Annual Report 1979

Monitoring the Marine Environment of Long Island Sound at Millstone Nuclear Power Station

Waterford, Connecticut

Northeast Utilities Service Company

March, 1980

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SUMMARY

MONITORING THE MARINE ENVIRONMENT OF LONG ISLAND SOUND AT MILLSTONE NUCLEAR POWER STATION WATERFORD, CONNECTICUT

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SUMMARY

Millstone Nuclear Power Station is located on the north shore of Long Island Sound (LIS) in Waterford, Connecticut. The station consists of two operational units with a combined cooling water flow of 2,155 cfs, and a third unit under construction.

Intense study of the potential impact of Millstone Station on LIS was initiated in 1968. Studies have been modified and expanded to assure that assessments represent state-of-the-art. This report presents 1979 results and provides comparisons with previous years as a basis for impact assessment.

Impingement

The total numbers of fish impinged in 1979 at Unit 1 and 2 were 39,403 and 26,479, respectively. The 1979 totals represented an increase compared to 1978 with Unit 1 increasing 59%. Winter flounder was the dominant species and together with silversides and three-spined stickleback comprised over 59% of the total at each unit.

The 1979 macroinvertebrate impingement total was 36,872. The total catch for each unit was similar. Squid and lady crabs combined represented 90 and 85% of the total at Units 1 and 2, respectively.

An adverse impact on local populations from impingement losses was not apparent for those species studied. This conclusion was based on trends

observed in the impingement data and on assessments made from routine otter trawl, seine and gill net collections, as well as from winter flounder and lobster population dynamics studies.

Plankton

Seasonal density of phytoplankton, zooplankton, fish eggs and fish larvae were monitored in 1979 and compared to the previous three years.

In 1979 the seasonal density and species composition of phytoplankton was similar to other years with a few exceptions. The density of phytoplankton was lower over April, May and June due to a decrease in the dominant diatoms *Skeletonema costatum* and *Thalassiosira* spp. Several other species of diatom or a group of chlorophyceans showed relative increases in density for 1979 which tended to restore phytoplankton cell densities to more usual levels in these spring months.

The zooplankton community monitored over the first four years of two-unit operation showed considerable similarity of species composition and seasonal density from one year to another. Operation of the power plant appeared to have little or no effect on the zooplankton community. Total zooplankton, *Acartia hudsonica*, and *Eurytemora herdmani* showed a slight increase in mean density in 1979 while *Temora longicornis*, *Centropages typicus*, *C. hamatus* and gammarid amphipods showed only a slight decline.

Fish eggs and fish larvae have also been similar in species composition and seasonal density over recent years. The few changes that occurred from one year to another appeared to be natural population responses. Density of total fish larvae increased in 1979, primarily a reflection of increases in sandlance larvae and anchovy larvae. Winter flounder larvae showed no significant differences in density over the last four years. Using winter flounder as an example of the order of magnitude of expected entrainment impact, the similarity of larval density and the sustained or increasing adult populations found in Niantic Bay together suggested minimal impact of plant operations on this local fish.

Intertidal Rocky Shore Survey

Rocky shore areas adjacent to Millstone Point support a rich and diverse community throughout the year. In 1979, a total of 103 algal species were collected from seven sites. Included were 45 red algae, 26 browns and 32 greens. Richest collections were usually made in the Fall.

Degree of exposure was the major factor influencing species distribution and the rate of recolonization. Grazing and predation also played an important role in structuring these communities, as evidenced by the exclusion cage studies.

Studies of Ascophyllum nodosum showed this alga to be present and growing at normal or enhanced rates within 70 m of the effluent discharge.

No detrimental differences occurring between stations in 1979 could be attributed to effects caused by power plant operation.

Benthic Sand Infauna

A total of 240 benthic infaunal samples was collected at 2 intertidal and 4 subtidal stations during quarterly sampling from September 1978 to June 1979. Deposit feeding annelids accounted for 79% of the 35,998 individuals collected. Polychaetes were most diverse with 103 species collected while oligochaetes were numerically most abundant. Densities were higher in 1979 than in the previous year; the increases were generally attributed to the smaller mesh sieves used in processing 1979 samples. Species diversity at most stations was similar to previous years.

The Intake site was most unique of all subtidal stations, particularly with respect to species composition and density. These differences were probably due to the tidal currents characteristic of the Intake area.

During 1979, no changes in subtidal or intertidal infaunal communities could be attributed to plant operation. Differences in species composition and density, between 1979 and previous years were probably due to the change in sample processing techniques and the naturally occurring fluctuation of shallow water benthic communities typical of those in the Millstone Bight.

Lobster Population Dynamics

Characteristics of the lobster population of the Millstone Point region were monitored in 1979 using pots set at three locations from May through October.

Total catch per unit effort in 1979 was higher than that reported previously. The difference was attributed to changes from wood to a complement of wood and wire pots. Seasonal catch variations resulted from increased activity relative to increased water temperatures and the occurrence of molting in the late spring and fall.

Size distribution was similar to that reported since 1976 and to those from surrounding areas. Length frequency histograms suggested the study area was subject to a high rate of exploitation. Percent of legal size lobsters was generally lower than in surrounding areas.

Except for a few individuals, movement between stations was minimal. The deepest station supported the highest percent of berried females and total females.

Molting periods in the spring and fall reported to occur in LIS also occurred in the Millstone area. The onset of molting appeared most affected by water temperature in the 14°C to 16°C range.

The mean monthly population size estimated from tag and recapture data increased in 1979 to 5,877 but remained within the 95% confidence limit of the 1978 estimate.

Since most of the population characteristics remained similar to those in prior years and to those in surrounding areas it was concluded that power plant operation was not adversely affecting the local lobster population.

Exposure Panels

The pctential impact of Millstone Station on marine boring and fouling organisms has been monitored since 1968 through the use of exposure panels. During 1979, twelve phyla composed of 102 taxa were reported from panels. The number of taxa at each station ranged from 40 to 81. Red algae were the most diverse flora followed by greens and browns. Molluscs and arthopods were the dominant faunal groups.

Community composition of fouling and wood boring organisms in 1979 was similar to previous years. Differences in abundance between wood and asbestos panels were attributed to the presence of large numbers of one or a few dominant species usually wood bores.

Seasonal variations at all stations but the Effluent were indicated by an increase in species abundance and diversity between May and November. Spatial differences in species composition at the Intake were attributed to physical factors; at the Effluent it was attributed to the warmed sea-water discharge.

Fish Ecology

Fish populations in the Millstone Bight have not been adversely affected by operation and construction of power plants on Millstone Point. Ten years of shore zone seine, eight years of gill net and six years of trawl collections provided the basis for assessments.

From May, 1969, through December, 1979, a total of 291,470 individuals representing at least 86 species of shore-zone, pelagic and ground fish was recorded from 4,637 samples. Total catch and total number of species varied periodically, however, no net change in these parameters was detected.

Power plant impact assessments focused on those fish species subject to impingement and entrainment which were abundant in trawls, seines and/or gill nets.

Winter flounder was most abundant in trawls during 1979. A shift in the area of dominant catch from Niantic River to Niantic Bay occurred and was thought to be a reflection of ecological changes in Niantic River.

Silversides, the second most important impinged fish, was caught in highest numbers by seines in Jordan Cove. Annual catches were not significantly different before and after power plant operations.

Cunner have become increasingly more abundant in gill nets at two near shore locations where riprap may have provided added habitat.

Adult menhaden catch in gill nets decreased over time whereas juvenile abundance in seines did not change. Abundance of several other important species including grubby, anchovies, tautog, silverhake and windowpane remained unchanged.

Winter Founder Population Dynamics

Tag and recapture information was used in the Jolly-Seber formulation to estimate winter flounder population size in the Niantic River from March through May, 1975-1979. The estimated population decreased from a peak of 160,000 in 1975 to lower but consistent levels thereafter. The number of spawning females ranged uniformly between 11,000 and 14,000.

Catch per effort in otter trawls also decreased from 1975 to 1976. Abundance over all stations increased in 1978 and peaked in 1979. Trends observed at Millstone reflected those reported regionally.

Various population parameters including age structure, fecundity, and length distribution were also determined for the Niantic River population. Age structure based on scales and otoliths since 1977 was uniform. Survival coefficients between ages 2 and 3 were within ranges reported in the literature. Mean length by age was found to decrease from the 1975 year class through the 1977 year class but reflected events operating in the larval stages in Niantic River.

Based on regional trends and on the various population parameters studied, it was concluded that operation and construction of power plants at Millstone have not had an adverse impact on the local winter flounder population.

Heavy Metal Analysis

Concentrations of copper, zinc, chromium and lead in seawater and in oyster and mussel tissue (exclusive of lead) were monitored five times each year since 1971. Of the metals studied, chromium and lead occurred in the smallest concentrations in seawater, usually less than 4.0 ppb. Concentrations of soluble and insoluble phases of all metals studied showed a general decline over the years. This decline was thought to reflect improvements in analytical technique rather than actual decreases.

Higher concentrations of heavy metals, particularly copper and zinc, were found in tissue of oysters and mussels influenced by the effluent. However, there was no noticeable long term increase in heavy metals in seawater or indicator molluscs in the surrounding waters.

Osprey

The osprey, Pandion haliaetus caralensis, or fish hawk, has received special attention at Millstone since 1967 when an artificial nesting platform was substituted for an unused derrick dismantled during construction of Unit 1. Two additional nests have been added since. To date, a total of 23 ospreys have been fledged from these nests representing 18% of all Connecticut fledglings since 1969.

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INTRODUCTION

Millstone Nuclear Power Station is located on the north shore of Long Island Sound (LIS) in Waterford, Connecticut. The station consists of three units located on a peninsula bounded by Jordan Cove on the east and on the west by Niantic Bay (Fig. 1). Millstone Unit 1, which commenced operation November 29, 1970, is a 652-MWe boiling water reactor (BWR). Unit 2 is an 870-MWe pressurized water reactor (PWR) and began operation October 17, 1975. The operating history of Units 1 and 2 is shown in Table 1. Construction of Unit 3, an 1,150-MWe PWR, was initiated in August, 1974. Commercial operation is planned for 1986.

All three units employ once-through condenser cooling water systems. Cooling water is drawn generally from depths greater than four feet below mean sea level by separate shoreline intakes located along Niantic Bay. The intake structures typify shoreline installations with coarse bar racks and traveling 3/8-inch mesh screens. The rated circulating flows for Units 1, 2 and 3 are 935, 1,220 and 2,000 cfs respectively. From discharge structures, the heated ($25^{\circ}F$ ΔT) cooling water flows through an abandoned granite quarry and returns to LIS through a cut equipped with a fish barrier.

The potential impact of Millstone Nuclear Power Station on LIS has been the focus of intense study since 1968. The early biological investigations included exposure panels for monitoring boring and fouling communities, surveys of the intertidal sand infaunal and rocky shore communities, and shore-zone fish seining. These programs are continuing and now represent over ten years of information. The program scope increased considerably

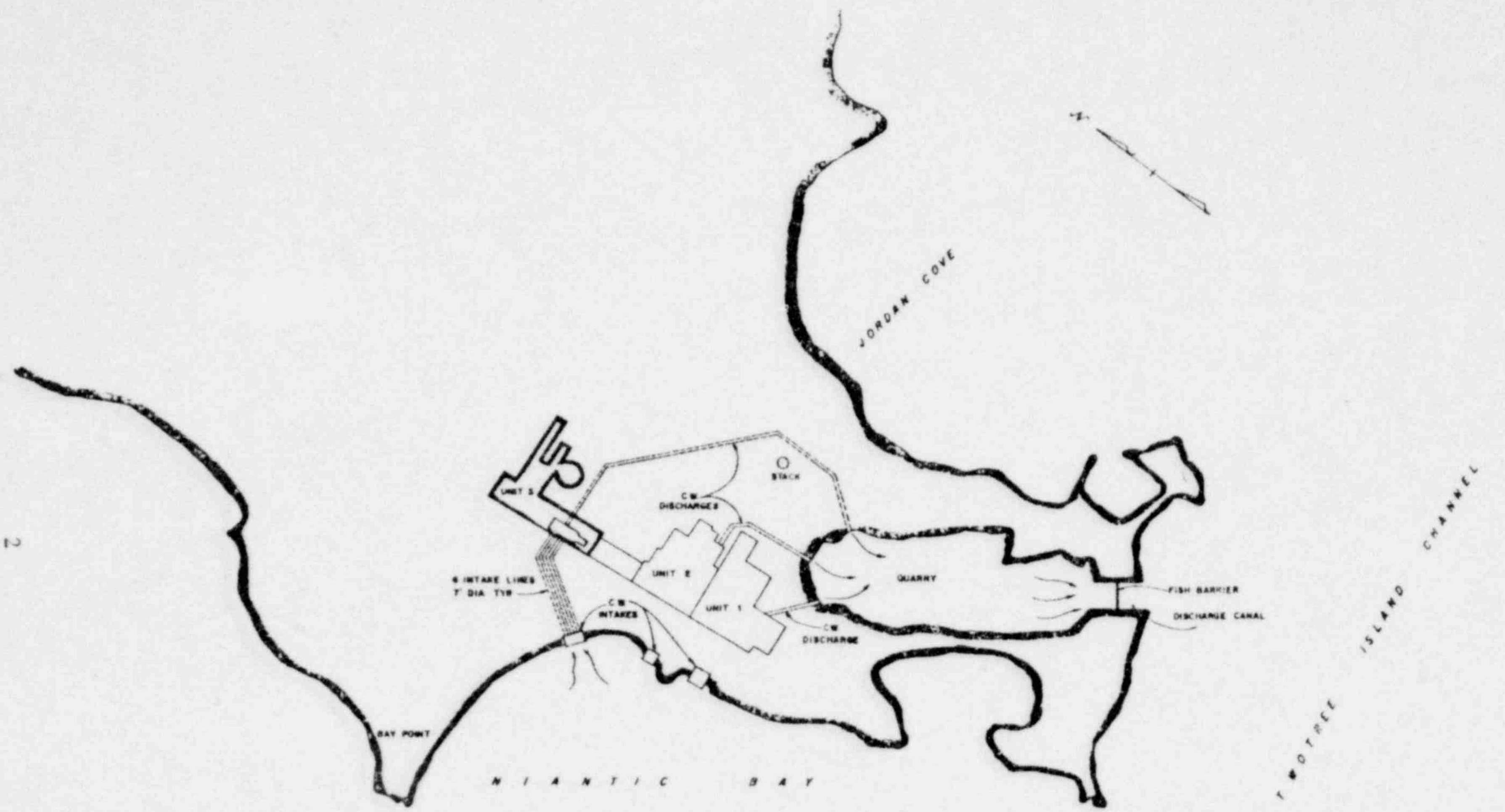


Figure 1. Once-through quarry discharge circulating water system, Millstone Nuclear Power Station

Table 1. Mean monthly electrical production in MWe (net) at Millstone Nuclear Power Station Units 1 and 2, 1970-1979

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Millstone 1	1970	-	-	-	-	-	-	-	-	-	-	-	82
	1971	204	185	318	459	443	480	624	508	314	162	616	576
	1972	664	155	564	671	654	641	607	540	0	0	0	0
	1973	0	0	252	362	0	0	21	491	363	368	411	294
	1974	472	470	483	520	513	474	512	441	0	0	479	573
	1975	566	396	559	591	575	579	469	324	225	101	371	581
	1976	645	570	225	402	624	644	550	425	539	9	0	502
	1977	572	618	608	619	632	482	592	593	595	566	392	337
	1978	580	562	180	267	594	615	500	576	627	639	652	589
	1979	346	544	610	558	0	31	612	634	603	651	615	586
Millstone 2													
	1975	-	-	-	-	-	-	-	-	-	-	26	156
	1976	280	309	403	537	464	642	480	555	724	726	729	363
	1977	406	776	762	569	151	147	536	780	712	624	517	0
	1978	0	0	0	31	669	767	752	756	748	797	806	809
	1979	705	799	224	0	168	544	852	313	850	851	0	691

between 1970 and 1973 with the addition of heavy metal analyses of seawater and mollusc tissue, studies of pelagic (gill net) and demersal fishes (trawls), lobster and winter flounder (Niantic River) population estimates, subtidal benthos and offshore ichthyoplankton (NUSCO 1975 and 1979).

Studies of entrained plankton were initiated in 1970 when Unit 1 became operational (Carpenter 1975); Unit 2 was included in 1975. To date the routine monitoring and special investigations have covered nearly all aspects of plankton including ichthyoplankton, phytoplankton, and zooplankton. Effects of chlorination and temperature on entrained phytoplankton were addressed as well as latent mortality of zooplankton subsequent to condenser passage (Carpenter, et al.1972; Carpenter, et al. 1974). Emphasis has been placed on entrained ichthyoplankton and the relative impact on fish populations in surrounding waters (NUSCO 1976 and 1979).

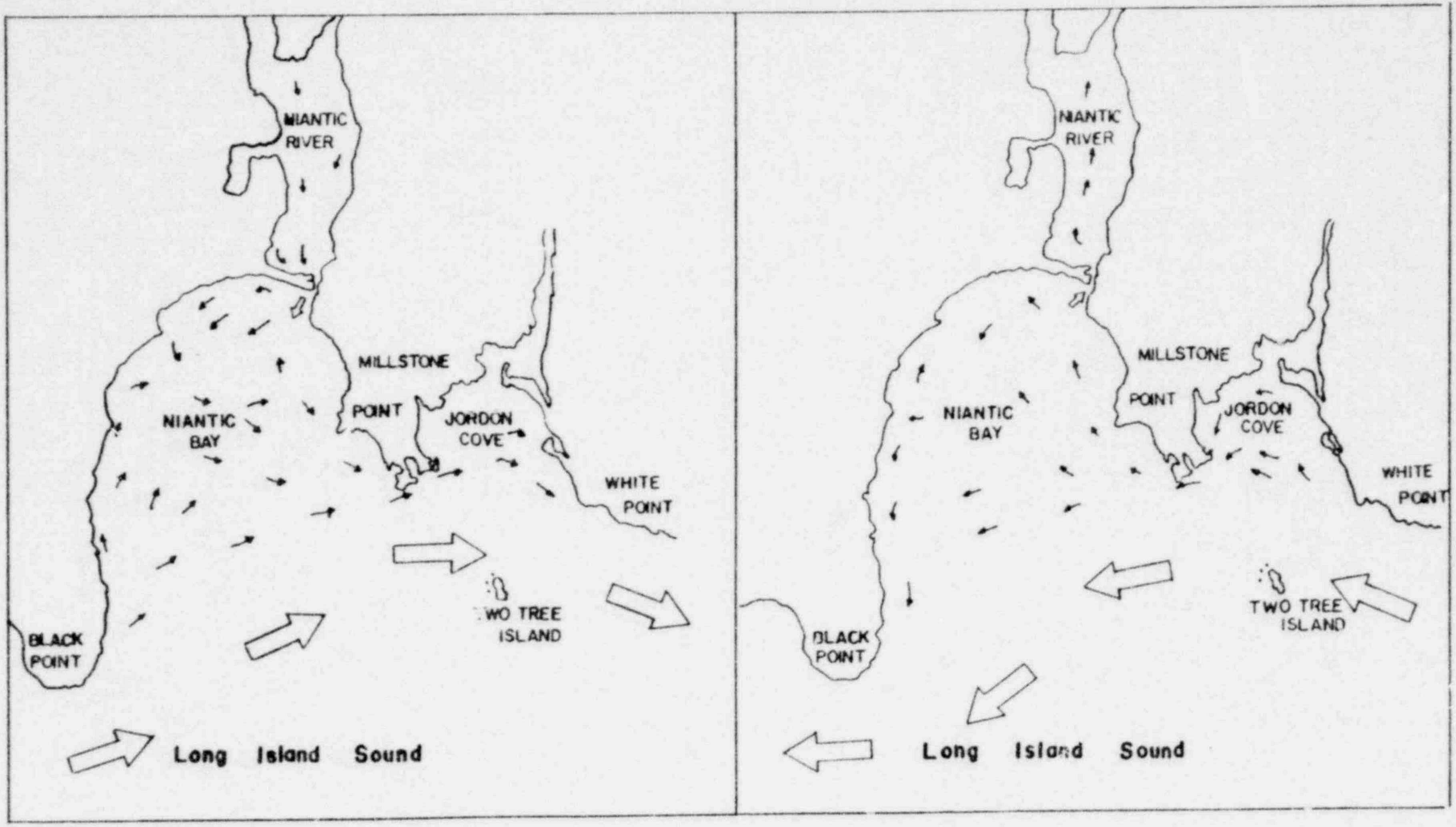
Impingement monitoring began at Unit 1 in 1971 and at Unit 2 in 1975. The program scope has varied from counting all impinged species (1972-1976) to the current program based on three 24-hour counts per week. Special studies included the effectiveness of several deterrent devices such as acoustic stimuli, underwater lighting and surface and bottom barriers (NUSCO 1976 and 1979).

The potential effect of three-unit operation on selected species was also considered. Mathematical population dynamics models were developed for the Niantic River winter flounder population (Hess, et al.1975) and for the regional menhaden population (NUSCO 1976). These models incorporate predicted entrainment and impingement losses over the life of the power station.

Numerous hydrographic studies were conducted starting as early as 1966 (NUSCO 1976). Predictive models for 1, 2 and 3 unit thermal plumes were developed based on hydrographic parameters taken from field surveys. A tidal circulation model was developed not only to predict current patterns and thermal distributions but also to simulate dispersion and entrainment of winter flounder fish larvae. Measured current patterns for the Millstone study area (referred to as the Greater Millstone Bight) are shown in Fig. 2.

As a result of these studies, the hydrographic and ecological characteristics of surrounding waters are well described. Studies have been intensified and modified to provide the most representive data with respect to changing concerns and state-of-the-art techniques. The present report provides study results for 1979 and summarizes results of previous years as a basis for evaluating any long-term impacts. The report also satisfies certain license and permit conditions stipulated by the Nuclear Regulatory Commission, the Connecticut State Department of Environmental Protection and the Connecticut State Power Facility Evaluation Council.

All ecological and hydrographic studies through 1976 were conducted by consulting laboratories most notably W.F. Clapp laboratories, Woods Hole Oceanographic Institution (Entrainment, 1970-1975), and Normandeau Associates (Entrainment, 1975-76). In 1977, Northeast Utilities Service Company began a phased in-house takeover of these studies starting with entrainment and impingement programs. Some benthic and lobster responsibilities were added in 1978 in conjunction with W. F. Clapp Laboratories. As of January 1980, all studies (excluding heavy metals) are being conducted



a. EBB

b. FLOOD

Figure 2. General circulation patterns in the vicinity of Millstone Point during ebb (a) and flood (b) tide.

and reported by NUSCo staff biologists based largely at the Millstone Environmental Laboratory. Critical scientific review is provided by a four member Ecological Advisory Committee (see acknowledgements) which has provided continuing support since 1968.

LITERATURE CITED

Carpenter, E. J., B. B. Peck, and S. J. Anderson. 1972. Cooling water chlorination and productivity of entrained phytoplankton. Mar. Biol. 16: 37-40

__________, S. J. Anderson, and B. B. Peck. 1974. Survival of copepods passing through a nuclear power station on the Northwest shore of Long Island Sound, U.S.A. Mar. Biol. 24: 49-55

__________. 1975. Integrated summary report to NUSCO on entrainment of marine organisms. Woods Hole Oceanographic Institution.

Hess, K. W., M. P. Sissenwine, and S. B. Saila. 1975. Simulating the impact of the entrainment of winter flounder larvae. In: Fisheries and Energy Production. S. B. Saila, ed. D. D. Heath Co. Lexington, Mass. 298 pp.

NUSCO 1975. Summary report ecological and hydrographic studies May 1966 through December 1974, Millstone Nuclear Power Station

NUSCO 1976. Environmental assessment of the condenser cooling water intake structures (316 (b) Demonstration), Vols. 1 and 2, submitted to the Connecticut State Dept. Environmental Production.

NUSCO 1979. Annual report, ecological and hydrographic studies, 1978. Millstone Nuclear Power Station.

IMPINGEMENT

IMPINGEMENT

INTRODUCTION

Impingement o: organisms on power plınt travelling screens has received increased attention in recent years s a potentially important ecological impact associated with electric power production (Ray 1976). Various authors have synthesized available information on impingement at major power plants (Sharma and Freeman 1977; Uziel 1978), others report the development of sophisticated mathematical models to assess impingement impacts (Murarka 1977). At Millstone, impingement studies began in 1971. Initially the program was designed to provide information regarding the organisms impinged on the travelling screens at Millstone Unit 1. In 1972, impingement collections were changed from qualitative observations to absolute counts. Over the years, the sampling program was modified to include Unit 2 and also to insure that the data were sufficient to support qualitative assessments. Daily sampling of organisms impinged over 24 hours continued through 1976 when sampling was altered to three 24-hour collections per week, with no more than 96 hours between collections. A general chronology of the impingement program at Millstone Station is provided in Table 1.

In addition to the routine monitoring, occasional studies were undertaken to better comprehend the impingement process. These studies included: day vs. night impingement (NUSCO 1976); equivalent adult calculations (NUSCO 1976); survival studies (NUSCO 1977), and length-weight fecundity relationships (NUSCO 1977).

This report summarizes impingement data from 1972 through 1979 for Units 1 and 2. Apparent trends are evaluated analytically in order to interpret the magnitude of impingement losses and to better understand the differences between units.

MATERIALS AND METHODS

Impingement results when fish and other organisms are caught against travelling screens located within the condenser cooling water intake structure. The screens prevent debris greater than 3/8" from entering the cooling water system. Whenever debris accumulates on the screens, a pressure drop occurs across its boundary resulting in automatic rotation at a pre-set Δp (difference in pressure). During rotation, the screens are washed with a high-pressure rinse, which directs the debris into a trough and eventually into a collection basket perforated with 1" holes to allow water drainage.

Since March 9, 1977, the fish and shellfish washed into the collection basket over 24 hours have been counted three times each week. Changes in the program prior to that time are shown in Table 1.

Once the organisms have been removed from the collection baskets, they are transported to the laboratory where they are identified, measured, and counted. Length measurements are total length for fish, carapace length for lobsters, carapace width for crabs, and mantle length for squid. Every effort is made to insure that all animals alive after collections are returned to Long Island Sound.

Table 1. Chronology of the impingement monitoring program at the Millstone Nuclear Power Station.

ITEM	1971	1972	1973	1974	1975	1976	1977	1978	1979
I. Researcher	——	——	—— CONTRACTED	——	——	——	NUSCO ——	——	——
II. Sampling Design	5/71 ——	1/172							
1. qualitative	IRREGULAR						3/10/77		
2. quantitative		——	——	DAILY ——	——	——	3 DAYS/WK. ——	——	——
III. Reporting Requiremen_s									
1. categories		COMPUTED	MEASURED	MEASURED	COMPUTED	COMPUTED	MEASURED	MEASURED	MEASURED
2. individual lengths		MEASURED				MEASURED			
				7/31/74					
IV. Special Studies			7/26/73	4/1/74			2/2/77		
1. day vs. night			1/8/73	2 SAMPLES PER DAY			2/1/77 5/23/77		
2. survival studies			LOBSTERS			ALL ORGANISMS	96 HR SURVIVAL	ALL ——	——
3. length/weight/fecundity							a		
V. Deterrent Devices		8/72 - 12/72	8/73 - 12/73	7/74 - 12/74	7/75 - 10/75	6/76 - 10/76	6/77 - 10/77		
1. surface		UNIT 1	UNIT 1	UNIT 1	UNIT 1	UNIT 2	UNIT 2		
2. bottom						UNIT 1			

a. winter flounder

Monthly estimates of the number of each species impinged were calculated as follows: monthly estimate = monthly ratio x actual counts made on the sampled days. Monthly ratio = (number of days in month/number of days sampled in month) - (number of days in month p mps shut down/number of days sampled pumps shut down). Pumps were deemed down if the flow rate was less than 5% of total flow capacity.

ANALYTICAL METHODS

McCloskey's Biological Index Value

The biological index value used by McCloskey (1970), as interpreted for the purposes of this report, is a measurement that indicates the seasonal and annual species presence. The species were ranked by season, with the most abundant species given the largest value in the ranking. Seasons were delineated as follows: winter-January through March; spring-April through June; summer-July through September; fall-October through December. Seasonal ranks were summed and expressed as a percentage of the theoretical maximum (the sum if a species ranked first for all seasons).

Friedman's Two-way Non-Parametric Analysis of Variance. Friedman's test (Conover 1971) was used to test differences between rankings of species throughout all the years, with respect to unit.

Clustering

An inverse clustering algorithm was applied to the percentage similarity matrix. Percent similarity was calculated by dividing each year's total by the total of all years, for each of the top species. It was then used to group species into associations at decreasing levels of similarity. The algorithm used was the group-averaging agglomeration or "unweighted pair-group method using arithmetic averages" (Boesch 1977). Clustering similarities were then illustrated in the form of a dendrogram.

General Linear Model Using Least Squares

A GLM computer programmed algorithm was used for interaction and nested effects (Helwig and Council et al. 1979). This test was used after standardizing the data for Units 1 and 2 by adjusting for mean monthly flow rates. Mean monthly flow rates were: Monthly flow per unit = mean monthly flow/maximum unit flow. Monthly totals were then generated for each unit: monthly total = estimated cc x monthly flow factor. Analysis was then run to see if any significant effects existed among years, units, and the nested effect of months within years.

Kolmogorov-Smirnov Two-Sample Test

A Kolmogorov-Smirnov two sample test (Campbell) was used to see if differences existed between the length frequency distribution of winter flounder at Units 1 and 2.

RESULTS AND DISCUSSION

The combined finfish impingement total for 1979 was 65,882, with 39,403 and 26,479 for Units 1 and 2, respectively (Table 2). Total fish impingement over all years was 214,412. The totals were represented by 100 fish taxa and 17 macroinvertebrate taxa. No new species were impinged in 1979. A list of rare species is given in NUSCO 1978.

Winter flounder (37765,20106)*, silversides (23131,7260)*, and three-spined stickleback (16134,10233)* constituted more than 50% of the overall total abundance at each unit. Total annual impingement at Units 1 and 2 has shown an upward trend, most pronounced at Unit 1 which increased 59% from 1978 to 1979. This figure does not adjust for May and June when Unit 1 was shut down.

During 1979, winter flounder (13149,9845)*, silversides (8594,3077)*, and three-spined stickleback (7638,2114)* composed more than 59% of the annual impingement at each unit (Table 3). Anchovies were impinged at a greater rate at Unit 2. However, plant pump records revealed Unit 1 was not pumping cooling water during a period of peak anchovy impingement. The months of January through April composed more than 50% of the annual finfish impingement.

Species dominance during 1978 and 1979 were compared using McCloskey's biological index. The index adjusts for those species that are highly

* Figures in parentheses (Unit 1, Unit 2) ** (1978, 1979)

Table 2. Total annual abundance and percent composition of finfish* impinged at Millstone Point Nuclear Power Station Units 1 and 2 intake structures from 1972 to 1979.

		Unit 1										Unit 2						
		1972	1973	1974	1975	1976	1977	1978	1979	Total	Percent	1975	1976	1977	1978	1979	Total	Percent
Winter Flounder	*Pseudopleuronectes americanus*	1,967	6,171	3,741	2,560	2,858	2,989	4,430	13,149	37,765	27	352	2,437	4,449	3,024	9,844	20,106	[illegible]
Silversides	*Menidia* spp.	557	1,074	1,189	737	729	748	9,504	8,594	23,131	17	262	704	468	2,749	3,077	7,260	10
Threespined Stickleback	*Gasterosteus aculeatus*	227	1,312	1,114	1,453	868	1,598	1,924	7,638	16,134	12	137	1,324	3,534	3,224	2,114	10,233	14
Grubby	*Myoxocephalus aenaeus*	212	1,280	1,278	927	1,078	897	3,485	1,935	11,101	08	151	878	1,230	3,998	1,581	7,838	10
Anchovy	*Anchoa* spp.	--	--	441	451	4,755	578	78	750	7,053	05	30	846	146	736	2,425	4,183	06
Cunner	*Tautogolabrus adspersus*	492	956	569	533	523	754	436	1,494	5,757	04	39	345	526	1,395	1,728	4,033	05
Blackfish	*Tautoga onitis*	493	803	303	718	416	654	334	285	4,006	03	22	458	75	716	570	1,841	02
Silver Hake	*Merluccius bilinearis*	--	60	15	1,408	205	617	240	448	2,993	02	1,018	552	261	222	322	2,375	03
Windowpane Flounder	*Scophthalmus aquosus*	1,560	722	212	236	252	209	143	493	3,827	03	107	408	147	216	477	1,355	02
White Perch	*Morone americana*	436	733	713	666	175	427	104	135	3,489	03	13	127	233	441	213	1,027	01
Tomcod	*Microgadus tomcod*	126	589	137	124	43	185	404	651	2,259	02	39	41	67	1,915	699	2,761	04
Northern Pipefish	*Syngnathus fuscus*	175	346	239	146	84	102	387	851	2,330	02	38	555	213	819	419	2,044	03
Menhaden	*Brevoortia tyrannus*	429	1,584	196	239	22	83	35	56	2,644	02	67	172	33	48	118	438	01
Blueback Herring	*Alosa aestivalis*	1,714	268	113	145	34	64	104	229	2,669	02	--	85	99	77	139	400	01
Smelt	*Osmerus mordax*	24	318	213	93	116	119	238	389	1,510	01	11	263	183	361	61	879	01
Lumpfish	*Cyclopterus lumpus*	3	36	132	63	21	245	587	322	1,409	01	--	21	244	188	244	697	01
Total for all species		9,256	18,013	11,754	11,855	13,370	11,893	23,617	39,401	139,181		2,438	10,398	13,704	21,612	26,479	75,231	

*Those fish which were ≥ .01 of total abundance.

Combined Total Impingement for Units 1 and 2 for all years and species 214,412

Table 3. Annual and monthly abundance and percent composition of finfish* impinged at Millstone Nuclear Power Station Units 1 and 2 intake structures during 1979.

Unit 1

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total	Percent
Pseudopleuronectes americanus	2,855	4,426	3,096	1,822	----	12	252	188	93	113	115	178	13,149	33
Menidia	6,090	448	997	954	----	----	-----	7	3	----	5	90	8,594	22
Gasterosteus aculeatus	142	299	1,288	4,933	----	----	----	9	5	----	25	937	7,638	19
Myoxocephalus aenaeus	301	293	288	542	----	2	26	2	10	13	12	446	1,935	05
Tautogolabrus adspersus	----	11	17	51	----	5	540	382	425	38	2	23	1,494	04
Syngnathus fuscus	----	----	267	494	----	----	14	22	3	9	9	34	851	02
Anchoa spp.	----	----	----	----	----	53	533	13	43	9	14	85	750	02
Microgadus tomcod	23	18	60	63	----	----	12	31	30	11	9	395	651	02
Scophthalmus aquosus	31	14	55	60	----	7	90	64	10	29	51	83	493	01
Peprilus triacanthus	2	----	----	----	----	2	14	135	55	64	23	181	476	01
Merluccius bilinearis	23	38	12	3		----	----	----	----	7	2	361	448	01
Total for all Species	9,662	5,713	6,612	9,502	----	93	2,033	966	883	486	386	3,062	39,403	

Unit 2

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total	Percent
Pseudopleuronectes americanus	1,078	5,345	433	751	379	920	274	141	220	84	30	209	9,843	37
Menidia sp.	2,236	505	252	44	2	---	2	---	3	4	5	28	3,077	12
Anchoa sp.	---	---	---	--	387	1,010	531	77	380	15	9	16	2,425	09
Gasterosteus aculeatus	38	548	514	330	73	25	---	2	5	--	2	575	2,114	08
Tautogolabrus adspersus	---	---	---	3	97	585	181	524	250	84	2	3	1,728	07
Myoxocephalus aenaeus	265	183	69	170	195	70	7	2	68	---	2	550	1,581	06
Peprilus triacanthus	---	---	---	---	7	95	21	334	240	267	18	98	1,081	04
Microgadus tomcod	21	15	2	23	67	140	17	29	70	22	12	281	699	03
Tautoga onitis	---	---	---	---	37	183	55	42	163	86	--	5	570	02
Scophthalmus aquosus	23	17	10	28	48	125	50	22	15	9	35	95	477	02
Syngnathus fuscus	---	2	40	119	166	25	21	9	20	4	--	13	419	01
Merluccius bilinearis	21	54	2	3	4	---	---	---	---	2	9	227	322	01
Total for all Species	3,829	6,813	1,478	1,672	1,726	3,563	1,297	1,262	1,628	718	156	2,337	26,479	

Combined Impingement - Units 1 & 2 Intake Structures for 1979 65,882

*Those fish which were ≥ .01 of total annual abundance.

seasonally abundant, while emphasizing the ones that are resident year round. Unit 1 had a similar ranking pattern between 1978 and 1979 with winter flounder (92,86)** first in both years (Table 4). Silversides (73,55)**, a seasonally abundant species, became less important as a year round resident, when ranked by seasons throughout the year. Unit 2 species dominance during 1978 and 1979 was dissimilar (Table 5). In 1978, a tight grouping existed between winter flounder (80), grubby (80), and three-spined stickleback (77), indicating a similar occurrence of these species. In contrast, 1979 showed a more stratified situation similar to Unit 1 with winter flounder (88) ranked above grubby (71) and three-spined stickleback (69). This stratification reflects the year-round influence of winter flounder on impingement in 1979.

The combined impingement total of macroinvertebrates for all years was 118,868 (Table 6). Squid (36853,19987)* and lady crabs (9854,6313)* made up more than 70% of species composition at each unit for all years. Totals for 1979 were 18,766 and 18,106 for Units 1 and 2 respectively, a rise of 300 percent or more from 1978. Squid and lady crabs combined composed 90% and 85% of annual abundance respectively at both units in 1979 (Table 7). November (6,548) and September (5,963) were the months of greatest impingement at Units 1 and 2, respectively.

Species dominance for macroinvertebrates during 1979 revealed lady crabs (78,83)** to be more prevalent at both units with squid (75,79)** having just a slightly lower index value (Table 8). Lobster showed a higher ranking at Unit 1, primarily due to increased abundance during the winter season.

Table 4. Seasonal and annual species dominance using McCloskey's biological index for fish* impinged at Millstone Nuclear Power Station Unit 1 intake structure, 1978 and 1979

1978

	Winter		Spring		Summer		Fall		Total	Index
	#	Rank	#	Rank	#	Rank	#	Rank	Rank	Value
Pseudopleuronectes americanus	3,082	(11)	687	(10)	60	(12)	601	(11)	44	92
Myoxocephalus aenaeus	2,109	(10)	868	(12)	15	(8)	493	(10)	40	83
Menidia sp.	4,440	(12)	49	(4)	11	(7)	5,004	(12)	35	73
Gasterosteus aculeatus	911	(9)	745	(11)	2	(5)	266	(9)	34	71
Microgadus tomcod	52	(3)	62	(5)	27	(10)	263	(8)	26	54
Tautogolabrus adspersus	142	(4)	243	(8)	37	(11)	14	(2.5)	25.5	53
Tautoga onitis	2	(1)	195	(7)	20	(9)	17	(4)	21	44
Cyclopterus lumpus	509	(8)	64	(6)	--	(2.5)	14	(2.5)	19	40
Fundulus majalis	200	(7)	36	(2)	--	(2.5)	123	(7)	18.5	39
Syngnathus fuscus	10	(2)	365	(9)	8	(6)	4	(1)	18	38
Osmerus mordax	170	(6)	44	(3)	--	(2.5)	24	(5)	16.5	34
Merluccius bilinearis	158	(5)	2	(1)	--	(2.5)	80	(6)	14.5	30

1979

	Winter		Spring		Summer		Fall		Total	Index
	#	Rank	#	Rank	#	Rank	#	Rank	Rank	Value
Pseudopleuronectes americanus	10,337	(11)	1,834	(10)	533	(9)	406	(8)	38	86
Gasterosteus aculeatus	1,729	(9)	4,933	(11)	14	(3)	962	(11)	34	77
Myoxocephalus aenaeus	881	(8)	544	(8)	38	(4)	471	(10)	30	68
Microgadus tomcod	101	(6)	63	(5)	73	(6)	415	(9)	26	59
Merluccius bilinearis	73	(4)	5	(2)	--	(1)	370	(7)	24	55
Menidia sp.	7,535	(10)	954	(9)	9	(2)	95	(3)	24	55
Scopthalmus aquosus	100	(5)	67	(6)	165	(7)	162	(5)	23	52
Tautogolabrus adspersus	28	(3)	56	(4)	1,348	(11)	63	(2)	20	45
Syngnathus fuscus	267	(7)	494	(7)	39	(5)	52	(1)	20	45
Anchoa sp.	--	(1)	53	(3)	589	(10)	108	(4)	18	41
Peprilus triacanthus	2	(2)	2	(1)	204	(8)	268	(6)	17	39

*Those fish which were ≥.01 of total annual abundance.

Table 5. Seasonal and annual species dominance using McCloskey's biological index for fish* impinged at Millstone Nuclear Power Station Unit 2 intake structure, 1978 and 1979

1978

	Winter #	Winter Rank	Spring #	Spring Rank	Summer #	Summer Rank	Fall #	Fall Rank	Total Rank	Index Value
Pseudopleuronectes americanus	1,065	(13)	928	(12)	75	(11)	956	(12)	4[illegible]	80
Myoxocephalus aenaeus	1,530	(14)	1,064	(13)	13	(7)	1,391	(14)	48	80
Gasterosteus aculeatus	136	(12)	1,515	(15)	2	(4)	1,441	(15)	46	77
Microgadus tomcod	104	(10)	653	(10)	21	(9)	1,137	(13)	42	70
Tautogolabrus adspersus	69	(8)	1,191	(14)	104	(13)	31	(6)	41	68
Menidia sp.	2,092	(15)	36	(3.5)	6	(6)	615	(11)	35.5	59
Anchoa sp.	--	(1.5)	490	(8)	166	(14)	80	(8)	31.5	53
Syngnathus fuscus	22	(7)	776	(11)	14	(8)	7	(2)	28	47
Scopthalmus aquosus	4	(5)	107	(5)	28	(10)	77	(7)	27	45
Tautoga onitis	--	(1.5)	616	(9)	81	(12)	19	(4)	26.5	44
Peprilus triacanthus	2	(3.5)	10	(2)	193	(15)	17	(3)	23.5	39
Osmerus mordax	90	(9)	249	(6)	--	(1.5)	22	(5)	21.5	36
Ammodytes americanus	2	(3.5)	36	(3.5)	5	(5)	174	(9)	21	35
Merluccius bilinearis	18	(6)	4	(1)	1	(3)	199	(10)	20	33

1979

	Winter #	Winter Rank	Spring #	Spring Rank	Summer #	Summer Rank	Fall #	Fall Rank	Total Rank	Index Value
Pseudopleuronectes americanus	6,857	912)	2,050	(12)	635	(10)	303	(8)	42	88
Myoxocephalus aenaeus	517	(9)	436	(9)	77	(5)	552	(11)	34	71
Gasterosteus aculeatus	1,102	(10)	428	(8)	7	(3)	578	(12)	33	69
Anchoa sp.	--	(2.5)	1,397	(11)	988	(12)	40	(3)	28.5	59
Tautogolabrus adspersus	--	(2.5)	684	(10)	955	(11)	89	(4)	27.5	57
Microgadus tomcod	38	(5)	230	(6)	115	(7)	315	(9)	27	56
Peprilus triacanthus	--	(2.5)	102	(3)	595	(9)	384	(10)	24.5	51
Scopthalmus aquosus	50	(7)	202	(4)	87	(6)	139	(6)	23	48
Tautoga onitis	--	(2.5)	220	(5)	259	(8)	91	(5)	20.5	43
Syngnathus fuscus	43	(6)	309	(7)	50	(4)	17	(1)	18	38
Merluccius bilinearis	77	(8)	6	(1)	--	(1)	238	(7)	17	35
Menidia	2,294	(11)	46	(2)	5	(2)	35	(2)	17	35

*Those fish which were ≥.01 of total annual abundance.

Table 6. Total annual abundance and percent composition of macroinvertebrates* impinged at Millstone Point Nuclear Power Station Unit 1 and Unit 2 intake structures from 1972 to 1979

		Unit 1										Unit 2						
		1972	1973	1974	1975	1976	1977	1978	1979	Total	Percent	1975	1976	1977	1978	1979	Total	Percent
Squid	*Loligo pealei*	----	6,640	1,382	4,684	8,673	2,913	2,029	10,532	36,853	46	542	5,079	1,054	2,371	10,941	19,987	50
Lady Crab	*Ovalipes ocellatus*	1,936	4,059	2,109	1,705	437	1,723	1,100	6,313	19,382	24	316	1,397	1,823	1,750	4,568	9,854	25
Blue Crab	*Callinectes sapidus*	2,025	920	836	640	367	174	393	952	6,307	08	39	557	135	484	974	2,189	06
American Lobster	*Homarus americanus*	975	1,232	1,394	876	480	176	219	316	5,668	07	56	654	248	242	408	1,608	04
Crab Species	*Cancer* spp.	490	1,021	620	847	376	195	283	261	3,832	05	180	441	344	384	488	1,837	05
Green Crab	*Carcinus maenas*	246	826	799	756	552	297	259	320	4,055	05	79	415	318	324	390	1,526	04
Spider Crab Species	*Libinia* spp.	770	134	317	485	353	275	55	26	2,415	03	53	1,237	176	87	89	1,642	04
Total for all species		6,488	14,863	7,556	10,070	11,285	5,836	4,401	18,766	79,265		1,309	10,338	4,169	5,681	18,106	39,603	

Combined totals for all species Units 1 & 2 118,868

*Total for those species $\geq$ .6% of total abundance.

Table 7. Annual and monthly abundance and percent composition of macroinvertebrates* impinged at Millstone Nuclear Power Station Unit 1 and 2 intake structures during 1979.

