae, not the eggs, of gobiids were collected since members of this family also lay demersal eggs.

An additional source of distinction between ichthyoplankton taxa and juvenile/adult species is that several important upper bay species are livebearers, giving birth to young in a highly developed state (especially embiotocids such as *Cymatogaster aggregata* but also the poeciliid *Gambusia affinis*).

Community Structure

Cumulative curves of species numbers produced by addition of sample sets were generally asymptotic in shape indicating that the sampling effort for species was sufficiently effective to capture essentially all members of the upper bay community. The more gradually rising curves of January (1978 and 1979), March and November may be due to the presence of smaller, patchier populations during these months. A greater number of species were more accessible to the sampling gear during the warmer months of May, July and September when abundances were generally elevated; thus, the curves for these months rose rapidly to asymptotic levels.

The eight species groups identified by cluster analysis included both resident and periodic species that occur in one or more of three upper bay habitats (channel, inshore and panne).

Pictorial representation of the species groups for three periods of the study illustrated not only the seasonal utilization of the upper bay but also the dynamic relationships of fishes in the three habitats and the spatial utilization (i.e., demersal, midwater, or surface zones) of the principal species. Development and decline of species groups marched with changes in habitat conditions which included, for example, disappearance of the halocline, an increase in primary productivity and formation of an inshore algal mat. Certain species (e.g., *Anchoa compressa*, *Atherinops affinis*) undertook movements between shallow and deeper waters. Juveniles of some species (e.g., *Fundulus parvipinnis*, *Gillichthys mirabilis*) occurred in the pannes while the adults occupied the inshore habitat. Still other juveniles (*Cymatogaster aggregata*, *Hypsopsetta guttulata*, *Mugil cephalus*) were found inshore (and, for *M. cephalus*, also in the pannes) whereas the adults were collected in the channel.

Influence of Abiotic Factors

Fluctuation of physical parameters on annual, seasonal or shorter time intervals is implicit in the definition of an estuarine environment. A measurable response of the fish community to these changes, therefore, is to be expected, for example, in the population size of resident species or in the number of periodic species. This expectation was realized in the dynamics of upper bay fishes. Temperature and salinity, two variables especially prominent in a fluctuating estuarine environment, were significantly correlated with species richness and abundance (numbers or biomass). These two factors along with depth of capture were found to be frequently and variously correlated with individual species abundances. The three factors in combination provided an environmental basis for the species associations identified in the dendrogram and illustrated in the diagrams.

Effects of Heavy Rainfall

The responsiveness of the fish community to fluctuating environmental conditions appeared to have been exemplified in several ways as a result of the unusually heavy rainfall (Table 11) during the first three months (January-March 1978) of the study period. Several observations and limited quantitative information indicated that upper bay fish populations are sensitive to excessive rainfall and the

Table 11. Monthly and annual rainfall (cm) at Newport Harbor (lower Newport Bay) for 1974, 1975, 1978 and a "Normal" year. (Compiled from climatological data for California, Environmental Data Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce).

YEAR	MONTH												ANNUAL TOTAL
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1974	10.3	0.3	8.4	0.8	0.3	<0.1	<0.1	0.0	0.0	0.6	0.1	13.2	33.9
1975	1.4	4.2	6.8	5.7	0.0	0.0	0.0	0.0	<0.1	0.2	0.5	0.5	19.3
1978	20.1	14.2	18.2	3.9	0.0	0.0	0.0	<0.1	5.3	<0.1	4.9	4.2	70.9
1979	10.8	3.7	13.2	0.0	<0.1								
"Normal" Year[1]	5.3	5.5	4.1	3.3	0.4	0.1	<0.1	0.1	0.4	0.7	3.9	4.4	28.1

[1] Based on data for the years 1941-1970.