Unit 1

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total	Percent
Loligo pealei	----	----	----	7	----	85	1,997	1,556	2,588	539	[illegible]	1,398	[illegible]	56
Ovalipes ocellatus	----	----	----	----	----	----	407	206	280	442	3,935	929	[illegible]	34
Callinectes sapidus	----	----	----	----	----	2	50	190	113	438	150	10	952	05
Carcinus maenas	6	7	10	34	----	27	55	13	18	38	58	57	[illegible]	02
Homarus americanus	6	----	19	77	----	3	62	29	35	44	32	8	[illegible]	02
Cancer irroratus	67	5	50	63	----	12	17	2	-----	2	----	18	235	[illegible]
Total for all Species	79	[illegible]	79	195	----	249	2,604	2,002	3,048	1,516	6,548	2,430	18,766	

Unit 2

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total	Percent
Loligo pealei	----	----	----	----	201	2,398	1,026	1,269	5,065	327	246	410	10,941	60
Ovalipes ocellatus	2	2	2	5	39	513	431	263	433	442	1,757	681	4,568	25
Callinectes sapidus	----	----	----	----	13	75	33	155	283	376	37	3	974	05
Cancer irroratus	96	13	24	98	43	48	21	7	15	2	9	36	412	02
Homarus americanus	----	----	----	10	15	83	93	77	68	49	12	3	408	02
Carcinus maenas	6	4	5	8	34	53	24	11	48	60	64	75	390	02
Total for all Species	107	19	31	129	458	3,280	1,671	1,799	5,963	1,308	2,132	1,210	18,106	

*Those species $\geq$.01 total abundance.

Table 8. Seasonal and annual species dominance using McCloskey's biological index for macroinvertebrates* impinged, at Millstone Nuclear Power Station Unit 1 and Unit 2 intake structures, 1979.

Unit 1

	Winter		Spring		Summer		Fall		Total	Index
	#	Rank	#	Rank	#	Rank	#	Rank	Rank	Value
Ovalipes ocellatus	--	(2)	115	(6)	893	(5)	5306	(6)	19	79
Loligo pealei	--	(2)	92	(5)	6140	(6)	4300	(5)	18	75
Homarus americanus	25	(5)	80	(4)	126	(3)	84	(2)	14	58
Carcinus maenas	23	(4)	60	(2)	86	(2)	152	(3)	11	46
Cancer irroratus	121	(6)	74	(3)	19	(1)	20	(1)	11	46
Callinectes sapidus	--	(2)	2	(1)	353	(4)	597	(4)	11	46

Unit 2

	Winter		Spring		Summer		Fall		Total	Index
	#	Rank	#	Rank	#	Rank	#	Rank	Rank	Value
Ovalipes ocellatus	4	(4)	557	(5)	1126	(5)	2880	(6)	20	83
Loligo pealei	--	(2)	2598	(6)	7359	(6)	98	(5)	19	79
Cancer irroratus	133	(6)	188	(4)	43	(1)	48	(1)	12	50
Carcinus maenas	15	(5)	94	(2)	82	(2)	199	(3)	12	50
Callinectes sapidus	--	(2)	88	(1)	471	(4)	415	(4)	11	46
Homarus americanus	--	(2)	108	(3)	238	(3)	63	(2)	10	42

*Those species $\geq$.01 of total abundance.

Length frequency distribution of winter flounder during March, April, and May of 1979 (spawning season in Niantic Bay), showed no significant difference between units based upon a Kolmogorov-Smirnov two-sample test (Fig. 1). The estimated number impinged during this period of time was 4,918 at Unit 1 and 1,563 at Unit 2. The Unit 1 estimate only included the months of March and April. Utilizing criteria set up for this year's age-length relationships (see winter flounder section) Unit 1 had 34% one year olds, 27% two year olds, and 39% three and four year olds; Unit 2 had 66% one year olds, 19% two year olds, and 16% three and four year olds.

Fish Boom

An investigation into the effectiveness of the fish boom in front of Unit 1 was undertaken to determine if an explanation of the difference in 1979 impingement rates between units could be found. The boom consists of a heavy rubber curtain bordered along the bottom with chain-link fence. It is located outboard of the intake face about 50 feet and extends parallel to the shore between two rocky outcrops. The boom rises off the bottom about six feet.

An initial look at the data for 1979 showed Unit 1 impinged almost one-third more fish than Unit 2 in two months less operating time. A test of the data for all years revealed a highly significant difference (p=.001) existed, using Friedman's non-parametric test for two-way analysis of variance between the rankings of species throughout the years at Unit 1. No significant difference existed at Unit 2. Unit 1 had a great deal of

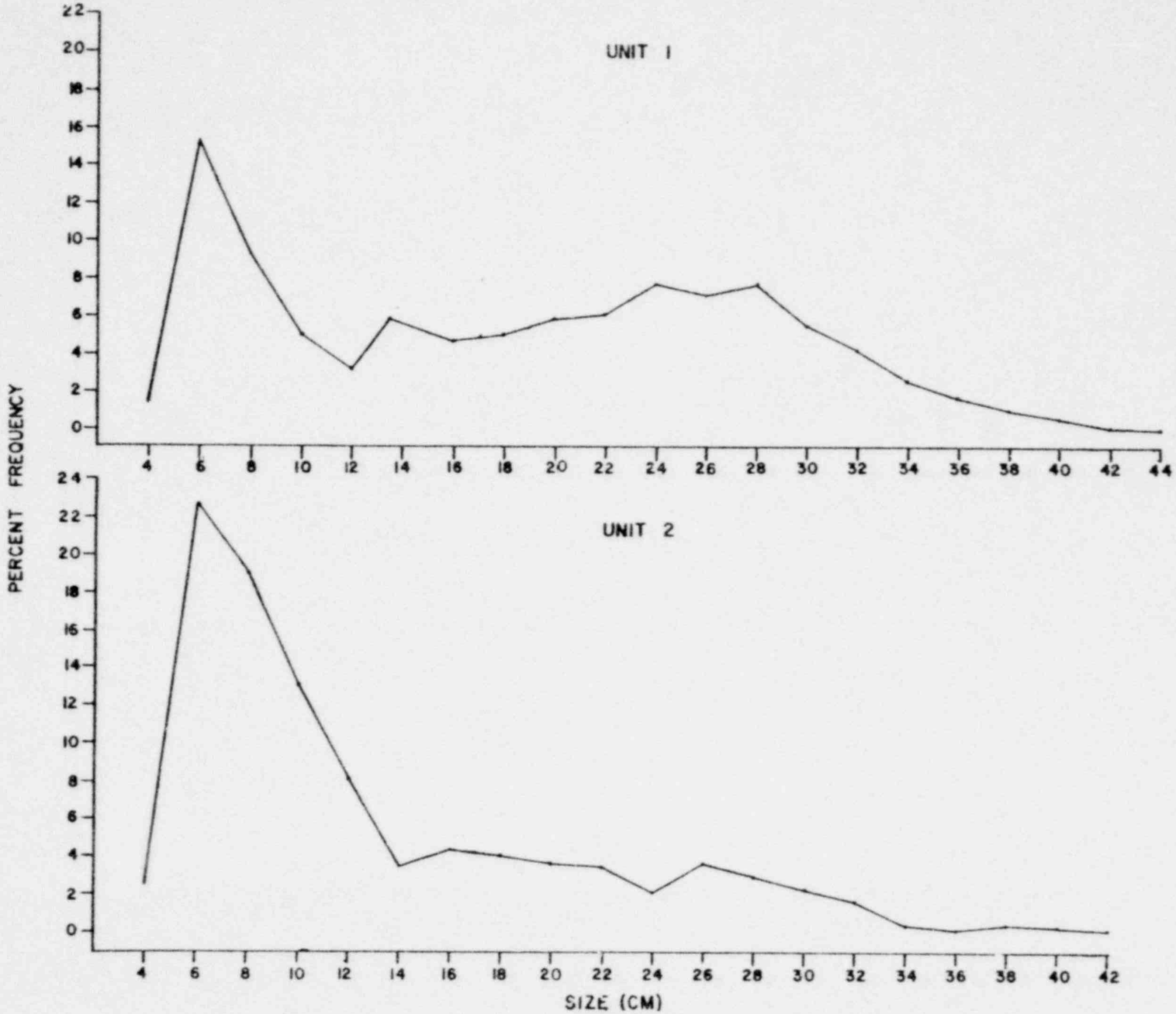


Figure 1. Length frequency of impinged winter flounder, units 1 and 2, 1979.

variability in the ranking and related abundance of species, while Unit 2 was relatively stable.

Inverse clustering showed no distinct groupings of species at Unit 1 (Fig. 2). A high clustering of winter flounder with northern pipefish and cunner with smelt can be attributed to similar patterns of fluctuations of abundance through the years. Blackfish and white perch cluster high with similar fluctuations as well. The rest of the species seem to cluster onto the groups with no discernable pattern. Species of similar ecological persuasion are not clustered closely.

Winter flounder, a locally important fish, was chosen to determine if any temporal trends were present. An analysis of variance on data from 1976 through 1979 revealed a highly significant difference ($p=.001$) between years, and when months were nested within years, independent of unit. The effect between units was not significant ($p=.270$) for all years. The effects due to years and month within years may be attributed to natural, seasonal, and yearly species fluctuations. Analysis of 1979 data showed a highly significant difference ($p=.001$) between months, while no significant difference was found between units ($p=.360$). It should be mentioned that data were standardized on a monthly basis, and for future analysis will be standardized to a daily basis.

A comparison of 1976 (a year in which the boom was virtually ineffective as a result of not being secured) and 1979 winter flounder length frequency data was made graphically for Units 1 and 2 (Figs. 1 and 3). The time period chosen was March through May, the local spawning season. A

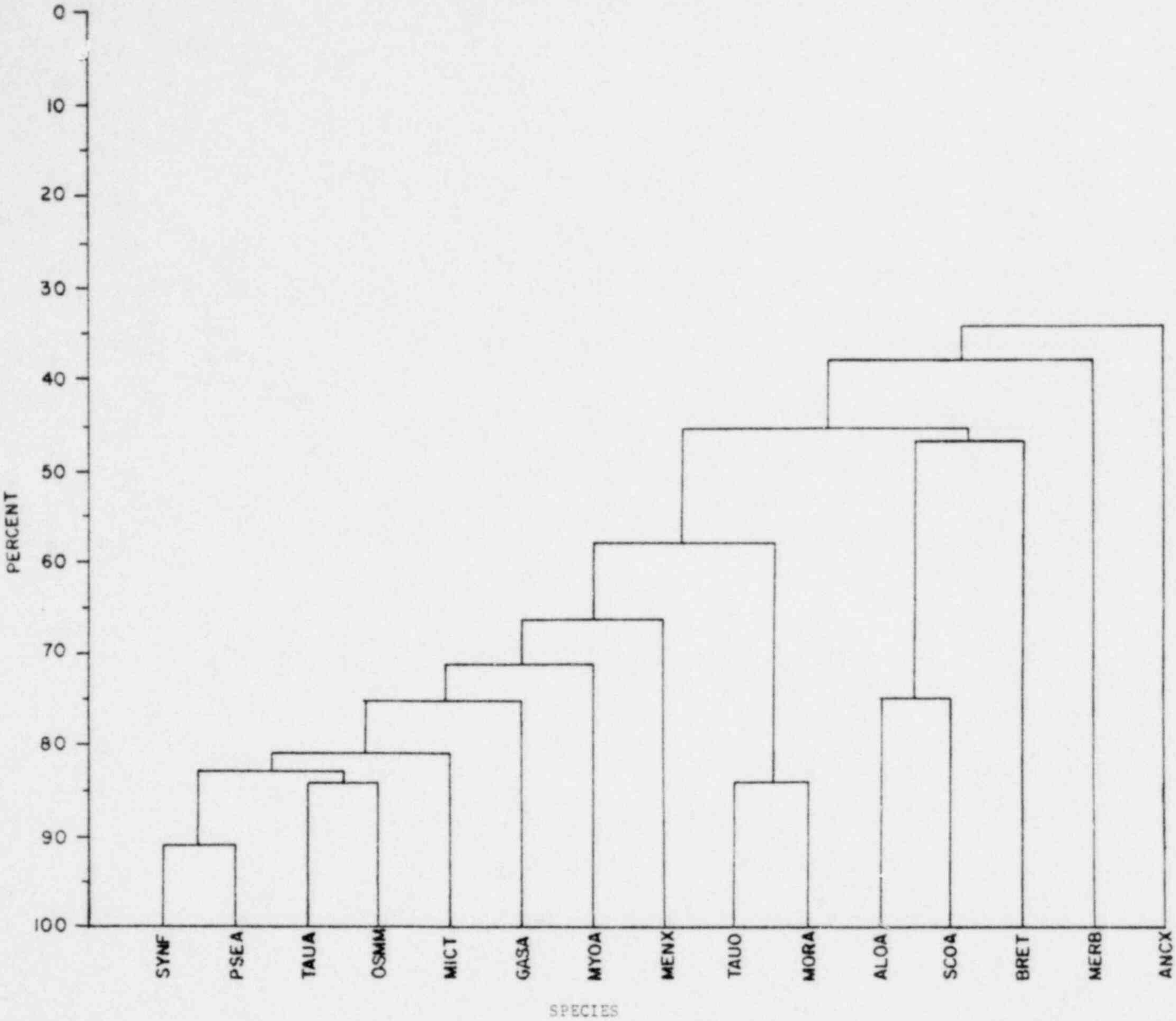


Figure 2. Inverse clustering of the top 15 species impinged at unit 1 during 1979.

SYNF-*Syngnathus fuscus*
PSEA-*Pseudopleuronectes americanus*
TAUA-*Tautogolabrus adspersus*
OSMM-*Osmerus mordax*
MICT-*Microgadus tomcod*
GASA-*Gasterosteus aculeatus*
MYOA-*Myoxocephalus aenaeus*
MENX-*Menidia sp.*
TAUO-*Tautoga onitis*
MORA-*Morone americana*
ALOA-*Alosa aestivalis*
SCOA-*Scopthalmus aquosus*
BRET-*Brevoortia tyrannus*
MERB-*Merluccius bilinearis*
ANCX-*Anchoa sp.*

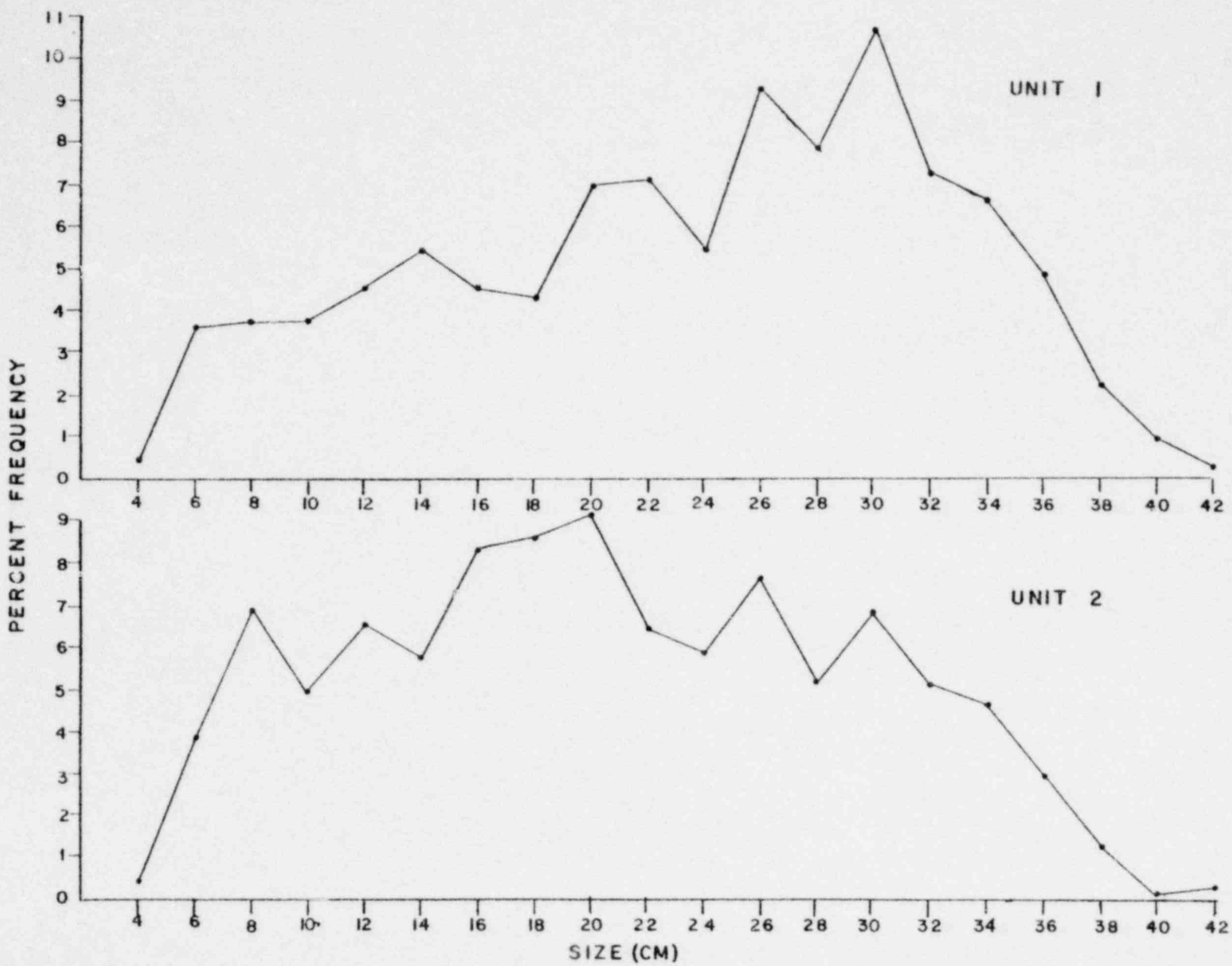


Figure 3. Length frequency of impinged winter flounder, units 1 and 2, 1976.

Kolmogorov-Smirnov two-sample test revealed no significant difference between units in the distribution of 1976 winter flounder length frequency data. Applying the same criteria that was used for 1979 age-length relationships, revealed the following for 1976: Unit 1 had 16% one year olds, 28% two year olds, and 56% three and four year olds; Unit 2 had 22% one year olds, 38% two year olds, and 40% three and four year olds. Comparison of the three and four year old groups for 1976 and 1979 revealed a 50% increase in the difference between units in 1979. Calculation of the average length impinged for each year, revealed a 64% increase in the difference between units in 1979.

The evidence presented, both observational and statistical, suggests that the fish boom in its present condition, has not been a deterrent to fish impingement.

SCUBA observations at Millstone Unit 1 Intake revealed that a diverse and productive community of fish exists around the boom. The boom seems to serve as an artificial reef for a variety of life forms. This, in conjunction with the knowledge that, "estimates of benthic sand infaunal densities in the vicinity of the Intake structures are considerably lower than those of other nearshore stations in the Millstone area" (see benthic section), suggests that the boom may act as a habitat for local fish.

A rigorous approach will be taken in monitoring the impingement rate at Unit 1 in 1980, with respect to the effects of the fish boom. Standardization of daily data and additional analytical techniques will be employed to detect any impact brought on by the boom.

It is hoped a model can be developed to take into account biological and physical parameters that will help us better understand the processes involved with impingement.

Summary and Conclusion

The combined finfish impingement total for 1979 was 65,882 with 39,403 and 26,479 for Units 1 and 2 respectively. Total annual impingement has shown an upward trend with Unit 1 increasing 59% from 1978 to 1979.

Winter flounder, silversides and three-spined stickleback composed more than 59% of the annual impingement at each Unit. Using McCloskey's biological index as an indicator, winter flounder was shown to be the most dominant species at both Units in 1978 and 1979. Silversides, a seasonally abundant species, becomes less important when ranked by seasons throughout the year.

The combined macroinvertebrate impingement total for 1979 was 36,872. The distribution by unit was similar. Squid and lady crabs combined composed 90 and 85% of annual abundance at Units 1 and 2 respectively.

Length frequency distribution of winter flounder during March, April and May 1979 showed no significant difference between units. During this period over three times more winter flounder were impinged at Unit 1 compared to Unit 2.

The bottom fish boom in front of Unit 1 seemed to be an ineffective barrier to the impingement of demersal fish.

Environmental assessment of the effects of impingement on the fish community in the greater Millstone area was monitored by trawls, gill nets and seines. Subsequently, the effects of impingement on local fish populations are addressed in the Fish Ecology section. On the basis of these studies and on the basis of trends observed in the impingement data, it has not been possible to determine any change in the local fish populations which appear to be power plant related.

LITERATURE CITED

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollutions. E.P.A. Environ. Res. Ser. EPA-600/3-77033. 155 pp.

Campbell, R. C. 1974. Statistics For Biologists. Cambridge University Press. New York. 385 pp

Conover, W. J. 1971. Practical Nonparametric Statistics. John Wiley and Sons, Inc. New York. 462 pp.

Helwig, J. T. and K. A. Council 1979. SAS Users Guide. SAS Institute Inc., Raleigh North Carolina. 494 pp.

McCloskey, L. R. 1970. The dynamics of the community associated with a marine scleractinian coral. Intern. Rev. Ges. Hydrobiologie. 55:13-81.

Murarka, I. P. 1977. A model for predicting fish impingement at cooling water intakes. Argonne National Laboratory/AA-8.

NUSCO. 1976. Annual report, ecological and hydrographic studies, 1976, Millstone Nuclear Power Station. Submitted to the U.S. Nuclear Regulatory Commission.

NUSCO. 1977. Annual report, ecological and hydrographic studies, 1977, Millstone Nuclear Power Station. Submitted to the U.S. Nuclear Regulatory Commission.

Ray, S. S., 1976. A state-of-the-art report on intake technologies. E.P.A. EPA-600/7-76-020.

Sharma, R. K. and R. F. Freeman, III. 1977. Survey of fish impingement at power plants in the United States. The Great Lakes. Argonne National Laboratory/ES-56 1.

Uziel, M. S. 1978. Impingment. Journal Water Pollution Control Federation. June:1553-1567.

PLANKTON STUDIES

INTRODUCTION

Plankton entrained in the condenser cooling water and present at different stations in waters adjacent to Millstone Power Station have been studied in various programs since 1970. Unit 1 (935 cfs, 660 MWe) began commercial operation at this time followed by Unit 2 (1220 cfs, 870 MWe) in the fall of 1975. A third unit (2000cfs, 1150 MWe) is presently under construction and is scheduled for commercial operation in late 1986. Hence, the current plankton programs provide both operational studies for the first two units and preoperational for the third. These plankton programs include both entrainment and offshore studies of plankton density and studies of direct and latent plant mortality. These have been reviewed extensively in our last annual report (NUSCO 1979b).

The ongoing plankton program reported herein includes three types of sampling for the period from October 1978 through October 1979 and a comparison of these results with earlier seasonal plankton cycles. The first plankton program at Millstone concerns the seasonality and density of ichthyoplankton, both fish eggs and larvae, entrained at the plant discharges and found simultaneously at a representative control station (Station 5) in mid-Niantic Bay (Fig. 1). A second plankton program concerns the zooplankton retained by the 0.333 mm mesh nets. These zooplankton consist primarily of the larger copepodites and reproductive adults of calanoid copepods and of the meroplanktonic developmental stages of many benthic invertebrates. The zooplankton are studied

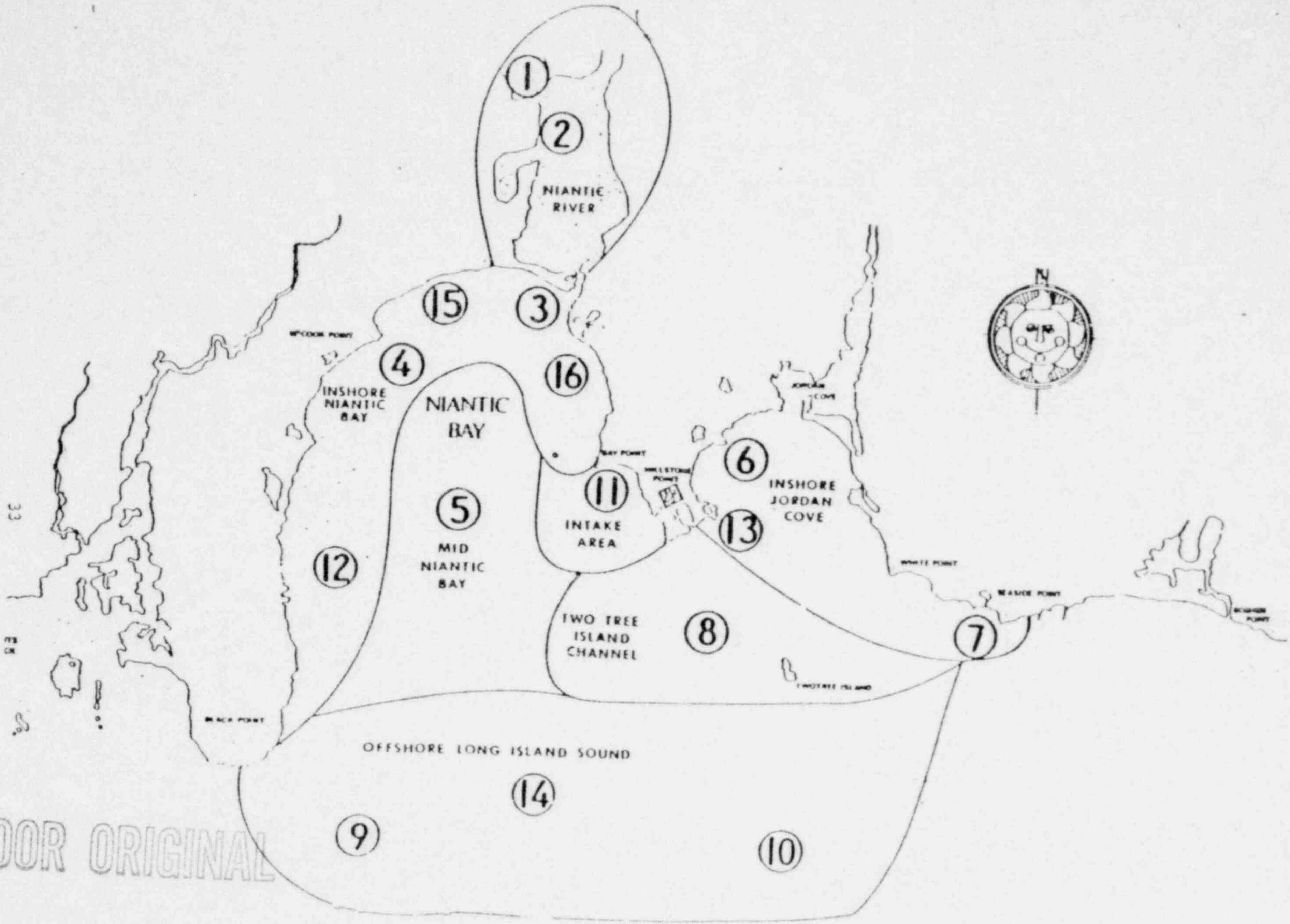


Figure 1. Location of plant and offshore ichthyoplankton stations.

primarily because of their trophic importance to the ichthyoplankton. The eggs and nauplii that adult copepods produce become the food of many of the fish larvae. Hence, the success of the zooplankton in reproducing may be related to the success of fish larvae in their own feeding, growth and survival. A third plankton group, the phytoplankton, have been studied because their abundance influences, in turn, the feeding, growth and reproductive success of the zooplankton.

The major objectives of the present report and of the plankton portion of the continuing environmental monitoring programs at Millstone are the following:

1. To provide quantitative estimates of the abundance and species composition of the phytoplankton, zooplankton, and fish eggs or larvae entrained.

2. To assess the impact of entrainment for selected plankton species or groups where supportive information from Millstone studies or the literature is available.

3. To examine closely the expected fluctuations in time or space of plankton relative to other plankton or climatological events so that some judgement could be made of the magnitude of natural versus plant-induced changes in marine communities.

4. To evaluate the responsiveness of the present plankton programs in characterizing the important ecological relationships in the plankton of the Millstone area and in detecting changes whether related to natural events or to operation of the plant.

METHODS AND MATERIALS

Field Sampling Methods

Eighteen ichthyoplankton net tows of about 400 m^3 volume filtered were collected each week at Unit 1 or 2 discharge. A 1.0 m diameter, 3.6 m long, 0.333 mm mesh, unbridled plankton net was deployed using an A-frame gantry system described previously (NUSCO 1978). Triplicate day and night samples were taken on each of three days per week. Volumes were measured using an array of three mechanical TSK flowmeters which recorded any variable horizontal or vertical current shear across the mouth of the net more adequately than the one sensor location of the electronic current meter system used previously (NUSCO 1978; 1979b). Samples were preserved immediately in the field in 5% buffered formalin.

Offshore ichthyoplankton net tows in 1979 were collected both day and night at Station 5 in mid Niantic Bay (Fig. 1). All samples were sawtooth oblique bongo net hauls proceeding from surface to near bottom and back to the surface over several cycles in the course of the fifteen minute tow. The bongo frame used was unbridled, and had paired 60 cm diameter, 0.333 mm mesh nets. Volume filtered in all cases (usually about 250 m^3) was estimated using a General Oceanics Model 2030M mechanical flowmeter both inside and outside the nets. Bi-weekly day and night paired tows were taken in January through March and September through December, a period of reduced biological activity when only one of the two resulting samples was analyzed.

From April through August, weekly day and night replicate net tows were taken at Station 5 and all of these samples were processed. Thus, during the growth seasons of many of the numerically dominant ichthyoplankton and zooplankton (NUSCO 1979b), sampling effort was increased each week by at least a factor of four.

One day and one night sample each week as available at both the discharges and Station 5 was chosen for processing of the zooplankton retained by a 0.333 mm mesh net.

Whole water bottle samples were collected weekly at either discharge for phytoplankton cell counts and chlorophyll a. Collections usually were made midweek coincident with zooplankton, ichthyoplankton and pumped microzooplankton samples. Samples for phytoplankton cell counts were preserved with Lugol's Iodine. Water samples for chlorophyll a determination were transported immediately to the laboratory in darkened bottles, filtered using 0.45 micron porosity Gelman type AE glass-fiber filters, desiccated and stored for less than two months following the procedures of SCOR-UNESCO (1966).

Phytoplankton Laboratory Processing

The Utermohl inverted microscope technique was used to enumerate and identify phytoplankton cells (Utermohl 1958; Lund et al. 1958). A 10-ml settling chamber was viewed at 400x and from 20 to 100 fields were observed. From 100 to 200 individual cells were counted and identified to lowest practical taxon. A grinding and 90% acetone extraction of chlorophyll a versus phaeo-pigments were determined by a fluorescence technique (Turner Model 111 fluorometer) described in SCOR-UNESCO (1966).

Zooplankton Laboratory Processing

One day and one night sample of the eighteen weekly ichthyoplankton samples from the discharge and of those taken by bongo tow at Station 5 were processed for the mesozooplankton. Processing was conducted following the methods described in NUSCO (1979b) except for a small change in the aliquoting procedure. A Stempel pipette was used to take several aliquots of one, five or ten ml depending on the density of organisms. These aliquots were taken in a 6-liter reservoir randomized by stirring with a large slotted piston. Aliquots of different volumes were examined until at least 300 organisms were counted and identified to lowest practical taxon. All or a portion (obtained from a Folsom-type plankton splitter) of each zooplankton sample was cleaned of larger interfering debris and used for an estimate of dry weight zooplankton biomass. The zooplankton material was dried at 70°C for 24 hours and weighed with a precision of 0.01g. All zooplankton and ichthyoplankton tows during June, July, and August were also sorted for the pelagic larval stages of the lobster, *Homarus americanus*.

Ichthyoplankton Laboratory Processing

All ichthyoplankton samples from the plant discharges or offshore stations were sorted under dissecting microscopes; about ten percent of the 1284 ichthyoplankton samples collected in 1979 were resorted as part of a quality assurance program. Processing methods were similar to those described in NUSCO (1979b). Fish larvae and fish eggs were removed from whole samples or from fractions obtained using a Folsom-type plankton splitter. A variety of taxonomic literature and type collections from other planktologists was used to characterize both larvae and eggs to the lowest practical category. Fish larvae were classified by such features as general body shape or size, fin arrangement, pigmentation patterns and jaw or head shape and so forth. Fish eggs were identified on the basis of egg shape or size, number or size of oil globules, size of the perivitelline space and any characteristics of the developing larvae where possible.

The eggs of the two common labrids of Long Island Sound, the cunner (Tautogolabrus adspersus), and the tautog (Tautoga onitis) were particularly difficult to identify with confidence since they have no oil globules, are very similar in appearance otherwise and are coincident in spawning season. Since the immunological approach suggested by Orlowski et al. (1972) was judged impractical for a field program, measurements of egg diameters were taken to investigate the apparent bimodality separating the two species through the growth season (similar to the work of Williams 1967). One hundred or more eggs each week were measured to the nearest one-hundredth of a millimeter. On the basis of the observed bimodality in egg diameter, cunner (the smaller egg) and tautog (the larger) were separated. The density of labrid eggs for that week was assigned on a percentage basis to either of the two species varying throughout the extensive spawning season. For comparison to other plankton programs, the time, egg diameter and temperature criteria associated with the differentiation of cunner and tautog are included in Table 1.

General Statistical Treatments

Because of the variability inherent in plankton distributions, all analyses use the logarithmic transformation of data before a parametric test. This transformation helped stabilize the variance. Analyses of variance (AOV) were conducted comparing the effect of different factors on the mean seasonal density. This quantity included all data from the first to the last occurrence each year and made no attempt to fill with zeroes some missing data points over the growth season. To provide a measure of the limits of changes in fish larval density that could be detected by this monitoring program, power calculations were made complementing the AOV approach. In addition, preliminary time series analyses were undertaken so that biological time-lagged responses could be better accounted for than by linear comparisons.

Table 1. Criteria for separation of cunner and tautog eggs on the basis of egg diameter range and bimodality over the 1979 growth season.

Date	Egg Diameter (mm)		Modal Egg Diameter (mm)		% of Total Labrids		Mean Weekly Temperature (^{o}C)
	Cunner	Tautog	Cunner	Tautog	Cunner	Tautog	
5/1-5/7	0.80-0.92	0.93-1.08	0.90	1.06	67	33	9.0
5/8-5/14	0.75-0.95	0.96-1.10	0.90	1.00	60	40	10.0
5/15-5/21	0.80-0.96	0.97-1.06	0.90	1.00	92	8	10.0
5/22-5/28	0.85-0.95	0.96-1.10	0.90	1.00	86	14	12.0
5/29-6/4	0.85-0.95	0.96-1.15	0.90	1.05	70	30	14.0
6/5-6/11	0.80-1.00	1.01-1.10	0.90	1.05	89	11	15.0
6/12-6/18	0.75-0.94	0.95-1.06	0.85	1.00	84	16	15.5
6/19-6/25	0.75-0.92	0.93-1.02	0.80	0.96	85	15	16.0
6/26-7/2	0.74-0.90	0.91-1.06	0.84	0.97	83	17	16.5
7/3-7/9	0.70-0.90	0.91-1.00	0.84	0.96	73	27	17.0
7/10-7/16	0.76-0.88	0.89-0.98	0.80	0.94	59	39	17.5
7/17-7/23	0.74-0.88	0.89-1.00	0.76	0.94	68	32	18.0
7/24-7/30	0.72-0.88	0.89-1.02	0.77	0.92	54	46	20.0
7/31-8/6	0.70-0.84	0.85-0.98	0.80	0.92	35	65	21.5
8/7-8/13	0.70-0.82	0.83-0.96	0.74	0.92	29	71	21.5
8/14-8/20	0.72-0.80	0.81-1.02	0.76	0.90	16	84	21.0
8/21-8/27	0.00-0.00	0.88-1.00	----	0.92	0	100	21.0
8/28-9/3	0.74-0.84	0.85-1.02	0.81	0.94	7	93	21.0

RESULTS AND DISCUSSION

Phytoplankton

Several floristic changes in mean phytoplankton density or rank order occurred over the period 1977 through 1979. Also, there was an overall trend for density reduction in 1979. The percent species composition, mean seasonal density, rank order based on percent, and number of samples where species were recorded were calculated for the fifteen most important species or taxonomic groups (Table 2). Skeletonema costatum was the most important diatom in 1979 as well as the previous two years. S. costatum ranked first and microflagellates were ranked second in 1977. These ranks were reversed in 1978 and 1979;while microflagellate density increased in 1978 and then decreased in 1979. S. costatum appeared to decrease each year. Unidentified chlorophyceans changed from rank 21 in 1977 to rank 3 in both 1978 and 1979. Phaeocystis spp. changed from rank 3 in 1977 to rank 5 in 1978 and then to rank 7 in 1979. While changing only two places in rank, Phaeocystis spp. was greatly reduced in density in 1979. This was probably related to the reduction in mean phytoplankton density. The cryptomonads appeared to be lower in density in 1979. Asterionella spp., Chaetoceros spp., and Leptocylindrus spp. were three genera of diatoms that showed an increase in mean density for 1979.

Seasonal fluctuations in phytoplankton abundance appeared somewhat different in 1979 (Figs. 2, 3 and 4). The mean weekly $\log_{10}$ transformed cells per liter for many of the dominant species was lower than in 1977

Table 2 . Percent species composition, seasonal density (mean #/L x 10^5), rank order, and number of samples where species present (N) for phytoplankton collected at the combined discharges from 1977 through 1979.

Species or Group	1979 %	1979 #/L	1979 Rank	1979 N	1978 %	1978 #/L	1978 Rank	1978 N	1977 %	1977 #/L	1977 Rank	1977 N
Unknown microflagellate	26.3	4.36	1	52	48.9	14.70	1	52	23.7	7.05	2	43
Skeletonema costatum	23.1	4.33	2	46	18.5	5.67	2	51	36.0	9.39	1	49
Unknown Chlorophyceae	18.1	4.73	3	33	9.3	6.91	3	21	0.1	0.19	21	8
Chaetoceros spp.	7.7	1.80	4	37	2.0	0.83	8	38	1.7	0.67	8	34
Cryptomonadaceae	6.1	1.06	5	50	4.6	1.81	4	40	5.5	1.68	4	42
Asterionella spp.	3.6	1.23	6	25	1.3	0.66	9	31	1.1	0.62	11	23
Phaeocystis spp.	2.7	2.92	7	8	3.8	19.81	5	3	17.3	22.05	3	10
Unknown pennate diatoms	2.3	0.38	8	52	1.1	0.34	10	50	2.1	0.54	6	49
Thalassiosira spp.	2.1	0.46	9	39	3.7	1.31	6	44	1.7	0.72	9	31
Leptocylindrus spp.	1.8	0.59	10	26	0.5	0.41	12	21	0.3	0.47	18	7
Unknown centrate diatoms	1.3	0.29	11	39	0.4	0.37	13	19	2.3	0.88	5	34
Thalassionema spp.	0.8	0.34	12	19	0.4	0.34	15	17	0.6	0.44	12	17
Prorocentrum spp.	0.4	0.26	13	14	<[illegible]	0.15	30	4	0.2	0.22	20	9
Detonula confervacea	0.4	0.67	14	5	0.3	0.55	16	8	0.1	0.14	32	5
Rhizosolenia delicatula	0.2	0.10	19	22	0.1	0.17	20	12	1.5	1.22	10	16
Ceratulina bergonii	0.2	0.29	21	7	2.2	3.8	7	9	2.1	2.92	7	9

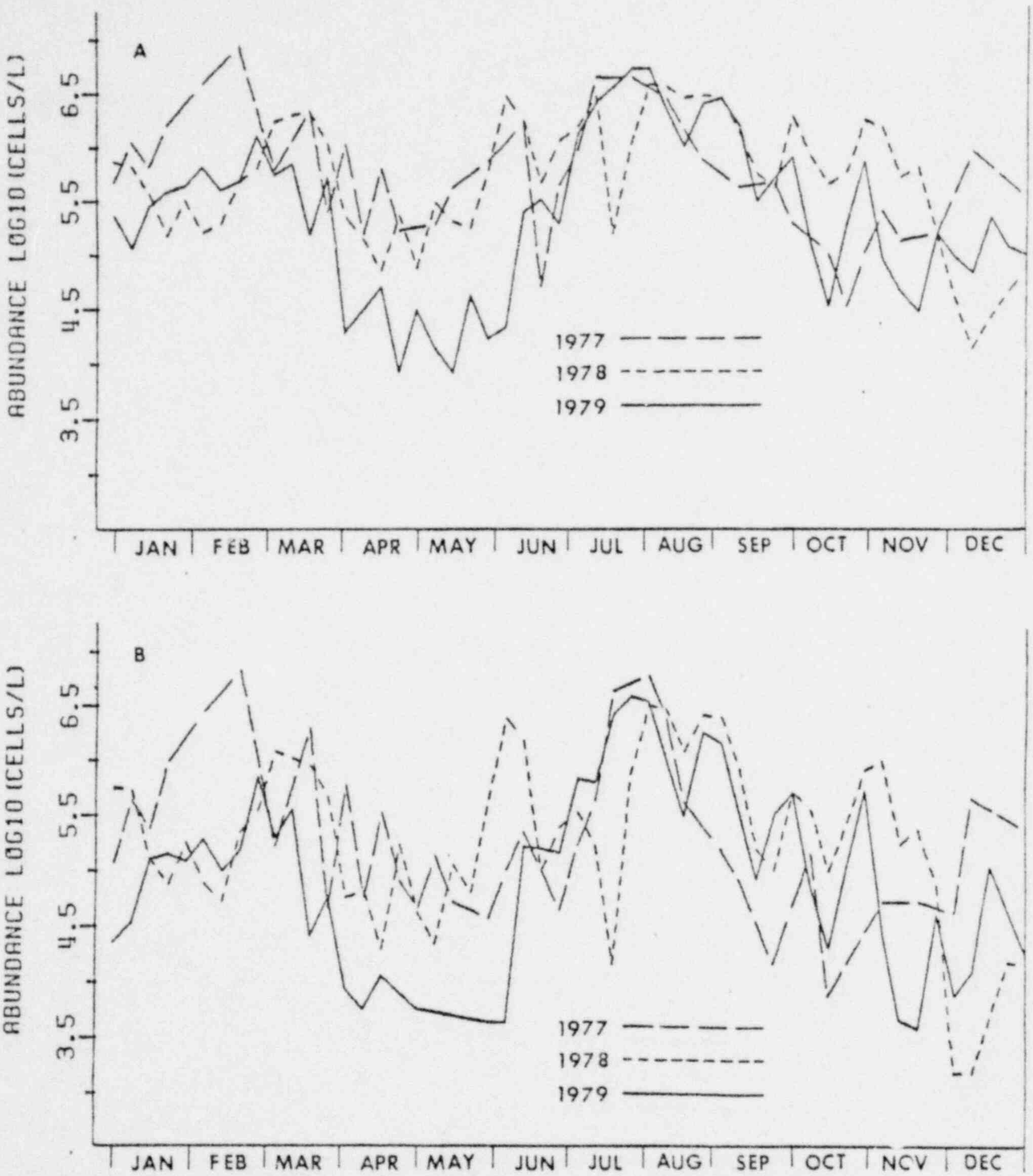


Figure 2. Panel A: Log_{10} transformed weekly density (cells/liter) of total diatoms from 1977 through 1979. Panel B: Similar plot for Skeletonema costatum.

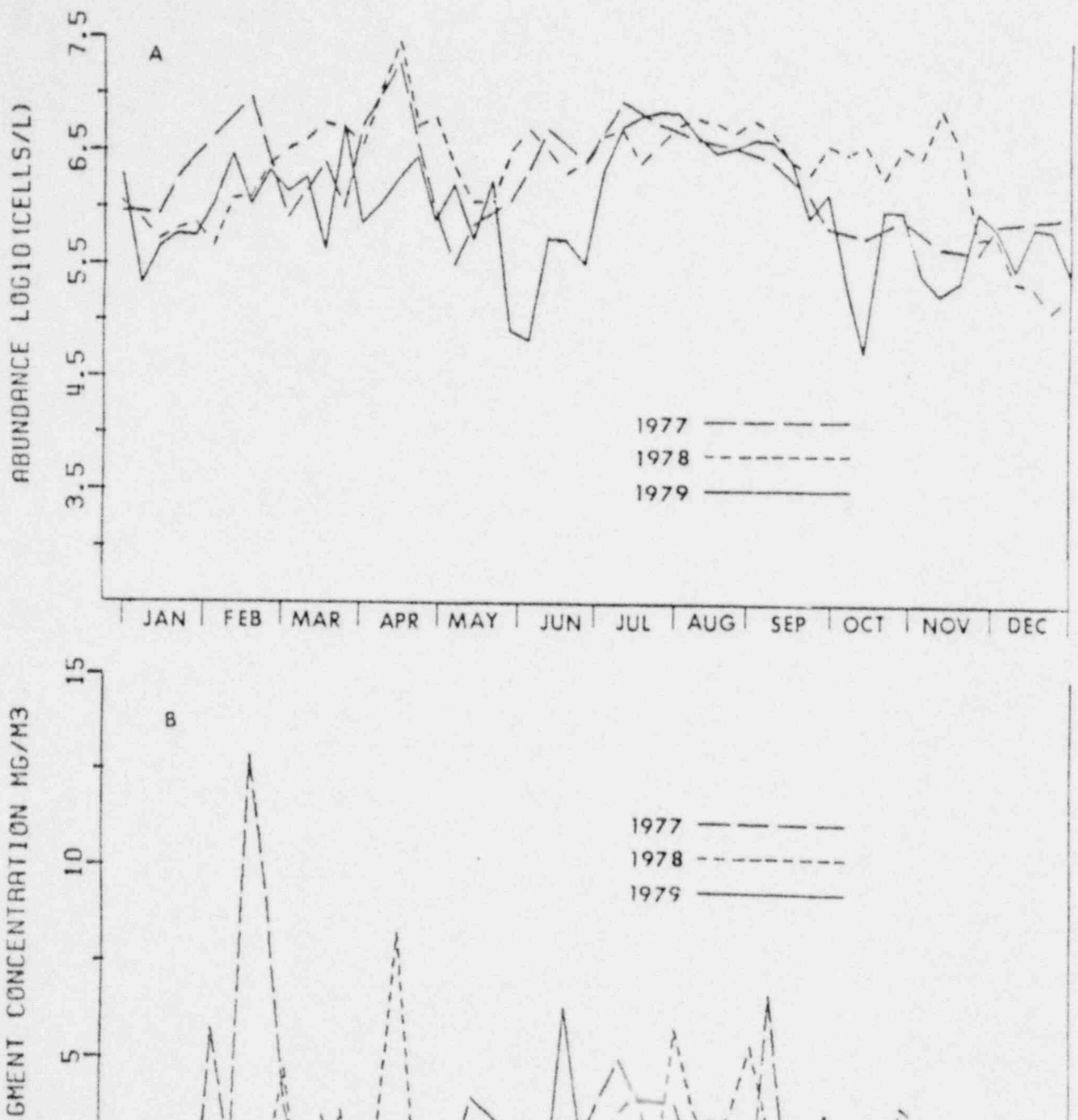


Figure 3. Panel A: Log_{10} transformed weekly density (cells/liter) of total phytoplankton from 1977 through 1979. Panel B: Chlorophyll a concentration. (mg/m^3) by week over the same time period.

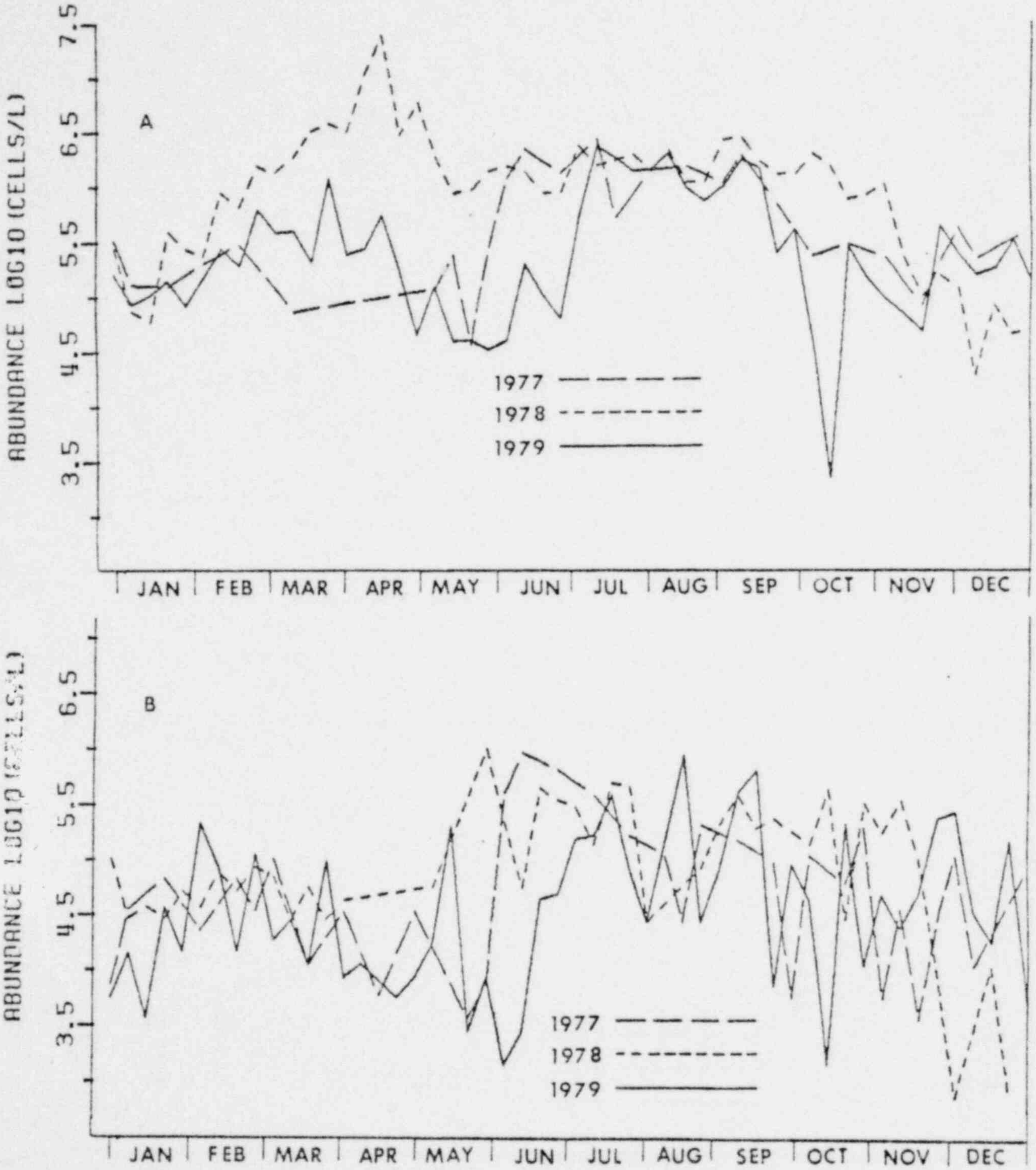


Figure 4. Panel A: Log_{10} transformed weekly density (cells/liter) of microflagellates from 1977 through 1979. Panel B: Similar plot of cryptomonad density.

or 1978. The peak density of some of these species was delayed in 1979. Also, their periods of low density were somewhat prolonged. Total diatom density was reduced in the spring due mainly to the decrease in the dominant diatom S. costatum (Fig. 2). Microflagellates and cryptomonads were less abundant from March through June 1979 than during similar periods in the previous two years (Fig. 3). Unidentified chlorophyceans were markedly more abundant during the spring of 1979 than during the spring of 1977. This group was not recorded in the spring 1978 samples, but were dominant enough during the second half of 1978 to achieve the highest mean annual density over the three year study period (Table 2).

Annual cycles of the total diatoms compared to cycles of the dominant, nondiatom species such as the cryptomonads, microflagellates, Phaeocystis spp., and the chlorophyceans suggested an inverse relationship such as observed by several local investigators (Conover 1956; Riley 1966; Durbin et al. 1975; Staker and Bruno 1978). Diatoms have been most dominant during the first three months of the year followed by a decrease in April and May and then by a period of multiple summer and fall transient peaks (Fig. 2). In comparison with 1977 and 1978, diatom numbers were lower from April through early June 1979. During this period, the unidentified chlorophyceans were very abundant, higher than in any previous spring. As these weekly chlorophycean densities dropped in early June, the diatoms and the dominant flagellated forms both increased markedly in density (Fig. 2, 3).

The apparent alteration from diatoms to other dominant forms through three annual cycles represented a complex floristic problem beyond the scope and objective of this phytoplankton program. Among the physical, chemical and biological factors probably involved, two of the most important for consideration may be seasonal nutrient availability and zooplankton grazing (Conover 1956; Riley 1966; Martin 1965, 1970; Pratt 1959, 1963; Hitchcock and Smayda 1976; Smayda 1973). Nitrogen and silicon concentrations were most important for diatom growth and seasonal concentrations may influence the initiation and magnitude of blooms (Pratt 1959, 1963; Vince and Valiella 1973; Paasche 1973, 1975; Sakshaug 1977; Furnas et al. 1975; Hitchcock 1978; Smayda 1973). Flagellated forms have been shown to grow better than diatoms under reduced nutrient conditions (Chan 1978; Smayda 1974; Sakshaug 1977). Increased zooplankton grazing would also be a potential explanation of the decline in diatoms and increase in flagellated forms in the late spring-early summer period (Conover 1956; Riley 1966; Pratt 1959, 1963; Martin 1965, 1970; Smayda 1973). Zooplankton exhibit a variety of feeding patterns which, either actively or passively, appear to select the largest or most dense phytoplankton cells available in their feeding size range (Frost, 1977; Paffenhofer and Knowles 1978; Cushing 1968; Allan et al. 1977; Richman et al. 1977). Hence, grazing pressure exerted by zooplankton or the exhaustion of different nutrients may both be influencing the seasonal phytoplankton density. Temperature, light, mixing and water column stability are some of the physical factors which also may influence phytoplankton cell densities.

Chlorophyll a concentrations (corrected for any phaeopigments) were presented as a chemical measure of the phytoplankton standing crop (Fig. 2). The fluctuations in chlorophyll a and total cell counts were roughly comparable especially over bloom periods (Fig. 2). An exact correspondence between chlorophyll *a* levels and cell counts would not be expected. Chlorophyll content per cell has been shown to vary with changes in physiological state and nutrient availability (Jensen and Sakshaug 1973; Sakshaug and Myklestad 1973). Larger cells detected by the chlorophyll analysis, but rare and undetected in cell counts may also account for some of the discrepancies. Larger and less abundant diatoms and dinoflagellates may be less well represented in the Utermohl settling technique than with net samples (Lund et al. 1958).

To see if the preceding observations of seasonal cell density or chlorophyll were real and not due to variability in the plankton data, an analysis of variance including Duncans Multiple Range Test was performed on the yearly means for chlorophyll *a* concentration and for total or dominant species cell counts (Table 3). Although mean chlorophyll *a* levels were not significantly different ($P < 0.05$) among the years, the total cell counts were significantly lower in 1979, showing perhaps the influence of a decrease in diatom density. *S. costatum* and *Thalassiosira* spp. were the major diatoms showing a decline in mean density for 1979 while *Asterionella* spp. and *Chaetoceros* spp. were diatoms that showed an increase for this year.

Variations in the seasonal cycles of water temperature may help explain some of the differences among the three annual cycles (Goldman and Carpenter 1974; Eppley 1972; Yoder 1979; Riley 1966). Figure 5 showed that 1979 was a warmer year than 1978, especially in the winter and spring. Water temperatures found in spring 1978 were colder over almost

Table 3 . Duncans Multiple Range Test for difference in $\log_{10}$ transformed annual means for total phytoplankton, chlorophyll a and selected important species in samples at the discharge from 1977 through 1979.

Species or Group	Years (decreasing mean density)		
Total cells	1978	1977	1979
Chlorophyll a	1977	1978	1979
Chaetoceros spp.	1979	1977	1978
Unknown Chlorophyceae	1978	1979	1977
Cryptomonadaceae	1978	1977	1979
Microflagellates	1978	1977	1979
Phaeocystis spp.	1977	1978	1979
Skeletonema costatum	1977	1978	1979
Thalassiosira spp.	1978	1977	1979
Total Diatoms	1977	1978	1979
Asterionella spp.	1979	1977	1978

the entire first six months of that year than in the other three plotted on Fig. 5. Temperatures observed in 1979 seemed more comparable to those observed in 1977 except for the unusually warm summer of 1979. September and October 1979 were similar to those months in other years while November and December were again warmer than both in 1977 and 1978. In the phytoplankton cycles for 1977 and 1978, the peak diatom density was observed from one to two weeks following the spring increase in water temperature (NUSCO 1979b). This relationship was not apparent in 1979. As the water temperature began to rise at the end of February, the diatoms actually decreased in density and remained lower than in previous years until early June when more densitites were again achieved (Fig. 3). During the spring of 1979, the chlorophyceans were more important than in any period in the previous two years. Microflagellates and cryptomonads seemed to be similar to other years although the timing of their peak densities was later in 1979. Changes in the annual cycles of total and individual phytoplankton densities did not appear to be a direct reflection of changes in seasonal water temperature alone. Other factors must have contributed to the floristic changes observed among the three annual cycles described.

In two previous reports, the very small potential impact of entrainment of phytoplankton in the cooling water cycle has been calculated and discussed (NUSCO 1978, 1979b). Based on the known rapid division rates, the cosmopolitan species distribution in adjacent waters, and the 98% dilution of phytoplankton into unaffected receiving waters, entrainment impact on the phytoplankton community at Millstone would be very low.

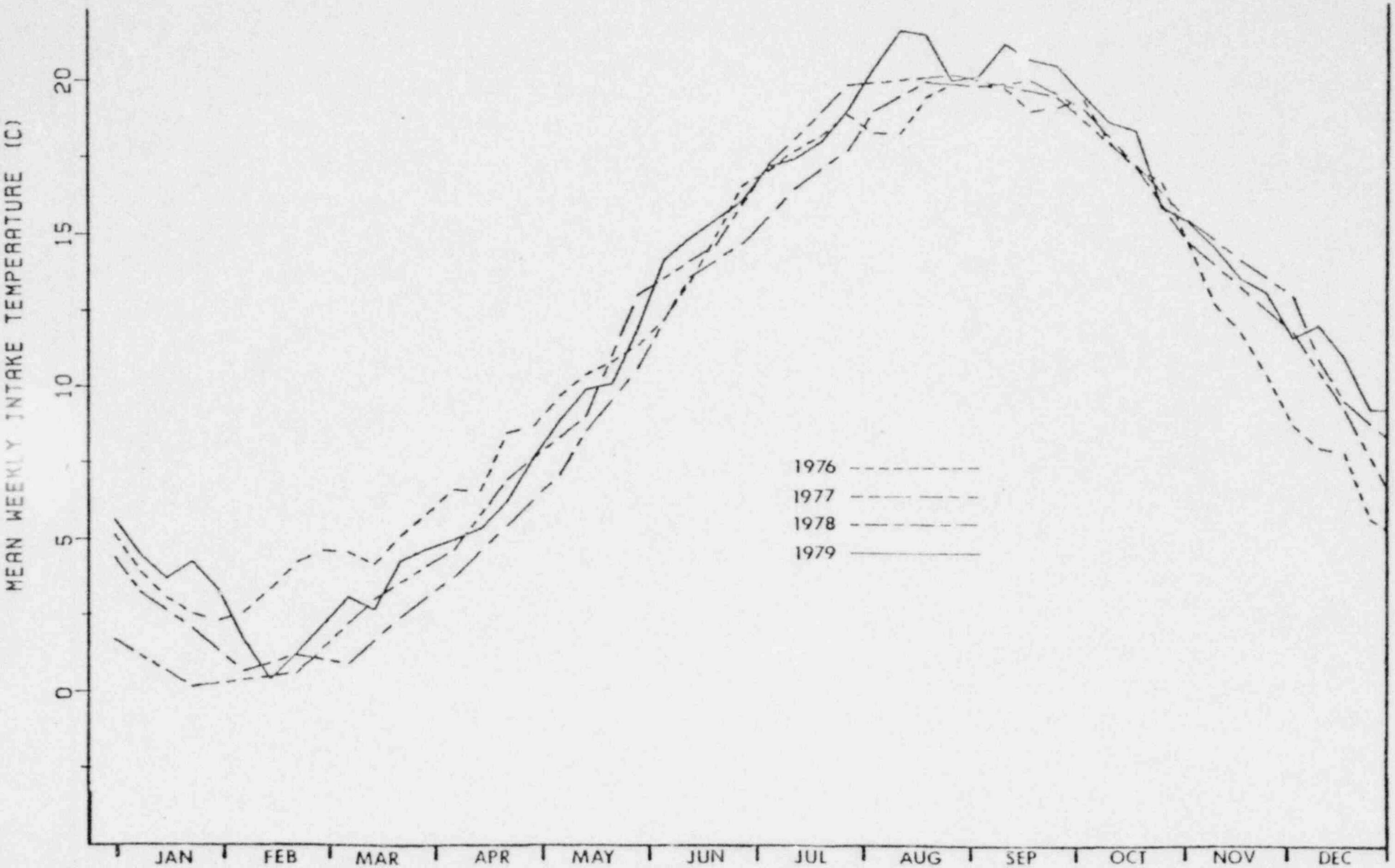


Figure 5. Mean weekly water temperatures (^{o}C) combining data from both intake structures 1976 through 1979.

Zooplankton (retained by 0.333 mm net)

Species Composition-Qualitative Changes over the Years

Species composition, mean seasonal density and rank order for dominant zooplankton species or groups found at the discharge from 1976 through most of 1979 showed considerable similarity from one seasonal cycle to another (Table 4). The zooplankton community in the area of Millstone and Long Island Sound (LIS) was dominated by two congeneric species of calanoid copepod, the winter-spring dominant *Acartia hudsonica* (cf. *clausi*) and the summer-fall congenere *Acartia tonsa*. Together these two species comprised about half of the percent species composition over the annual cycle. Secondly, winter-spring occurring species were *Temora longicornis*, *Pseudocalanus minutus*, *Centropages hamatus*, and *Eurytemora herdmani*. Summer-fall secondary dominants occurring with *A. tonsa* were *Pseudodiaptomus coronatus* and *Centropages hamatus*. Gastropod egg or veliger, cirripede (barnacle) nauplii or cyprids and brachyuran zoea were important meroplanktonic larvae of benthic invertebrates in each annual cycle. Gammarid amphipods were occasional migrants from the epibenthos (tychoplankton) which were incidentally important in the plankton.

Although the seasonal zooplankton community consisted each year of similar species groups, there appeared to be some fluctuation in rank order or mean seasonal density.

Table 4 . Percent species composition, mean seasonal density (#/m^3) and rank order of zooplankton collected at the discharges 1976 through 1979.

Species or Group	1979 %	1979 #/m^3	1979 Rank	1978 %	1978 #/m^3	1978 Rank	1977 %	1977 #/m^3	1977 Rank	1976 %	1976 #/m^3	1976 Rank
Acartia hudsonica	48.3	968.8	1	24.7	347.4	1	21.7	400.5	2	8.6	108.8	3
Acartia tonsa	11.4	232.7	2	22.2	404.2	2	37.8	716.0	1	34.1	409.1	1
Temora longicornis	8.6	162.5	3	12.5	171.9	4	9.7	184.5	3	11.5	132.0	2
Centropages hamatus	7.5	112.3	4	6.6	82.9	5	6.0	96.9	4	7.3	72.7	5
Pseudocalanus minutus	4.6	85.7	5	12.5	168.8	3	4.4	82.1	5	7.7	86.8	4
Gastropod egg	2.9	51.5	6	3.3	55.3	7	1.9	41.1	8	6.4	77.4	6
Gammaridea	2.5	43.7	7	4.0	53.6	6	4.1	69.4	6	0.8	8.5	16
Eurytemora herdmani	2.3	14.7	8	2.9	79.4	8	0.3	25.7	23	0.0	0.5	66
Gastropoda veliger	1.2	22.0	9	0.6	13.4	13	1.5	41.3	10	2.4	32.2	9
Evadne spp.	1.2	55.4	10	0.2	20.3	29	0.5	30.7	17	0.6	13.1	19
Penilia avirostris	1.2	70.5	11	---	------	--	--	--	--	0.2	20.6	27
Cirripedia cypris	1.1	38.0	12	0.3	10.8	21	0.7	29.0	14	1.6	29.1	10
Brachyuran zoea	1.0	31.5	13	0.9	29.7	11	0.9	30.4	12	1.0	19.1	15
Cirripedia nauplii	0.9	17.6	14	0.6	14.4	14	0.6	19.0	15	1.1	14.5	14
Pseudodiaptomus coronatus	0..	26.4	15	2.1	42.4	9	2.3	49.8	7	3.9	54.4	8

Table 4 showed that A. hudsonica, Evadne spp., and Penilia avirostris were more abundant and ranked higher in 1979 than in previous years. It appeared that A. hudsonica has been increasing in importance every year since 1976. P. coronatus, A. tonsa, and T. longicornis seemed to be less important than in earlier years, although this probably was related to the data including only part of the growth season. T. longicornis, P. minutus and E. herdmani had their best relative year in 1978, when the mean density of A. hudsonica was reduced slightly. This suggested possible competition among these four winter-spring species. A. tonsa and the gammarid amphipods were most dominant in 1977 compared to other years similar to that shown at the Shoreham site opposite New Haven on Long Island (LILCO 1979). The meroplanktonic forms in Table 4 appeared to be relatively more dominant in 1976 than in the other years where colder springs may have retarded prereproductive phases (Fig. 5).

Seasonal Density

Although Table 4 shows some similarity in rank order, percent species composition and mean seasonal density for dominant holoplankton and meroplankton, there are considerable fluctuations in density on a weekly time scale. Plots of the mean weekly density ($\log_{10}$ transformed) per m^3 combining both weekly day and night tows were prepared for total zooplankton (Fig. 6), the winter spring dominant copepod Acartia hudsonica (Fig. 7) and the summer-fall dominant Acartia tonsa (Fig. 8). Vertical differences in mean weekly density between one year and another may appear small, but they actually were greater due to the log transformation. For instance, in late September 1979 density dropped from about $1000/m^3$ one

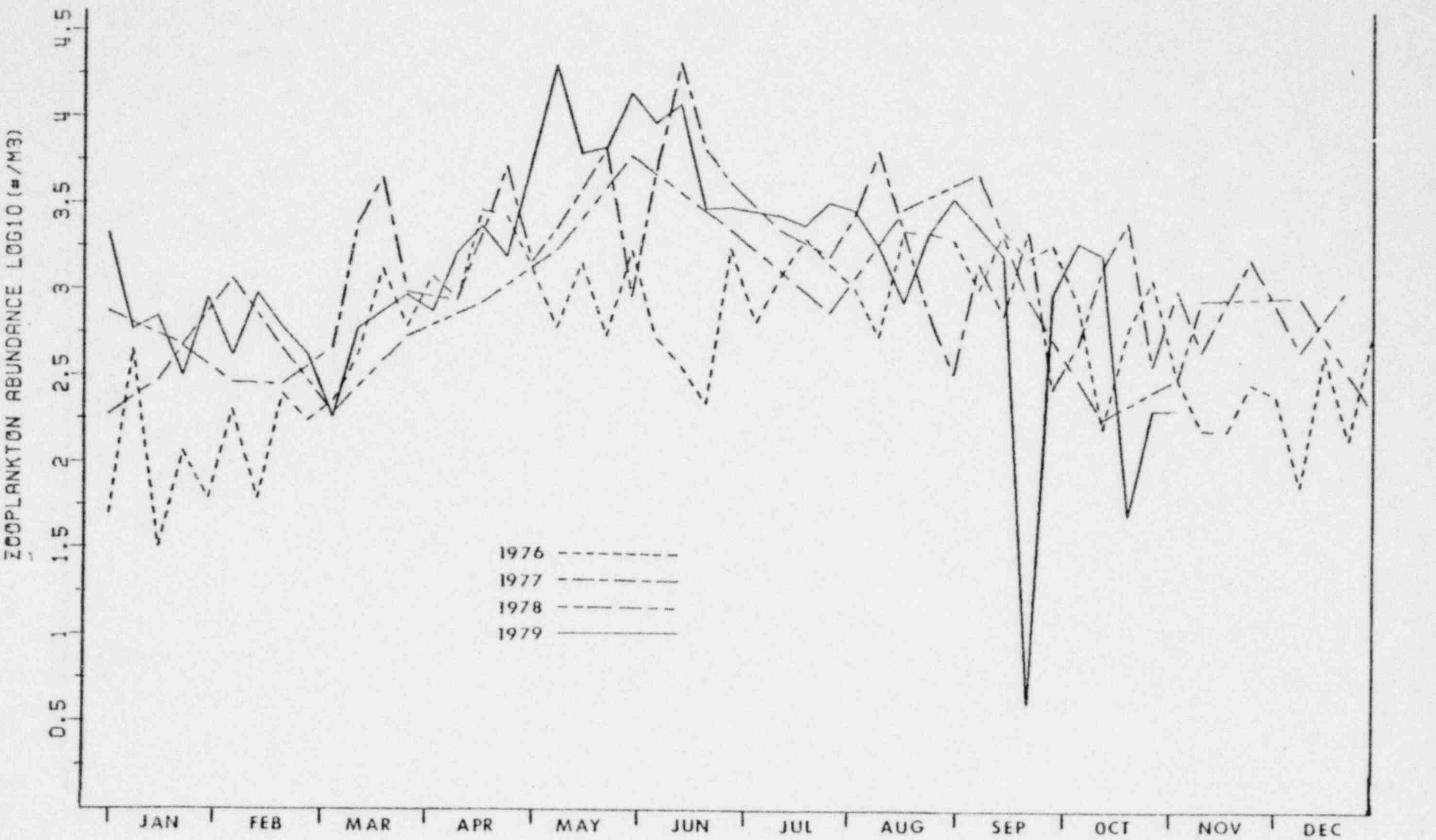


Figure 6. Log_{10} transformed mean weekly density (#/m^3) for total zooplankton at the discharge from January 1976 through October 1979.

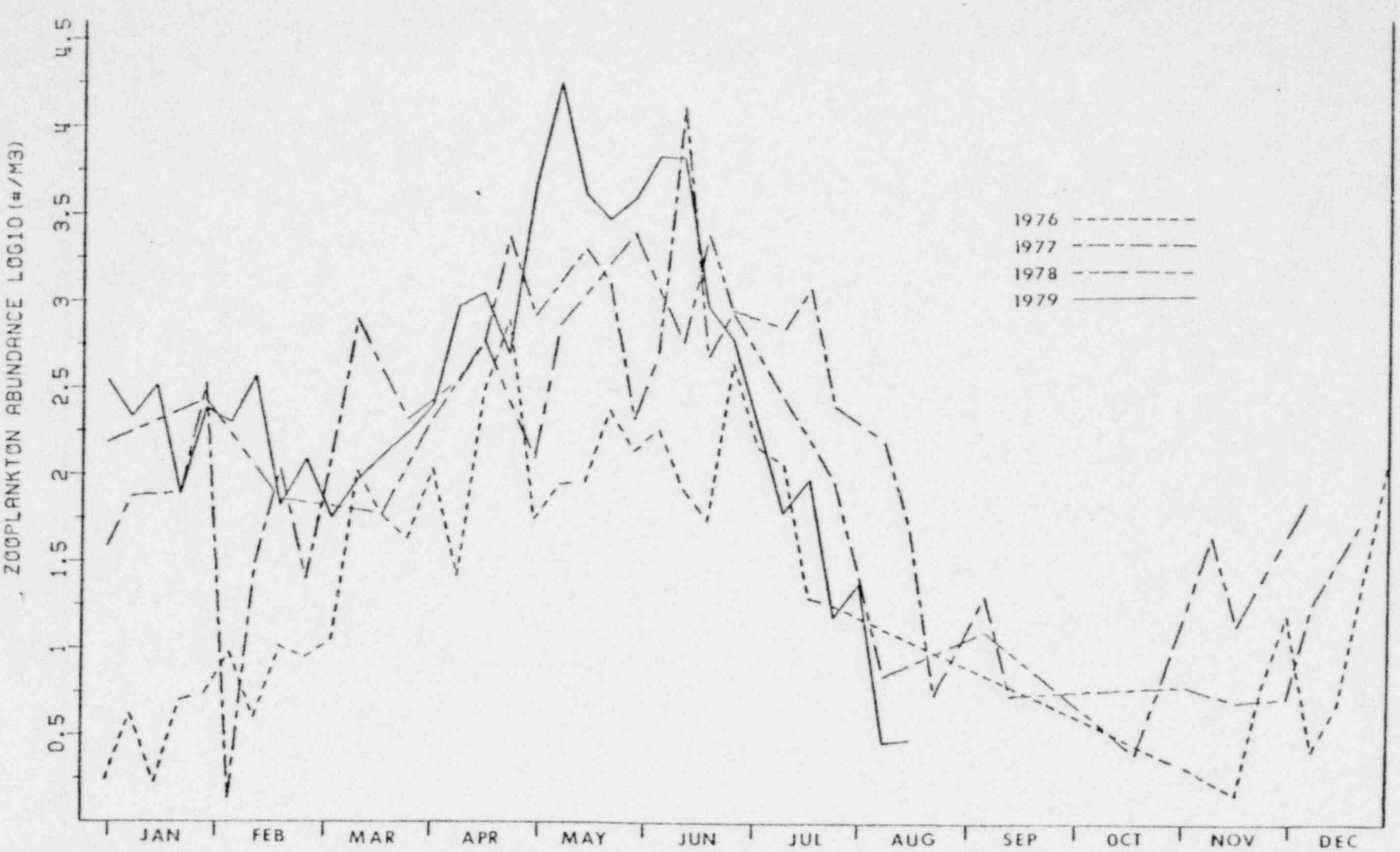


Figure 7. Log$_{10}$ transformed mean weekly density (#/m^3) of *Acartia hudsonica* adults at the discharge from January 1976 through October 1979.

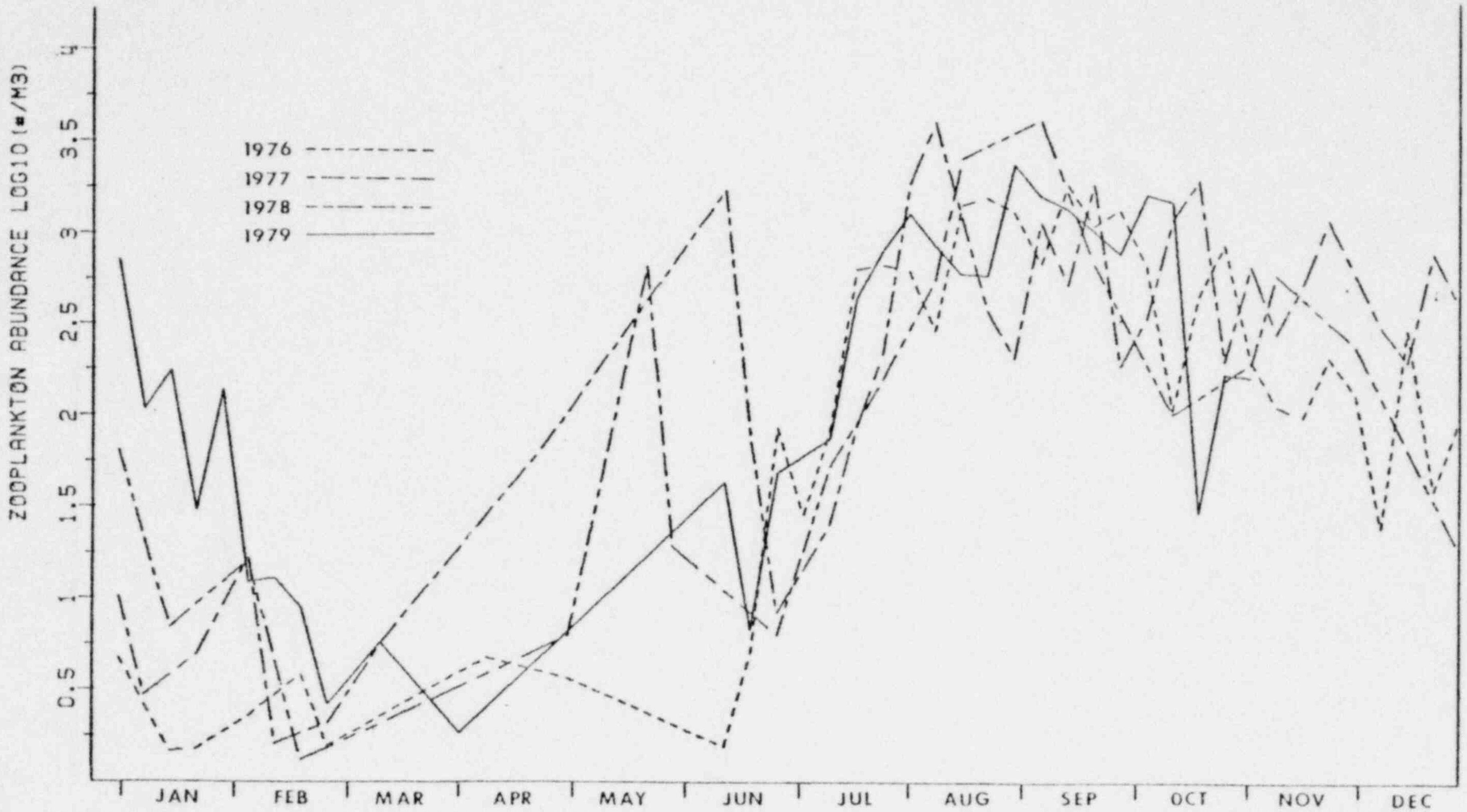


Figure 8. Log_{10} transformed mean weekly density ($\#/m^3$) of Acartia tonsa adults at the discharge from January 1976 through October 1979.

week down to less than $10/m^3$ the next. Although changes of this order of magnitude were exceptional, changes in total zooplankton density of up to ten times were frequently observed and expected. Similarly, the densities of A. hudsonica and A. tonsa fluctuated considerably from week to week over their growth season each year.

There appeared to be some differences in density of A. hudsonica of the four growth seasons shown in Fig. 7. In 1976, the mean weekly density over the season appeared lower than in the other three years. A broad period of peak density from mid-May to late June was present in 1979 when compared to previous years. The usual decline of A. hudsonica in the summer and replacement by A. tonsa was somewhat delayed in 1978 when peak densities extended into July and August. The last three years showed either a comparable or even an increasing trend in the density of A. hudsonica from April through June.

Over its normal growth season from about mid-June in one year through January the next, A. tonsa peaked in July through August and declined gradually through the fall and early winter (Fig. 8). Apparent peaks in the period March through June were largely artifacts of the reduced dominance of A. tonsa during the bloom of its relative A. hudsonica. Density levels for the months of August through December were very comparable from one year to another.

The seasonal density of meroplanktonic larvae of lobster (Homarus americanus) was also examined as in earlier years (NUSCO 1977; 1978; 1979b). Lobster larvae were found in only 18 of the over 250 samples examined from June through August. A total of 60 larvae (all of which were Stage I) were collected, 25 coming from one sample and illustrating the extremely contagious distribution of this organism. Although this number of 60 collected in 1979 compared roughly with the 71, 19, and 25 larvae collected in 1978, 1977 and 1976, respectively, this year was quite different from the other three, first in having no larvae found after July 11, and second in having no specimens of later developmental stages found. Consistent with other years, almost three times as many larvae were collected from night samples than from samples collected during the day.

To test the statistical significance of the differences or similarities observed in the percent species composition (Table 4) and the seasonal density graphs (Figs. 6, 7, 8), an analysis of variance was performed in order to test difference by year, station location, or day versus night. The separate factors of year, station location and day/night were considered for dominant species and for total zooplankton. In each case, the mean seasonal density by the three factors was compared using Duncan's Multiple Range Test.

The analysis of variance on the mean density over years showed that total zooplankton, A. hudsonica, and E. herdmani were lower in 1976 and had a gradual increasing trend thereafter with the highest density in 1979 (Table 5). Centropages typicus was more abundant in 1978 than in any of the other three years. Amphipods were significantly less abundant in 1976. The extraordinary biomass of these amphipods added to the normal community of holoplanktonic copepods in 1978 and 1977 especially and made the mean annual dry weight biomass of zooplankton higher than

Table 5 . Duncan's Multiple Range Test for difference in $\log_{10}$ transformed annual means (α=0.05) by year. Entrainment zooplankton data from discharges 1 and 2 in the years 1976 through 1979 has been used. Means for years connected by or overlapping the same line are not significantly different.

Species or Group	Years (decreasing mean density) →			
Total zooplankton	1979	1978	1977	1976
Acartia hudsonica	1979	1977	1978	1976
Temora longicornis	1977	1979	1978	1976
Eurytemora herdmani	1979	1978	1977	1976
Centropages typicus	1978	1977	1976	1979
Amphipods	1978	1977	1979	1976
Centropages hamatus	1977	1978	1979	1976

in any other year. (see NUSCO 1979b). T. longicornis was higher in density in 1977 than in the other years. A similar AOV on zooplankton at Station 5 (mid-Niantic Bay, Fig. 1) showed that C. typicus, T. longicornis, and C. hamatus had similar patterns of yearly density changes when compared to the discharge.

When station location (Station 5 versus the discharge in 1979) was examined by AOV for any significant differences in mean density inshore versus offshore, there were significantly greater densities ($p < 0.05$) for total zooplankton, P. minutus, T. longicornis and C. hamatus at the offshore station compared to the discharge. These results were consistent with earlier data showing that dominant zooplankton species except A. hudsonica were more abundant at offshore stations (NUSCO 1978, 1979b).

Several species of zooplankton have shown an extreme density variability over the short time scale of day versus night. For all four years at the discharge and for 1979 at Station 5, gammaridean amphipods were significantly higher ($p < 0.05$) in density for night samples versus the day. This result was similar to those described earlier (NUSCO 1978; 1979b) and may be the result of night active feeding (Greze 1968) or reproductive behavior. For all years at the discharge and for 1979 at Station 5, Pseudodiaptomus coronatus was found to be significantly more abundant in night samples. Jacobs (1968) found that adults and late copepodites were epiphytic during the day and actively feeding planktonic omnivores in the water column at night. Except for 1977, the discharge data showed that harpacticoid copepods were more abundant at night suggesting again some form of nocturnal behavior pattern. At

Station 5 only, total zooplankton was found to be more abundant in night samples compared to the day. Another interesting apparent day/night anomaly occurred in 1979 at Station 5 where both T. longicornis and C. hamatus were more abundant at night. This pattern had never been observed at the discharge. This may have been due to hydraulic considerations at the intake where cooling water has been drawn from about the bottom third of the water column. If T. longicornis and C. hamatus were distributed near the bottom during the day and more uniformly in the water column at night, then the sawtooth oblique tow path at Station 5 in 1979 would sample this species less efficiently during the day than at night. Because of this proposed bottom preference, there would not be any great differences in day and night density expected or observed at the discharge. The density of T. longicornis was usually much greater in bottom samples at a nearby LIS site (LILCO 1979). This gave some evidence supporting the possible effect of diurnal vertical movement of zooplankton on the observed differences between day and night at the offshore station compared to the discharge.

Factors Associated with Density Changes in Zooplankton

In the last two annual reports (NUSCO 1978; 1979b), some of the factors associated with increases or decreases in the standing stock of zooplankton were discussed. Temperature and thermal stability of the water column were associated with considerable portions of the variability in zooplankton density (up to 50%). Seasonal changes in wind speed and direction seemed to be cyclic and related to the annual cycle of water temperature (Fig. 5). Strong storms like hurricanes or northeasters frequently were associated with transient washouts and subsequent renewals of zooplankton population density. Predation by ctenophores, jellyfish, postlarval or juvenile fish, and predatory copepods were probably also associated with declines in zooplankton density (Thayer et al. 1974; Hulsizer 1976; Huntley and Hobson 1978). Lastly, the amount of phytoplankton available as food for the zooplankton population may also have influenced the seasonal standing crop and turnover of herbivorous zooplankton.

Because of the expected dependence of the zooplankton population on food resources, possible predator-prey relationships between zooplankton and phytoplankton species were investigated. The grazing dependence of zooplankton on phytoplankton may account for similarities and differences in zooplankton densities from one year to another. Since an apparent inverse relationship between the chainforming diatom Skeletonema costatum and the copepod Acartia hudsonica has been described before (NUSCO 1979b), and since both of these species had undergone recent changes in seasonal density (Table 3, 5 and Fig. 2, 7), this predator-prey pair was chosen for a cross-spectral analysis performed on a three-year series of weekly densities ($\log_{10}$ transformed). These time series analyses from 1977 through 1979 accounted for much of the variance in the combined data and provided tests for similarity of patterns from year to year and from one species to another. Through coefficients of sine and cosine functions, this spectral analysis approach related different frequencies corresponding to the weekly data points for species density. How close frequency came to tracing the pattern of the actual density data was a measure of the importance of that frequency. A test of the significance of the fit of a cyclical time series was performed both S. costatum and A. hudsonica in order to determine if these patterns of density over time were well fitted to a time series model. The results of Fisher's Test (Fuller 1976) for the largest periodogram ordinate indicated that the hypothesis of "white noise," namely no cyclical pattern, could be rejected at $P < 0.01$ for both species. Zooplankton and phytoplankton were related as predator and prey.

The cross spectral portion of this time series approach analysed the coupling of the most important frequencies associated with each species. These two species were highly inversely related for a twenty-five week cycle and were highly positively related for a seventy-four week cycle. Similarity of the cycles was more apparent in the longer time period because of lagging of A. hudsonica density peaks which produced an inverse relationship in the shorter cycle and suggested periods of intense grazing of this zooplankter on S. costatum. Two results substantiated this predator-prey hypothesis. First, the F-test of the hypothesis of zero coherency at a dominant frequency indicated a significant ($P < 0.05$) degree of dependence between the time series of S. costatum and A. hudsonica. Further, the frequencies corresponding to the 74, 49, 25 and 21 week periods accounted for the overwhelming portion of the variability in both time series as indicated by the F-test for seasonal frequencies ($P < 0.05$).

Effect of Entrainment on Local Zooplankton

Operation of the power plant appeared to have little or no effect on the zooplankton community. The zooplankton community monitored over the first four years of two-unit commercial operation (1976-1979) showed considerable similarity of species composition and seasonal density from one year to another. Total zooplankton, A. hudsonica and E. herdmani, showed a slight decline (Table 5). These fluctuations observed week to week or year to year were usually not significant statistically given the variability of the zooplankton community; changes were probably a result of complex interrelationships of food availability, temperature, advection, mixing, behavior, predation and other natural processes.

Ichthyoplankton (Fish Eggs and Larvae)

Seasonality of Fish Larvae

Percent species composition, rank order and mean seasonal density of fish larvae entrained from 1976 through October 1979 are given in Table 6. A total of 54 taxa were found, many of which were extremely rare and not included in the table. The top twenty species found at the discharge from January through October of 1979 were included as well as menhaden (Brevoortia tyrannus) and mackerel (Scomber scombrus) which had earlier been more important consitutents of the ichthyoplankton. Seven or fewer taxa have comprised more than 90% of the annual species composition over this four year period. The anchovies (Engraulidae-primarily Anchoa mitchilli), winter flounder (Pseudopleuronectes americanus), and the sand lance (Ammodytes spp.) have historically been among the most abundant taxa found since the beginning of the ichthyoplankton monitoring program in early 1973. These three species alone comprised 80 to 88% of the species composition over the last four years. Anchovies ranked first in

Table 6 . Percent species composition, mean seasonal density ($\#/m^3$) and rank order of ichthyoplankton (based on percent composition) collected at the discharges 1976 through 1979.

Species or Group	1979 %	1979 $\#/m^3$	1979 Rank	1978 %	1978 $\#/m^3$	1978 Rank	1977 %	1977 $\#/m^3$	1977 Rank	1976 %	1976 $\#/m^3$	1976 Rank
Engraulidae	71.71	1.820	1	30.32	0.407	2	63.37	1.109	1	71.19	1.260	1
Ammodytes sp.	10.10	0.234	2	43.73	0.538	1	11.85	0.199	2	2.91	0.053	3
Pseudopleuronectes americanus	6.08	0.195	3	13.26	0.261	3	5.40	0.183	3	11.30	0.271	2
Unidentified	2.29	0.044	4	1.12	0.020	7	2.75	0.046	4	1.48	0.036	5
Myoxocephalus sp.	2.27	0.065	5	2.21	0.047	5	2.42	0.075	6	1.34	0.039	7
Pholis gunnellus	1.43	0.048	6	1.56	0.034	6	1.26	0.041	9	0.64	0.021	13
Syngnathus fuscus	0.95	0.026	7	0.82	0.015	10	0.84	0.021	12	0.41	0.015	14
Tautogolabrus adspersus	0.72	0.048	8	0.13	0.008	18	2.59	0.163	5	1.47	0.089	6
Ul aria subbifurcata	0.68	0.050	9	0.95	0.056	8	0.25	0.031	19	0.93	0.048	10
T. atoga onitis	0.59	0.042	10	0.13	0.010	17	2.07	0.091	7	1.82	0.082	4
I paris sp.	0.55	0.039	11	2.52	0.071	4	1.13	0.069	10	0.28	0.018	17
nchelyopus cimbrius	0.53	0.035	12	0.83	0.036	9	0.51	0.039	14	0.32	0.018	15
Scophthalmus aquosus	0.53	0.028	13	0.26	0.008	13	1.45	0.042	8	1.08	0.031	9
Cynoscion regalis	0.26	0.088	14	0.00	0.004	37	0.19	0.062	20	0.05	0.034	28
Stenotomus chrysops	0.22	0.062	15	0.04	0.012	22	0.41	0.061	16	0.29	0.071	16
Anguilla rostrata	0.22	0.014	16	0.34	0.015	12	0.35	0.027	17	0.10	0.008	25
Clupeidae	0.18	0.027	17	0.08	0.007	19	0.10	0.009	23	0.02	0.003	34
Menidia sp.	0.15	0.014	18	0.22	0.010	15	0.03	0.007	31	0.14	0.015	23
Peprilus triacanthus	0.09	0.024	19	0.15	0.013	16	0.26	0.026	18	1.25	0.101	8
Prionotus sp.	0.07	0.025	20	0.02	0.010	26	0.17	0.059	21	0.20	0.030	19
Brevoortia tyrannus	0.05	0.012	21	0.79	0.026	11	0.59	0.025	13	0.77	0.022	12
Scomber scombrus	0.01	0.010	32	0.06	0.011	20	0.93	0.105	11	0.17	0.034	21

order of dominance in 1976, 1977 and 1979, comprising 63 to 72% of the species composition at the discharge. The anchovies comprised only 30% of the species composition in 1978 when a cold and prolonged spring (Fig. 5) prereproductive phase may have been less favorable for anchovies than for a group of cold-water, demersal egg species such as the sand lance (44%), winter flounder (13%) and radiated shanny (Ulvaria subbifurcata). This colder period in 1978 may have been unfavorable for several other summer-fall resident and migratory pelagic egg spawners including the anchovies, weakfish (Cynoscion regalis), scup (Stenotomus chrysops), the butterfish (Peprilus triacanthus), and the spring spawning labrids, cunner (Tautogolabrus adspersus) and tautog (Tautoga onitis). All of these species showed a decreased relative importance in 1978 and a slight resurgence in the spring and summer of 1979 when the highest summer temperatures in recent years were observed (Fig. 5). Weakfish larvae were greater relative importance in the warm summer-fall of 1979 than in 1978, which was the coldest summer-fall period in study history. A very successful spawn of weakfish was observed in 1978 in more southerly areas, such as the Delaware Bay (PSEG 1979), which suggests that colder temperatures may have limited northerly occurrences of this species.

Some of the more rare species of ichthyoplankton (not shown with the dominants in Table 6) collected in the monitoring program over the late summer and fall were essentially southern species whose larvae drift in shelf or Gulf Stream waters and may come largely from parcels of this water transported into eastern Long Island Sound. These species included such southern fish as the cusk (Rissola marginata), black sea bass (Centropristis striata), the Atlantic croaker (Micropogon undulatus), and a new species collected in 1979, the eyed flounder (*Bothis ocellatus*). In the case of the eyed flounder, the literature strongly suggested that the larvae hatched in waters of the continental shelf and Gulf Stream just north of Cape Hatteras were transported around the tip of Long Island by currents or water mass intrusion into these coastal waters (Smith et al. 1975). These pieces of circumstantial information may also help to explain the occurrence in the fall of some other species of southern fish in the impingement samples (Section 2).