accompanying effects (reduced salinity, increased sedimentation). These include: 1) Atherinops affinis was not collected at Stations 1 and 2 until May. These two upper stations were the most subject to reduced salinity and increased siltation and turbidity early in the year. 2) Cymatogaster aggregata was caught only in small numbers with the otter trawl throughout the year at Stations 1 and 2. This result is in contrast to the much larger samples obtained by Allen (1976) in 1974-75 (years of less rainfall - see Table 11) also with an otter trawl at generally the same locations. 3) Goby densities were lower than they might have been in a year with less severe conditions. This belief is based on the much higher densities obtained at Station 3 in April 1979 following a drier first quarter than in 1978 (Table 11) and on the much higher density estimates (6X-40X our highest values) of Clevelandia ios made by Macdonald (1975) for a similar habitat (Anaheim Bay). 4) Diversity values were no higher than those reported by Allen (1976) in the upper bay for 1974-75 even though he used only an otter trawl to sample juvenile/adult fishes. This comparison is tempered, however, by the extremely high abundance of Atherinops affinis in 1978, the effects of which would be to lower diversity estimates. 5) With the exception of the large numbers of Anchoa compressa eggs collected in May, the abundance and diversity of ichthyoplankton on either a monthly or per station basis were lower than the values obtained by White (1977) in

1974-75 using a similar sampling strategy. 6) A final observation related to increased rainfall is that four freshwater species were collected during the study including Gambusia affinis, the third most abundant species in the samples.

Statements 1-5 are offered with caution since factors other than rainfall could be responsible for the apparent effects, including conditions in other years that may have affected recruitment in 1978. Nevertheless, these observations point to the strong year-to-year fluctuations that occur in upper bay fish populations.

CONCLUSIONS

Upper Newport Bay fish populations are numerically dominated by low trophic-level species that variously utilize this estuarine environment in advancing through their life history stages. The upper bay fulfills the classically recognized dual function of an estuary in that it serves as a spawning and a nursery ground for a variety of coastal fishes. The nursery function involves a larger number of species and therefore can be considered as the more important of the two functions.

The fish community is a dynamic combination of species groups composed of resident and periodic species that occupy channel, inshore and panne habitats of the upper bay. Members of the community respond to fluctuations in environmental parameters and usually march to seasonal peaks of abundance in accord with increases in temperature, salinity and levels of productivity. Population fluctuations occur on time scales of months to years emphasizing the necessity for periodic monitoring and mathematical modeling if thorough understanding and effective management are to be achieved.

The fish community of upper Newport Bay can be considered significant and worthy of preservation for at least three reasons: 1) it contains an assemblage of resident species not duplicated in any other coastal habitat; 2) it contains the life history stages (especially the early ones) of a variety of coastal species; and 3) it contains large populations of small, primarily resident fishes (adults or juveniles) that serve as forage for several larger, primarily periodic fishes including those of sport and commercial importance and also for various birds associated with estuarine habitats.

RECOMMENDATIONS FOR FUTURE STUDIES

1. Quarterly monitoring of fish populations at one or more stations in the upper bay should be undertaken on a continuing basis to assess the status of the fish community. In addition, a mathematical model of the distribution and abundance of upper bay fish populations should be developed to provide predictability. These needs are identified because of the seasonal and year-to-year fluctuations in environmental conditions (e.g.,

rainfall and associated effects) and hence, the variations in distribution and abundance of the fish populations.

2. The dynamics of egg and larval populations over short (24 hr; tidal) time intervals require further elucidation. This type of research would provide information on the magnitude of ichthyoplankton transport from and into the upper bay. (A study of ichthyoplankton dynamics over the diel and tidal cycles at one station just above the Pacific Coast Highway bridge is near completion by F. A. Edmands for an M.A. thesis at California Station University, Fullerton).

3. The feeding ecology and energetics of the *Mugil cephalus* (striped mullet) populations should be studied. This is a large fish that carries out its life cycle utilizing the upper bay. The species feeds on diatoms and particulate matter on shallow mudflats. A substantial amount of energy is evidently channeled through the population and, in turn, is transported out of the bay when the fish returns to sea for spawning. Adequate estimates of the population size could possibly be made from a helicopter.

4. The feeding and distributional ecology of *Atherinops affinis* should be further investigated. During bloom periods of inshore, green macroalgae (*Enteromorpha*, *Ulva*, *Chaetomorpha*), this fish shifts to a herbivorous diet. An important question is whether the large upper bay population migrates out of the bay

transporting significant amounts of energy into coastal waters. A mass marking program could help determine populations movements.

5. The upper bay goby populations require additional study. Their estimated important position in the bay food web needs to be verified. Feeding ecology, competitive interactions and predator-prey relationships should be investigated for gobies to determine their place in energy transfer processes. Furthermore, the ecological interactions and potential impact of the introduced Asian goby, *Acanthogobius flavimanus*, should be assessed in the very near future. Although few were captured during the study period, samples taken as part of gear efficiency trials conducted at Station 3 in April 1979 showed *A. flavimanus* to be highly abundant - the most abundant goby captured. This species has undergone rapid expansion in central California locations and has recently been observed in Los Angeles Harbor. It has the potential to alter the relative abundance of other fishes and perhaps invertebrates in the upper bay ecosystem. (A comparative study of behavioral interactions and metabolic rates of *A. flavimanus* and *Leptocottus armatus* is near completion by C. A. Usui for an M.A. thesis at California State University, Fullerton.)

6. An illustrated handbook or field guide to the fishes of upper Newport Bay should be written. It would provide a needed revision of the booklet written by Bane (1968) and could incorporate the findings of the present study into a useful publication accessible to scientists, naturalists and members of the general public interested in the ecological reserve.

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APPENDIX

Scientific name, common name and family of fish species collected in upper Newport Bay during seven bimonthly periods (January 1978-January 1979). (Arranged in alphabetical order by scientific name).

SCIENTIFIC NAME	COMMON NAME	FAMILY
Acanthogobius flavimanus	Yellowfin goby	Gobiidae
Albula vulpes	Bonefish	Albulidae
Anchoa compressa	Deepbody anchovy	Engraulidae
Anchoa delicatissima	Slough anchovy	Engraulidae
Anisotremus davidsoni	Sargo	Pristipomatidae
Atherinops affinis	Topsmelt	Atherinidae
Clevelandia ios	Arrow goby	Gobiidae
Cymatogaster aggregata	Shiner surfperch	Embiotocidae
Cynoscion nobilis	White seabass	Sciaenidae
Damalichthys vacca	Pile surfperch	Embiotocidae
Embiotoca jacksoni	Black surfperch	Embiotocidae
Engraulis mordax	Northern anchovy	Engraulidae
Fundulus parvipinnis	California killifish	Cyprinodontidae
Gambusia affinis	Mosquitofish	Poeciliidae
Genyonemus lineatus	White croaker	Sciaenidae
Gibbonsia sp.[2]	Kelpfish (1 of 3 spp.)	Clinidae
Gillichthys mirabilis	Longjaw mudsucker	Gobiidae
Girella nigricans	Opaleye	Girellidae
Heterostichus rostratus	Giant kelpfish	Clinidae
Hypsoblennius jenkinsi[2]	Mussel blenny	Blenniidae
Hypsopsetta guttulata	Diamond turbot	Pleuronectidae
Ictalurus melas	Black bullhead	Ictaluridae
Ilypnus gilberti	Cheekspot goby	Gobiidae
Lepomis cyanellus	Green sunfish	Centrarchidae
Lepomis macrochirus	Bluegill	Centrarchidae
Leptocottus armatus	Staghorn sculpin	Cottidae
Leuresthes tenuis	California grunion	Atherinidae
Menticirrhus undulatus	California corbina	Sciaenidae
Morone saxatilis	Striped bass	Percichthyidae
Mugil cephalus	Striped mullet	Mugilidae
Mustelus californicus	Gray smoothhound	Carcharhinidae
Myliobatis californica	Bat ray	Myliobatidae
Paralichthys californicus	California halibut	Bothidae
Paralabrax maculatofasciatus	Spotted sand bass	Serranidae
Paralabrax nebulifer	Barred sand bass	Serranidae
Peprilus simillimus	Pacific butterfish	Stromateidae
Phanerodon furcatus	White surfperch	Embiotocidae
Pleuronichthys coenosus[1]	C-O turbot	Pleuronectidae
Pleuronichthys ritteri	Spotted turbot	Pleuronectidae
Polydactylus approximans	Blue bobo	Polynemidae
Porichthys myriaster	Specklefin midshipman	Batrachoididae
Quietula ycauda	Shadow goby	Gobiidae

Appendix (continued)

SCIENTIFIC NAME	COMMON NAME	FAMILY
Sebastes sp.[2]	Unidentified rockfish	Scorpaenidae
Seriphus politus	Queenfish	Sciaenidae
Sphyraena argentea	California barracuda	Sphyraenidae
Symphurus atricauda	California tonguefish	Cynoglossidae
Syngnathus auliscus	Barred pipefish	Syngnathidae
Syngnathus leptorhynchus	Bay pipefish	Syngnathidae
Umbrina roncador	Yellowfin croaker	Sciaenidae
Urolophus halleri	Round stingray	Dasyatidae

1 - Eggs only   *2* - Larvae only