Mean weekly densities of larvae at the discharge versus time were examined in order to determine whether changes in the dominance of individual species, over the past four years, were associated with real changes in abundance or were artifacts resulting from changes in abundance of other species. Mean weekly densities of total larvae, over the past four years, ranged from a minimum of about $0.004/m^3$ to a maximum of about $10/m^3$ (Fig. 9). Winter-spring and summer-fall peaks characterized the fish larvae of eastern Long Island Sound. The most abundant winter fish larva, the sand lance, was largely responsible for the peaks of total ichthyoplankton density in late December through about late March (Fig. 9) and its mean density appears to have increased in recent years compared to 1976 (Fig 10). Winter flounder was the dominant larval species in late March through May each year (Fig. 11). Although there did not appear from the density plots to have been much change year to year in the mean density of these larvae, there was considerable variation in the time of maximum density at the discharge. In 1976 peak density occurred in the third week of April, in 1977 the second week of May, in 1978 the last week of May and in 1979 peaks in April, May and early

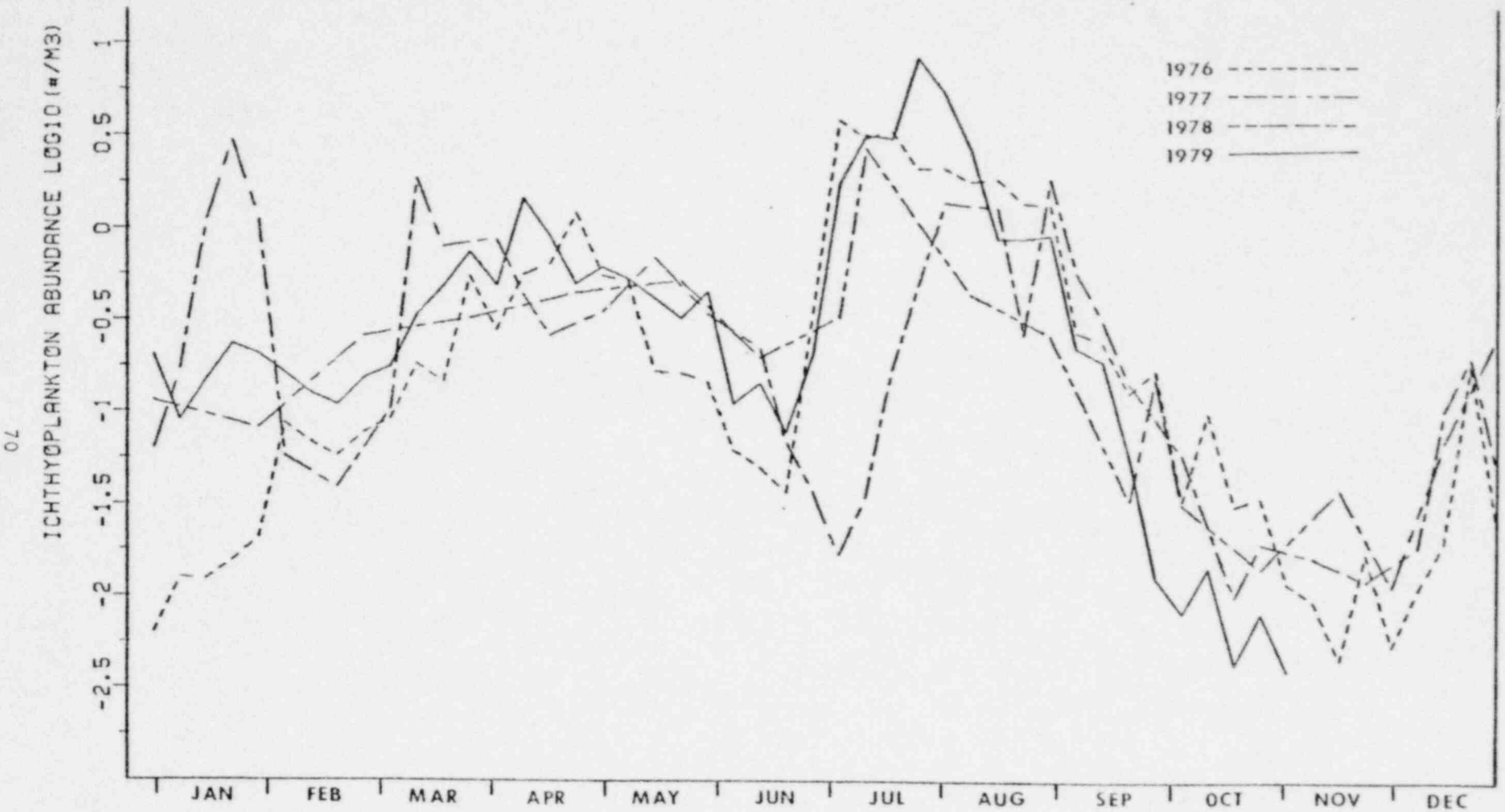


Figure 9. Log_{10} transformed mean weekly density ($\#/m^3$) for total fish larvae at the discharge from January 1976 through October 1979.

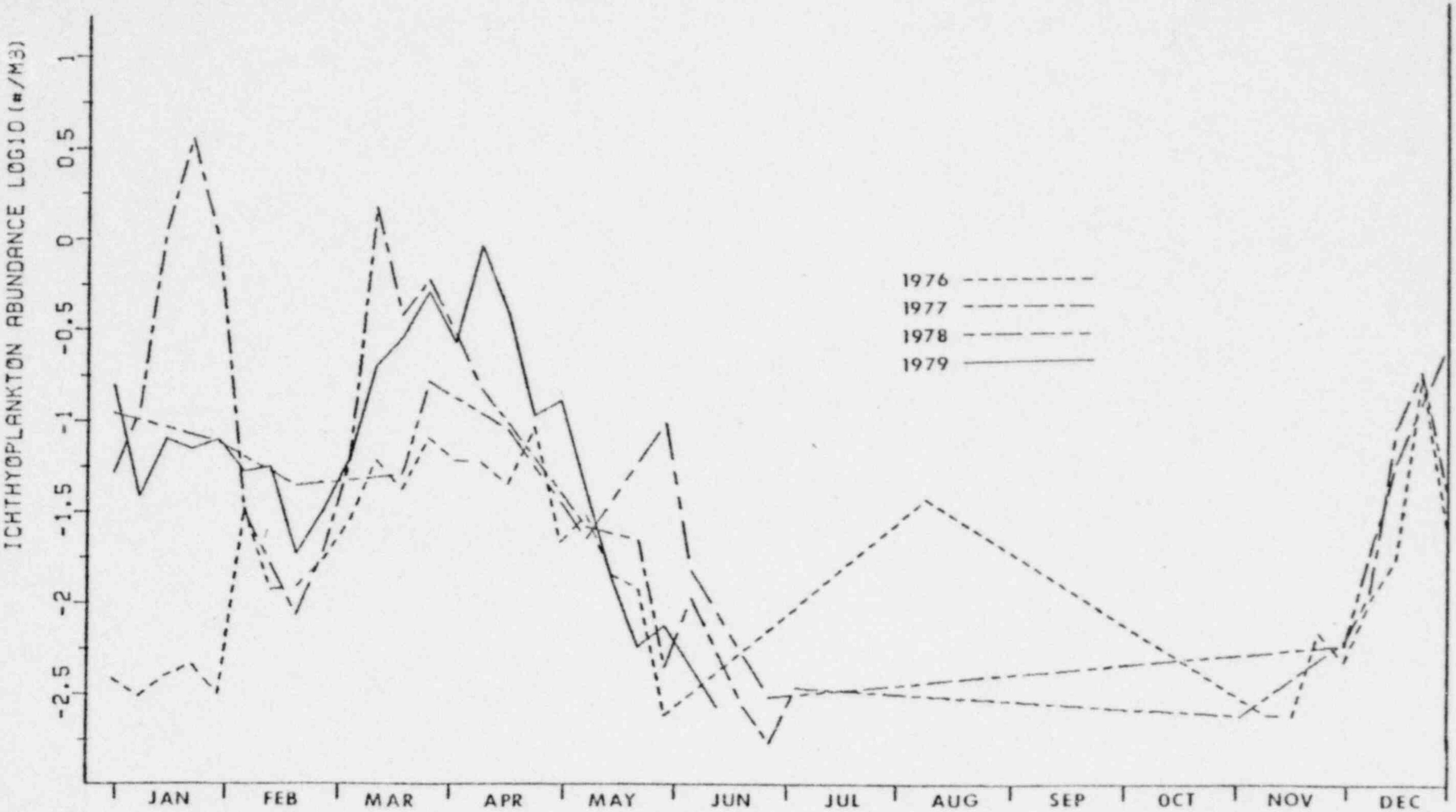


Figure 10. Log_{10} transformed mean weekly density ($\#/m^3$) for sand lance larvae at the discharge from January 1976 through October 1979.

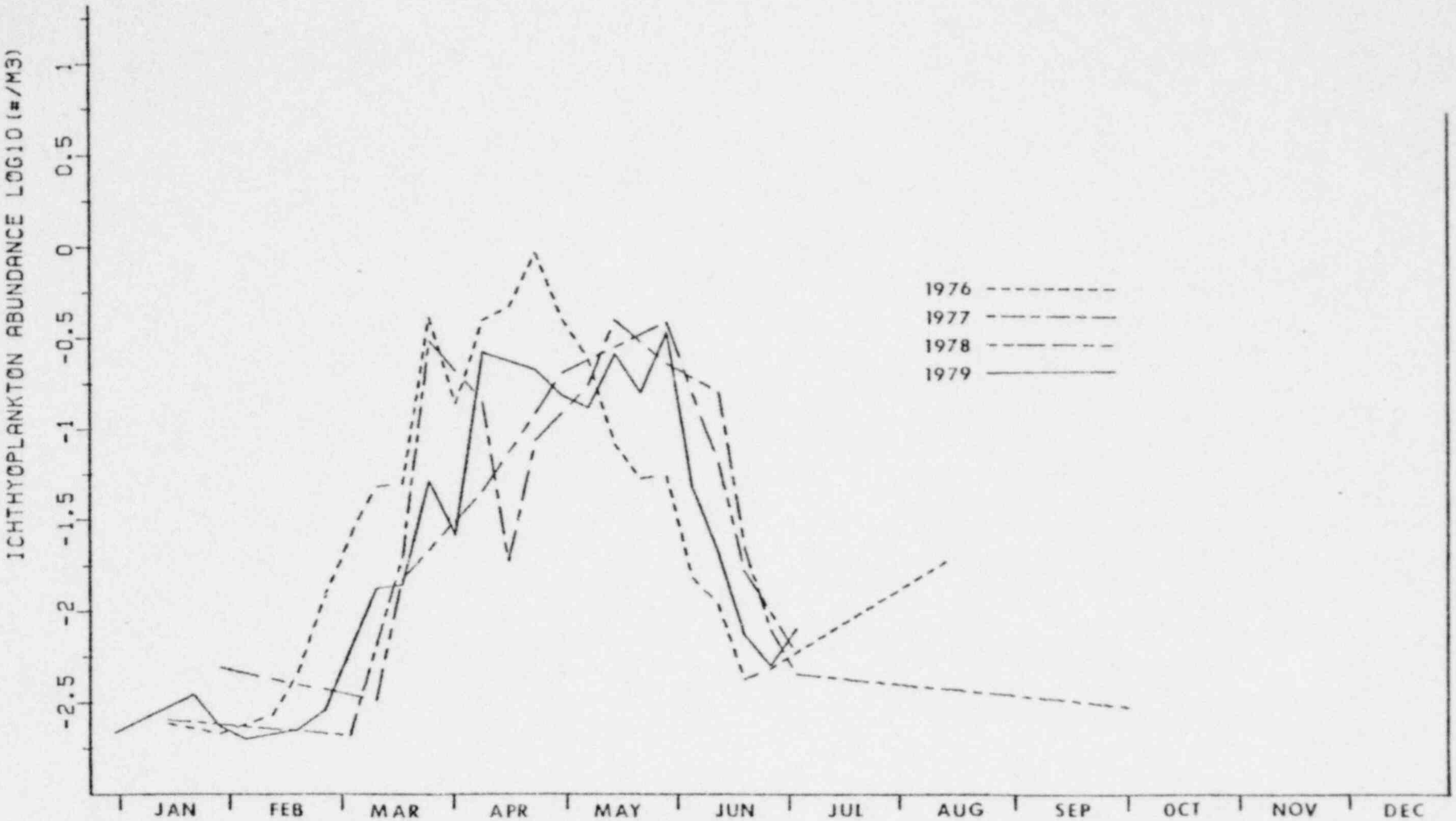


Figure 11. Log_{10} transformed mean weekly density (#/m3) for winter flounder larvae at the discharge from January 1976 through October 1979.

June. The warmer temperatures throughout the winter and spring of 1976 (Fig. 5) may account in part for the earlier rise and fall of winter flounder density compared to other years.

The anchovies historically have dominated the fish larvae in the summer-fall season, especially in the months of July and August with their numbers declining thereafter (Fig. 12). Peak densities of anchovies for all four study years occurred in a temperature range of 17 to 20°C above which density declined. Anchovy density appeared to be higher in 1979 along with the higher summer temperatures (Fig. 5) while, in the relatively cold 1978 season, their densities were reduced dramatically and their peak delayed until early August. Pipefish (Sygnathus fuscus), cunner, tautog, and the fourbeard rockling (Enchelyopus cimbrius) were also important species in this summer-fall period which was dominated by the anchovies.

Year to year differences in larval density were tested using one-way analysis of variance and Duncan's Multiple Range Test on $\log_{10}$ transformed data (Table 7). Total fish larvae were found to be significantly more abundant in 1979 than in the preceding three years largely reflecting increases in the mean density of both sand lance and anchovies. Sand lance had significantly ($\alpha = 0.05$) lower mean larval density in 1976 compared to any subsequent year. Sand lance has shown a trend for increased larval abundance in the Millstance area since 1974. A similar trend in larval and adult sand lance abundance was observed on the shelf waters of the Northwest Atlantic from Cape Hatteras northward (Meyer et al. 1979; Smith et al. 1978). Anchovies (mostly the bay anchovy

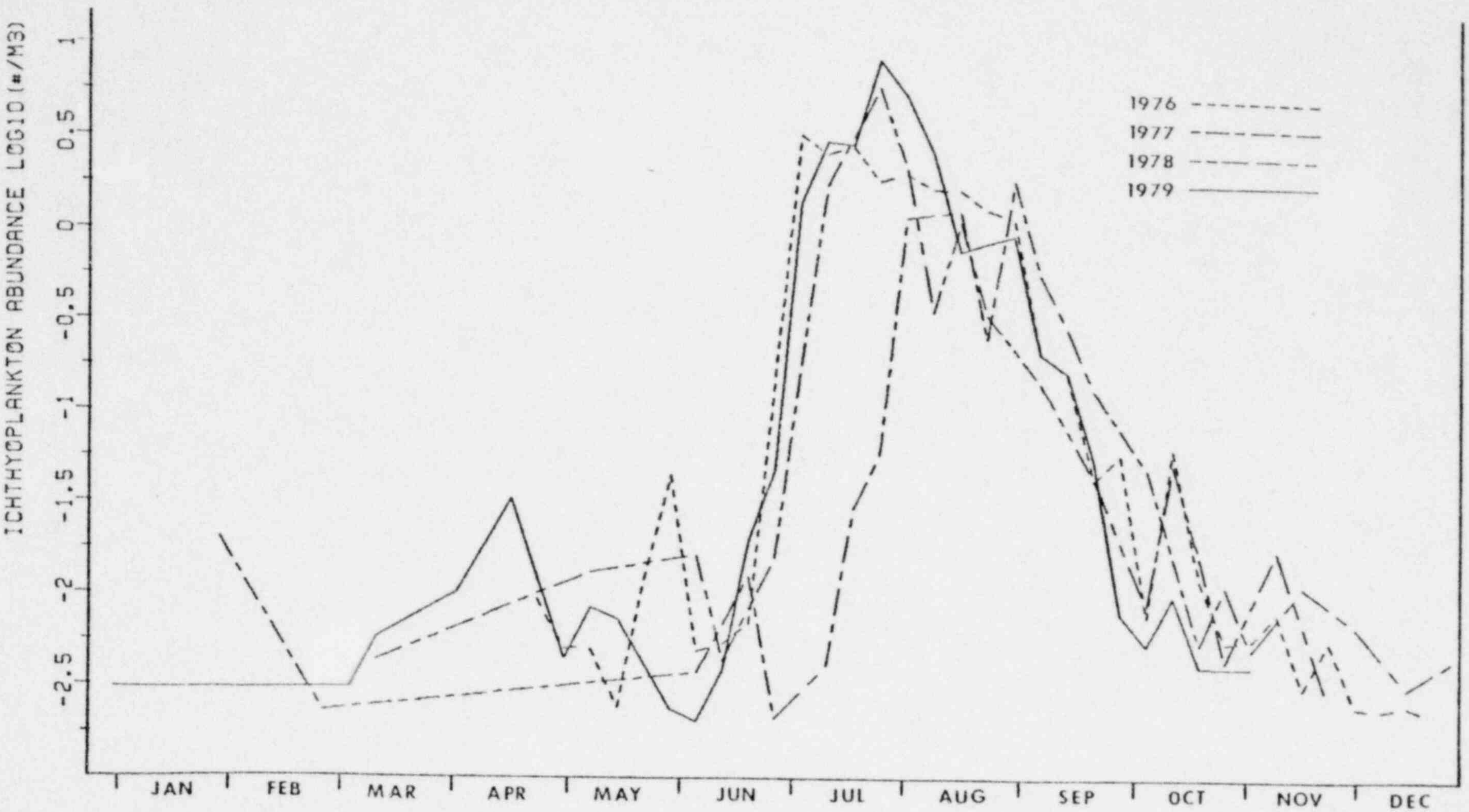


Figure 12. Log_{10} transformed mean weekly density (#/m^3) for anchovy larvae at the discharge from January 1976 through October 1979.

Table 7. Duncans Multiple Range Test for difference in $\log_{10}$ transformed annual means (α=0.05) by year. Entrainment ichthyoplankton data from discharges 1 and 2 in the years 1976 through 1979 has been used. Means for years connected by or overlapping the same line are not significantly different.

Species or Group	Years (decreasing mean density) →			
Total Eggs	1976	1979	1978	1977
Total Larvae	1979	1977	1978	1976
Ammodytes spp.	1979	1978	1977	1976
Anchoa spp.	1979	1976	1977	1978
Pseudopleuronectes americanus	1978	1976	1977	1979
Scomber scombrus	1977	1976	1978	1979
Tautoga onitis	1976	1977	1979	1978
Tautogolabrus adspersus	1977	1976	1979	1978

Anchoa mitchilli) had a significantly lower mean density in 1978 than in warmer years. Total fish eggs and winter flounder larvae had no significant year to year difference in mean annual density over the first four years of two-unit commercial operation. The labrids, cunner and tautog, were both found to have significantly lower densities in 1978 (similar to the anchovies) than in the other three years; both species showed a slight resurgence in density for 1979. Mackerel was found in significantly higher numbers in 1977 than any other of these four study years.

Previous reports have described several ichthyoplankton species whose densities appeared to be greater in night samples than in the day (NUSCO 1978; 1979b). A one-way AOV using $\log_{10}$ transformed density data from the discharge and Station 5 (mid-Niantic Bay, Fig. 1) in 1979 was conducted to see if ichthyoplankton density was different in the day versus the night. Total eggs, total larvae, sand lance, cunner, tautog and mackerel showed no significant ($\alpha = 0.05$) day or night mean density for either the discharge or Station 5 in 1979. However, winter flounder, anchovies and the grubby sculpin (Myoxocephalus aeneus) mean densities were significantly higher at night only at the offshore Station 5.

A one-way AOV of $\log_{10}$ transformed data was used to examine station location (Station 5 versus the discharge) as a factor in the mean density of several species of ichthyoplankton for 1979. Sand lance, grubby sculpins, winter flounder, and total fish larvae showed no significant ($\alpha = 0.05$) differences in density between the two stations. Anchovies, cunner, mackerel, and total eggs, however, were higher in density at Station 5 in mid-Niantic Bay than at the discharge. However, restricting the analyses to the period of peak and post-peak abundance, it was found that the discharge had significantly ($\alpha = 0.05$) greater mean density than Station 5 for both winter flounder and anchovies.

The time dependence of densities at the discharge was apparently related to a greater frequency of larger larvae (6 to 8 mm T.L.) found at the discharge compared to Station 5 (Fig. 13). Comparison of day and night sampling indicated that the frequency of the larger larvae was lower during the day at both the discharge and Station 5 and, for both day and night samples, the discharge had a higher frequency of larger larvae than at Station 5 (Fig. 13). The lower frequency of larger larvae collected during daylight at Station 5 compared to both night collections at Station 5 and daylight collections at the discharge suggested that the larvae were able to avoid net capture during the day at Station 5. Assuming no visual avoidance of the intake structure in either day or night, the higher frequency of larger larvae collected at the discharge during night compared to day suggested some type of day-night activity pattern causing a greater susceptibility to entrainment during the night.

This hypothesized day-night activity pattern by the larger larvae was substantiated for winter flounder and also indicated for anchovy larvae from the examination of an earlier stratified offshore sampling program (NUSCO 1979a). Larger larvae for both anchovy and winter flounder appeared congregate near the bottom during daylight and disperse vertically during the night. The increased frequency of larger larvae collected during night at Station 5 could be attributed to vertical movement more

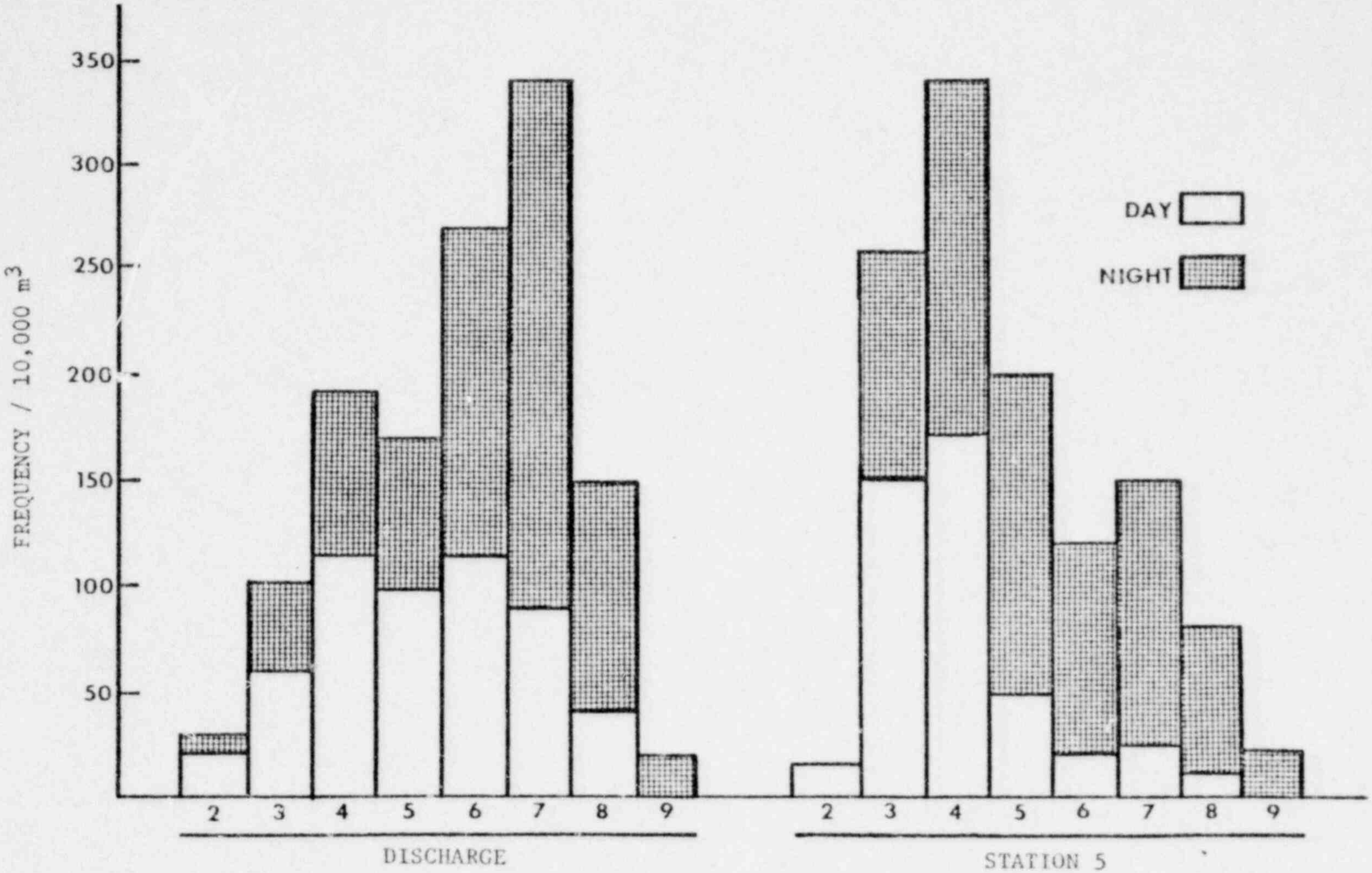


Figure 13. Winter flounder length frequency (2-9mm) distributions (adjusted to 10,000 m^3) at the discharge and Station 5 for day and night samples in 1979.

into the direct path of the sawtooth oblique tow. At the discharge, the increased frequency of larger larvae could be attributed to the increased vertical movement off the bottom putting these larvae into the source water for cooling (primarily in the bottom third of the water column near the intakes) and thereby increasing their susceptibility to entrainment.

Besides the effect of vertical behavior on the quality of ichthyoplankton density sampling, other factors which may effect the seasonal density estimate are temperature (considered in NUSCO 1978 and 1979b and throughout this section), weather (seasonal shift in wind speed and direction as well as catastrophic storm events), food availability (density of copepod nauplii required for successful growth or survival) and predation (loss to planktivorous fish, jellyfish and so forth). Because of the varying response times or lags in the effect on ichthyoplankton density of these factors, some of the previous linear correlations (of temperature with larval density, for example) may be misleading. Future time series or autoregressive approaches will be used to try to resolve the problem of lag in response time of populations and of the confounding effect of many of these factors working at the same time.

Ability of Monitoring Program to Detect Changes in Larval Density

Statistical analyses are used to determine if there are significant differences between means. Frequently the actual probability of detecting a specific difference in the means tested based on the sampling program is not calculated. The power of a statistical test, used in testing differences in means, is the probability of detecting a specified difference between the means under the parameters of the sampling program (namely, the variance, sample size).

Absolute differences between ichthyoplankton population means that would indicate a plant-related impact are not known. Therefore, power curves were constructed for a range of hypothetical differences in means. Power curves between Station 5 and the discharge in 1979 and between pairs of years from 1976 through 1979 at the discharge were calculated for total larvae and five important local taxa (winter flounder, sand lance, cunner, anchovies, and tautog). The curves were based on a two-tail test of $\alpha = 0.05$ and the data were transformed by $\log_{10}$ to better satisfy the normal assumptions of parametric test used. The hypotheses tested were:

$$H_o: \mu_i - \mu_2 = 0$$
$$H_A: \mu_i - \mu_2 = \delta, \ \delta \neq 0$$

where:

μ_1 = true mean, level 1

μ_2 = true mean, level 2

= hypothetical true difference of the two means

The large number of samples ($N > 100$) for testing differences in yearly means allows the use of the normal deviate test. Since it can be assumed that the σ^2 was known, the power of the test is:

$$P\left[\frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\sigma^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} > 1.96 - \frac{\delta}{\sqrt{\sigma^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}\right]$$

where:

$\bar{x}_i$ = mean of samples from level i

n_i = number of samples from level i

$$\sigma^2 = \frac{\sum_{j=1}^{n_1} (x_{1j} - \bar{x}_1)^2 + \sum_{k=1}^{n_2} (x_{2k} - \bar{x}_2)^2}{(n_1 + n_2 - 2)}$$

Two parameters from the sampling program for estimating mean density that effect the power are the variability of sample densities (σ^2) and the number of samples in which the taxon was present.

Power curves for spatial differences between the discharge and Station 5 in 1979 were almost identical for winter flounder, sand lance, cunner and tautog (Fig. 14). The power of detecting a specific difference in means for $\log_{10}$ transformed data was highest for total larvae and lowest for the anchovies (that is, the probability of detecting a difference in means of 0.25 was 0.97 for total larvae and 0.45 for the anchovies). The highest power for total larvae corresponds to the greatest number of samples. The lowest power for anchovies indicated greater variability in sample density since anchovies were the second most frequently sampled taxon. The similarity in power curves for winter flounder, tautog, cunner and sand lance indicated the same probability of detecting a specified difference in density between the discharge and Station 5. Evaluation of an environmental sampling program based on power should be treated with some caution when comparing different taxa since the magnitude of the population mean for each taxon will determine the actual difference in means that are ecologically important to detect.

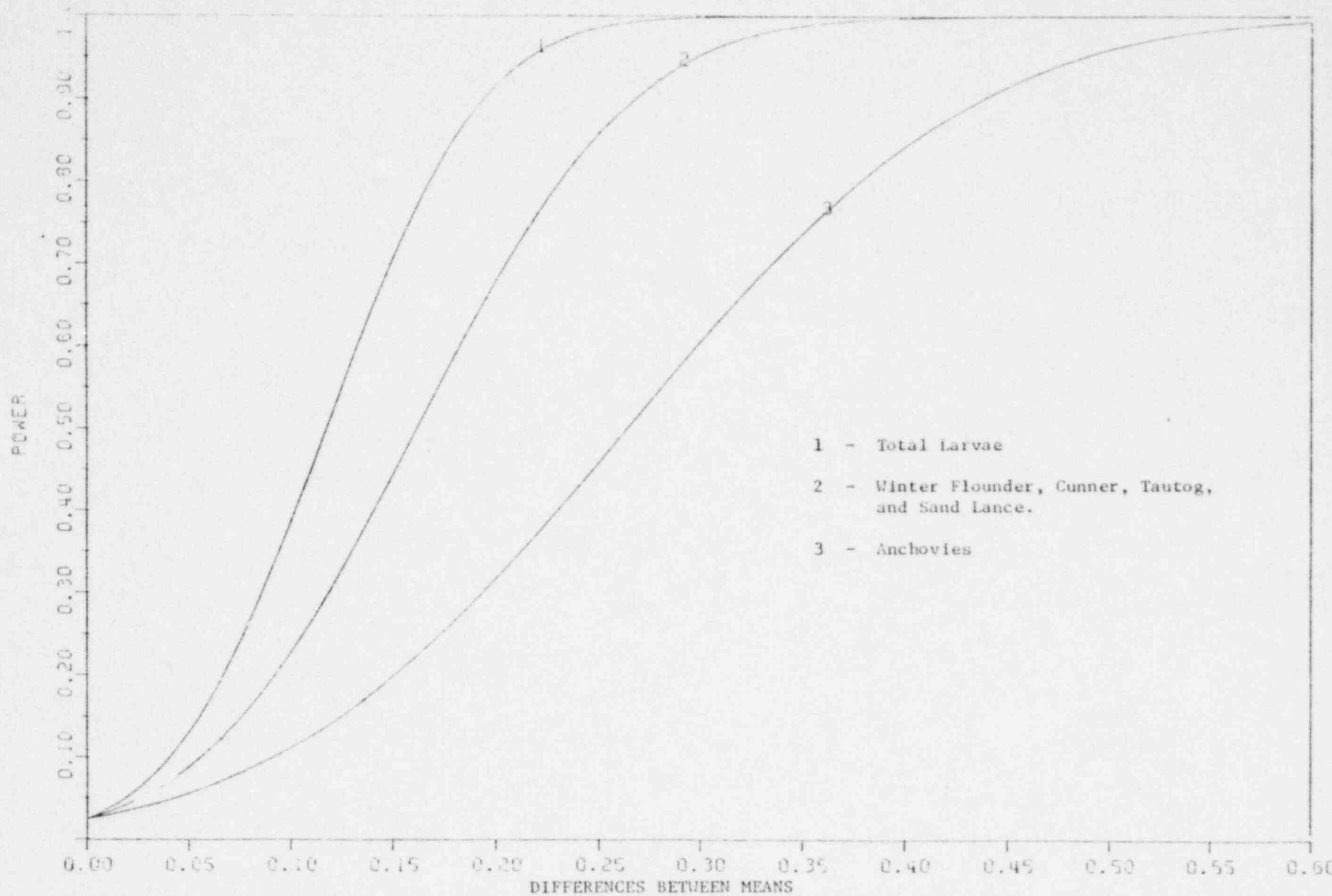


Figure 14. Power curves for selected larval species and total larvae calculated from the discharge and Station 5 in 1979 for a two-tail test at alpha=0.05. Power is the probability of detecting a specific difference between the discharge and Station 5 means ($\log_{10}$ transformed).

One of the most important tasks of the ichthyoplankton monitoring program is to detect temporal changes in density at the discharge from year to year. For each of the six taxa, the power curves for detecting differences between yearly means at the discharge were almost identical for the six paired comparisons of years 1976 through 1979. This similarity in power curves irrespective of which years were compared indicated a similar probability of detecting a specified change in mean density for any two years. Due to the similarity, only the power curves for differences between 1978 and 1979 are presented for comparison with each of the six taxa used in this analysis (Fig. 15). The probability of detecting a difference of 0.15 in mean density from $\log_{10}$ transformed data, between 1978 and 1979 for total larvae, sand lance, winter flounder, cunner, anchovies and tautog was 0.97, 0.76, 0.61, 0.52, 0.47 and 0.38, respectively. As stated previously, caution should be used when comparing taxa since the size of the population mean will determine the ecological importance of a specific difference between yearly means.

Seasonality of Pelagic Fish Eggs in 1979 at the Discharge

In the period from May through October when most of the pelagic fish eggs have been collected (Fig. 16), there were a total of 33 species groups of pelagic fish eggs collected. The thirteen most abundant species were included in percent species composition, rank order and mean seasonal density table similar to the fish larvae (Table 8). Cunner (Tautogolabrus adspersus) accounted for 62% of the eggs collected. An additional 18% were accounted for by the other local labrid, tautog (Tautoga onitis). Anchovies were the second most dominant group of

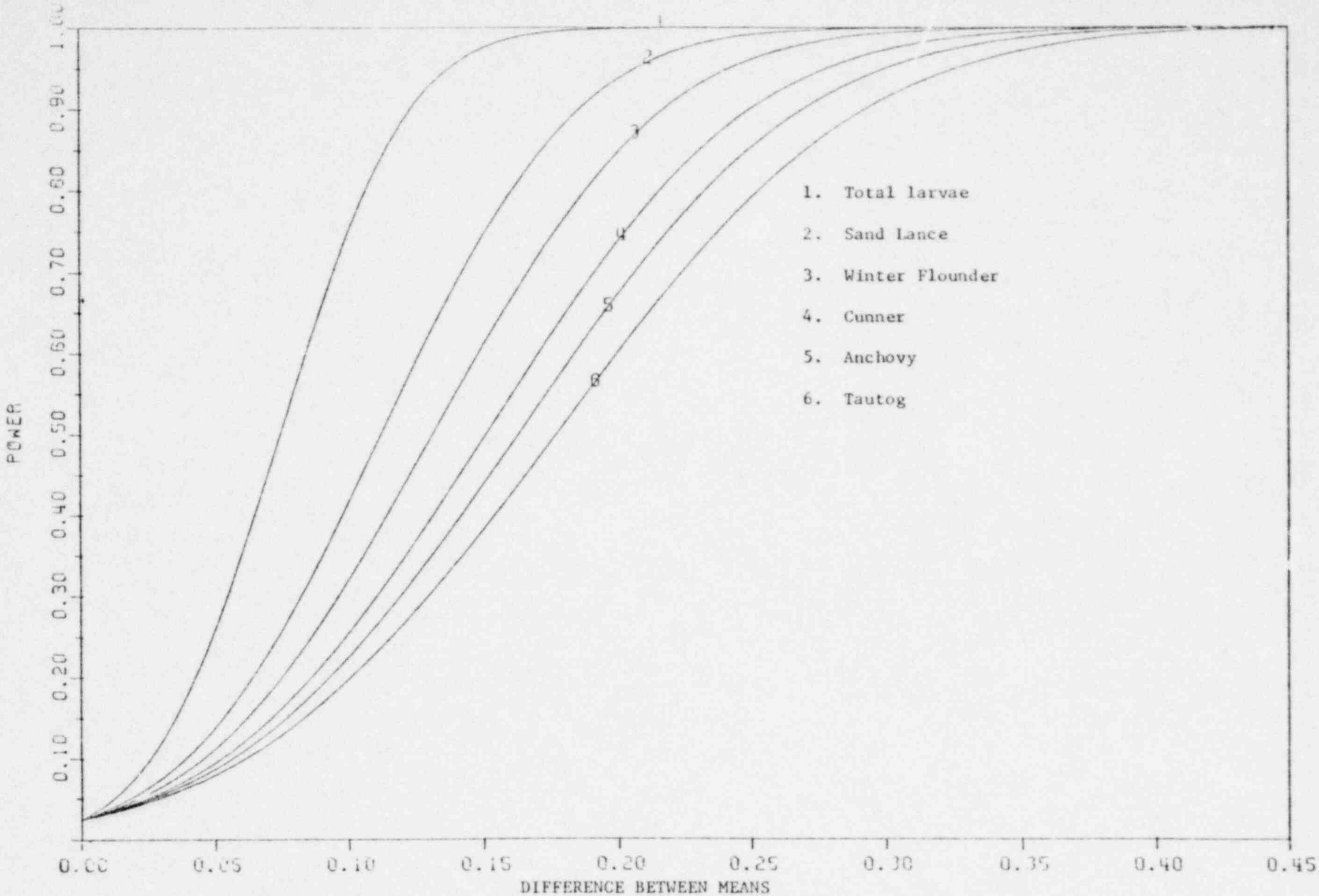


Figure 15. Power curves for selected larval species and total larvae calculated from 1978 and 1979 discharge data for a two-tail test with alpha=0.05. Power is the probability of detecting a specific difference between 1 .8 and 1979 discharge means ($\log_{10}$ transformed).

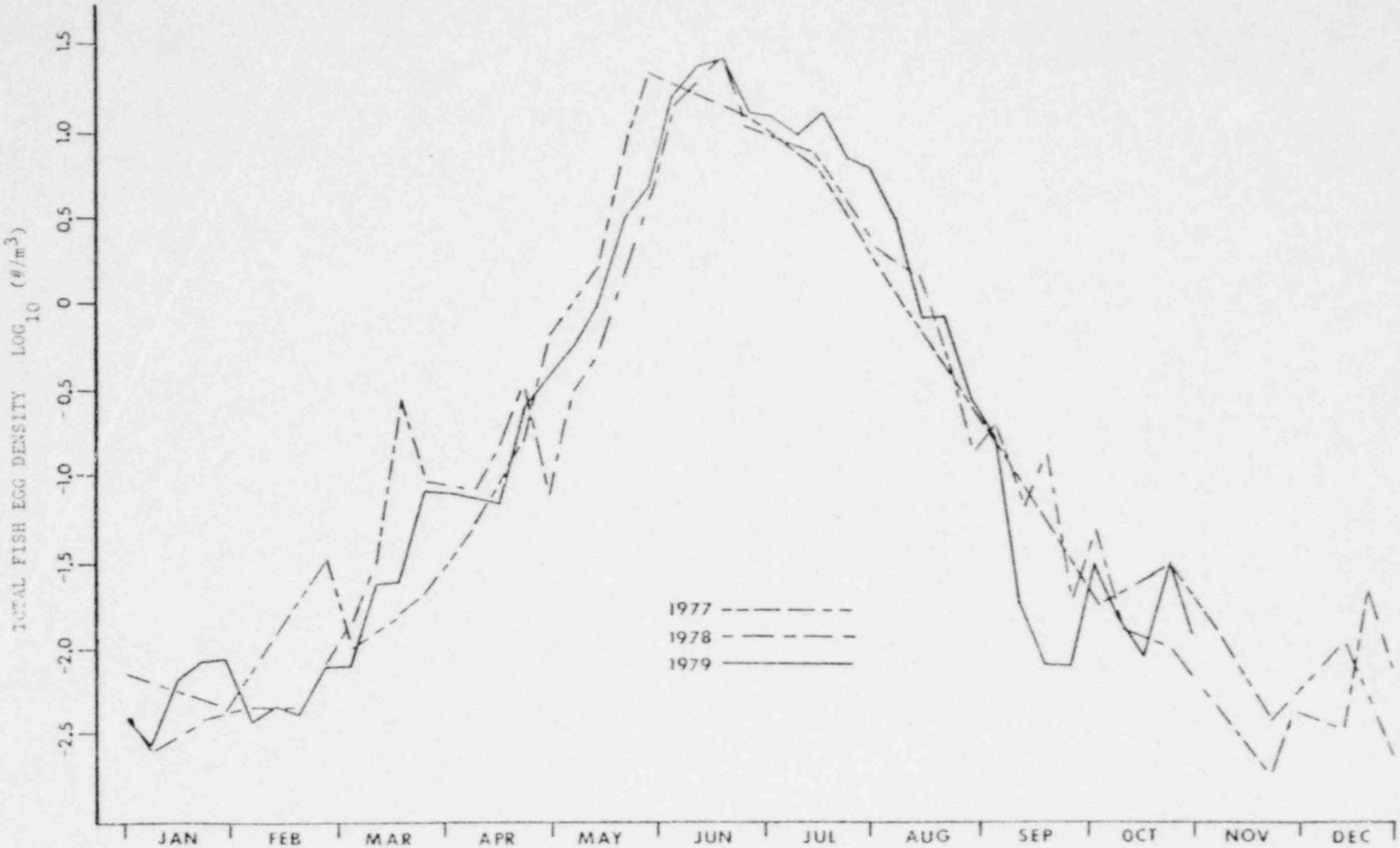


Figure 16. Log_{10} transformed mean weekly density of total fish eggs at the discharge from 1977 through 1979.

Table 8. Percent species composition, mean seasonal density ($\#/m^3$) of fish eggs collected at the discharges May through October 1979.

Species or Group	Percent	$\#/m^3$
Tautogolabrus adspersus	61.67	10.26
Tautoga onitis	17.81	2.25
Anchoa mitchilli	7.65	2.02
Alosa sp.	6.76	12.61
Anchoa hepsetus	1.84	0.81
Eggs (unidentifiable)	1.40	0.94
Scopthalmus aquosus	0.81	0.35
Prionotus sp.	0.72	0.45
Enchelyopus cimbrius	0.32	0.20
Stenotomus chrysops	0.27	0.39
Scomber scombrus	0.12	0.19
Trinectes maculatus	0.12	2.04
Cynoscion regalis	0.11	0.05

pelagic fish egg, comprising almost 10% of the total eggs collected. Bay anchovy (Anchoa mitchilli) and striped anchovy (Anchoa hepsetus) were ranked third and fifth, respectively. Because of the similarity in the appearance of eggs between two or more species, the generic grouping for Alosa spp. and Prionotus spp. was used for taxonomic and data purposes. A relatively small portion (1.4%) of these pelagic eggs had to be classified as unidentified due either to the damaged condition of the eggs or to insufficent taxonomic information. Although these unidentified eggs had passed through the cooling water cycle and been collected by net tow, relatively few eggs were mechanically damaged (ruptured or collapsed).

Most of the local winter and spring spawning fish such as winter flounder and sand lance have adhesive, demersal eggs so that the seasonal variation in density of total eggs (Fig. 16) consisted largely of the summer and fall pelagic egg spawners between May and October (Table 8). In 1979, the peak mean weekly density of total eggs occurred in the second week of June at a density of over $50/m^3$. The broad peak in egg density from this second week of June through the first week of July corresponded to the highest densities of labrid (cunner and tautog) eggs. The highest mean density of eggs occurred one week earlier in 1979 than in 1978 when a peak density of $43/m^3$ and about two weeks earlier than 1977 when the peak density was at a comparable $50/m^3$ level. Total egg density averaged over the entire year was, however, not significantly different among the years 1976 through 1979 (Table 7).

As would be expected, the local distributions of spawning adults (especially inshore versus offshore) influenced the number of eggs (Table 8) or larvae (Table 6) present in discharge samples. Data from the seine, gill-net and other trawl programs (Section 8) and the impingement studies (Section 2) was used to judge the seasonal and area distribution of reproductive adults of the dominant seven pelagic egg species. The percentage of the total catch in each collection area (Fig. 1) and method was then calculated. The bay anchovy, striped anchovy, cunner, and tautog were most abundant as adult fish inshore. The bay and striped anchovies were important in beach seine samples in early June, comprising 10% of the total catch there. Tautog also comprised an additional 10% of total June catch from seines, otter trawls and gillnets. Cunner was 50% of the total gillnet catch in June in the area of the thermal plume. For these four species whose spawning adults appeared to be more abundant inshore, egg densities peaked slightly after adult catch and larval densities peaked slightly after the eggs. Alosa spp. was also more abundant inshore, comprising 15% of the August beach seine catch in Jordan Cove (Fig. 1). These nearshore spawners made up the most dominant pelagic egg species in entrainment samples. Cunner comprised 62%, Anchoa spp. 10%, Alosa spp. 6% and tautog 18% of the total eggs entrained (Table 8).

In contrast to the nearshore spawners, windowpane flounder and the searobins were most commonly found by ottertrawl in deeper offshore stations. Windowpane appeared to be most dense in the area of Bartlett's Reef in August. Searobin catch was highest in Twotree Channel in July. Windowpane ranked low in the composition of eggs (0.81%) and larvae (0.53%). Searobins comprised only 0.47% of the eggs and 0.07% of the larvae. These low numbers of eggs and larvae entrained supported the belief that these species were more out of the source area for cooling water than the five dominant nearshore spawners.

The seasonal density of each of the seven top pelagic eggs was plotted against temperature as in Fig. 5. The graphical coincidence between peak egg density and temperature could be described as follows. All seven most dominant egg types (Table 8) were spawned at temperatures ranging from 15 to 21.5^{o}C. The minimum temperature at which a peak density occurred was 15^{o}C; these were the eggs of Alosa spp. during the second week of June. Cunner and tautog eggs followed a pattern where egg density increased with increasing temperature, peaking during the last two weeks of June at temperatures from 15.5 to 16^{o}C. Windowpane flounder eggs were also most abundant at the end of June (16^{o}C). The bay and striped anchovy eggs showed very similar graphs of density versus temperature or of density versus time. Each reached a maximum density during the last week in July (18^{o}C). The searobin spawned at the highest temperature (21.5^{o}C) of the seven species, peaking in mid-August. Each of these seven dominant egg types also had a secondary peak of density later in the season at temperatures ranging from 18 to 21.5^{o}C. This second peak appeared as a shoulder on the graph of density versus temperature or time corresponding to the period from late July to mid-October.

Relative Impact of Egg and Larval Entrainment on Local Fish Species

In the preceding sections, the seasonal density of fish eggs and larvae in the cooling water of Unit 1 and 2 discharge has been described and compared to earlier studies. The density of total fish larvae was significantly higher in 1979 than in the three previous years mostly as a result of anchovy and sand lance (Table 7). Total fish egg and larval winter flounder density showed no significant difference from 1976 through 1979. The changes which did occur (cunner and tautog) may have been related to a cold spring in 1978 or some other natural factors. Power plant operation has not adversely affected the density of fish eggs or fish larvae in adjacent waters.

In previous annual reports, estimates of the numbers of fish eggs and larvae entrained were extrapolated to several indices of impact including percent standing crop removed, fraction of annual egg production, and equivalent adults (NUSCO 1977, 1978, 1979b). These approaches have shown generally that the effect of fish egg and larval entrainment was on the order of magnitude of one to several thousand mature fish. The most direct evidence suggesting little if any adverse plant related impacts of entrainment on local fish populations is the annual maintenance of similar ichthyoplankton density (Table 7) as well as sustained annual catches of adult fish (Section 8, 9).

Because of the dominance of winter flounder as a species vulnerable to capture by many of the monitoring programs, this species was chosen several years ago for hydrodynamic and population models of the effect on entrainment (Hess et al. 1975; Saila 1976) and for monitoring of successive population size and age structure in Niantic River (Section 9). Despite the entrainment of larvae and impingement of juvenile and adults, no changes in the size or structure of the Niantic River population of winter flounder were attributed to factors other than plant operation. For example, the catch per unit effect of adult winter founder in Niantic Bay has recently been increasing and peaked in 1979 (Section 8).

Because there is considerable life history information concerning winter flounder (especially the Niantic River spawning population), this resident demersal species was used to model the expected magnitude of entrainment impact on fish populations. Two approaches were used.

First, it was determined that the Niantic River population could sustain itself with larvae remaining in the system independent of those entrained at the plant intakes. The annual egg production (6.7×10^9 eggs in 1979) was converted to hatched larvae (3.5×10^9) assuming a 53% hatching success as suggested in Saila (1976). Then, on the basis of the tidal exchanges over the growth season of these larvae (120 tidal cycles), a figure for the survival (0.0025) to metamorphosed benthic larvae within the Niantic River system was used to estimate the number of benthic stage larvae (8.88×10^6) (NUSCO 1977). Using the survival coefficients (in parentheses) of Saila (1976) and NUSCO (1977), these metamorphosed larvae (x 0.035) would produce 310,700 Age 0 recruits in Niantic River. Extrapolating these survivors up to the older age classes, there would be (x 0.14) 43,498 Age 1 recruits, (x 0.33) 14,354 Age 2 recruits, (x 0.33) 6172 Age 3 recruits, and (x 0.33) 2037 Age 4 recruits. Based on these extrapolated numbers, the successive sizes of one year class were very similar to the average age structure observed in the Niantic River population (about 37,000 Age 1 recruits to Age 2, 11,000 to 25,000 Age 2 recruits to Age 3 and 5,000 to 18,000 Age 3 recruits to Age 4 as described in Section 9). This calculation suggested that there were enough larvae remaining in the Niantic River system each year to support the observed population levels and that the loss of larvae through entrainment may not influence this population directly.

Secondly, it was found that Niantic River population could not only sustain itself, but also could provide many of the larvae (and presumtive adults or juveniles) entrained during plant operation. Pearcy (1962) and Saila (1962) found between 18 and 44 Age 1 survivors (or Age 0 recruits) per unit of 100,000 eggs laid in nearby Mystic River and Charlestown Pond respectively. At the mean Age 0 survivorship of 30/100,000 eggs, about 2,010,000 Age 0 recruits would have survived from the 6.7×10^9 eggs produced in 1979. Using the same Age 0 to 1 (0.14) and Age 1 to 2 (0.33) survival coefficients as in the previous extrapolations, these Age 0 recruits would be equivalent to 92,862 Age 2 recruits to Age 3. This Age 3 initial population size was from about 4 to 9 times the actual estimated Niantic River population size over the years 1976 through 1979 (Section 9).

Future studies using a Leslie matrix approach similar to Saila (1976) will concentrate on refining the survival coefficients used between age classes and established the most critical life stages accounting for any variation in population structure.

Plankton Summary

Seasonal density of phytoplankton, zooplankton, fish eggs and fish larvae were monitored in 1979 and compared to the previous three years.

In 1979 the seasonal density and species composition of phytoplankton was similar to other years with a few exceptions. The density of phytoplankton was lower over April, May and June due to a decrease in the dominant diatoms Skeltonema costatum and Thalassiosira spp. Several other species of diatom or a group of chlorophyceans showed relative increases in density for 1979 which tended to restore phytoplankton cell densities to more usual levels in spring.

The zooplankton community monitored over the first four years of two-unit operation showed considerable similarity of species composition and seasonal density from one year to another. Operation of the power plant appeared to have little or no effect on the zooplankton community. Total zooplankton, Acartia hudsonica, and Eurytemora herdmani showed a slight increase in mean density in 1979 while Temora longicornis, Centropages typicus, C. hamatus and gammarid amphipods showed only a slight decline.

Fish eggs and fish larvae have also been similar in species composition and seasonal density over recent years. The few changes that occurred from one year to another appeared to be natural population responses. Density of total fish larvae increased in 1979, primarily a reflection of increases in sandlance larvae and anchovy larvae. Winter flounder larvae showed no significant differences in density over the last four years. Using winter flounder as an example of the order of magnitude of expected entrainment impact, the similarity of larval density and the sustained or increasing adult populations found in Niantic Bay together suggested minimal impact of plant operations on this local fish.

LITERATURE CITED

Allan, J.D., S. Richman, D.R. Heinle, and R. Huff. 1977. Grazing in juvenile stages of some estuarine copepods. Mar. Biol. 43: 317-331.

Carpenter, E.J., S.J. Anderson, and B.B. Peck. 1974. Survival of copepods passing through a nuclear power station on northwestern Long Island Sound, U.S.A. Mar. Biol. 24: 49-55.

Chan, A. 1978. Comparative physiological study of marine diatoms and dinoflagellates in relation to irradiance and cell size. I. Growth under continuous light. J. Phycol. 14: 396-402.

Conover, S.M. 1956. Oceanography of Long Island Sound, 1952-1954. II. Phytoplankton. Bull. Bingham Oceanogr. Coll. 15: 62-112.

Cushing, D.H. 1968. Grazing by herbivorous copepods in the sea. J. Cons. 32: 70-82.

Deevey, G.B. 1952. Quantity and composition of the zooplankton of Block Island Sound. Bull. Bingham Oceanogr. Coll. 13: 120-164.

__________ 1956. Oceanography of Long Island Sound, 1952-1954. V. Zooplankton. Bull. Bingham Oceanogr. Coll. 15: 133-155.

Durbin, E.G., R.W. Krawiec, and T.J. Smayda. 1975. Seasonal studies on the relative importance of different size fractions of phytoplankton in Narragansett Bay. Mar. Biol. 32: 271-287.

Eppley, R.W. 1972. Temperature and phytoplankton growth in the sea. Fish. Bull. 70(4): 1063-1085.

Fuller, W.A. 1976. Introduction to Statistical Time Series. John Wiley, N.Y. 293 pp.

Furnas, M.J., G.L. Hitchcock, and T.J. Smayda. 1976. Nutrient-phytoplankton relationships in Narragansett Bay during the 1974 summer bloom In: Estuarine Processes Vol. 1, Academic Press, N.Y. 118-133.

Greze, I.I. 1968. Feeding habits and food requirements of some amphipods in the Black Sea. Mar. Biol. 43: 316-321.

Harris, E. and G.A. Riley. 1956. Oceanography of Long Island Sound. VIII. Chemical composition of the plankton. Bull. Bingham Oceanogr. Coll. 15: 315-323.

Hess, K.W., M.P. Sissenwine, and S.B. Saila. 1975. Simulating the impact of the entrainment of winter flounder larvae. In: Fisheries and Energy Production. S. B. Saila, ed. D.D. Heath Co., Lexington, Mass. 298 pp.

Hitchcock, G.L. and T.J. Smayda. 1977. The importance of light in the initiation of the 1972-1973 winter-spri diatom bloom in Narragansett Bay. Limnol. and Oceanog.. 22: 126-131.

Hulsizer, E.E. 1976. Zooplankton of lower Narragansett Bay. Ches. Sci. 17(4): 260-270.

Jacobs, J. 1968. Animal behavior and water movement as co-determinants of phytoplankton distribution in a tidal system. Sarsia 34: 355-370.

Jeffries, H.P. and W.C. Johnson. 1973. Distribution and abundance of zooplankton. In: Coastal and Offshore Environmental Inventory Cape Hatteras to Nantucket Shoals. Univ. R.I. Mar. Publ. Ser.

Jensen, A. and E. Sakshaug. 1973. Studies on the phytoplankton ecology of the Trondheimsfjord. II. Chloroplast pigments in relation to abundance and physiological state of the phytoplankton. J. exp. mar. Biol. Ecol. 11: 137-155.

LILCO. 1979. Preoperational Aquatic Ecology Study Shoreham Nuclear Power Station, Unit 1, 1977-1978 prepared by Equitable Environmental Health for Long Island Lighting Company.

Lund, J.W.G., C. Kipling, and E.D. LeCren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. Hydrobiol. 11: 143-170.

Martin, J.H. 1965. Phytoplankton--zooplankton relationships in Narragansett Bay. Limnol. Oceanogr. 10: 186-191.

____________ 1970. Phytoplankton--zooplankton relationships in Narragansett Bay. IV. The seasonal importance of grazing. Limnol. Oceanogr. 15: 413-418.

Meyer, T., R. Cooper, and R. Langton. 1979. Relative abundance, behavior, and food habits of the American sand lance, *Ammodytes americanus*, from the Gulf of Maine. Fish. Bull. 77(1): 243-253.

Miller, C.B. and J.K. Johnson. 1977. Growth rules in the marine copepod genus *Acartia*. Limnol. Oceanogr. 22: 326-335.

NUSCo. 1977. Annual Report, Ecological and Hydrographic Studies, 1976. Millstone Point Entrainment Studies, Units 1 and 2, prepared by Northeast Utilities Service Company.

NUSCo. 1978. Annual Report, Ecological and Hydrographic Studies, 1977. Millstone Point Entrainment Studies Units 1 and 2, prepared by Northeast Utilities Service Company.

NUSCo. 1979a. Evaluation of past offshore ichthyoplankton programs at Millstone Point and recommendations for the 1979 sampling program. Technical report to Ecological Review Board; Northeast Utilities Service Company.

NUSCo. 1979b. Annual Report, Ecological and Hydrographic Studies, 1978. Millstone Point Entrainment Studies Units 1 and 2, prepared by Northeast Utilities Service Company.

Orlowski, S.J., S.S. Herman, R.G. Malsberger, and H.N. Pritchard. 1972. Distinguishing cunner and tautog eggs by immunodiffusion. J. Fish. Res. Bd. Canada. 29: 111-113.

Paasche, E. 1973. Silicon and the ecology of marine plankton diatoms. II. Silicate uptake kinetics in five diatom species. Mar. Biol. 19: 262-269.

____________ 1975. Growth of the plankton diatom *Thalassiosira nordenskioldii* at low silicate concentrations. J. exp. mar. Biol. Ecol. 18: 171-186.

Paffenhöfer, G.A. and S.C. Knowles. 1978. Feeding of marine planktonic copepods on mixed phytoplankton. Mar. Biol. 48: 143-152.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder, *Pseudopleuronectes americanus*. II. Distribution and dynamics of larvae. Bull. Bingham. Oceanogr. Coll. 18: 17-37.

Pratt, D.M. 1959. The phytoplankton of Narragansett Bay. Limnol. Oceanogr. 4: 425-439.

___________ 1963. The winter-spring diatom flowering in Narragansett Bay. Limnol. Oceanogr. 7: 173-189.

PSEG. 1979. Annual environmental operating report for 1978 (non-radiological). Salem Nuclear Generating Station Unit 1. Docket No. 50-272. Prepared for Public Service Electric and Gas Company, Newark, New Jersey.

Richman, S., D.R. Heinle, and R. Huff. 1977. Grazing by adult estuarine calanoid copepods of the Chesapeake Bay. Mar. Biol. 42: 69-84.

Riley, G.A. 1966. The plankton of estuaries. In: Estuaries AAAS publication, Washington, D.C. 761 pp.

Saila, S.B. 1962. Contribution of estuaries to the offshore winter flounder fisheries of Rhode Island. Gulf and Caribbean Fisheries Inst. Proc. 14th Annual Session, November, 1961. pp. 95-109.

___________ 1976. Effects of power plant entrainment on winter flounder population near Millstone Point. Univ. Rhode Island. NUSCo Rep. No. 5.

Sakshaug, E. and S. Myklestad. 1973. Studies of the phytoplankton ecology of the Trondheimsfjord. III. Dynamics of phytoplankton blooms in relation to environmental factors, bioassay experiments, and parameters for the physiological state of the populations. J. exp. mar. Biol Ecol. 11: 157-188.

___________ 1977. Limiting nutrients and maximum growth rates for diatoms in Narragansett Bay. J. exp. mar. Biol. Ecol. 28: 109-123.

SCOR-UNESCO. 1966. Monographs on oceanographic methodology. I. Determination of photosynthetic pigments in seawater. UNESCO, Paris. 69 pp.

Smayda, T.J. 1973. Growth of *Skeletonema costatum* during a winter spring bloom in Narragansett Bay, Rhode Island. Norw. J. Bot. 20: 219-247.

__________ 1974. Bioassay of the growth potential of the surface water of lower Narragansett Bay over an annual cycle using the diatom *Thalassiosira pseudonona* (oceanic clone, 13-1). Limnol. Oceanogr. 19: 889-901.

Smith, W.G., J.D. Sibunka, and A. Wells. 1975. Seasonal distributions of larval flatfishes (Pleuronectiformes) on the Continental Shelf between Cape Cod, Massachusetts and Cape Lookout, North Carolina. NOAA Tech. Rep. NMFS, SSRF - 691. 70 pp.

__________, L. Sullivan, and P. Berrien. 1978. Fluctuations in production of sand lance larvae in coastal waters off the northeastern United States, 1974 to 1977. Int. Counc. Explor. Sea. C.M. 1978/L:30.

Staker, R.D. and S.F. Bruno. 1978. An annual phytoplankton study in coastal waters off eastern Long Island (Block Island Sound) Bot. Mar. 21: 439-449.

Thayer, G.W., D.E. Hoss, M.H. Kjelson, W.F. Hettler, and M.W. LaCroix. 197'. Biomass of zooplankton on the Newport River Estuary and the influence of post larval fishes. Ches. Sci. 15: 9-16.

Ütermohl, H. 1958. Zur Vervollkommnung der quantitativen Phytoplankton-Methodek. Mitl. Intern. Ver. Limnol. 9: 1038.

Vince, S. and I. Valiela. 1973. The effects of ammonium and phosphate enrichments on chlorophyll a, pigment ratio, and species composition of phytoplankton of Vineyard Sound. Mar. Biol. 19: 69-73.

Williams, G.C. 1967. Identification and seasonal size changes of eggs of the labrid fishes, *Tautogolabrus adspersus* and *Tautoga onitis*, of Long Island Sound. Copeia 2: 452-453.

Yoder, J.A. 1979. A comparison between the cell division rate of natural populations of the marine diatom *Skeletonema costatum* (Greville) Cleve grown in dialysis culture and that predicted from a mathematical model. Limnol. Oceanogr. 24: 97-106.

ROCKY SHORE

ROCKY SHORE SURVEY

INTRODUCTION

The rocky intertidal zone in the vicinity of the Millstone Nuclear Power Station (MNPS) is easily accessible, and supports a wide range of organisms that are sessile or slow-moving, and mostly field identifiable, these organisms are potential tools of monitoring as bio-indicators of environmental change. A large volume of literature concerning the rocky intertidal region and its biota permits comparisons of our control and experimental areas with areas studied elsewhere. Gradients of many parameters affecting shore populations result in almost universal patterns of zonation (Chapman 1946; Lewis 1964; Zaneveld 1969; Stephenson and Stephenson 1972); some of these parameters can be quantified and characterized over time, and some can be experimentally manipulated in an effort to determine causal relationships (Connell 1961; Paine 1966; Dayton 1975; Menge 1975). Perturbation of the marine environment, particularly thermal pollution, would be evidenced first and most obviously in the intertidal region; this, and all the above factors, make the rocky shore an ideal area for biological monitoring.

The primary objectives of the Rocky Shore Survey were to characterize the intertidal sites in the vicinity of MNPS, to identify the attached plant and animal species at these sites, and to determine if differences in the biota of these sites exist that could be attributed to the operation of the power station. The environmental monitoring program included qualitative algal collections, estimation of percentage of substratum coverage by intertidal organisms, measurement of recolonization rates and patterns following small scale denudations, experimental exclusion of grazers and predators from selected areas, and growth studies of *Fucus vesiculosus* and *Ascophyllum nodosum*.

MATERIALS AND METHODS

Sampling Procedures

The seven rocky intertidal stations (Fig. 1) and their resident biota were sampled monthly, beginning in February 1979 and continuing through December 1979. The physical character and other relevant features of these stations have been described in previous reports (Battelle 1977).

Qualitative algal samples were identified fresh, or after short-term freezing. Voucher specimens were preserved in 4% formalin/seawater, as herbarium mounts, or on microscope slides. Plant features such as general condition, cytology, age, habit, and reproductive status were noted where applicable.

Quantitative studies were also instituted. At each station, five half-meter wide strips were established perpendicular to the waterline, and extending from Mean High Water to Mean Low Water levels. These strips (which will be referred to as undisturbed transects) were marked with stainless steel screws at their extremities. The transects were non-destructively sampled with the use of paired lines, marked at half-meter intervals, defining 50 x 50 cm quadrats. At low tide, the percent coverage of all organisms and remaining free space was subjectively determined and recorded. To give a more accurate representation of species that were partially or

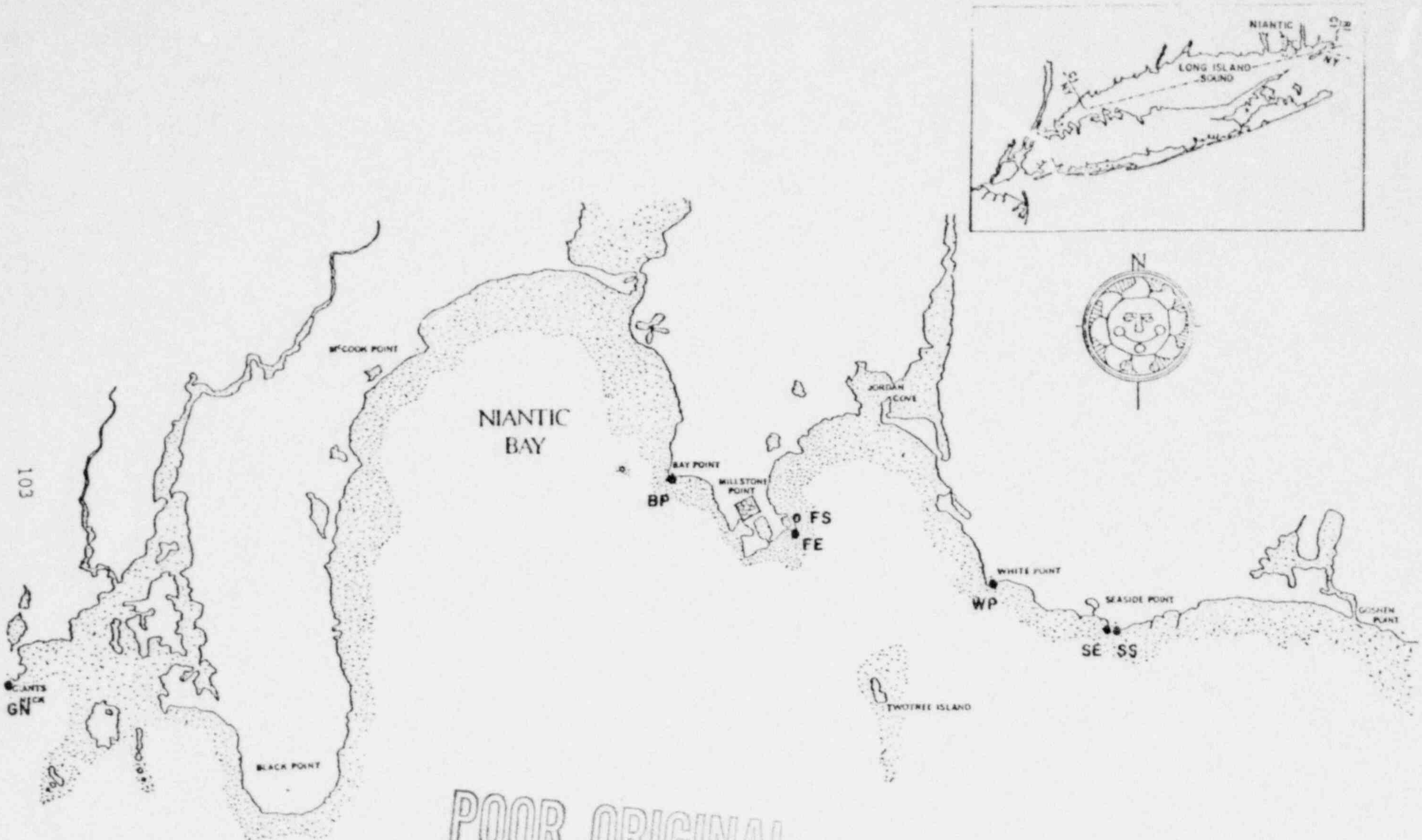


Figure 1. Location of rocky intertidal sampling sites. GN- cs Neck, BP-Bay Point, FE-Fox Island (Exposed), FS-Fox Island (Sheltered), WP-White Point, SE-Seaside Exposed, SS-Seaside Sheltered

totally obscured by the canopy layer, an additional percentage was given for the occurrence of 'understory' organisms.

Each transect was divided into three zones, each characterized by a specific biota: Zone I - upper intertidal, with blue-green algae and *Balanus* dominating, Zone II - mid intertidal, largely covered with *Fucus* and/or *Ascophyllum*, and Zone III - low intertidal, dominated by *Chondrus*.

Data from all five transects at a station were pooled to generate an average percent cover for each organism in each zone. The rationale for pooling data was statistically acceptable because the variability between transects was much less than the variability between stations, between sampling periods, and between the zones of a single transect.

For convenience and clarity, each organism and substrate type was assigned to one of eight general categories:

Class 1 - free space, includes rock, sand and mud.

Class 2 - barnacles; mostly *Balanus balanoides*.

Class 3 - mussels, mostly *Mytilus edulis*.

Class 4 - fucoids; *Ascophyllum nodosum* and *Fucus* spp.

Class 5 - carrageenoids; *Chondrus crispus* and *Gigartina stellata*.

Class 6 - ephemeral algae, includes host specific epiphytes, non-specific epiphytes, lithophytes and crusts.

Class 7 - grazers, mostly *Littorina* spp., but includes any primary consumer.

Class 8 - predators; mostly *Urosalpinx cinerea* and *Thais lapillus*, but includes any carnivore that will attack barnacles, mussels, or the herbivores.

These classes were established to condense a large amount of data into an easily understandable and more readily presentable form; all rankings and calculation of diversity and similarity indices were performed using the entire species list.

Recolonization studies were done at four of the stations: Giants Neck, White Point, Fox Island-Exposed, and Fox Island-Sheltered. At each of the first three sites, three transects additional to those previously described were established in April 1979. After initial determination of species composition and percentage of substratum covered, each strip was scraped free of all attached algae and invertebrates and subsequently burned with a Liquid Petroleum Gas torch; this procedure was repeated until all organic matter was removed. Algae in areas adjacent to the denuded strips (which will be referred to as recolonization transects) were removed to minimize the possibility of edge effect, e.g. shading or whiplash. These nine transects, together with three strips at Fox Island-Sheltered (which had been burned and cleared in June 1978), were sampled monthly in the same manner as described for the undisturbed transects.

At each of the four recolonization sites, nine exclusion cages were attached, three cages in each tidal zone, i.e. upper, middle, and low tidal level. The cages (20 x 20 x 5 cm) were constructed from 3 mm stainless steel mesh and were fastened with stainless steel screws to flat rock surfaces which had been burned and cleared in the same way as had the recolonization transects. Each cage had a gasket-like strip around the edge to discourage entry of predators and grazers. Adjacent to each cage, a 20 x 20 cm patch was burned and cleared, to be used as a control.

Percent coverage by benthic plants and animals in the experimental and control areas was determined and recorded on a monthly basis. Additionally, *Fucus* plants, when present, were measured in each cage and control area. The cages were inspected, and cleaned as necessary.

Ascophyllum tip length was measured at three stations (Giants Neck, White Point, and two sites at Fox Island-Exposed, one low intertidal and one mid-upper intertidal) to determine growth. Fifty plants at each of the four sites were tagged with methods similar to those of Vadas et al. (1976). A numbered plastic tag was fastened to the base of the plant, and five apices were marked with colored plastic tape. Measurements were made from the top of the most recently formed bladder to the apex or apices if branching has occurred. In April and May 1979, the bladders were too small to be securely tagged; measurements were made of five tips on each of 50 randomly chosen plants. Monthly measurements of tagged plants began in June. To estimate tag and tip mortality, lost tags were not replaced. Loss of the entire plant was assumed when the base tag and tip tags were missing; tip mortality was equated with loss of colored tape. Therefore, the measure of tip mortality includes a combination of actual tip loss and tag loss; studies are in progress to distinguish between the two.

Data Analysis

Relative abundances of intertidal organisms were represented as ranks, performed on the basis of percent substratum coverage of each taxon and remaining free space.

Diversity of the intertidal communities was represented by the Shannon information index, H', and evenness coefficient, J, as outlined in the Benthic Sand Infaunal section of this report, substituting percent coverage of each species for abundance values.

Similarity of the communities was determined by a percent standardized form of the Bray-Curtis coefficient (Sanders 1960) calculated as:

$$S_{jk} = \sum_{i=1}^{n} \min (P_{ij}, P_{ik})$$

where P_{ij} is the percent of species i at station j, P_{ik} is the percent for station k, and n is the number of species in common. The same clustering algorithm was applied to the resulting similarity matrix as was outlined in the Benthic Sand Infaunal section.

Ascophyllum growth data were subjected to an analysis of covariance to determine whether growth rates differed significantly between stations.

RESULTS AND DISCUSSION

Qualitative Collections

A total of 103 species of algae, exclusive of diatoms and blue-green algae, were collected from the rocky intertidal stations from February to December 1979. No single collection period or the combined collections at a single station included all species. The maximum number of species collected in any one month was 65 in August; the most collected at one station was 76 at Fox Island-Exposed. In general, the richest collections were made in autumn

(Aug.-Nov.), and the poorest in species number were in winter and early spring. Species lists for each month at any station are presented in Table 1, and for each station during any month in Table 2. Species lists for each station by month are included in Appendix 1.

Of the 103 algal species, 45 were reds, 26 were browns, and 32 were greens. Number of species in each division at each station are given in Table 3. Increases in total number of species cited, as well as the relative proportion of Rhodophyta to the other algal divisions, over previous years (Battelle 1978) were due primarily to increased intensity of sampling, especially from the sub-littoral fringe, i.e. the zone immediately below mean low water level.

Undisturbed Transects

Average percent coverage of each zone and at each station is summarized in Table 4a, species data for each month are presented in Appendix II.

Zone I was characterized by a blue-green algal turf (primarily a *Calothrix-Lyngbya* association) that was present in the spring, disappeared in the summer, and returned in autumn. The Fox Island-Exposed station was unique in having high *Fucus* (35%) and barnacle (29%) coverage in this zone.

Zone II was largely covered by *Fucus vesiculosus*, except at White Point, where the dominant species was *Ascophyllum nodosum*. Bay Point was atypical in having very low fucoid coverage; instead, dominated by mussels and barnacles. The sharp decrease in percent coverage of mussels between August and September at this station (Appendix II) corresponded to the

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Table 1. Algal species collected at any rocky intertidal station, by month.

	M	A	M	J	J	A	S	O	N	D
Goniotrichum alsidii								X	X	
Erythrotrichia carnea						X				
Bangia atropurpurea	X	X				X	X	X	X	X
Porphyra leucosticta		X	X	X		X				
Porphyra umbilicalis	X	X	X	X	X	X	X	X	X	
Audouinella purpurea		X								
Audouinella secundata						X	X	X	X	
Gelidium crinale									X	
Nemalion helminthoides						X				
Bonnemaisonia hamifera		X	X	X	X	X				
Neoagardhiella baileyi		X			X		X	X		
Polyides rotundus			X		X	X	X	X	X	X
Cystoclonium purpureum	X	X	X	X		X	X	X	X	X
Cystoclonium purpureum v. cirrhosum	X	X	X	X	X		X		X	X
Ahnfeltia plicata	X	X	X	X	X	X	X	X	X	X
Phyllophora pseudoceranoides		X	X	X		X		X		
Phyllophora truncata					X	X				X
Chondrus crispus	X	X	X	X	X	X	X	X	X	X
Gigartina stellata			X	X	X	X	X	X	X	X
Rhodophysema georgii	X			X	X	X				
Corallina officinalis	X	X	X	X	X	X	X	X	X	X
Dumontia incrassata	X	X	X	X						
Choreocolax polysiphonia			X							
Palmaria palmata	X	X	X	X	X	X	X	X		X
Champia parvula					X	X	X	X	X	X
Lomentaria baileyana							X	X	X	X
Antithamnion cruciatum			X		X	X	X	X	X	X
Callithamnion corymbosum				X		X	X		X	
Callithamnion roseum						X	X	X	X	X
Callithamnion tetragonum					X	X		X	X	X
Ceramium diaphanum		X			X	X	X	X	X	X
Ceramium rubriforme					X	X		X		X
Ceramium rubrum	X	X	X	X	X	X	X	X	X	X
Spermothamnion repens						X	X	X	X	X
Grinnellia americanum								X		
Phycodrys rubens		X	X			X	X			
Dasya baillouviana						X	X	X	X	X
Chondria tenuissima		X				X				
Polysiphonia fibrillosa								X		
Polysiphonia harveyi		X		X	X	X	X	X	X	X
Polysiphonia lanosa	X	X	X	X	X	X	X	X	X	X
Polysiphonia nigra			X			X				X
Polysiphonia negrescens	X	X	X	X	X	X	X	X	X	X
Polysiphonia urceolata	X	X	X	X	X	X	X			
Rhodomela confervoides	X	X	X	X					X	X
Ectocarpus siliculosis	X	X	X	X	X	X	X		X	
Giffordia mitchellae								X		
Pilayella littoralis	X	X	X	X	X	X	X		X	
Spongonema tomentosum								X		
Ralfsia verrucosa	X	X	X	X	X	X	X	X	X	X
Elachista fucicola	X	X	X	X	X	X	X	X	X	

Table 1. (cont.)

	M	A	M	J	J	A	S	O	N	D
Leathesia difformis				X	X	X				
Chordaria flagelliformis		X	X	X	X	X	X	X		
Asperococcus fistulosus	X	X	X				X			
Desmotrichum undulatum	X									
Punctaria latifolia	X	X		X						
Punctaria plantaginea			X				X			
Petalonia fascia	X	X	X	X	X			X	X	X
Scytosiphon lomentaria	X	X	X	X	X	X	X		X	X
Desmarestia aculeata			X			X				
Desmarestia viridis	X	X	X	X						
Chorda filum				X	X					
Chorda tomentosa		X	X							
Laminaria longicruris						X	X	X		
Laminaria saccharina	X	X	X	X	X	X	X	X	X	X
Sphacelaria cirrosa					X	X	X	X	X	X
Ascophyllum nodosum	X	X	X	X	X	X	X	X	X	X
Fucus distichus v. edentatus	X	X							X	
Fucus distichus v. evanescens	X	X	X	X						X
Fucus spiralis								X	X	X
Fucus vesiculosus	X	X	X	X	X	X	X	X	X	X
Ulothrix flacca	X	X	X		X			X	X	X
Urospora penicilliformis	X	X	X	X						
Urospora wormskjoldii	X	X								
Monostroma grevillei	X	X	X	X						
Monostroma pulchrum	X	X	X	X						X
Spongomorpha arcta	X	X	X	X						
Spongomorpha aeruginosa		X	X	X	X	X	X			
Capsosiphon fulvescens			X	X						
Blidingia minima	X	X	X	X	X	X	X	X	X	X
Blidingia marginata			X							
Enteromorpha clathrata type I	X	X			X	X	X	X	X	X
Enteromorpha clathrata type II						X	X	X	X	X
Enteromorpha flexuosa subsp. flexuosa							X	X		X
Enteromorpha flexuosa subsp. paradoxa							X	X		
Enteromorpha groenlandica			X	X						
Enteromorpha intestinalis	X	X	X	X	X	X	X	X	X	X
Enteromorpha linza	X	X	X	X	X	X	X	X	X	X
Enteromorpha prolifera			X	X	X	X	X	X	X	X
Enteromorpha torta				X		X		X	X	
Percursaria percursa				X						
Ulva lactuca	X	X	X	X	X	X	X	X	X	X
Ulva rigida							X	X	X	
Prasiola stipitata					X	X		X	X	X
Chaetomorpha linum	X	X	X	X	X	X	X	X	X	X
Chaetomorpha aerea					X		X	X	X	X
Cladophora albida	X	X	X	X		X		X	X	
Cladophora refracta				X	X	X	X	X	X	X
Cladophora sericea	X	X	X		X	X	X	X	X	X
Rhizoclonium riparium					X	X	X	X	X	
Bryopsis plumosa				X	X	X	X	X	X	
Derbesia marina	X					X	X	X	X	X
Codium fragile	X	X	X	X	X	X	X	X	X	X

Table 2. Algal species collected in any month, by station.

	GN	BP	FE	FS	WP	SE	SS
Goniotrichum alsidii		X		X			
Erythrotrichia carnea		X					
Bangia atropurpurea	X	X	X	X	X	X	X
Porphyra leucosticta			X	X	X	X	
Porphyra umbilicalis	X	X	X	X	X	X	X
Audouinella purpurea			X				
Audouinella secundata	X	X	X	X			X
Gelidium crinale				X			
Nemalion helminthoides			X				
Bonnemaisonia hamifera		X			X	X	X
Neoagardhiella baileyi	X		X	X		X	
Polyides rotundus	X	X		X	X	X	X
Cystoclonium purpureum	X	X	X	X	X	X	
Cystoclonium purpureum v. cirrhosum	X	X	X	X	X	X	X
Ahnfeltia plicata	X	X	X	X	X	X	X
Phyllophora pseudoceranoides			X		X	X	X
Phyllophora truncata	X		X	X		X	X
Chondrus crispus	X	X	X	X	X	X	X
Gigartina stellata			X	X	X	X	X
Rhodophysema georgii					X		X
Corallina officinalis	X	X	X	X	X	X	X
Dumontia incrassata	X	X		X	X	X	X
Choreocolax polysiphonia	X						
Palmaria palmata	X	X	X	X	X	X	X
Champia parvula	X	X	X	X	X	X	X
Lomentaria baileyana	X		X	X	X	X	
Antithamnion cruciatum	X	X	X	X	X	X	X
Callithamnion corymbosum		X	X	X	X		X
Callithamnion roseum	X		X	X	X		X
Callithamnion tetragonum	X	X	X	X	X		X
Ceramium diaphanum	X	X	X	X	X	X	X
Ceramium rubriforme	X	X			X		
Ceramium rubrum	X	X	X	X	X	X	X
Spermothamnion repens	X	X	X	X	X	X	X
Grinnellia americanum					X		
Phycodrys rubens					X		X
Dasya baillouviana		X	X	X	X		X
Chondria tenuissima		X	X				
Polysiphonia fibrillosa					X		
Polysiphonia harveyi	X	X	X	X	X	X	X
Polysiphonia lanosa	X	X	X		X	X	X
Polysiphonia nigra	X	X		X	X		
Polysiphonia negrescens	X	X	X	X	X	X	X
Polysiphonia urceolata	X	X	X	X	X	X	
Rhodomela confervoides	X	X	X	X		X	X
Ectocarpus siliculosis	X	X	X	X	X	X	X
Giffordia mitchellae			X				
Pilayella littoralis	X	X		X	X	X	
Spongonema tomentosum			X				
Ralfsia verrucosa	X	X	X	X	X	X	X
Elachista fucicola	X	X	X	X	X	X	X

Table 2. (cont.)

	GN	BP	FE	FS	WP	SE	SS
Leathesia difformis	X		X		X		
Chordaria flagelliformis	X	X	X	X	X	X	X
Asperococcus fistulosus	X				X	X	
Desmotrichum undulatum							X
Punctaria latifolia				X	X	X	X
Punctaria plantaginea				X	X		
Petalonia fascia	X	X	X	X	X	X	X
Scytosiphon lomentaria	X	X	X	X	X	X	X
Desmarestia aculeata							X
Desmarestia viridis	X	X	X	X	X		X
Chorda filum		X			X		X
Chorda tomentosa			X	X			
Laminaria longicruris			X			X	X
Laminaria saccharina	X	X	X	X	X	X	X
Sphacelaria cirrosa	X	X	X		X		
Ascophyllum nodosum	X	X	X	X	X	X	X
Fucus distichus v. edentatus	X	X	X	X			
Fucus distichus v. evanescens	X	X	X	X	X	X	X
Fucus spiralis	X	X					
Fucus vesiculosus	X	X	X	X	X	X	X
Ulothrix flacca	X	X	X	X	X	X	X
Urospora penicilliformis	X	X	X	X	X		X
Urospora wormskjoldii			X				
Monostroma grevillei	X	X	X	X	X	X	X
Monostroma pulchrum	X	X	X	X	X	X	X
Spongomorpha arcta	X	X	X	X	X	X	X
Spongomorpha aeruginosa	X	X		X	X	X	
Capsosiphon fulvescens				X			X
Blidingia minima	X	X	X	X	X	X	X
Blidingia marginata		X					
Enteromorpha clathrata type I	X	X	X	X	X		X
Enteromorpha clathrata type II	X		X	X	X		X
Enteromorpha flexuosa subsp. flexuosa		X	X				X
Enteromorpha flexuosa subsp. paradoxa	X				X		X
Enteromorpha groenlandica		X					X
Enteromorpha intestinalis	X	X	X	X	X	X	X
Enteromorpha linza	X	X	X	X	X	X	X
Enteromorpha prolifera	X		X	X	X	X	X
Enteromorpha torta	X	X	X	X	X		
Percursaria percursa			X	X			
Ulva lactuca	X	X	X	X	X	X	X
Ulva rigida		X	X	X		X	X
Prasiola stipitata						X	X
Chaetomorpha linum	X	X	X	X	X	X	X
Chaetomorpha aerea		X	X	X	X		
Cladophora albida	X	X	X	X	X		X
Cladophora refracta	X	X	X		X	X	X
Cladophora sericea	X	X	X	X	X	X	X
Rhizoclonium riparium	X		X	X	X		
Bryopsis plumosa	X	X	X	X	X	X	
Derbesia marina	X	X	X				
Codium fragile	X	X	X	X	X	X	X

Table 3. Total number of species from each division collected at each station in each month (qualitative collections).

Station	Division	Month										Yearly Total
		Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Giants Neck	Rhodophyta	11	12	10	10	6	8	9	12	11	16	29
	Phaeophyta	11	13	11	10	9	8	5	6	5	4	17
	Chlorophyta	7	7	8	6	4	6	7	6	6	4	23
	Monthly total	29	32	29	26	19	22	21	24	22	24	69
Bay Point	Rhodophyta	10	6	12	6	6	19	9	8	13	13	31
	Phaeophyta	7	6	8	9	5	6	4	5	6	7	16
	Chlorophyta	8	10	6	7	6	8	4	7	11	13	24
	Monthly total	25	22	26	21	17	33	17	20	30	33	71
Fox Island-Exposed	Rhodophyta	11	16	7	8	10	18	13	17	12	12	32
	Phaeophyta	9	8	11	9	8	9	6	8	7	5	18
	Chlorophyta	12	11	10	9	10	15	12	15	10	9	26
	Monthly total	32	35	28	26	28	42	31	40	29	26	76
Fox Island-Sheltered	Rhodophyta	6	9	6	5	5	6	15	16	16	12	32
	Phaeophyta	6	11	11	8	3	2	4	4	5	6	16
	Chlorophyta	11	7	6	7	5	6	8	10	4	3	24
	Monthly total	23	27	23	20	13	14	27	30	25	21	72
White Point	Rhodophyta	7	16	13	10	12	18	17	22	12	11	34
	Phaeophyta	10	10	9	9	12	7	8	5	5	6	18
	Chlorophyta	7	11	8	12	10	10	7	13	8	5	23
	Monthly total	24	37	30	31	34	35	32	40	25	22	75
Seaside-Exposed	Rhodophyta	6	12	13	9	7	11	9	10	11	10	27
	Phaeophyta	10	9	9	8	7	6	7	4	3	4	14
	Chlorophyta	3	6	10	7	4	8	6	8	6	8	17
	Monthly total	19	26	32	24	18	25	22	22	20	22	58
Seaside-Sheltered	Rhodophyta	4	9	10	10	13	20	19	9	13	12	29
	Phaeophyta	6	6	9	9	7	8	5	4	3	2	16
	Chlorophyta	5	6	9	11	7	8	7	9	6	6	23
	Monthly total	15	21	28	30	27	36	31	22	22	20	68

Totals at all stations in all months:

Chlorophyta	32
Rhodophyta	45
Phaeophyta	26
Total species found	103

Table 4. Average percent cover of rocky intertidal stations - a) undisturbed transects b) recolonization transects.

Zone	Class*	Station GN	BP	FE	FS	WP	SE	SS	Mean
1	rock	60.5	61.1	18.8	84.2	63.3	42.6	53.6	54.9
	barnacles	0.9	17.3	29.1	0.5	3.0	10.3	11.0	10.3
	mussels	0.1	2.8	0.2	0.0	0.1	0.2	0.1	0.5
	fucoids	4.3	0.3	34.5	0.1	8.5	3.7	8.2	8.5
	carrageenoids	0.0	0.1	0.0	0.0	0.1	0.3	0.7	0.2
	ephemerals	33.2	16.2	16.7	14.2	24.1	42.5	24.9	24.5
	grazers	1.0	2.1	0.8	1.0	0.8	0.8	1.3	1.1
	predators	0.0	0.1	0.1	0.0	0.1	0.0	0.2	0.1
2	rock	14.4	12.7	13.0	32.9	25.9	15.1	22.9	19.6
	barnacles	15.4	62.0	6.8	15.4	17.3	26.8	16.4	22.9
	mussels	2.3	13.7	0.3	0.6	0.5	0.4	0.2	2.5
	fucoids	63.3	1.4	59.7	46.1	48.1	35.3	39.5	41.9
	carrageenoids	0.4	1.7	2.0	0.2	3.9	8.3	13.8	4.3
	ephemerals	2.2	4.5	17.7	2.6	1.5	12.2	4.3	6.4
	grazers	2.0	3.5	0.6	3.1	2.7	2.0	3.0	2.4
	predators	0.0	0.6	0.2	0.1	0.3	0.2	0.3	0.2
3	rock	19.6	17.9	4.0	42.7	18.5	17.0	30.4	21.4
	barnacles	9.2	12.4	1.3	6.9	7.3	7.4	4.4	7.0
	mussels	8.8	16.4	0.1	0.2	0.1	0.2	0.1	3.7
	fucoids	10.1	0.5	16.3	37.7	3.6	10.7	19.0	14.0
	carrageenoids	37.3	35.4	35.3	5.5	58.8	47.0	32.2	35.9
	ephemerals	12.2	13.4	42.9	3.4	7.5	14.6	8.1	14.6
	grazers	2.8	3.3	0.5	3.5	4.1	2.4	5.8	3.2
	predators	0.3	1.0	0.4	0.5	0.5	0.5	0.2	0.5

b) Recolonization Transects

Zone	Class*	Station GN	FE	FS	WP	Mean
1	rock	78.6	52.1	84.7	74.0	72.3
	barnacles	11.6	8.3	7.9	0.1	7.0
	mussels	0.1	0.0	0.1	0.0	0.1
	fucoids	6.7	1.7	0.1	0.0	2.1
	carrageenoids	0.0	0.1	0.1	0.0	0.1
	ephemerals	1.4	37.3	5.6	24.5	17.2
	grazers	1.6	0.6	1.7	0.7	1.2
	predators	0.0	0.1	0.0	0.7	0.2
2	rock	55.8	20.2	38.5	49.8	41.1
	barnacles	31.0	23.6	54.8	34.9	36.0
	mussels	0.1	0.1	0.1	0.1	0.1
	fucoids	9.6	26.1	1.0	5.0	10.4
	carrageenoids	0.0	0.3	0.0	0.1	0.1
	ephemerals	1.1	27.6	0.5	7.8	9.2
	grazers	2.4	1.4	5.0	2.1	2.8
	predators	0.0	0.7	0.2	0.2	0.3
3	rock	26.5	26.1	31.5	39.6	30.9
	barnacles	50.1	13.8	57.1	39.6	40.1
	mussels	0.9	0.0	0.1	0.1	0.3
	fucoids	10.0	6.8	3.7	6.6	6.8
	carrageenoids	3.1	6.7	0.2	3.0	3.2
	ephemerals	5.4	43.0	1.0	5.8	13.8
	grazers	4.0	2.3	5.0	3.8	3.8
	predators	0.1	1.3	1.5	1.5	1.1

* see Materials & Methods for additional explanation of classes.

passage of Hurricane David (Sept. 5-6). The more gradual loss of *Fucus* from the other stations from late summer to early autumn was also attributed to summer storms, but the mechanism of loss was different. Observations made immediately after major storms showed that mussels had been lost as large mats, but that *Fucus* plants were lost as individuals after having been weakened by the storms.

Zone III was characterized by highest coverage of *Chondrus crispus* (36%), fucoids and ephemerals (14% each). Fox Island-Sheltered differred from the other stations by having less *Chondrus* in Zone III (<6%), but more *Fucus* and more bare rock (38 and 43%, respectively). In general, percent coverage of ephemerals was inversely related to that of *Chondrus*. Since the percentages cited reflect canopy coverage, a decrease for *Chondrus* does not necessarily indicate mortality or removal of these plants; rather, they became overgrown with other algae. In the spring, *Monostroma pulchrum* was the dominant epiphyte on *Chondrus*, it disappeared by summer, and *Polysiphonia harveyi* became the most common ephemeral, until late autumn.

Seasonal patterns of species abundance were also reflected in species ranks, summarized by station (Table 5) and by station and month (Appendix III). It is significant that free rock substratum was available at all zones and at all stations throughout the year; clearly, competition for space was not the major limiting factor for recruitement and growth of algae and benthic invertebrates. The more likely principal factor for determining the degree of substratum coverage was the relative abundance of grazers and predators. Evidence that biological factors largely control intertidal distributions will be examined in more detail in sections dealing with recolonization.

Table 5. Relative species abundance (rank values) at each station for 1979 reporting period.

	Undisturbed Transects							Recolonization				Cages				Control Areas			
	GN	BP	FE	FS	WP	SE	SS	GN	FE	FS	WP	GN	FE	FS	WP	GN	FE	FS	WP
Zone 1																			
rock	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B.balanoides	-	2	2	-	-	4	3	2	4	2	-	2	2	-	-	2	-	-	5
Blue-green	2	3	4	2	2	2	2	5	2	3	2	3	4	2	2	4	2	2	2
F. vesiculosus	3	-	1	-	5	-	4	3	-	-	-	4	3	-	-	-	-	-	-
L.littorea	5	-	-	4	-	-	-	4	-	4	5	-	-	-	5	3	-	-	4
U.flacca	-	-	-	3	4	3	-	-	3	5	3	-	5	-	3	-	3	-	3
B.minima	-	-	5	-	-	-	-	-	5	-	-	-	-	-	-	-	4	-	-
A.nodosum	4	-	-	-	3	-	5	-	-	-	-	-	-	-	-	-	-	-	-
M.edulis	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U.lactuca	-	5	-	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
U.penicilliformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
B.atropurpurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
E.linza	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-
U.cinerea	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-
Zone 2																			
F.vesiculosus	1	-	1	1	3	1	1	3	1	4	3	2	-	2	3	-	1	3	4
rock	3	3	2	2	2	3	2	1	3	2	1	1	3	3	2	1	2	1	2
B.balanoides	2	1	3	3	4	2	3	2	2	1	2	3	1	1	1	2	4	2	1
L.littorea	-	4	-	4	-	-	-	4	-	3	5	-	-	-	-	5	-	4	3
M.edulis	5	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
A.nodosum	4	-	-	-	1	-	5	-	-	-	-	-	-	-	-	-	-	-	-
P.harveyi	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	3	-	-
Blue-green	-	-	-	5	-	-	-	5	-	5	-	-	-	-	-	4	-	-	-
U.flacca	-	-	-	-	-	-	-	-	5	-	4	-	-	5	4	-	5	-	-
U.lactuca	-	-	5	-	-	5	-	-	-	-	-	-	5	-	-	-	-	-	-
E.fucicola	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E.intestinalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
E.linza	-	-	-	-	-	-	-	-	-	-	-	4	4	4	5	-	-	-	-
C.crispus	-	5	-	-	5	4	4	-	-	-	-	-	-	-	-	-	-	-	-
R.verrucosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
P.umbilicalis	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-
Zone 3																			
C.crispus	1	1	1	5	1	1	1	5	5	-	-	-	-	-	-	-	-	-	-
rock	2	2	-	1	2	2	2	2	1	2	2	2	-	1	1	2	2	1	1
F.vesiculosus	3	-	3	2	-	3	3	3	4	4	3	3	-	-	-	3	-	3	4
B.balanoides	4	4	-	4	3	4	-	1	3	1	1	1	1	2	3	1	4	2	2
L.littorea	-	-	-	-	4	-	5	4	-	3	5	-	-	-	-	5	-	4	5
P.harveyi	-	5	2	-	-	5	-	-	2	-	-	5	5	-	-	-	1	-	-
M.pulchrum	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
M.edulis	-	3	-	-	-	-	-	-	-	-	-	-	2	3	2	-	-	-	-
A.nodosum	-	-	-	3	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U.lactuca	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-	-	-	-	-
U.rigida	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-
R.verrucosa	-	-	-	-	-	-	-	-	-	-	4	-	-	-	4	4	-	-	3
P.umbilicalis	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-
B.atropurpurea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
C.linum	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C.refracta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
C.fragile	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U.cinerea	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-
sand	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
E.linza	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-

Species diversity, number of species, and evenness of each zone at each station for each month are listed in Table 6. Although values are variable, general trends are evident from these data. Peaks in both diversity and species number occurred in spring (Apr.-May) and in autumn (Oct.-Nov.), with minima in summer (July-Aug.). In general, diversity and species number were lowest in Zone I, and higher in Zones II and III. Fox Island-Exposed was again the exception, owing to the fucoid coverage in Zone I. Seasonal trends were not apparent from the evenness data, nor were there consistent patterns between stations or zones.

Similarity indices are depicted in the form of clustering dendrograms (Fig. 2). When data for all months are analyzed by station and zone (Fig. 2a), three groups are apparent at the 35 percent level, representing the three designated shore zones. The inclusion of Fox Island-Exposed Zone I and Fox Island-Sheltered Zone III in a cluster therwise composed of Zone II stations was attributed to the high proportion of *Fucus* at the former and the absence of *Chondrus* at the latter. Bay Point Zone II is less closely related to the other Zone II stations because of high mussel coverage, and the paucity of *Fucus* plants. Within each zone, patterns of interstation affinities are not apparent.

When data for all stations and zones are pooled and analyzed by month (Fig. 2b), four groups are apparent at the 70 percent level. These appear to correspond to the seasons, and represent autumn, winter, summer, and spring floras.

Table 6 . Measures of species diversity at rocky intertidal stations - undisturbed transects.

Station	Zone		Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Giants Neck	1	H'*	1.37	1.37	1.33	1.08	0.50	1.49	1.29	1.41	1.37	1.14
		J	0.457	0.531	0.475	0.384	0.214	0.576	0.499	0.543	0.457	0.441
		S	8	6	7	7	5	6	6	6	8	6
	2	H'	2.08	2.21	2.26	2.09	2.04	1.87	2.21	2.21	2.16	1.95
		J	0.656	0.596	0.631	0.603	0.679	0.564	0.666	0.696	0.681	0.587
		S	9	13	12	11	8	10	10	9	9	10
	3	H'	2.34	2.49	2.72	2.49	2.69	2.71	2.67	2.35	2.51	2.72
		J	0.833	0.694	0.734	0.674	0.897	0.755	0.700	0.740	0.659	0.701
		S	7	12	13	13	8	12	14	9	14	9
Bay Point	1	H'	2.02	2.44	1.92	1.80	1.53	0.91	1.51	1.53	1.46	1.12
		J	0.607	0.659	0.518	0.541	0.592	0.455	0.436	0.482	0.518	0.434
		S	10	13	13	10	6	4	11	9	7	6
	2	H'	1.82	1.87	1.79	1.60	1.70	1.71	1.86	2.05	2.00	1.66
		J	0.492	0.478	0.459	0.421	0.435	0.495	0.503	0.513	0.499	0.462
		S	13	15	15	14	15	11	13	16	16	12
	3	H'	2.46	2.61	2.83	2.38	2.74	2.68	2.36	2.71	2.52	2.04
		J	0.664	0.652	0.644	0.582	0.645	0.705	0.638	0.733	0.662	0.591
		S	13	16	21	17	19	14	13	13	14	11
Fox Island Exposed	1	H'	2.15	2.07	2.12	2.14	2.04	2.24	2.30	2.27	2.32	2.25
		J	0.717	0.576	0.668	0.617	0.590	0.675	0.665	0.657	0.671	0.651
		S	8	12	9	11	11	10	11	11	11	11
	2	H'	1.77	2.13	2.06	1.94	1.59	1.73	2.47	2.20	2.55	2.11
		J	.480	0.510	0.528	0.540	0.406	0.442	0.592	0.595	0.613	0.569
		S	13	18	15	12	15	15	18	13	18	13
	3	H'	1.93	2.39	2.51	2.65	3.00	0.03	2.30	2.34	2.40	2.57
		J	0.483	0.627	0.601	0.571	0.720	0.028	0.588	0.615	0.588	0.605
		S	16	14	18	25	18	2	15	14	17	19
Fox Island Sheltered	1	H'	1.18	1.05	0.83	1.10	1.05	0.03	0.07	0.19	0.16	0.12
		J	0.457	0.453	0.320	0.473	0.450	0.028	0.032	0.117	0.100	0.121
		S	6	5	6	5	5	2	4	3	3	2
	2	H'	1.93	1.98	1.59	1.84	1.49	1.49	1.60	1.81	1.67	1.49
		J	0.610	0.571	0.478	0.513	0.430	0.498	0.532	0.646	0.594	0.498
		S	9	11	10	12	11	8	8	7	7	8
	3	H'	1.48	2.67	2.45	2.97	2.84	2.53	2.05	1.95	1.97	1.80
		J	0.467	0.683	0.683	0.688	0.767	0.707	0.618	0.544	0.591	0.568
		S	9	15	12	20	13	12	10	12	10	9

Table 6. (cont.)

			Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
White Point	1	H'	2.09	2.32	2.21	0.95	1.70	1.63	0.74	1.16	1.28	1.19
		J	0.456	0.669	0.666	0.317	0.535	0.489	0.233	0.415	0.403	0.360
		S	8	11	10	8	9	10	9	7	9	10
	2	H'	2.19	2.47	2.38	2.52	2.34	2.46	2.25	2.33	2.35	2.35
		J	).592	0.571	0.570	0.680	0.653	0.602	0.590	0.612	0.657	0.587
		S	13	20	18	13	12	17	14	14	12	16
	3	H'	1.37	2.66	2.15	2.53	1.86	2.13	2.01	1.84	1.86	1.93
		J	0.456	0.698	0.505	0.606	0.465	0.545	0.543	0.498	0.489	0.494
		S	8	14	19	18	16	15	13	13	14	15
Seaside-Exposed	1	H'	1.69	2.25	2.16	2.00	1.75	0.92	1.34	1.42	2.01	1.61
		J	0.563	0.649	0.651	0.578	0.623	0.329	0.477	0.551	0.635	0.507
		S	8	11	10	11	7	7	7	6	9	9
	2	H'	2.36	2.92	2.79	2.35	2.35	2.47	2.48	2.53	2.53	2.42
		J	0.637	0.701	0.635	0.588	0.574	0.650	0.634	0.633	0.664	0.606
		S	13	18	21	16	17	14	15	16	14	16
	3	H'	1.89	2.90	3.13	2.33	2.53	2.38	2.28	2.57	2.07	2.04
		J	0.527	0.696	0.711	0.538	0.607	0.663	0.583	0.657	0.577	0.551
		S	12	18	21	20	18	12	15	15	12	13
Seaside-Sheltered	1	H'	1.67	2.24	1.93	2.13	1.73	1.40	0.81	1.95	1.93	1.11
		J	0.526	0.648	0.538	0.594	0.577	0.467	0.314	0.563	0.609	0.396
		S	9	11	12	12	8	8	6	11	9	7
	2	H'	2.43	2.80	2.65	2.81	2.33	2.59	2.72	2.63	2.44	2.53
		J	0.657	0.716	0.679	0.687	0.674	0.679	0.713	0.691	0.705	0.684
		S	13	15	15	17	11	14	14	14	11	13
	3	H'	2.08	2.67	2.75	2.50	2.77	2.10	2.16	2.51	2.21	2.34
		J	0.626	0.684	0.721	0.598	0.653	0.586	0.603	0.613	0.640	0.632
		S	10	15	14	18	19	12	12	17	11	13

* Explanation of diversity indices (also apply to Tables 7-9).

H' - Shannon information index
J - Evenness component
S - Number of species

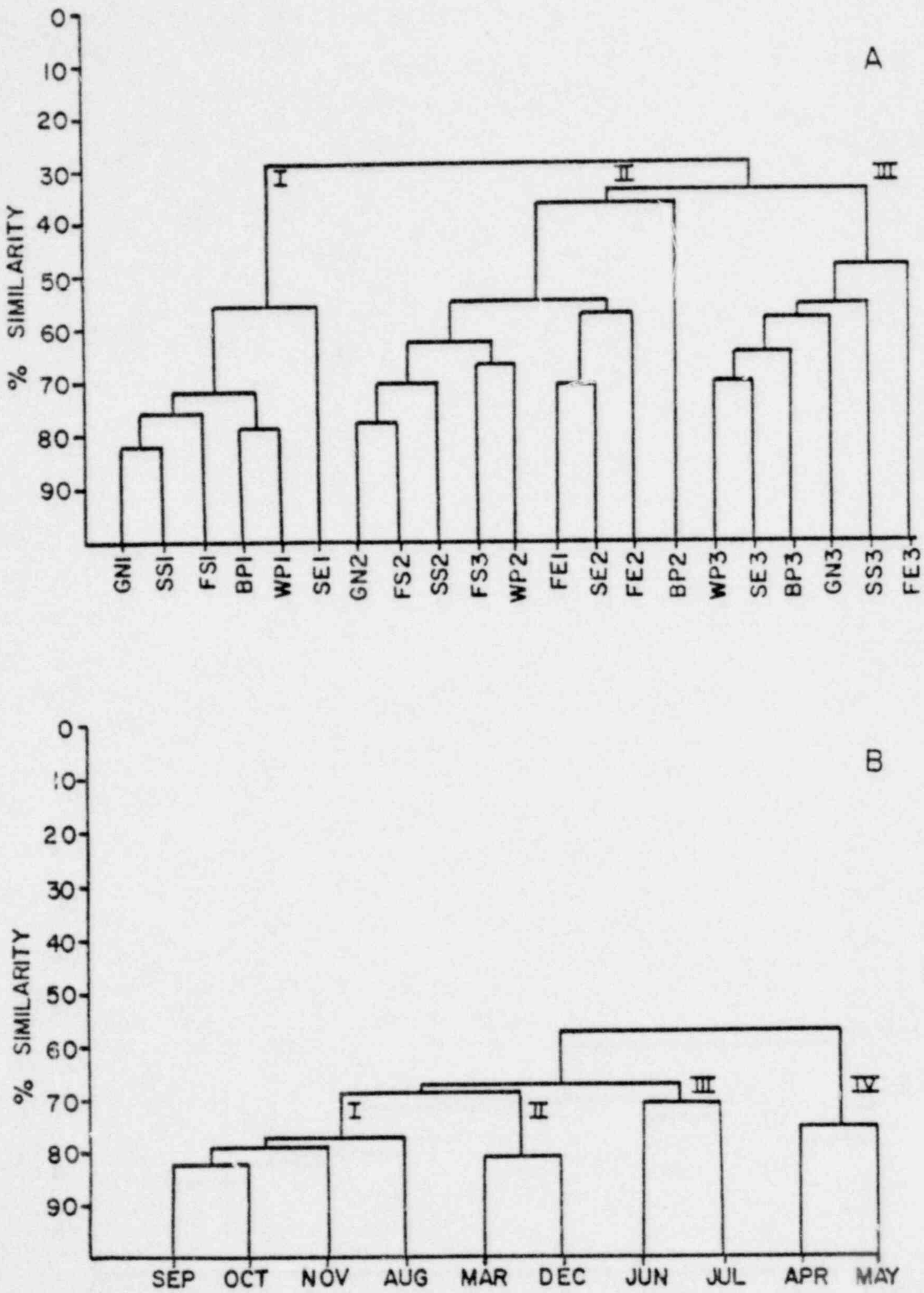

Figure 2. Clustering dendrograms of percent similarity, a) by station and zone, b) by month.

Recolonization Transects

Average percent cover and top ranked species at each recolonization station are summarized in Tables 4b and 5; data by month are presented in Appendices IV and V.

The length of time between denuding the transects and their recovery to pre-experimental conditions appears to be inversely related to the degree of exposure. At Fox Island-Sheltered, the least exposed station, the transect strips were still very distinct 18 months after burning; barnacle coverage at this station was extensive, especially in Zone III (57%), but algal colonization was sparse. At Fox Island-Exposed, however, the strips were almost indistinguishable from undisturbed areas after nine months. The other two stations were intermediate in their degree of recolonization, with White Point being more exposed and more completely recovered than Giants Neck. In the following discussions, "sheltered stations" refer to Fox Island-Sheltered and Giants Neck; Fox Island-Exposed and White Point are "exposed stations".

Zone I in the recolonization transects was characterized by barren rock and barnacles at the sheltered stations, and by rock and ephemerals at the exposed stations. The ephemerals were predominantly *Ulothrix* and blue-green algae, and their percent coverage generally followed a seasonal pattern of being high in winter and summer, and lower in spring and autumn.

The seasonality of these plants corresponded to the vertical migration and subsequent distribution of the littorinid grazers; they moved from the high intertidal areas to nearer low water level when temperatures became extreme.

In Zone II, percent coverage of recolonizing organisms was also directly related to the degree of exposure, and inversely related to concentrations of grazers and predators. At Fox Island-Exposed, individuals of *Urosalpinx* (predator) were more abundant than at other stations, and barnacles (prey) were least abundant. At the same station, littorinids (grazers) were less common, and coverage values for *Fucus* and ephemerals were virtually the same in December as they were prior to clearing. These observations indicate that increased wave action at the exposed stations may influence species composition two ways: directly, by minimizing desiccation, and indirectly, by controlling distribution of grazers and predators, which in turn regulate the abundance of algae and sessile invertebrates.

In Zone III of the recolonization transects, a dense barnacle set occurred between April and May, and by June accounted for ca. 65% coverage at all stations. This coverage decreased throughout the remainder of the year, both at sheltered stations, where no major algal canopy occurred, and at exposed stations, where recovery of *Fucus*, *Chondrus*, and other algae was more rapid. These data indicate that predation is the major factor directly controlling barnacle abundances in the low intertidal areas.

Diversity, evenness, and richness of the recolonization transects (Table 7) were all generally low in Zone I; values were higher in Zones II and III, and Fox Island-Exposed was usually the station with the most diverse community. There was a general trend toward increased diversity measurements with time since denuding, but values were variable, and patterns related to seasonality were no_ evident.

Exclusion Cages and Controls

Data from the exclusion cage studies support the conclusions made in the previous section and those of other researchers: that rate of recolonization is greater in more exposed areas (Keser 1978), and that grazers and predators exert a profound effect on the structure of the recolonization community (Jones 1948, Southward 1956; Menge 1976; Keser et al. 1977). Diversity, evenness, and number of species were usually higher under the exclusion cages than in adjacent control areas, and values for these indices increased with increasing degree of exposure (Tables 8 and 9).

In Zone I, beneath the experimental cages where snails were excluded, percent cover by barnacles and algae were consistently higher than in corresponding control areas (Table 10, Appendices VI and VII); this is also represented in species ranks (Table 5, Appendices VIII and IX). The control areas remained mostly rock throughout the study period, and only at the most exposed station (Fox Island-Exposed) was there appreciable cover by ephemerals, primarily *Ulothrix* and blue-green algae.

Zone II control areas were characterized primarily by rock and barnacles, except at Fox Island-Exposed, where a summer peak of *Enteromorpha linza* (85%)

Table 7 . Measures of species diversity at rocky intertidal stations - recolonization transects.

Station	Zone		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Giants Neck	1	H'	1.40	0.49	0.35	0.74	0.55	0.60	0.74	1.07	1.21
		J	0.468	0.485	0.221	0.469	0.349	0.377	0.469	0.459	0.522
		S	8	2	3	3	3	3	3	5	9
	2	H'	0.79	0.80	0.76	1.14	1.04	1.04	1.22	1.32	1.57
		J	0.283	0.798	0.482	0.719	0.655	0.655	0.609	0.566	0.558
		S	7	2	3	3	3	3	4	5	7
	3	H'	2.80	0.93	1.19	1.05	1.08	1.58	1.65	1.90	2.53
		J	0.808	0.934	0.752	0.527	0.340	0.497	0.823	0.600	0.763
		S	11	2	3	4	9	9	4	9	10
Fox Island Exposed	1	H'	2.01	1.26	1.09	1.35	1.19	1.55	1.28	0.74	2.05
		J	0.719	0.798	0.688	0.583	0.596	0.466	0.427	0.287	0.728
		S	7	3	3	5	4	10	8	6	7
	2	H'	2.33	1.90	1.43	2.93	2.81	2.61	2.39	2.35	2.29
		J	0.583	0.819	0.476	0.733	0.738	0.668	0.598	0.574	0.550
		S	16	5	8	16	14	15	16	17	18
	3	H'	2.69	1.51	2.40	3.00	1.66	1.23	1.93	2.51	1.217
		J	0.646	0.582	0.614	0.811	0.399	0.388	0.493	0.660	0.320
		S	18	6	15	13	18	9	15	14	14
Fox Island Sheltered	1	H'	--	0.76	1.12	0.95	1.08	0.43	0.63	0.57	0.39
		J	--	0.381	0.559	0.473	0.467	0.272	0.271	0.245	0.247
		S	--	4	[illegible]	4	5	3	5	5	3
	2	H'	--	0.80	1.37	1.20	1.48	1.26	1.53	1.37	1.28
		J	--	0.401	0.530	0.599	0.571	0.542	0.660	0.686	0.640
		S	--	4	6	4	6	5	5	4	4
	3	H'	--	0.47	1.12	0.76	1.51	1.88	2.14	1.84	1.68
		J	--	0.297	0.400	0.325	0.454	0.565	0.645	0.614	0.560
		S	--	3	7	5	10	10	10	8	8
White Point	1	H'	1.22	0.29	0.18	1.00	0.78	0.00	1.10	0.96	0.96
		J	0.609	0.185	0.078	0.996	0.784	--	0.393	0.607	0.413
		S	4	3	5	2	2	1	7	3	5
	2	H'	2.43	1.15	1.30	1.15	1.17	1.04	1.46	1.58	1.74
		J	0.766	0.726	0.464	0.444	0.368	0.404	0.486	0.612	0.525
		S	9	3	7	6	9	6	8	6	10
	3	H'	1.76	0.97	1.19	0.73	1.10	1.902	2.09	2.13	1.40
		J	0.625	0.971	0.460	0.314	0.393	0.678	0.629	0.710	0.440
		S	7	2	6	5	7	7	10	8	9

Table 8 . Measures of species diversity at rocky intertidal stations - exclusion cages.

Station	Zone		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Giants Neck	1	H'	0.95	1.25	1.37	1.33	2.03	1.20	1.26	1.36
		J	0.601	0.786	0.588	0.787	0.517	0.517	0.447	0.485
		S	3	3	5	5	6	5	7	7
	2	H'	0.90	1.52	1.91	1.75	0.86	1.13	1.58	1.12
		J	0.901	0.960	0.822	0.623	0.541	0.486	0.609	0.561
		S	2	3	5	7	3	5	6	4
	3	H'	0.97	1.63	1.75	2.36	2.28	1.27	2.12	1.37
		J	0.609	0.632	0.552	0.604	0.719	0.454	0.567	0.488
		S	3	6	9	15	9	7	12	7
Fox Island Exposed	1	H'	1.55	1.42	1.40	1.49	2.70	2.49	1.98	2.31
		J	0.987	0.611	0.603	0.643	0.813	0.718	0.767	0.769
		S	3	5	5	5	10	11	6	8
	2	H'	1.80	0.60	1.62	1.76	2.51	2.39	2.34	1.83
		J	0.776	0.231	0.628	0.587	0.725	0.646	0.737	0.610
		S	5	6	6	8	11	13	9	8
	3	H'	1.05	0.83	2.46	1.81	1.82	1.81	1.85	2.03
		J	0.662	0.294	0.877	0.546	0.783	0.903	0.714	0.642
		S	3	7	7	10	5	4	6	9
Fox Island Sheltered	1	H'	0.00	0.00	0.96	0.97	0.00	0.92	0.97	0.99
		J	--	--	0.960	0.971	--	0.918	0.971	0.987
		S	1	1	2	2	1	2	2	2
	2	H'	0.89	1.08	1.52	1.73	1.33	1.57	1.56	1.30
		J	0.345	0.538	0.587	0.744	0.442	0.676	0.983	0.651
		S	6	4	6	5	8	5	3	4
	3	H'	0.36	2.28	2.55	2.63	1.75	0.81	0.21	0.34
		J	0.218	0.658	0.768	0.761	0.624	0.348	0.132	0.172
		S	3	11	10	11	7	5	3	4
White Point	1	H'	0.06	0.00	0.82	0.96	0.00	0.52	0.41	1.01
		J	0.058	--	0.514	0.960	--	0.223	0.257	0.434
		S	2	1	3	2	1	5	3	5
	2	H'	1.25	0.84	0.64	1.34	1.53	1.44	1.65	1.51
		J	0.788	0.361	0.405	0.577	0.765	0.556	0.637	0.583
		S	3	5	3	5	4	6	6	6
	3	H'	0.86	1.43	3.32	1.58	1.08	1.73	1.84	1.45
		J	0.860	0.398	0.830	0.499	0.465	0.670	0.555	0.457
		S	2	12	16	9	5	6	10	9

Table 9 . Measures of species diversity at rocky intertidal stations - control areas.

Station	Zone		May	June	July	Aug.	Sept.	Oct	Nov.	Dec.
Giants Neck	1	H'	0.44	0.36	0.38	0.00	0.16	0.36	1.00	0.63
		J	0.274	0.227	0.378	--	0.160	0.226	0.499	0.397
		S	3	3	2	1	2	3	4	3
	2	H'	0.69	0.41	0.92	0.81	1.02	0.93	1.28	1.28
		J	0.687	0.414	0.918	0.811	0.645	0.589	0.641	0.550
		S	2	2	2	2	3	3	4	5
	3	H'	0.97	1.00	0.84	0.87	0.95	1.12	1.93	2.29
		J	0.971	0.998	0.531	0.291	0.369	0.400	0.607	0.721
		S	2	2	3	8	6	7	9	9
Fox Island-Exposed	1	H'	1.16	1.43	0.92	1.05	1.62	1.26	1.15	1.96
		J	0.731	0.714	0.582	0.663	0.627	0.543	0.576	0.760
		S	3	4	3	3	6	5	4	6
	2	H'	1.50	1.67	2.42	0.77	2.44	1.70	1.46	0.83
		J	0.945	0.717	0.861	0.332	0.813	0.604	0.440	0.415
		S	3	5	7	5	8	7	10	4
	3	H'	1.95	1.72	2.29	1.92	1.17	1.50	2.37	1.70
		J	0.838	0.573	0.721	0.742	0.416	0.501	0.641	0.512
		S	5	8	9	6	7	8	13	10
Fox Island - Sheltered	1	H'	0.00	0.00	0.72	0.21	0.00	0.00	0.00	0.00
		J	--	--	0.722	0.211	--	--	--	--
		S	1	1	2	2	1	1	1	1
	2	H'	1.07	1.08	1.32	1.00	1.03	0.94	1.11	1.22
		J	0.674	0.538	0.660	0.631	0.647	0.593	0.698	0.609
		S	3	4	4	3	3	3	3	4
	3	H'	0.55	0.92	1.73	1.17	1.31	1.02	0.87	1.26
		J	0.344	0.459	0.616	0.505	0.656	0.441	0.376	0.543
		S	3	4	7	5	4	5	5	5
White Point	1	H'	0.03	0.00	0.97	0.57	0.00	0.19	0.06	0.06
		J	0.032	--	0.971	0.567	--	0.194	0.058	0.058
		S	2	1	2	2	1	2	2	2
	2	H'	1.00	1.08	0.74	1.07	1.03	0.96	1.21	1.41
		J	0.997	0.682	0.467	0.534	0.647	0.414	0.605	0.707
		S	2	3	3	4	3	5	4	4
	3	H'	0.97	0.81	0.80	1.01	0.65	1.69	1.75	1.81
		J	0.971	0.313	0.398	0.504	0.337	0.602	0.677	0.664
		S	2	7	4	4	4	7	6	7

Table 10. Average percent cover of rocky intertidal stations - a) exclusion cages b) control areas.

a) Exclusion Cages

Zone	Class*	Station GN	FE	FS	WP	Mean
1	rock	57.7	44.0	70.2	77.3	62.3
	barnacles	24.0	26.0	0	0.1	12.5
	mussels	0	2.7	0	0	0.7
	fucus	6.3	6.3	0	0	3.1
	carrageenoids	0	0	0	0	0
	ephemerals	11.5	19.4	29.8	22.4	20.8
	grazers	0.5	1.3	0	0.2	0.5
	predators	0	0.3	0	0	0.1
2	rock	33.9	12.7	15.1	29.7	22.9
	barnacles	23.4	37.5	47.3	53.5	40.4
	mussels	0	16.0	0.2	0.4	4.1
	fucus	30.2	4.3	32.0	10.4	19.3
	carrageenoids	0	0	0	0	0
	ephemerals	12.0	27.5	4.9	5.6	12.5
	grazers	0.5	2.0	0.5	0.4	0.8
	predators	0	0	0	0	0
3	rock	27.3	7.8	46.6	26.6	27.1
	barnacles	31.4	25.6	22.3	22.5	25.5
	mussels	1.1	18.5	10.2	23.4	13.3
	fucus	24.2	0.2	2.3	0.3	6.7
	carrageenoids	0.5	0.1	0	0.2	0.2
	ephemerals	14.4	47.6	16.7	26.5	26.3
	grazers	1.1	0.2	0.2	0.4	0.5
	predators	0	0	1.7	0.1	0.4

b) Control Areas

Zone	Class*	Station GN	FE	FS	WP	Mean
1	rock	91.6	50.9	97.1	92.7	83.1
	barnacles	7.5	1.6	0	0.1	2.3
	mussels	0	0	0	0	0
	fucus	0	0	0	0	0
	carrageenoids	0	1.3	0	0	0.3
	ephemerals	0.3	42.5	2.9	7.0	13.2
	grazers	0.6	3.7	0	0.2	1.1
	predators	0	0	0	0	0
2	rock	70.8	18.7	54.4	37.5	45.4
	barnacles	26.6	16.0	44.0	60.1	36.7
	mussels	0	0.1	0	0	0.03
	fucus	0.1	29.2	1.0	0.9	7.8
	carrageenoids	0	0	0	0	0
	ephemerals	1.7	34.5	0	0.1	9.1
	grazers	0.8	1.4	0.6	1.3	1.0
	predators	0	0.1	0	0.1	0.05
3	rock	19.5	23.4	47.4	42.6	32.2
	barnacles	60.9	10.2	48.0	37.0	39.0
	mussels	0	0.1	0.2	4.2	1.1
	fucus	13.3	6.2	2.8	3.1	4
	carrageenoids	0.3	0.7	0	0.3	[illegible].3
	ephemerals	4.4	57.8	0.5	10.8	18.4
	grazers	1.5	1.0	1.0	2.0	1.4
	predators	0.1	0.6	0.1	0	0.2

* see Materials & Methods for additional explanation of classes.

was followed by a steady increase of *Fucus* that averaged 85% cover by December. This pattern was also observed by other researchers working on exposed coasts (Southward 1956; Menge 1976, Grant 1977; Southward and Southward 1978). Beneath the exclusion cages, barnacle coverage was generally greater than in the controls, although it was at time obscured by attached ephemerals, *Fucus*, and mussels. In Zone II, mussels were common only under exclusion cages at Fox Island-Exposed; at this site, in early June, mussels settled into the caged areas that were dominated by barnacles (85%). The mussels grew rapidly, and by late summer they had outcompeted the barnacles in terms of space occupied; similar observations have been made by others (Menge 1975; Grant 1977).

Competition for space between barnacles and mussels was seen more clearly in Zone III (Fig. 3 and 4). Under the cages in this zone, mussels again outcompeted barnacles, as was seen in Zone II. Coverage by mussels increased up to 100% in the cages by late summer. In the control areas, however, *Urosalpinx* effectively prevented mussels from becoming dominant. This pattern was evident at all stations except Giants Neck, where mussels were never dominant, even under the cages.

To determine if adult mussels could survive without protection from predation, several cages were permanently removed at various times during the autumn, after maximum mussel coverage had occurred. In each instance, total mortality occurred within a week of cage removal, but the mechanism of loss differed between exposed and sheltered stations. At the exposed

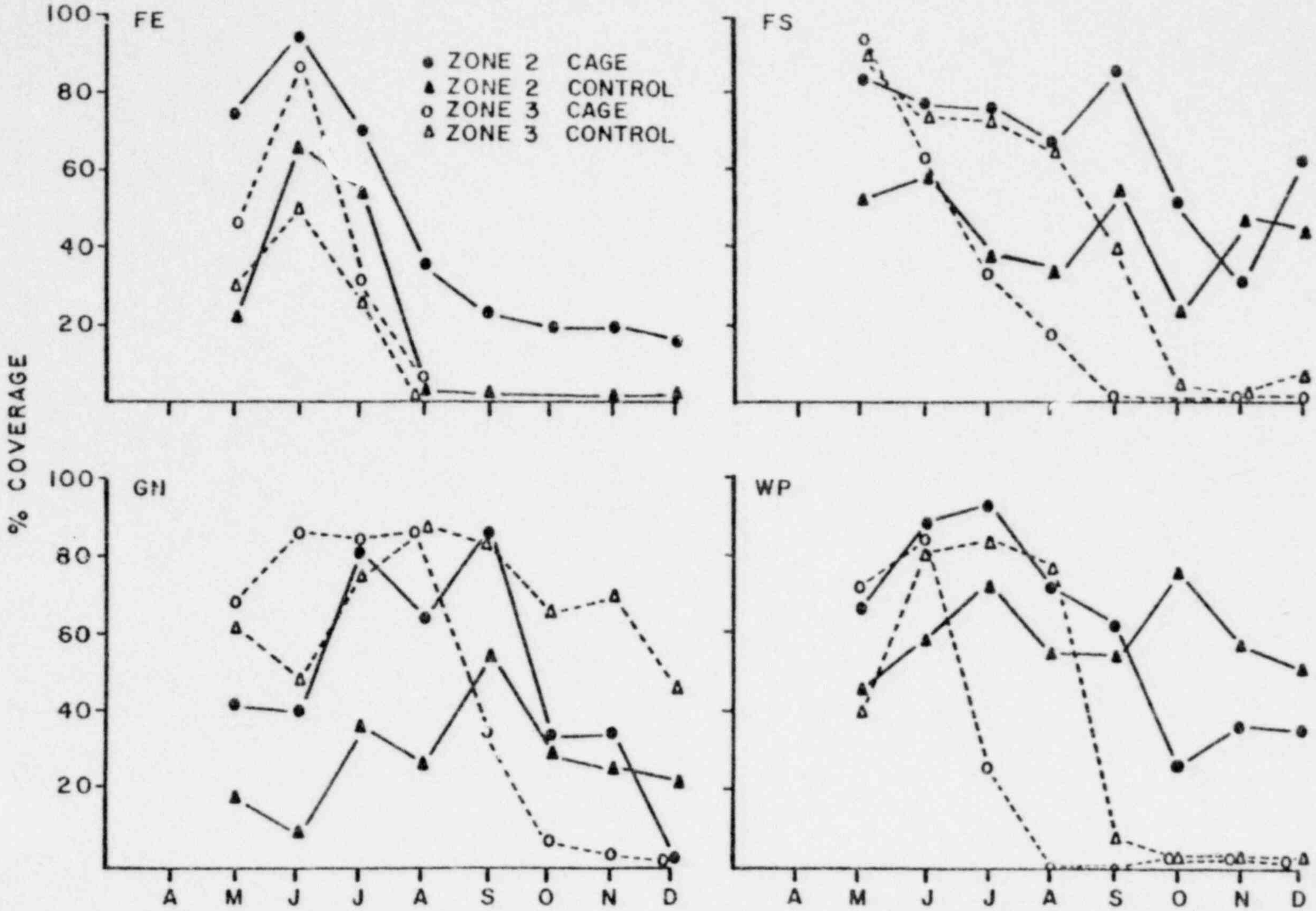

Figure 3. Percent substratum coverage by barnacles, by station and zone. FE-Fox Island (Exposed), FS-Fox Island (Sheltered), GN-Giants Neck, WP-White Point.

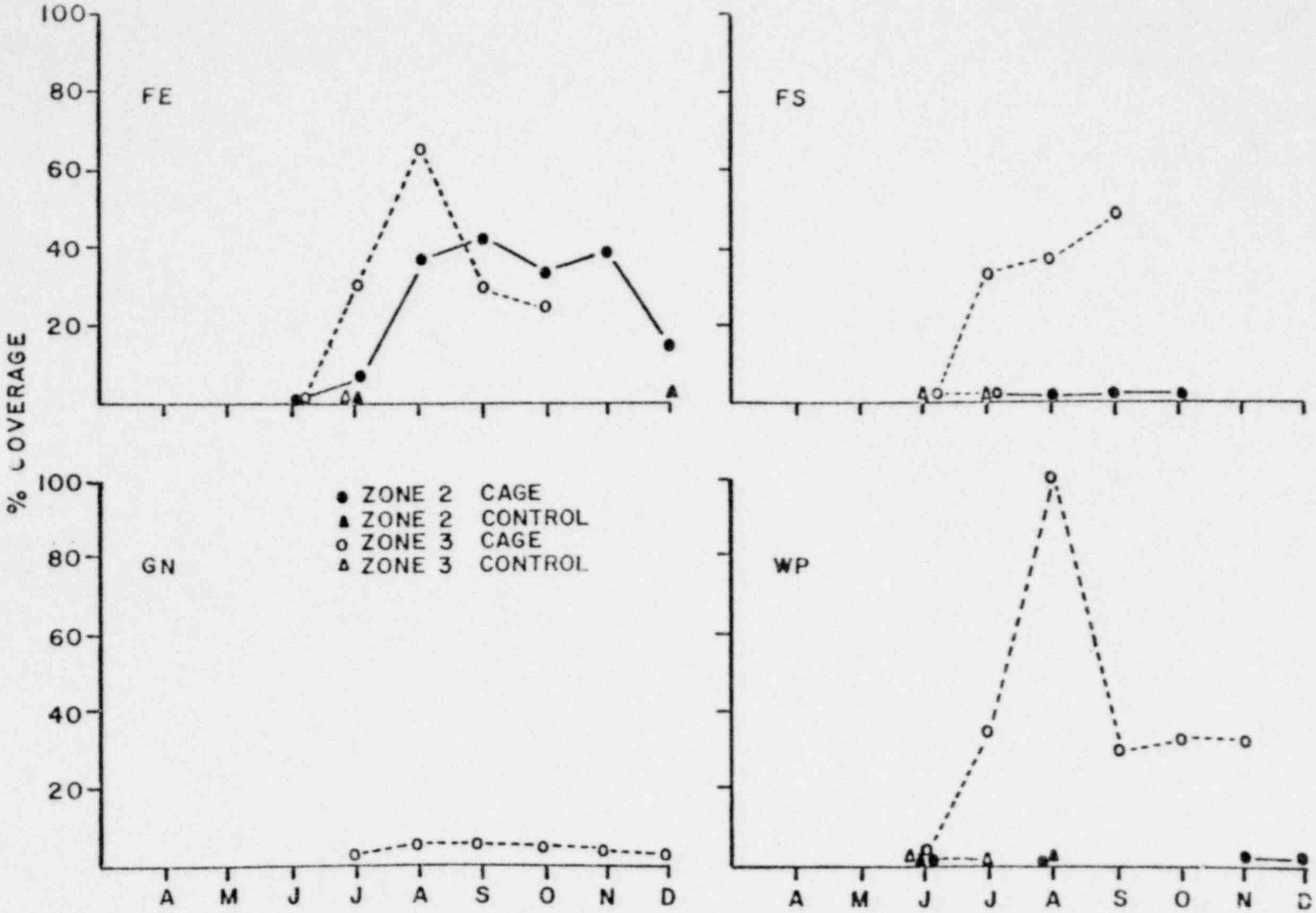

Figure 4. Percent substratum coverage by mussels, by station and zone. FE-Fox Island (Exposed), FS-Fox Island (Sheltered), GN-Giants Neck, WP-White Point.

stations, the mussels were lost as they were not sufficiently well attached to the rock, and were quickly removed as a mat. At Fox Island-Sheltered, predation was the primary cause of mortality. Six days after one cage had been sufficiently loosened to permit predator entry, 200+ *Urosalpinx* specimens were found in the 20 x 20 cm area, and each mussel shell had been drilled. One shell was noted to have five holes drilled in it.

These experiments indicate that mussels are physiologically capable of setting and growing at all the recolonization sites. Absence of mussels, even at Fox Island-Exposed, was directly related to predation, rather than to a thermal effect, as had been previously considered (Battelle 1977).

Fucus Growth Studies

The first appearance of *Fucus* in the exclusion cages and in the control areas occurred between three and nine months after denudation. Appreciable growth of *Fucus* germlings was apparent at most sites by August, five months after clearing. *Fucus* growth was variable between stations and between zones (Fig. 5 and 6).

Growth in Zone II, as measured by average length increase and by percent coverage, was highest in the control areas at Fox Island-Exposed, where plants grew from 10 mm in July to 221 mm in December, and reached a maximum of 85% cover. *Fucus* growth was less under the exclusion cages at this station, owing to dense mussel settlement; *Fucus* recruitment into

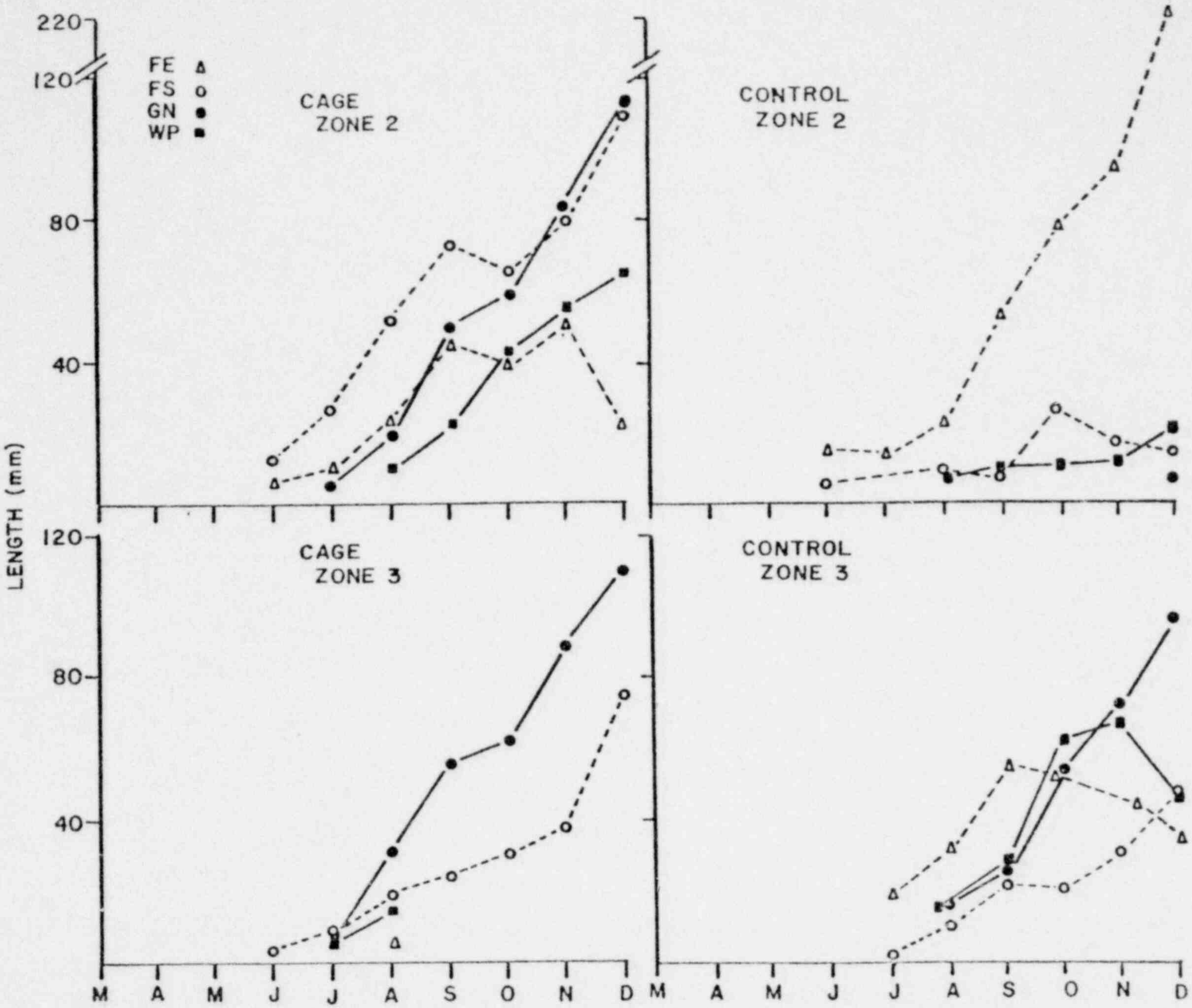

Figure 5. *Fucus* growth, average blade length. FE-Fox Island (Exposed), FS-Fox Island (Sheltered), GN-Giants Neck, WP-White Point.

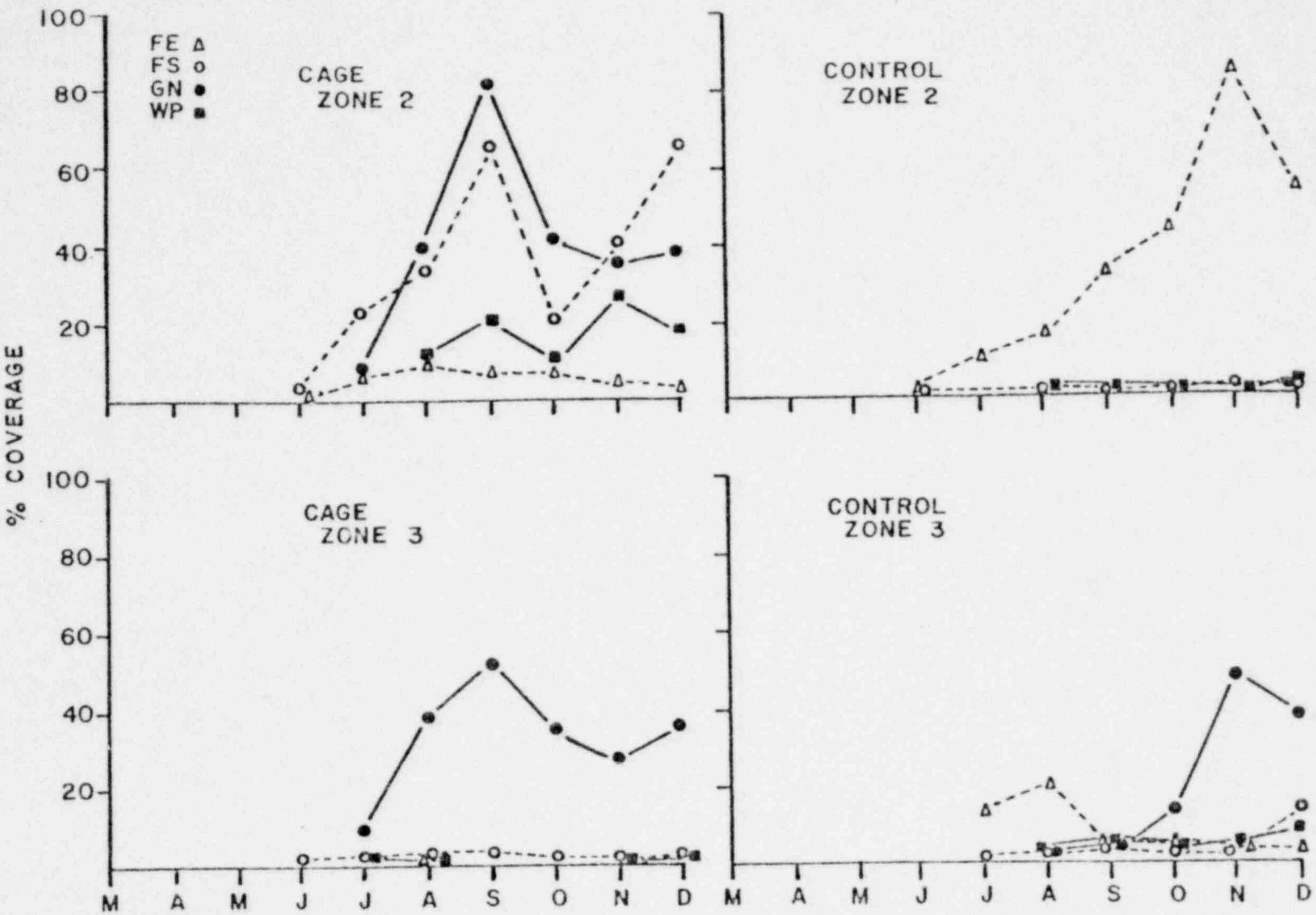

Figure 6. *Fucus* growth, percent substratum coverage. FE-Fox Island (Exposed), FS-Fox Island (Sheltered), GN-Giants Neck, WP-White Point.

mussel beds and subsequent growth is low (Menge 1975; Grant 1977). At the other stations, with less mussel coverage, *Fucus* in Zone II grew better beneath the cages than in the control areas by both measures of growth, i.e. length increase and percent coverage of substratum.

In Zone III, *Fucus* growth was highest at Giants Neck, and slightly higher in the cages at this site than in the adjacent control areas. At the other stations, percent coverage by *Fucus* was low in both cages and controls, again concommitant with an appreciably dense mussel cover.

The variability of growth measures supports conclusions of Knight and Parke (1950), of Mathieson et al. (1976), and of Keser (1978) that blade length is not an adequate measure of *Fucus* growth; difficulty in marking individual plants, their relatively loose attachment to the substratum, and the irregular branching habit of *Fucus* make measurement of growth rate of this genus very difficult. Estimation of percent coverage as a measure of growth also had disadvantages, and neither method accurately assessed fucoid growth rates.

Ascophyllum Growth Studies

Results of the *Ascophyllum* studies are summarized in Fig. 7 and 8. Highest growth occurred at the lower Fox Island site where tip length in December averaged 113.3 mm; lowest total growth was at Giants Neck, 68.9 mm. The highest growth rate at all stations, as indicated by monthly incremental growth (Fig. 7), occurred between July and August, ranging from 25.8 mm/mo. at the lower Fox Island site to 16.7 mm/mo. at

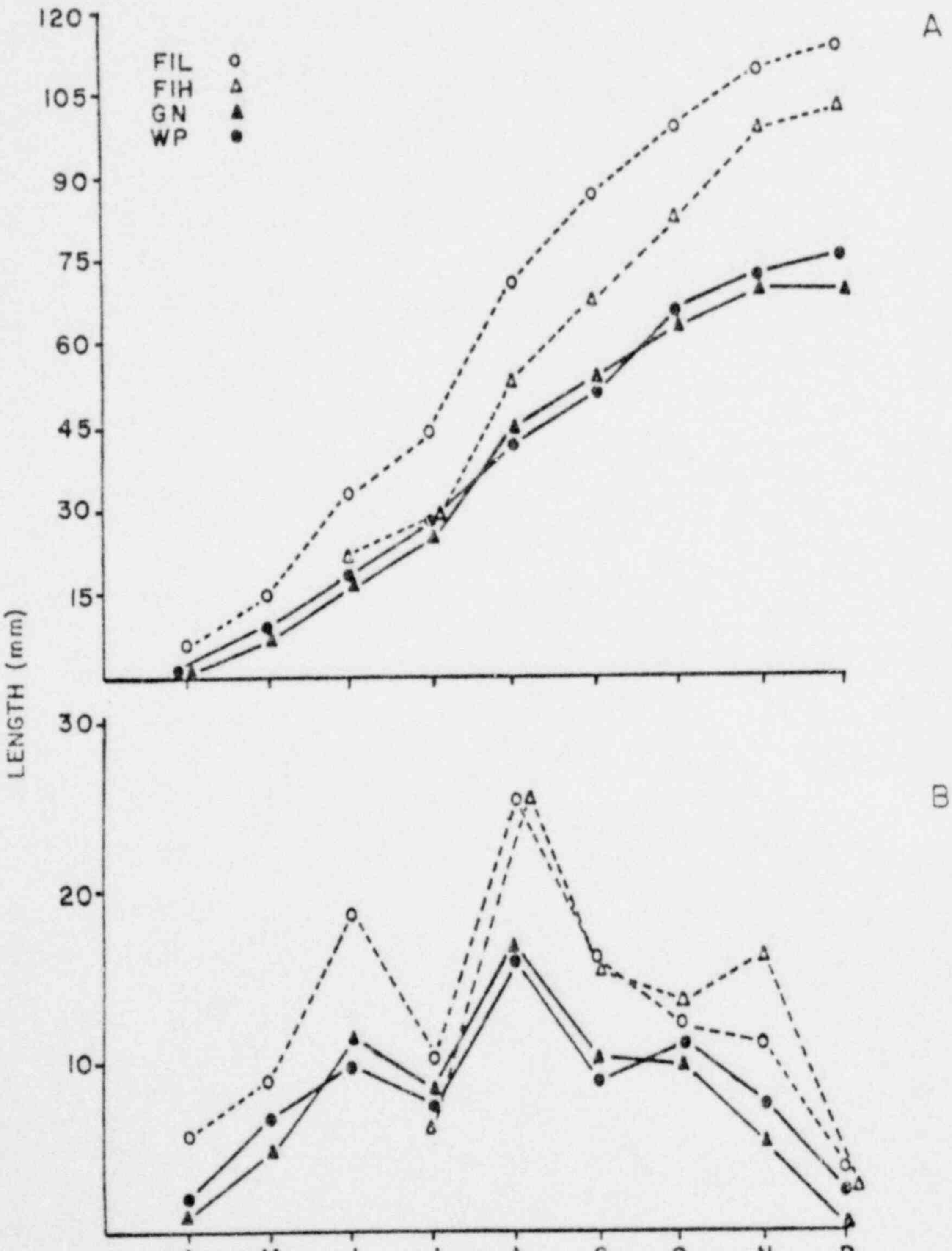

Figure 7. *Ascophyllum* growth, a) total length, b) monthly increments. FIL-Fox Island (Lower), FIH-Fox Island (Higher), GN-Giants Neck, WP-White Point.

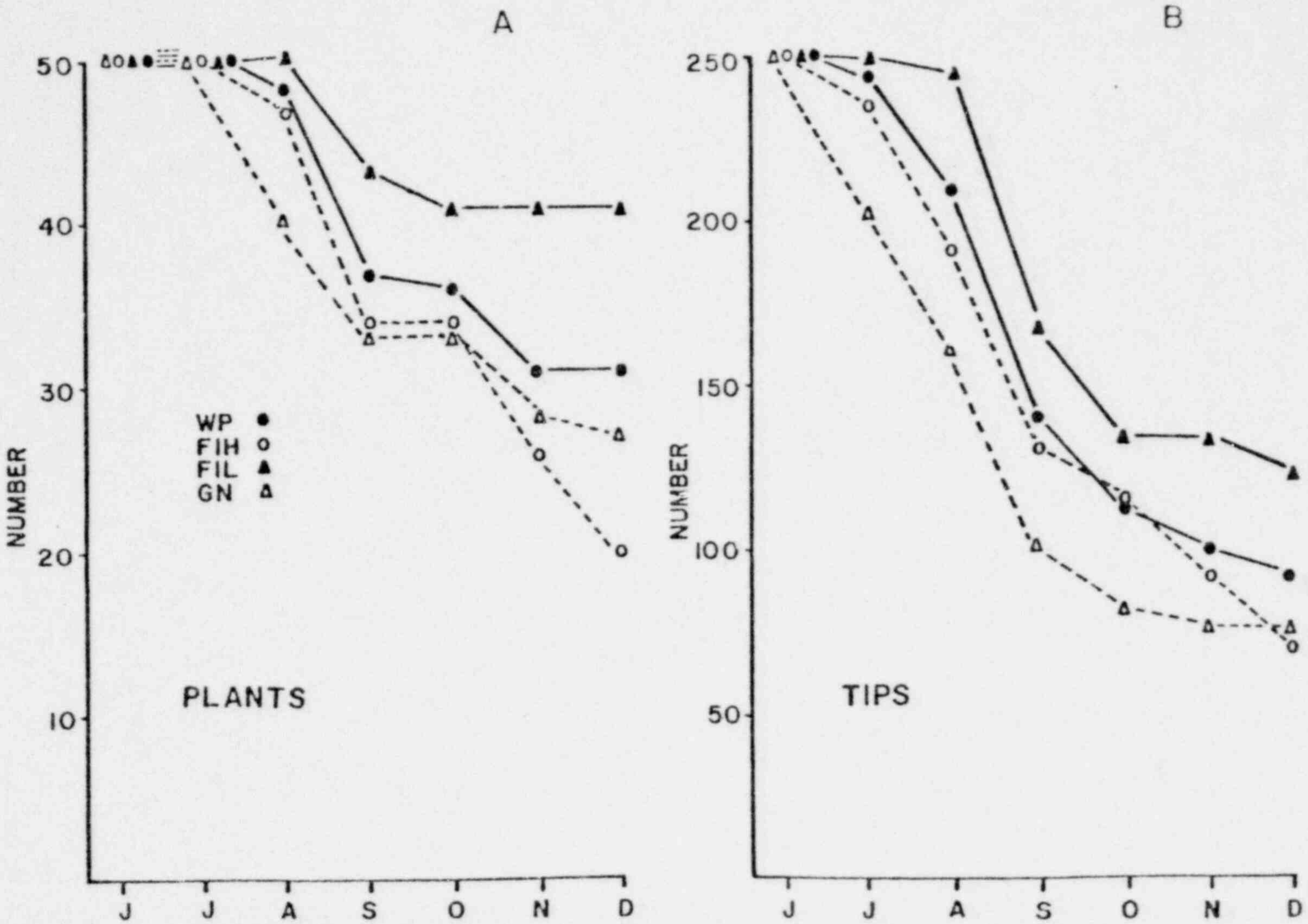

Figure 8. *Ascophyllum* mortality, a) plant loss b) tip loss. WP-White Point, FIH-Fox Island (Higher), FIL-Fox Island (Lower), GN-Giants Neck.

White Point.

These field studies showed that growth at all stations started in late March-early April. Since the average length in April at the lower Fox Island site (5.7 mm) was greater than at the other two sites (1.7 and 2.1 mm), it is apparent that the initial growth rate was highest at Fox Island-Low. Fox Island-High was not sampled until June, but then the average length at this station (21.0 mm) was slightly higher than at Giants Neck or White Point (17.8 and 18.7 mm). Analysis of covariance indicated that growth at both Fox Island sites was significantly greater than at the Giants Neck-White Point station pair ($p<0.05$), but that differences within pairs were not significant.

Other researchers have shown that environmental conditions (e.g. temperature, tide height, exposure) affect the growth of *Ascophyllum* (Printz 1956, Baardseth 1970; Keser 1978). Our observations that Ascophyllum cannot survive in the immediate vicinity of MNPS thermal effluent support the conclusions based on field studies (Vadas et al. 1976) and laboratory experiments (Strömgren 1977) which indicate the lethal affect of sustained high temperatures (>30°C). However, the increased growth at sites within 70 m of the discharge supports findings of Vadas et al. that a slight thermal addition can have an enhancement effect on *Ascophyllum* growth

Ascophyllum mortality at the study sites is represented in Fig. 8. Loss of both plants and tips was highest at Fox Island-High and lowest at Fox Island-Low. Both forms of mortality were primarily the result of mechanical damage, especially during summer storms. Hurricane David (Sept. 5-6) coincided with the period of maximum loss rate at all stations. Additional loss of plants occurred when the rocks to which they were attached were removed by wave action.

Secondarily, plant and especially tip mortality resulted from the feeding activity of grazers, particularly *Littorina obtusata* and *L. littorea*. Grazer-produced holes in apices and bladders were common; on occasion, several snails were observed within a damaged bladder.

Ascophyllum growth and mortality patterns at all stations fell within the ranges reported in other studies of *Ascophyllum* populations in New England (Mathieson et al. 1976, Vadas et al. 1977; Wilce et al. 1978), even though this was the southernmost population studied.

SUMMARY AND CONCLUSIONS

1) The rocky shore in the vicinity of the Millstone Nuclear Power Station supports a rich and diverse benthic marine community throughout the year, characteristic to that of other areas of southern New England where the biota has been studied.

2) The abundance and distribution of predators and grazers play a dominant role in the structuring of intertidal communities during recolonization and under undisturbed conditions.

3) Degree of exposure is also a major factor influencing distribution of intertidal algae and sessile invertebrates, directly, as storm forces

or by minimizing desiccation, and indirectly, by controlling the distribution of predators and grazers.

4) Degree of exposure, and the concommitant effect on grazers and predators, are also directly related to the rate of recolonization of intertidal communities, the time between perturbation and recovery ranged from nine months at an exposed site to incomplete recovery after 18 months at a sheltered site.

5) Blade length of *Fucus vesiculosus* is an inadequate measure of growth of this plant; more useful results were obtained by measuring percentage of substratum covered.

6) *Ascophyllum* was not present immediately adjacent to the thermal effluent, but plants were found within 25 m of the discharge, and extensive populations showing normal or enhanced growth occurred at sites within 70 m of the discharge.

7) During 1979, detrimental differences between potentially impacted and control stations were not detected, adverse effects on the rocky shore communities resulting from operation of MNPS were not evident.

LITERATURE CITED

Baardseth, E. 1970. Synopsis of biological data on knobbed wrack *Ascophyllum nodosum* (Linnaeus) Le Jolis. FAO Fisheries, Synopsis #38, Rev. 1.

Battelle-William F. Clapp Laboratories. 1977. A monitoring program on the ecology of the marine environment of the Millstone Point, Connecticut area. Annual Report for the year 1976. Presented to the Northeast Utilities Service Company.

Battelle-William F. Clapp Laboratories. 1978. A monitoring program on the ecology of the marine environment of the Millstone Point, Connecticut area. Annual Report for the year 1977. Presented to the Northeast Utilities Service Company.

Chapman, V. J. 1946. Marine algal ecology. Bot. Rev. 12:628-672.

Connell, J. H. 1961. Effects of competition, predation by *Thais lapillus* and other factors on natural populations of the barnacle, *Balanus balanoides*. Ecol. Monogr. 31:61-104.

Dayton, P. K. 1975. Experimental evaluation of dominance in a rocky intertidal algal community. Ecol. Monogr. 45:137-159.

Grant, W. W. 1977. High intertidal community organization on a rocky headland in Maine, U.S.A. Mar. Biol. 44:15-25.

Jones, N. S. 1948. Observations and experiments on the biology of *Patella vulgata* at Port St. Mary, Isle of Man. Proc. Liverpool Biol. Soc. 56:60-77.

Keser, M. 1978. Ecological effects of harvesting on the growth of *Ascophyllum* and the growth dynamics of *Fucus*. Ph.D. thesis, Univ. Maine, 138 pp.

Keser, M., R. L. Vadas and B. Larson. 1977. Growth of *Ascophyllum nodosum* in Maine under various harvesting regimes. IXth International Seaweed Symposium August 20-28, 1977, Santa Barbara, California. J. Phycol. 13 (suppl.):82.

Knight, M. and M. W. Parke. 1950. A biological study of *Fucus vesiculosus L.* and *F. serratus L.* J. Mar. Biol. Assoc. U.K. 29:437-514.

Lewis, J. R. 1964. The Ecology of Rocky Shores. English Univ. Press. London. 323 pp.

Mathieson, A. C., J. W. Shipman, J. R. O'Shea and R. C. Hasevlat. 1976. Seasonal growth and reproduction of estuarine fucoid algae in New England. J. Exp. Mar. Biol. Ecol. 25:273-284.

Menge, B. A. 1976. Organization of the New England rocky intertidal community: role of predation, competition and environmental heterogeneity. Ecol. Monogr. 46:355-393.

Menge, J. 1975. Effect of herbivores on community structure on the New England Rocky intertidal region: distribution, abundance, and diversity of algae. Ph.D. Thesis. Harvard Univ., Cambridge, Mass. 164 pp.

Paine, R. T. 1966. Food web complexity and species diversity. Amer. Natur. 100:65-75.

Printz, H. 1956. Recuperation and recolonization in *Ascophyllum*. Second Int. Seaweed Symp., 194-197.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft bottom community. Limnol. Oceanogr. 5:138-153.

Southward, A. J. 1956. The population balance between limpets and seaweeds on wave beaten rocky shores. Rep. Mar. Biol. Sta. Port Erin, 68:20-29.

Southward, A. J., and E. C. Southward. 1978. Recolonization of rocky shores in Cornwall after use of toxic dispersants to clean up the Torrey Canyon spill. J. Fish. Res. Board Can. 35: 682-702.

Stephenson, T. A. and A. Stephenson. 1972. Life between tide marks. Academic Press London. 385 pp.

Strömgren, T. 1977. Short-term effects of temperature upon the growth of intertidal fucales. J. Exp. Mar. Biol. Ecol. 29:181-195.

Vadas, R. L., M. Keser, and B. Larson. 1977. Marine Algae. in Semi-Annual Environmental Surveillance Report X, Maine Yankee Atomic Power Co., pp. 226-251.

Vadas, R. L., M. Keser, and B. Larson, 1978. Effects of reduced temperatures on previously stressed populations of an intertidal alga. DOE Symposium Series, Springfield, V.A., 1978, J. H. Thorp and J. W. Gibbons (Eds.) pp 434-451, (CONF-771114, NTIS).

Wilce, R. T., J. Foertch, W. Grocki, J. Kilar, H. Levine, J. Wilce. 1978. Flora: Marine Algal Studies. in Benthic Studies in the Vicinity of Pilgrim Nuclear Power Station, 1969-1977. Summary Report, Boston Edison Co. pp.307-656.

Zaneveld, J. S. 1969. Factors influencing the limitation of littoral benthic marine algal zonation. Amer. Zool. 13:367-390.

SAND INFAUNA

BENTHIC SAND INFAUNA

INTRODUCTION

The benthic infauna is an important component of marine ecosystems serving as food for demersal fish populations and contributing to the energy and nutrient recycling processes necessary for the maintenance of ecosystem productivity (Peterson 1918; Magnum 1964; Richards and Riley 1967; Aller 1978; Woodin 1978). Traditionally, studies of benthic assemblages have included descriptions of density, distribution, and species composition (Coe 1956; Smith 1971; Wade 1972; Maurer et al. 1978).

Shallow water benthic assemblages, similar to those found in the Millstone Bight, characteristically undergo wide fluctuations in species composition and density on both a seasonal and annual basis, reflecting the unpredictable physical environment and varying levels of biological interaction (Coe 1956; McCall 1975; Whitlatch 1977). For example, disturbances by storms can have dramatic effects on shallow water infaunal populations (McCall 1975; Yeo and Risk 1979). Biological interactions, i.e., competition and predation, are also important factors influencing patterns of species composition and density (Paine and Vadas 1969; Paine 1974; Woodin 1974; Connel 1975). These variations in species composition and density, make the collection of multiple samples over extended periods of time necessary before man induced changes in benthic communities can be distinguished from natural changes (Cairns 1976). Despite the inherent variability associated with benthic communities, the generally sedentary nature and the sensitivity of infaunal species to physical and biological stress, make them an important tool for evaluating the potential impacts of man's activities (Reish 1960; Wilhm and Dorris 1966; Wilhm 1970).

The nearshore benthic infauna have been studied at the Millstone Nuclear Power Station since 1968. Potential stresses on the benthic community induced by operation of the Millstone Station include substrate scouring, temperature elevation, and entrainment. Scouring at both intake and discharge structures might result in localized changes in the benthic community; however, increased thermal regimes and entrainment of pelagic stages of infaunal organisims could influence density and species compositon over a much larger area.

The objectives of this study were: (1) to characterize the shallow-water subtidal and intertidal infaunal assemblages with respect to density and species composition, (2) to compare infaunal communities at stations located near and away from the Millstone plant, (3) to evaluate the significance of temporal changes in infaunal communities based on previous studies of the Millstone Bight.

MATERIALS AND METHODS

The Millstone Nuclear Power Station is located on the north shore of Long Island Sound (LIS) in southeastern Connecticut (lat. 41° 18' 25" long. 72° 10'). Benthic infaunal sand samples were collected quarterly (September and December 1978 and March and June 1979), at four subtidal and two intertidal stations (Fig. 1). The Giants Neck subtidal and

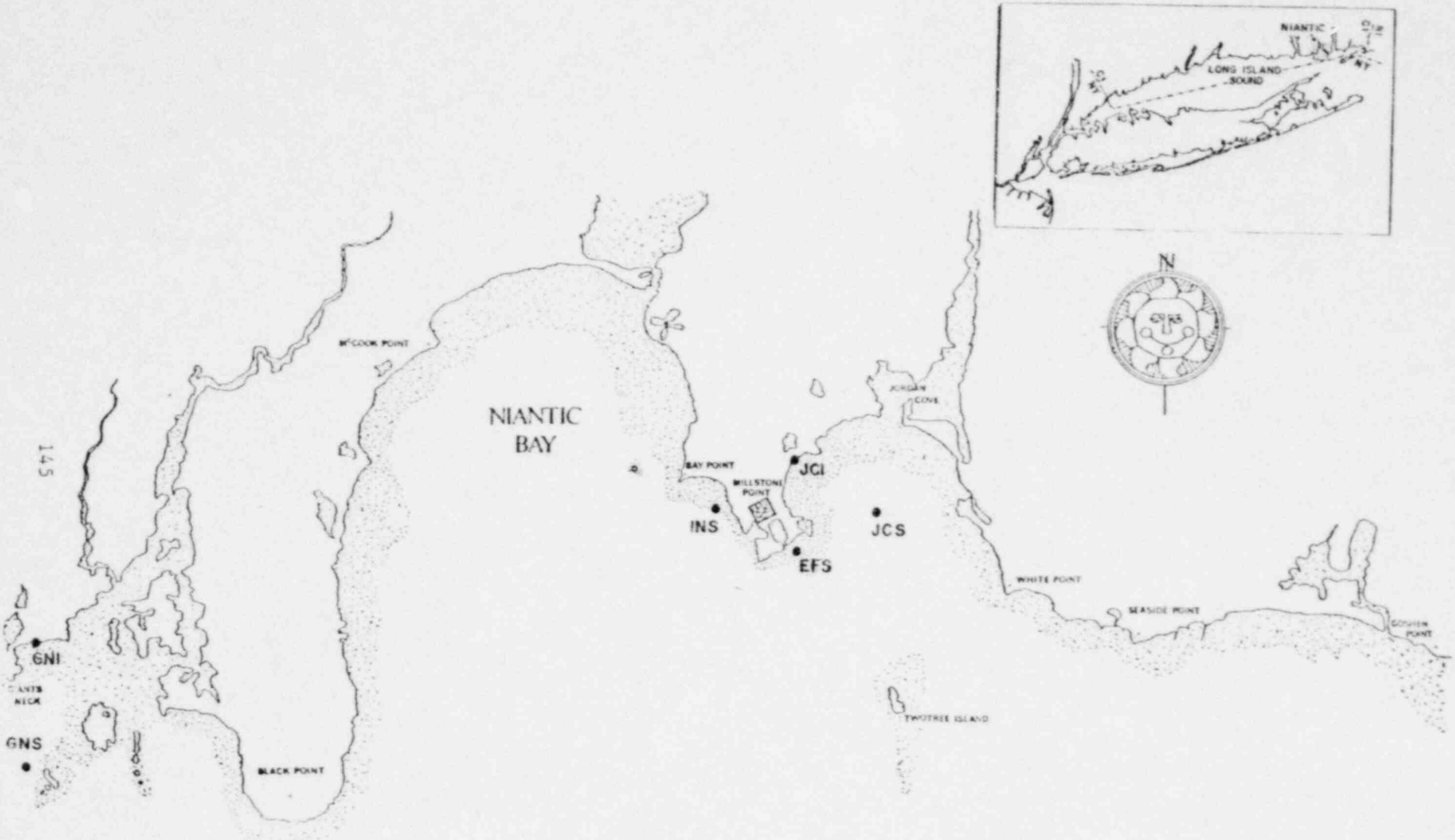

Figure 1. Map of the Millstone Point area showing the location of subtidal and intertidal sand stations. (GNS= Giants Neck subtidal, EFS= Effluent subtidal, INS= Intake subtidal, JCS= Jordan Cove subtidal, GNI= Giants Neck intertidal, JCI= Jordan Cove intertidal).

intertidal sites were considered reference stations (non-impacted) for this study while the Intake, Effluent, and Jordan Cove subtidal and the Jordan Cove intertidal stations were considered potentially impacted. A more detailed description of stations is given in Battelle (1975). For this study, samples collected from September 1978 to June 1979 will hereafter be referred to as the 1979 collection period.

SCUBA divers, using a corer 10 cm in diameter and 5 cm deep, collected ten replicate samples within 3 m of each subtidal station marker. Each sample was placed in a .333 mm mesh nitex bag and brought to the surface. Ten replicate intertidal sand samples were collected along a 3 m transect parallel to the waterline at mean low water.

An additional five samples were collected at each subtidal and intertidal station in March and June 1979. These samples were collected to evaluate the effects of using a 0.5 mm sieve during sample processing in 1979 instead of the 0.7 mm sieve used in studies from previous years.

After sampling, all replicates were returned to the laboratory and fixed with 10% buffered formalin; after a minimum of 48 h, organisms were floated from the sediments (Sanders et al. 1965), stained with rose bengal, and preserved in 70% ethyl alchohol. Samples collected in September were sieved through a 0.7 mm sieve, while a 0.5 mm sieve was used on all successive samples. Both 0.5 and 0.7 sieves were used to process the five addition cores, and organisms retained on each were preserved separately. Separation of organisms from sediments was done with the aid of a dissecting microscope. Initially all organisms were sorted into the following categories: (1) annelids, (2) arthropods, (3) molluscs, (4) miscellaneous invertebrates. Subsequently, they were counted and identified to the lowest possible taxon. Organisms not sampled adequately by our methods because of their small size, e.g., Nematoda, Copepoda, and Foraminifera were excluded from data analyses. Biomass of each replicate was obtained for the annelid, mollusc, and arthropod fractions. Samples were dried in an oven at $80^{\circ}C$ for 72 h and weighed to the nearest 0.01 g. Values for the ten replicates were summed and reported in g/m^2 dry weight for each station and sampling period.

Sediment for sand grain analysis was collected at each site at the time of infaunal sampling. Mechanical analysis using the dry sieving method as outlined by Folk (1974) was performed on one, 5 cm deep core. His method of moments technique was used to calculate the arithmetic mean phi (ϕ) and standard deviation ($\sigma\phi$) for 1/2 class intervals. The standard deviation ($\sigma\phi$) was verbally described as the degree sorting, and refers to the distribution of particle size classes in the sample.

Data Analysis

The quantitative measures used in this report were calculated for each collection period (seasonal) by summing species counts in the ten replicate samples. The mean species count over the four sampling periods was used for all annual calculations.

Diversity

Seasonal species diversity for each station was expressed using the Shannon information index (H') and was calculated as:

$$H' = -\sum_{i=1}^{s} \frac{n_i}{N} \log_2 \frac{n_i}{N} \qquad \text{(Pielou 1977)}$$

where n_i = number of individuals in the i^{th} species

N = total number of individuals for all species

S = number of species

This index is sensitive to both the number of species and the distribution of individuals among the species (evenness). The evenness component (J) was calculated as:

$$J = \frac{H'}{H\ max} \qquad \text{(Pielou 1977)}$$

where Hmax = $\log_2 S$ and represents the theoretical maximum diversity when all species are equally abundant. This index is scaled from zero to one, thus, as abundance becomes more even among species, J approaches one.

Diversity calculations excluded taxa not identified to the species level, i.e., oligochaetes and rhynchocoels and organisms not identified to species because of their poor physical condition.

Biological Index Value

The Biological Index Value (BIV) of McCloskey (1970) was calculated for the ten most abundant species by assigning a rank to each species for each collection period and then summing these ranks over all collection periods. The sum for each species was then expressed as a percentage of a theoretical maximum sum, which occurs if a species ranked first for all collection periods. For example, if a species ranked 1st in abundance in four collections when ten species were collected, the theoretical maximum would be equal to 40. This value mitigates the effects of one large seasonal collection of a single species on overall community dominance.

Jaccard's Coefficient

The overlap of infaunal species (affinity) was calculated for the entire year and for each sampling period for each subtidal and intertidal station. The coefficient was calculated as:

$$CO = \frac{A}{B + C - A} \qquad \text{(Grieg-Smith 1964)}$$

where A = number of species shared by two sites

B = number of species at site B, but not at C

C = number of species at site C, but not at B

This similarity index is sensitive only to presence/absence and is not affected by the abundance of individual species.

Similarity

The Bray-Curtis similarity coefficient is one of the most frequently used quantitative measures in ecological studies (Boesch 1977). In this study the index was used to classify sites (normal analysis) and species (inverse analysis) for each sampling period and over the entire year using log transformed species counts [ln (count +1)]. The coefficient is calculated as:

$$S_{jk} = \frac{2 \sum_i \min (X_{ij}, X_{ik})}{\sum_i (X_{ij} + X_{ik})} \qquad \text{(Clifford and Stevenson 1975)}$$

where x_{ij} = abundance of attribute i at entity j.

x_{ik} = abundance of attribute i at entity k.

For normal analysis, species were considered attributes and stations entities while for inverse analysis species were considered entities and stations attributes. Inverse analysis was performed using the ten numerically abundant species throughout the year and any additional species having a higher BIV than the numerically dominant organisms.

Cluster Analysis

A clustering algorithm was applied to the normal and inverse Bray-Curtis similarity matrices to group stations and species at decreasing levels of similarity. The group-averaging agglomeration or "unweighted pair-group" method using arithmetic averages was used and the results presented as dendrograms (Boesch 1977).

This algorithm calculates one resemblance between groups k and h when k is formed from the fusion of groups i and j as:

$$C_{hk} = \frac{n_i}{n_k} C_{hi} + \frac{n_j}{n_k} C_{hj}$$

where C_{hi} = resemblance of group h to i and n_i, n_j, n_k are the number of entities in groups i, j, k.

Trophic Group Classification

Analysis of population trophic structure was performed for each station over the entire year and for each sampling period by assigning feeding types to each species based on current literature, habitat, or specific morphological features, which suggested potential feeding modes and possible food sources. Although classification of community trophic structure based on such broad feeding type categories may suffer because of the feeding-plasticity of many benthic animals (Boesch 1973), this type of analysis can still provide useful data on resource utilization and partitioning by local infaunal populations.

The feeding types used were based on those listed by Maurer, Watling, Leathem and Kinner (1979) for polychaetes, molluscs, and crustaceans, and Biernbaum (1979) for amphipods. Additional information on polychaete feeding behavior were obtained from Fauchald and Jumars (1979). The classifications were:

Suspension feeders (SF)	-	organisms removing food from the water column.
Herbivores (H)	-	feeding on live plant material.
Detritivores (DT)	-	obtaining nutrients from decaying plant matter.
Deposit feeders (DF)	-	organisms feeding on surface or subsurface sediments and the organic matter, bacterial films and unicellular algae associated with them.
Omnivores (O)	-	obtaining food indiscriminately.
Carnivores (C)	-	those individuals that actively search for other live organisms.

RESULTS

Sediment Characteristics

Subtidal - Sediment composition at subtidal sites ranged from medium sand to sandy mud (Table 1). Giants Neck sediments were of finest grain size and least sorted of all subtidal stations, while the Jordan Cove sediments were coarsest. The sediments at Effluent were of intermediate size, and the best sorted. The highest seasonal fluctuation in sand grain size occurred at Jordan Cove, where mean grain size ranged from fine to very coarse sand.

The silt content of the Giants Neck sediments was highest of all subtidal stations ranging from 36.4-59.5%, while the Effluent sediments generally contained the least amount of silt (0.0-14.1%). Seasonally, silt content was lowest in the fall and values less than 1% were obtained in September at Jordan Cove and Effluent.

Table 1. Sediment characteristics of Millstone subtidal stations sampled September 1978 - June 1979.

Station	Month	Mean Ø	% Silt/Clay	σØ	Sorting[1]
Giants Neck	Sept.	2.62	36.4%	2.66	VP
	Dec.	2.61	44.5%	2.06	VP
	Mar.	3.29	59.5%	2.08	VP
	June	2.62	38.3%	2.16	VP
Jordan Cove	Sept.	0.08	0.0%	1.09	P
	Dec.	1.36	16.9%	2.02	VP
	Mar.	2.18	7.0%	1.04	P
	June	1.25	14.7%	1,87	P
Intake	Sept.	1.66	2.8%	1.18	P
	Dec.	2.58	17.5%	1.36	P
	Mar.	1.65	9.5%	1.81	P
	June	2.18	13.5%	1.69	P
Effluent	Sept.	1.71	0.0%	0.66	M
	Dec.	1.97	3.1%	0.86	M
	Mar.	1.94	2.5%	0.84	M
	June	2.00	14.1%	1.60	P

[1] VP = very poor
P = poor
M = moderate

Intertidal - Intertidal sediment characteristics are summarized in Table 2. Sediments at the Jordan Cove intertidal site were poorly sorted and composed of very coarse to medium sand, while those at Giants Neck were poorly to moderately sorted medium sands.

Silt content in Jordan Cove sediments was low, and ranged from 1.2% in March to 4.3% in September. Giants Neck sediments contained very low silt fractions throughout the year with the high 1.9% occurring in June.

The sediment composition at each subtidal station varied seasonally during 1979. The range of grain size and silt content were within those reported in 1978 (Battelle 1978). The grain size and silt content of Jordan Cove and Giants Neck intertidal sediments during 1979 were also similar to the values reported in previous studies. Historically mean grain size and silt content of Giant's Neck sediments vary little over the year. In contrast, mean grain size and silt content at Jordan Cover undergo larger seasonal variation.

General Community Structure

A total of 194 species and 35,998 individuals were collected at all Millstone subtidal and intertidal stations during the 1979 sampling program (Table 3). Annelids were the most abundant phylum and comprised 79% of the organisms collected. Of the 194 species, polychaetes were most numerous (103), while fewer crustacean (31) and molluscan (42) species were collected. Total polychaete abundance increased from 8943 in 1978 to 16,548 in 1979 and the numbers of crustaceans rose from 1788

Table 2. Sediment characteristics of Millstone intertidal stations sampled September 1978 - June 1979.

Station	Month	Mean ϕ	% Silt/Clay	$\sigma\phi$	Sorting[1]
Giants Neck	Sept.	1.08	0.00%	1.14	P
	Dec.	1.71	0.00%	0.75	M
	Mar.	1.59	0.00%	0.78	M
	June	1.44	1.9%	1.00	P
Jordan Cove	Sept.	-0.04	4.3%	1.45	P
	Dec.	1.39	3.3%	1.13	P
	Mar.	0.85	1.2%	1.21	P
	June	1.14	2.1%	1.14	P

[1] P = poor
M = moderate

Table 3. Total number of individuals, families and species of the four major taxa collected at Millstone Point subtidal and intertidal stations sampled from Sept. 1978 - June 1979.

	Oligochaetes		Polychaetes		Mollusca		Crustacea	
	1978	1979	1978	1979	1978	1979	1978	1979
# Individuals	14884	12,015	8943	16548	447	551	1788	6884
% Composition	57	33	34	46	2	1	7	19
# Families	-[a]	-	31	28	24	21	23	24
# Species	-	-	99	103	34	31	44	49

[a] Identified to class only.

to 6884. The total numbers of oligochaetes and molluscs collected were generally similar to the numbers found in the previous year.

The higher abundance of infaunal organisms observed in 1979 was probab'y due to the change from the 0.7 mm to 0.5 mm mesh sieves. Estimates of infaunal density in March and June 1979 averaged 36% higher at all sites when a 0.5 mm seive was used (Appendix 1); this increase was similar to the 38% increase in total abunaance observed between sampling years.

The number of taxonomi. families and species represented in benthic samples remained fair., consistent between 1978 and 1979. Most of the newly collected species reported in 1979 (Table 4) were small polychaetes tlat .ere probably most susceptible to the smaller mesh sieve used in the 1979 program.

Species Dominance

Subtidal - The infaunal communities at all Millstone subtidal stations were dominated by oligochaetes and polychaetes (Table 5). The total number of individuals for each species collected during each sampling period is presented in Appendices 2-5. The ten numerically dominant species accounted from 82.1% (Intake) to 87.6% (Giants Neck) of all the individuals collected.

Oligochaetes and the polychaetes, *Aricidea catherinae*, *Capitella* spp., and *Chaetozone* spp., were the only organisms among the ten dominants

Table 4. New species collected at Millstone subtidal and intertidal stations sampled from September 1978-June 1979.

RHYNCHOCOELA
- *Cerebratulus lurdis*

MOLLUSCA
- Bivalvia
  - Nuculidae
    - *Nucula annulata*

ANNELIDA
- Polychaeta
  - Ampharetidae
    - *Hypaniola grayi*
  - Nephtyidae
    - *Nephtys caeca*
  - Phyllodocidae
    - *Nereiphylla* spp.
  - Sabellidae
    - *Chone* spp.
    - *Euchone elegans*
  - Spionidae
    - *Scolelepis cf bousfieldi*
  - Syllidae
    - *Syllides convoluta*
    - *Syllides fulva*
    - *Syllides verrilli*
    - *Syllides sexoculata*
  - Terebellidae
    - *Nicolea venustula*

ARTHROPODA
- Pychnogoida
  - *Anoplodactylus lentus*
- Crustacea
- Ostracoda
  - *Sarsiella americana*
- Amphipoda
  - Photidae
    - *Photis macrocoxa*

Table 5. Annual Mean Density (#/m^2) Percent Contribution and Biological Index Value for the ten dominant species collected at Millstone subtidal stations, September 1978-June 1979.

	$\bar{x}$	%	Cum %	BIV
Effluent				
Oligochaeta	5430	36.3	36.3	97.3
Chaetozone sp.	3325	22.2	58.6	65.8
Aricidea catherinae	1552	10.4	69.0	90.8
Polycirrus eximius	560	3.7	72.7	80.9
Protodorvillea gaspeensis	426	2.8	75.6	57.2
Tellina agilis	400	2.7	78.2	64.5
Caulleriella spp.	339	2.3	80.5	63.8
Exogone hebes	259	1.7	82.2	67.1
Capitella spp.	205	1.4	83.6	49.3
Microphthalmus aberrans	198	1.3	84.9	42.7
Rhynchocoela	198	1.3	86.3	53.3
Giants Neck				
Oligochaeta	6602	38.1	38.1	98.2
Aricidea catherinae	3139	18.1	56.2	89.3
Tharyx spp.	1997	11.5	67.7	83.0
Chaetozone spp.	1210	7.0	74.6	80.4
Capitella spp.	461	2.7	77.3	48.2
Mediomastus ambiseta	403	2.3	79.6	52.7
Polycirrus eximius	390	2.3	81.9	54.5
Phoxocephalus holbolli	381	2.2	84.1	48.2
Lumbrineris impatiens	377	2.2	86.2	45.5
Protodorvillea gaspeensis	224	1.2	87.6	38.4
Intake				
Ampelisca verrilli	1258	25.1	25.1	82.6
Aricidea catherinae	1216	24.2	49.3	97.8
Capitella spp.	736	14.7	64	95.7
Oligochaeta	307	6.1	70	88.0
Chaetozone spp.	122	2.4	72.5	62.0
Tellina agilis	118	2.4	74.9	70.7
Gammarus lawrencianus	112	2.2	77.1	48.4
Clymenella torquata	109	2.2	79.3	65.8
Unciola irrorata	77	1.5	80.8	54.3
Exogone hebes	67	1.3	82.1	58.7
Jordan Cove				
Oligochaeta	8858	48.8	48.8	98.8
Aricidea catherinae	2787	15.3	64.1	85.1
Lumbrineris impatiens	694	3.8	67.9	51.2
Polycirrus eximius	627	3.5	71.4	67.9
Mediomastus ambiseta	576	3.2	74.6	75.6
Capitella spp.	476	2.6	77.2	66.7
Lumbrineris tenuis	387	2.1	79.3	61.9
Sarsiella americana	326	1.8	81.1	53.6
Parapionosyllis longicirrata	304	1.7	82.8	59.3
Chaetozone spp.	304	1.7	84.5	70.2

that were common to all subtidal stations. Oligochaetes were the most abundant organisms at all but the Intake site, accounting for 36-48% of the total population. The gammaridean amphipod, Ampelisca verrilli, was numerically dominant at the Intake; this species constituted 25% of all the individuals collected at this site. Aricidea catherinae was a co-dominant member of the infaunal community at each subtidal site, averaging over $1000/m^2$ and comprising 15.3-24.2% of the total number of individuals collected throughout 1979. Chaetozone spp. ranked second at the Effluent and accounted for 22% of the total number; however, at other subtidal stations it contributed only 1.7-7.0% to the total. Over the entire year, Tharyx spp. was abundant ($> 1000/m^2$) at only Giants Neck and was not included among the ten numerically dominant forms at any other site.

The Biological Index Value indicated that Oligochaetes were the most consistently dominant organisms at Giants Neck, Jordan Cove, and Effluent where the BIV was over 97% (Table 5). Aricidea catherinae ranked second at all subtidal sites indicating seasonal consistency in its numerical dominance. At the Effluent, Chaetozone spp. ranked second numerically, but large seasonal fluctuations in abundance resulted in a low BIV (65.8%). The Intake species assemblage was numerically dominated by A. verrilli over the year, but seasonally wide variations in abundance resulted in a BIV, which ranked fourth.

On a seasonal basis, the dominant species complement of most subtidal sites was generally similar although the species rankings in terms of abundance, varied (Appendix 6). Over half of the ten dominant organisms collected at Giants Neck, Jordan Cove, and Intake were abundant in three or more collections during the year. The dominant species at the Effluent were most variable of al subtidal sites and only three of the ten dominant species fall into this category.

The dominant species at all subtidal sites during 1979 were similar to those reported in 1978 (Battelle 1978). Differences between years involved variations in species abundance rather than species presence or absence. At the Effluent, a high density of Chaetozone spp., in September 1978, resulted in a higher mean density in 1979 relative to 1978. In addition, a sharp increase in the overall abundance of A. catherinae and a decrease in P. eximius occurred at this site. The density of A. catherinae, Lumbrineris impatiens, and Mediomastus ambiseta increased at Jordan Cove in 1979. Although overall infaunal density at Giants Neck increased in 1979, the numerical ranking of species was similar to that of the 1978. An increase in mean abundance of A. verrilli was the only major change in species dominance that occurred at Intake in 1979.

Intertidal - Annelids also dominated the annual infaunal assemblage at the Jordan Cove and Giants Neck intertidal sites; however, oligochaetes were a major component only at Jordan Cove (Table 6). The total number of individuals for each species collected during each sampling period is presented in Appendices 7-8. Oligochaetes, rhynchocoels, and the polychaetes, Hediste diversicolor, Scolecolepides viridis, and Capitella spp. were among the ten most abundant organisms at both intertidal sites. The numerically abundant species accounted for 97.1% and 99.4% of the individuals collected at Jordan Cove and Giants Neck, respectively. At Jordan Cove,

Table 6. Annual mean density ($\#/m^2$) percent contribution, and Biological Index Value for the ten dominant species collected at Millstone intertidal stations, September 1978 - June 1979.

	$\bar{x}$	%	Cum %	BIV
Giants Neck				
Haploscoloplos acutus	634	22.1	22.1	77.2
Haploscoloplos fragilis	493	17.2	39.3	88.2
Scolecolepides viridis	493	17.2	56.5	91.2
Rhynchocoela	346	12.1	68.6	70.0
Paraonis fulgens	256	8.9	77.5	80.9
Capitella spp.	205	7.1	84.7	61.0
Oligochaeta	195	6.8	91.5	77.9
Hediste diversicolor	106	3.9	95.2	46.3
Hydrobia totteni	32	1.1	96.3	36.8
Gemma gemma	22	0.8	97.1	38.2
Jordan Cove				
Oligochaeta	17,056	81.3	81.3	100.0
Microphthalmus sczelkowii	1,072	5.1	86.4	50.0
Capitella spp.	826	3.9	90.4	59.1
Rhynchocoela	819	3.9	94.3	77.2
Scolecolepides viridis	560	2.7	97.0	60.8
Gammarus lawrencianus	138	0.7	97.6	54.5
Streblospio benedicti	134	0.6	98.2	47.7
Gammarus mucronatus	106	0.5	98.7	46.6
Polydora ligni	90	0.4	99.2	45.5
Hediste diversicolor	42	0.2	99.4	67.6

oligochaetes averaged 17,056/m^2 over the year, and accounted for 81% of the total number of individuals. Although four other species had densities over 500/m^2, their contributions to community dominance was low (< 6%). In contrast, the Giants Neck assemblage included four taxa, Haploscoloplos acutus, Paraonis fulgens, Scolecolepides viridis, and rhynchocoels, which contributed over 10% of the total number of individuals collected. Oligochaetes accounted for only 6.8% of the organisms collected at this site.

In addition to the faunistic differences observed between the two intertidal stations, the number of species that consistently contributed to the overall faunal dominance, as reflected by the BIV, was also different. At Jordan Cove, oligochaetes consistently ranked first in abundance over the year resulting in a BIV of 100%. Of the remaining nine numerically abundant organisms, only rhynchocoels, Hediste diversicolor, and Scolecolepides viridis had BIV's above 60%, while seven of the ten dominant species at Giants Neck had BIV's over 60%.

Seasonal changes in the species that dominated intertidal assemblages were also evident on a numerical basis (Appendix 9). Of the ten dominant species at Jordan Cove, only oligochaetes and rhynchocoels were abundant in more than two seasonal collections; however, at Giants Neck, seven species were numerically dominant on three or more occasions.

The species that dominated the Jordan Cove assemblage were generally the same as those reported in previous years, although, the mean density of some species varied (Battelle 1978). Scolecolepides viridis, the most abundant species during 1978, ranked fifth in abundance in 1979. Three species, Micropthalmus sczelekowii, Streblospio benedicti, and Gammarus mucronatus were among the numerically dominant species in 1979, but not in 1978. In 1979, these species were found only in the September collections. The infaunal assemblage at Giants Neck included higher numbers of Haploscolopolos acutus, and H. fragilis in 1979 than in 1978, while two abundant members of the 1978 assemblage, Chaetozone spp. and Polydora ligni were not among the ten dominant species in 1979.

Infaunal Trophic Structure

Subtidal - Over the entire year, deposit-feeders dominated subtidal benthic communities (Fig. 2). All feeding types were present at Giants Neck and Jordan Cove. The contributions of omnivores, herbivores, and suspension-feeders were higher, and carnivores and detritivores lower, at Jordan Cove than at Giants Neck. Deposit feeders also dominated at the Effluent; carnivores constituted the second most abundant feeding type (9.25%). The Intake station differed from other stations, in that the numbers of deposit-feeders were lower and numbers of detritivores and suspension-feeders higher, than at other stations. In addition, this site was the only subtidal station that lacked herbivores.

Deposit-feeders were the dominant organisms in each seasonal collection made at the Effluent, Jordan Cove, and Giants Neck sites (Appendix 10). At Giants Neck, the other feeding groups consistently occurred in low numbers. Jordan Cove communities had large numbers of herbivores in

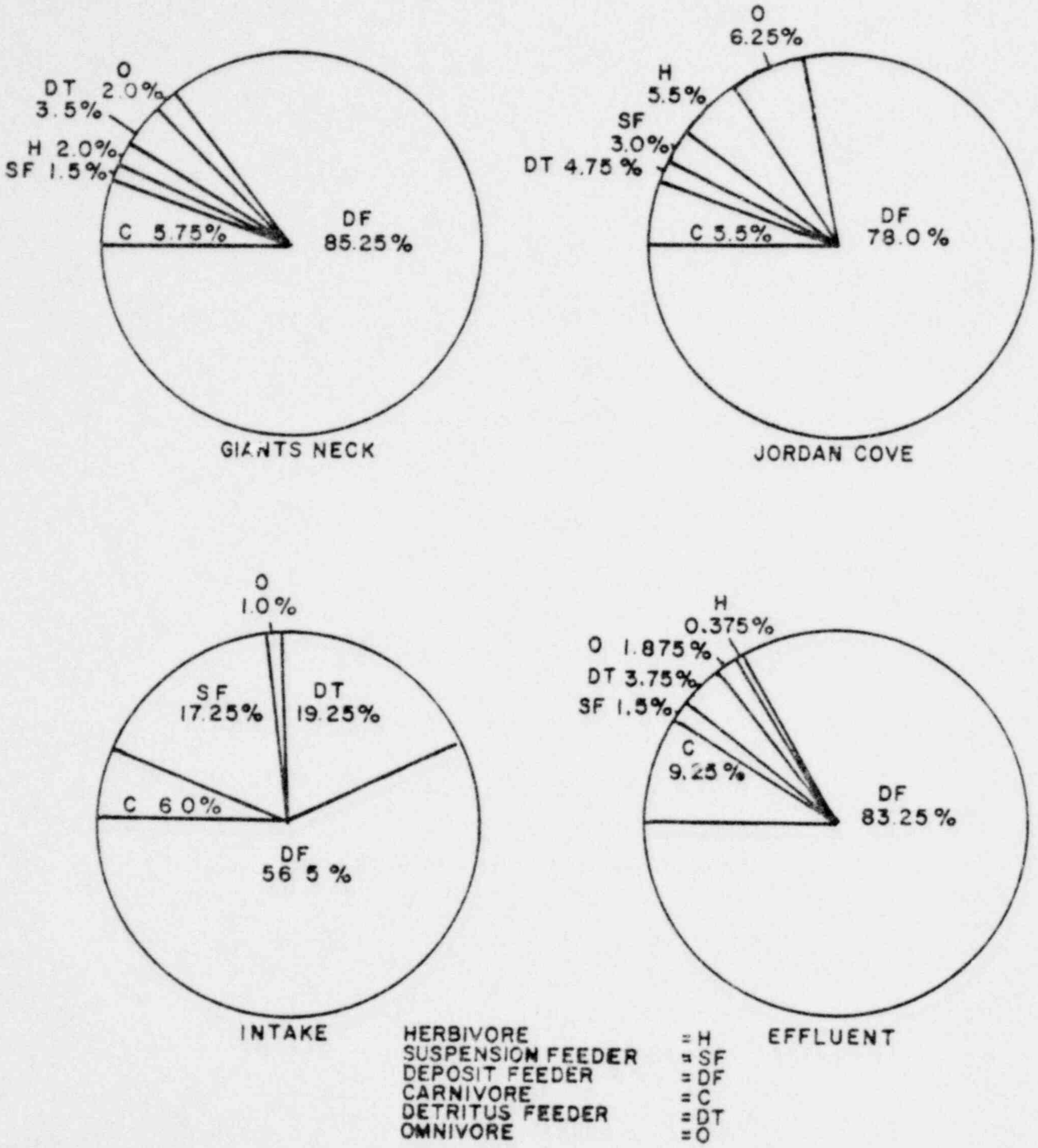

Figure 2. Annual percentage of infaunal species for the six feeding types represented at each Millstone Point subtidal station.

September and omnivores in March. At the Effluent, changes in trophic structure occurred in March and June, when no herbivores were found. Seasonal variations in feeding types were greatest at the Intake, deposit-feeders dominated in all months except June, when detritivores dominated. The abundance of suspension-feeders at this site declined from September through June.

Intertidal - Deposit-feeders generally dominated intertidal populations at both stations throughout the year (Fig. 3). Differences between the two stations were evident in the number and proportion of the other feeding types present. The Giants Neck assemblage included high numbers of carnivores, low numbers of suspension-feeders, omnivores, and detritivores, and no herbivores. The Jordan Cove fauna included higher numbers of detritivores and lower numbers of carnivores and omnivores than the Giants Neck community.

The seasonal variations in feeding types at Giants Neck were greater than at Jordan Cove (Appendix 11). At Jordan Cove, deposit feeding oligochaetes totally dominated throughout the year, with September being the only time when all feeding types were represented. In contrast, Giants Neck displayed more seasonal hetereogeneity in trophic composition. December was the only month in which deposit-feeders and carnivores were present. The deposit feeding community at Giants Neck was also different from Jordan Cove because its dominant members were polychaetes rather than oligochaetes.

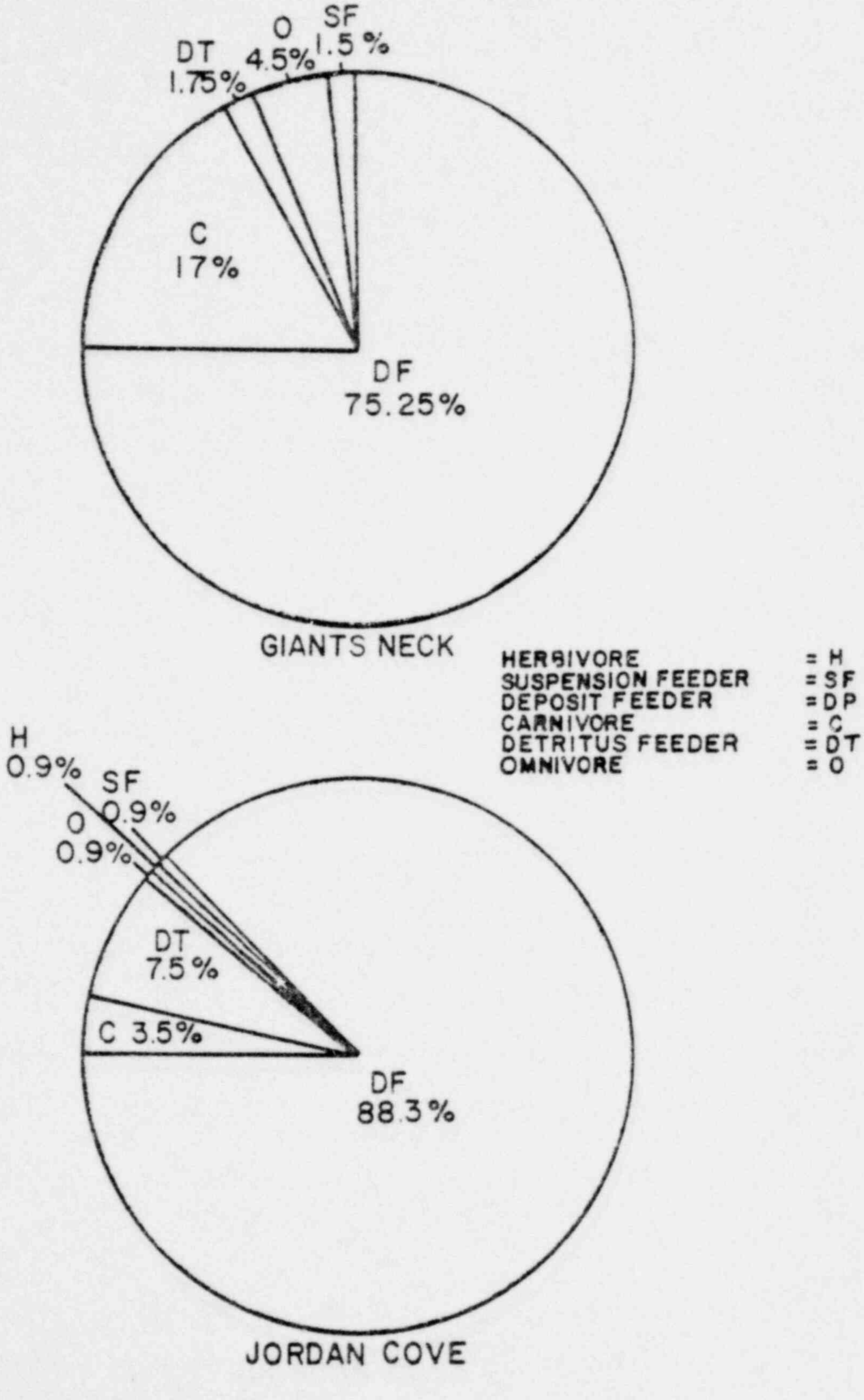

Figure 3. Mean percents of the six feeding types represented at each Millstone Point intertidal station for the 1979 sampling year.

D nsity and Biomass

Subtidal - Infauna density at subtidal stations varied over the year at all sites (Table 7). Density was highest at Jordan Cove averaging 31,331/m^2 and lowest at Intake (6742/m^2). Seasonally, density varied least at Giants Neck and most at Jordan Cove. Infaunal density at Jordan Cove and Effluent increased from September to December, decreased in March and increased again in June. At Giants Neck population densities increased from September through March and decreased in June while at the Intake they decreased through March and increased in June.

The mean population densities of subtidal macrofauna were higher during 1979 than 1978; the average density at each station increased two-fold in 1979 relative to 1978. This increase is believed primarily attributable to the smaller mesh sieve used in the 1979 study (Appendix 1).

Subtidal biomass estimates ranged from 103.55 g/m^2 at the Effluent in September to 0.89 g/m^2 at Giants Neck in December (Table 7). Biomass at Jordan Cove, Giants Neck, and the Intake was higher in September and March and lower in December and June. At the Effluent biomass decreased from September to June. Biomass estimates in 1979 were higher than those in 1978 at all stations except Giants Neck.

Intertidal - Jordan Cove population densities were consistently higher than those at Giants Neck, averaging 22,322/m^2 and 2985/m^2, respectively (Table 7). Highest density at Giants Neck occurred in September and lowest in December. At Jordan Cove, highest densities were in March and lowest in December.

Table 7. Infaunal density ($\#/m^2$) and dry weight biomass (g/m^2) at Millstone subtidal and intertidal stations, September 1978- June 1979.

	Sept. 1978	Dec. 1978	Mar. 1979	June 1979
		Subtidal		
Effluent				
biomass	103.55	26.24	4.74	2.43
density	18,022	22,886	8,307	18,585
Jordan Cove				
biomass	6.27	2.43	18.56	7.04
density	36,032	39,244	20,032	30,016
Intake				
biomass	29.69	2.17	5.50	1.28
density	13,235	4,864	2,265	6,604
Giants Neck				
biomass	7.42	0.89	6.78	4.48
density	19,712	26,752	27,904	20,838
		Intertidal		
Jordan Cove				
biomass	1.92	0.13	0.90	0.90
density	20,812	6,092	33,356	29,030
Giants Neck				
biomass	13.44	4.10	1.92	0.77
density	6,003	1,139	2,342	2,457

At Giants Neck highest biomass occurred in September (13.44 g/m^2) and decreased steadily to June. Biomass at Jordan Cove exceeded 1 g/m^2 only in September, while at Giants Neck biomass exceeded this value in three of the four sampling periods. Unlike Giants Neck, trends in biomass closely parallel changes in population size at Jordan Cove.

Annual estimates of population density and biomass at the Jordan Cove intertidal site showed pronounced differences from the 1978 estimates. There was a 3-fold increase in density coupled with a 4-fold decrease in biomass at this site. Annual density estimates at Giants Neck were slightly higher than 1978 estimates, while, biomass was more than 6 times that found in the previous year.

Station comparisons based on biomass estimates are often misleading, since the presence of a few large rare individuals will result in overestimation of infaunal biomass. In this study we believe density estimates yielded a better indication of standing crop than biomass estimates.

Diversity

Subtidal - Species diversity was highest at Jordan Cove, averaging 4.035 over the year (Table 8). At the remaining three stations mean diversity ranged between 3.482 and 3.519. Seasonally, the range of infaunal diversity at Giants Neck was small (3.163-3.894). All other sites exhibited more seasonal variability with high diversity in December and low diversity in September. Evenness (J) at all but the Giants Neck station followed

Table 8. Species diversity at the Millstone subtidal station, September 1978-June 1979.

		Sept. 1978	Dec. 1978	March 1979	June 1979
Jordan Cove	H'	3.413	4.668	4.211	3.849
	J	0.611	0.860	0.739	0.639
	S	48	43	52	65
	N	1061	196	656	958
Intake	H'	2.628	4.165	3.712	3.370
	J	0.497	0.738	0.781	0.717
	S	39	50	27	26
	N	824	301	151	194
Giants Neck	H'	3.894	3.169	3.163	3.850
	J	0.659	0.628	0.576	0.644
	S	60	33	45	63
	N	764	448	1065	1048
Effluent	H'	2.144	4.520	3.174	3.877
	J	0.369	0.726	0.552	0.671
	S	56	75	54	55
	N	1108	625	451	721

Table 9. Species diversity at the Millstone intertidal stations, September 1978-June 1979.

		Sept. 1978	Dec. 1978	March 1979	June 1979
Giants Neck	H'	2.091	1.885	3.207	2.291
	J	0.660	0.730	0.867	0.662
	S	9	6	13	11
	N	416	70	74	165
Jordan Cove	H'	2.173	1.585	0.789	0.430
	J	0.487	1.00	0.305	0.143
	S	22	3	6	8
	N	248	3	43	174

H' = Shannon index
J = Evenness
S = Number of species
N = Number of individuals

a similar pattern of high values in December and low values in September. The high December diversity at Jordan Cove was coupled with a more even distribution of individuals among species with the number of species remaining fairly constant. At the Effluent and Intake, high diversity in December was reflective of increasing numbers of species and evenness.

No clear seasonal trends in the number of species collected at the subtidal stations were evident. With the exception of the December collection, the infaunal assemblages at the Intake had the fewest number of species. Diversity, evenness, and the number of species at most subtidal sites sampled in 1979 were generally similar to those reported in 1978. However, a considerable change in mean diversity occurred between years at Jordan Cove (2.984 in 1978, 4.035 in 1979).

Intertidal - Species diversity at the Millstone intertidal stations were generally lower than those obtained for subtidal stations (Table 9). The mean diversity at Giants Neck was 2.68; diversity was lowest in December and highest in March. Average diversity at Jordan Cove was lower (1.244) than that of Giants Neck, because of the very low values obtained in March (.789) and June (.430). Evenness was higher throughout the year at Giants Neck ($\overline{x}$ = .730) than Jordan Cove ($\overline{x}$ = .484). The total number of individuals at both stations was highest in September and June and lowest in December and March.

During the past two years, diversity at the intertidal stations has fluctuated seasonally with no apparent patterns within stations. Diversity is generally more uniform and equitability higher at Giants Neck than

Jordan Cove; the latter is characterized by low evenness and large seasonal variations in diversity, abundance, and number of species.

The effects of the smaller mesh size (0.5 mm rather than 0.7 mm), used to process samples during the 1979 study, appeared to have little effect on diversity (Appendix 12). The differences observed between stations and years are probably not an artifact of sampling, but rather reflect real fluctuations in species composition.

Faunal Affinity

Subtidal - Over the entire year, species overlap between subtidal stations ranged from 38-49% (Table 10). Giants Neck and Jordan Cove shared the most species while Jordan Cove and Intake shared the fewest. Generally the highest species overlap between stations occurred in June and the lowest in December (Table 11). Giants Neck and Jordan Cove were most consistent in their faunal affinity throughout the 1979 sampling period. The faunal affinity between the Intake population and other sites was consistently low throughout the year and did not exceed 30%.

Temporal variations in species composition at each subtidal site were high, resulting in low faunal affinity (Table 12). Faunal affinity at Jordan Cove was most consistent, followed by the Effluent, Intake and Giants Neck. At Jordan Cove and Giants Neck, overlap generally exceeded 35%, while Effluent and Intake values were similar to each other and usually less than 35%.

Table 10. Macrobenthic faunal affinity among Millstone subtidal and among intertidal stations during the 1979 sampling period.

Subtidal

	GNS	JCS	EFS	INS
GNS		49	48	43
JCS			40	38
EFS				43
INS				

Intertidal

	JCI
GNI	24

Table 11. Seasonal macrobenthic affinity between sampling periods for each Millstone subtidal and intertidal station, September 1978-June 1979.

Subtidal

September 1978

	GNS	JCS	EFS	INS
GNS		46	28	28
JCS			32	30
EFS				24
INS				

December 1978

	GNS	JCS	EFS	INS
GNS		40	19	18
JCS			18	18
EFS				17
INS				

March 1979

	GNS	JCS	EFS	INS
GNS		38	26	23
JCS			32	27
EFS				18
INS				

June 1979

	GNS	JCS	EFS	INS
GNS		42	42	26
JCS			44	26
EFS				25
INS				

Intertidal

September 1978

	GNI
JCI	21

March 1979

	GNI
JCI	15

December 1978

	GNI
JCI	18

June 1979

	GNI
JCI	29

Table 12. Macrobenthic faunal affinity between sampling periods for each Millstone subtidal and intertidal station sampled, September 1978-June 1979.

Subtidal

Giants Neck

	Sept.	Dec.	Mar.	June
Sept.		35	49	44
Dec.			37	30
Mar.				38
June				

Jordan Cove

	Sept.	Dec.	Mar.	June
Sept.		42	39	42
Dec.			38	42
Mar.				40
June				

Effluent

	Sept.	Dec.	Mar.	June
Sept.		34	33	34
Dec.			32	28
Mar.				29
June				

Intake

	Sept.	Dec.	Mar.	June
Sept.		29	30	26
Dec.			25	25
Mar.				41
June				

Intertidal

Giants Neck

	Sept.	Dec.	Mar.	June
Sept.		58	44	64
Dec.			44	54
Mar.				40
June				

Jordan Cove

	Sept.	Dec.	Mar.	June
Sept.		12	11	18
Dec.			18	13
Mar.				23
June				

Intertidal - The faunal affinity between Giants Neck and Jordan Cove intertidal assemblages was 24% (Table 10). Variability in species composition between these sites resulted in low overlap throughout the year (Table 11). Affinity between sites decreased from September to March, then nearly doubled to 29% in June. Species overlap among seasonal collections was higher at Giants Neck (40-64%) then at Jordan Cove (11-23%).

COMMUNITY ANALYSIS

Numerical Classification of Stations

Classification of stations, based on faunal collections throughout the 1979 study, was performed to relate stations that had similar species composition and species abundance. Two distinct station clusters separated intertidal from subtidal sites (Fig. 4). On an annual basis, Jordan Cove, Giants Neck and the Effluent subtidal sites were faunistically similar and linked at around 60%. All pairwise comparisons of these sites using Spearman Rank Correlation revealed significant ($p < .10$) positive correlations in species abundances (Appendix 13). The fauna at Intake was most unique of all subtidal sites clustering at 34%. The only significant ($p < .10$) positive correlation was between the Intake and the Effluent. The annual infaunal populations of intertidal sites linked with each other at 42%, and the Spearman Rank Correlation Coefficient was not significant ($p < .10$).

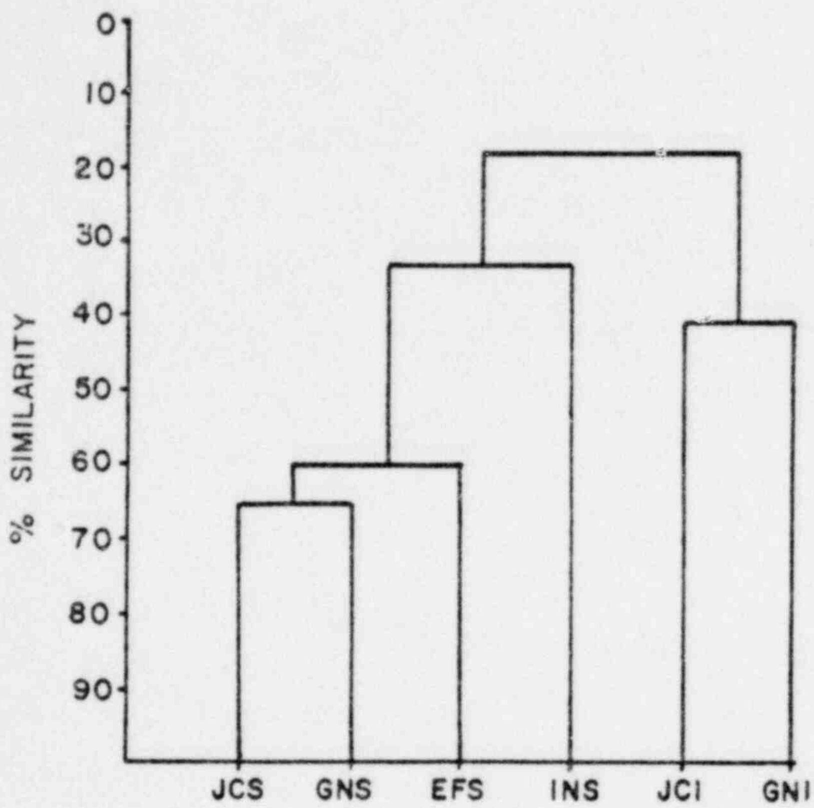

Figure 4. Dendrogram of similarity between ''llstone subtidal and intertidal stations based on macrofaunal collections during the 1979 sampling period.

Comparison of the stations by season yielded a dendrogram of two large groups that generally separated subtidal from intertidal sites, but no consistent seasonal relationships were apparent (Fig. 5). Within the subtidal group (A), the Jordan Cove and Giants Neck sites formed numerous pair-wise comparisons, linking between 40% and 50% similarity. Effluent collections in September and March were the most similar of all subtidal collections within Group A; however, seasonal variations of infaunal populations at this site resulted in large changes in similarity between Effluent collections and other subtidal samples. Two Intake collections, September and December, formed a station pair at 48% but these were considerably different from all other subtidal collections and linked with them at around 30%.

The second major group (B) was divided into two distinct clusters that exhibited low similarity to each other. The first of these groups (C) was composed of Giants Neck and Jordan Cove intertidal collections, and these showed a higher similarity within a station rather than between stations.

The second group (D) included both intertidal and subtidal stations. Two Intake samples formed the most similar pair-wise comparison (63%) and these were linked to the March intertidal collection from Giants Neck. Another unusual pair-wise group of September Giants Neck intertidal and December Giants Neck subtidal, linking at 45% similarity, was included in group D. Since the stations composing cluster D had low species numbers and low density, the presence of one organism in high abundance (*Capitella* spp.) at these sites greatly influenced their relationships with other stations.

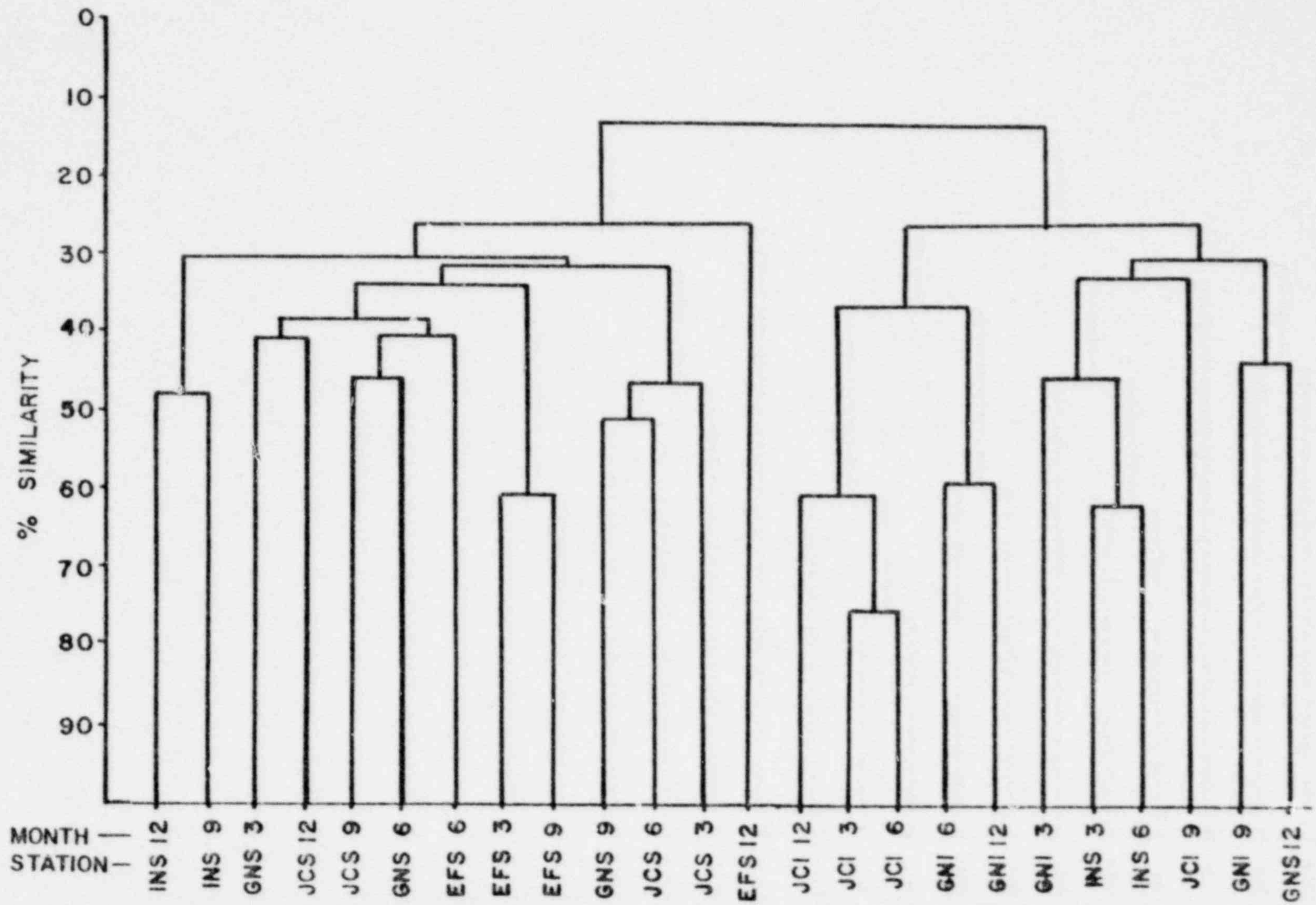

Figure 5. Dendrogram of similarity between Millstone subtidal and intertidal stations based on seasonal macrobenthic collections, September 1978-June 1979.

The relationship among subtidal stations in 1979 was somewhat different from that reported in the previous year, although the strong similarity between Jordan Cove and Giants Neck remained evident. During 1978, the Intake assemblage was closely associated with Jordan Cove and Giants Neck (50% similarity level); however, in 1979, the similarity between Intake, Jordan Cove and Giants Neck was less than 40%.

Numerical Classification of Species

Classification of the ten most abundant species was performed to identify similarities between species collected at each station over the entire year, and the dendrogram is presented in Figure 6; each species name is listed in Table 13. The clustering procedure resulted in two distinct faunal groups which separated subtidal (Group I) from intertidal (Group II) species. Higher similarity generally occurred among subtidal species groups than intertidal.

The subtidal cluster was subdivided into Groups A, which included species abundant only at the Intake, and Group B, which consisted of species common to more than one station. Additional subdivisions of Group B included a cluster of species that were numberically dominant and generally ubiquitous (Group D). Species in Groups E and F however, were less abundant and more restricted in their distribution, being found at generally less than two of the four sites.

The intertidal species cluster (II) also separated the numerically abundant forms, (Group G) from those of lower abundance (Group H). The

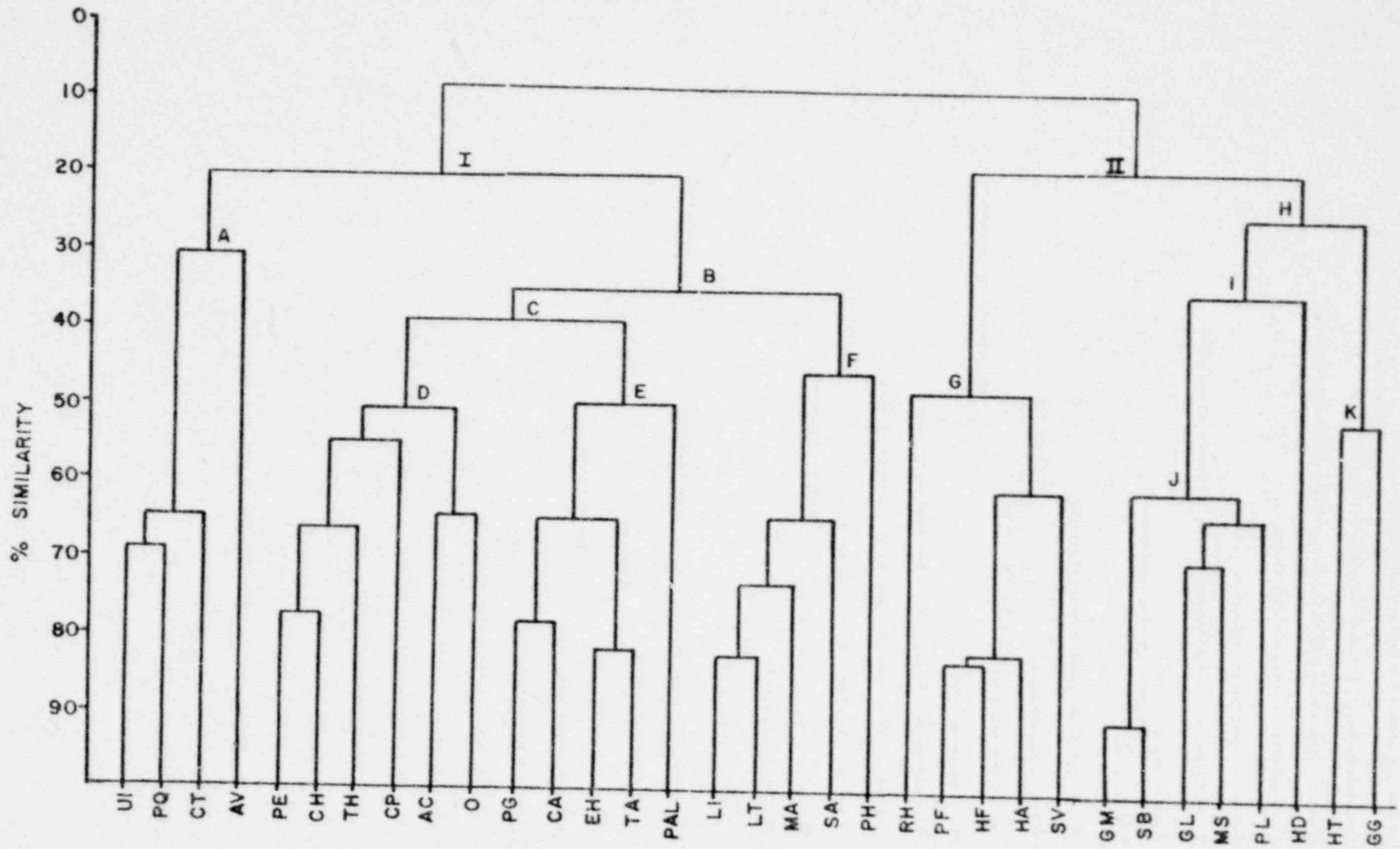

Figure 6. Dendrogram of similarity between the ten numerically abundant infaunal species collected at all Millstone subtidal and intertidal stations, September 1978-June 1979.

Table 13. Species names corresponding to codes used with inverse classification of subtidal and intertidal species collected at Millstone benthic stations sampled from Sept. 1978 - June 1979.

Species	Species
Gammarus mucronatus-GM	*Protodorvillea gaspeensis*-PG
Streblospio benedicti-SB	*Caullereilla spp.*-Ca
Gammarus lawrencianus-GL	*Exogone hebes*-EH
Microphthalmus sczelkowii-MS	*Tellina agilis*-TA
Polydora ligni-PL	*Parapionosyllis longicirrata*-PAL
Hediste diversicolor-HD	*Polycirrus eximius*-PE
Hydrobia totteni-HT	*Chaetozone spp.*-CH
Gemma gemma-GG	*Tharyx spp.*-TH
Paraonis flugens-PF	*Capitella spp.*-CP
Haploscolopolos fragilis-HF	*Aricidea catherinae*-AC
Haploscolopolos acutus-HA	*Oligochaeta*-O
Scolecolepides viridis-HV	*Unciola irrorata*-UI
Lumbrineris impatiens-LI	*Polydora quadralobata*-PQ
Lumbrineris tenuis-LT	*Clymenella torquata*-CT
Mediomastus ambiseta-MA	*Ampelisca verrilli*-AV
Sarsiella americana-SA	*Microphthalmus aberrans*-MI
Phoxocephalus holbolli-PH	*Owenia fusiformis*-OF
Rhynchocoela-RH	*Nucula proxima*-NP
Lyonsia hyalina-LH	

very low similarity between these groups is reflective of a spatial discontinuity in intertidal species distribution. Three of the five species in Group G and both species in Group K were numerically dominant only at Giants Neck. Group I was composed of six species, five of which (Group J) were abundant only at Jordan Cove and one species that was common at both intertidal sites.

Numerical Classification of Species by Station

Inverse cluster analysis for each subtidal and intertidal station was performed using the Bray-Curtis similarity coefficient, based on the ten numerically dominant species (Fig. 7). Stations were analyzed separately to eliminate differences in the spatial distribution of species thus maximizing the temporal relationships. The Biological Index Value was included as an indicator of species dominance.

Cluster analysis of the dominant species complement of each subtidal and intertidal site resulted in one large group (A) that linked with small species groups (B and C) at less than 50%. At the Giants Neck, Jordan Cove, and Effluent subtidal sites, the large group (A) included species that varied seasonally in abundance, as reflected by low BIV's. The variable species linked with the more consistently abundant ones between 40-47%.

In contrast the large species group (A) at the Intake site was composed of eight species that were generally dominant throughout the year.

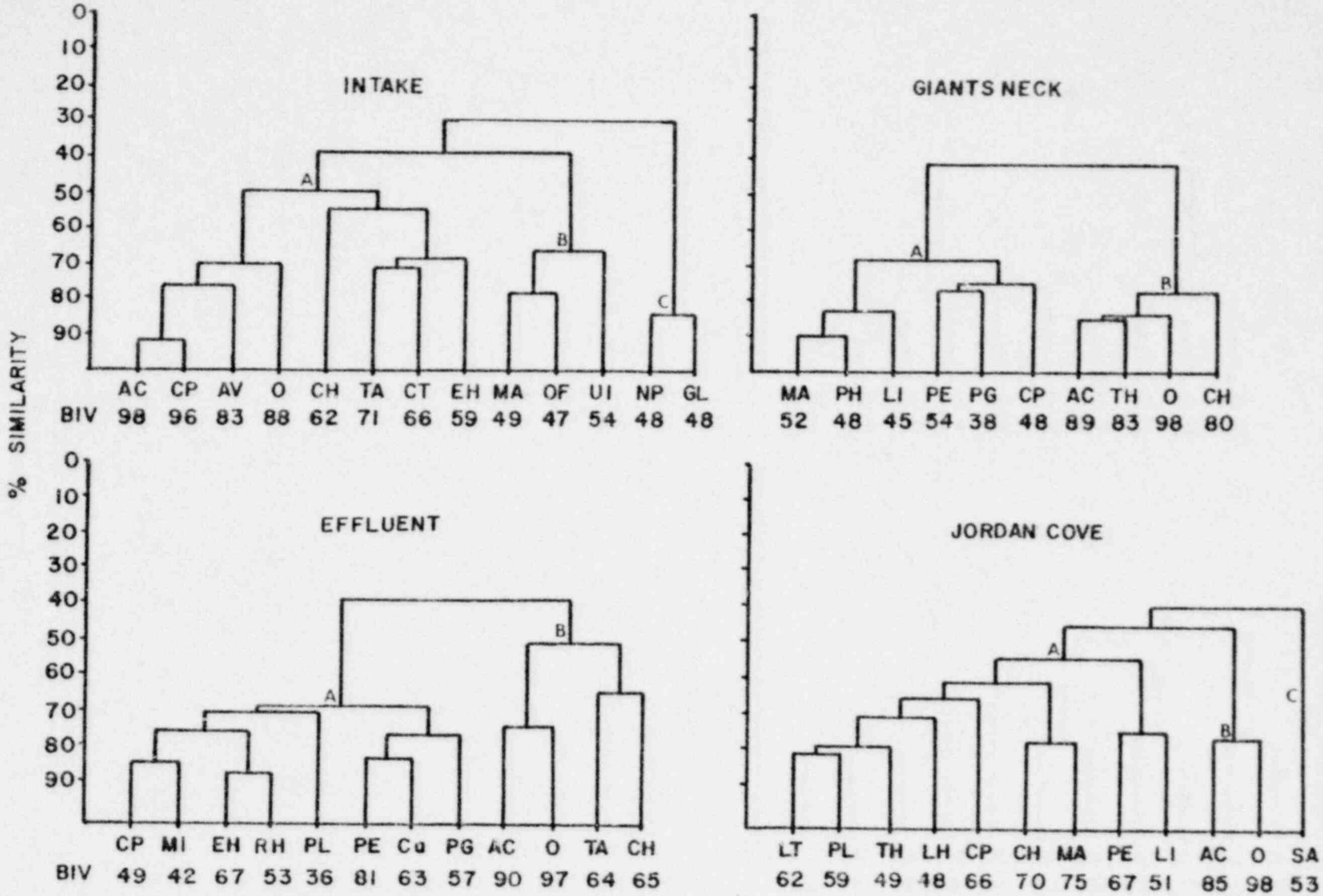

Figure 7. Dendrogram of similarity between the ten numerically abundant infaunal species collected at each Millstone subtidal station from Sept. 1978–June 1979.

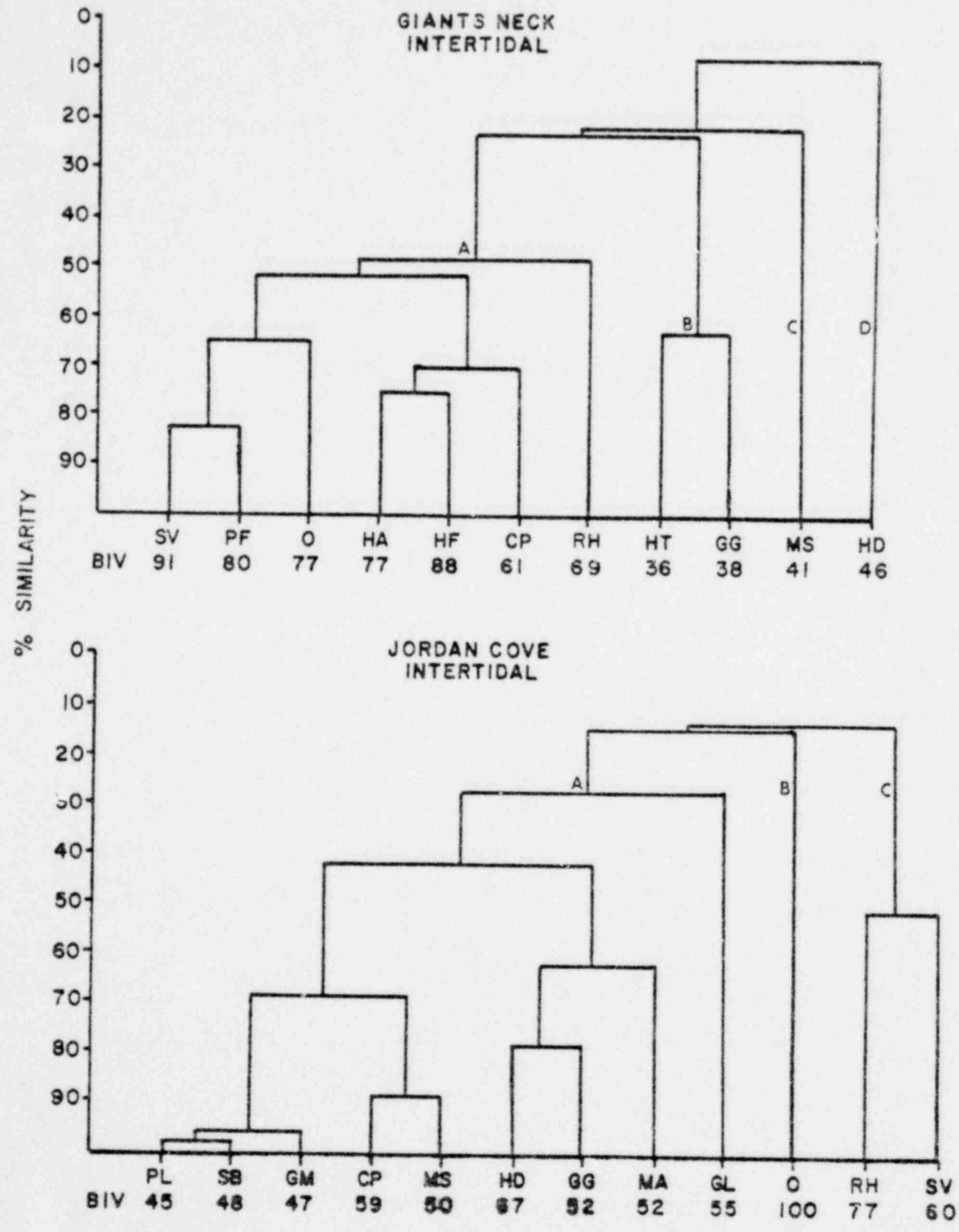

Figure 8. Dendrogram of similarity between the ten numerically abundant infaunal species collected at each Millstone intertidal station from Sept. 1978-June 1979.

At the Jordan Cove intertidal site the abundance of most species was seasonally variable resulting in a large species group (A) that had low BIV's (Fig. 8). In contrast, Giant's Neck species formed a large cluster (A) composed of seven consistently dominant species.

DISCUSSION

The benthic communities of the Millstone Point area are heterogenous assemblages that are numerically dominated by deposit feeding annelids. The dominant feature of this community are the large fluctuations in species density and composition that occur among stations and between sampling periods. These fluctuations are characteristic of shallow water infaunal assemblages (Coe 1956; Sanders 1960, Maurer, Leathem, Kinner and Tinsman 1979).

Seasonal variability of benthic infaunal density and composition in Long Island Sound has been attributed to an unpredictable physical environment (Sanders 1968), however, the importance of biological factors has also been stressed (Rhoads and Young 1970, Rhoads et al. 1978). McCall (1975) related the temporal variability of Long Island Sound polychaete assemblages to continual disturbances of the local seafloor. Biernbaum (1979) attributed seasonal fluctuations in amphipod populations to changes in sediment texture, and Franz (1976) reported that fluctuations in molluscan abundance were related to physical and biological factors affecting survival of larval and post-larval stages.

Subtidal - Despite the large temporal fluctuations in density and species composition at our sites, some distinct differences were evident among the subtidal stations. The infaunal community at Giants Neck was unique because of the presence of high densities of Tharyx and other cirratulid species. The sediment composition at Giants Neck was also different from other sites, being of smallest grain size and containing the highest percentage of silt. This site was located near rocky outcrops that supported large numbers of the blue mussel, Mytilus edulis, and as a result large amounts of broken shell become incorporated into local sediments. This shell might help stabilize the sediment, by reducing current velocities across the sediment-water interface, and thus allow settling of fine silty material. A relationship between high abundances of cirratubid species, including Tharyx, and pockets of silty material has been described by Jumars (1975). A shell-sediment habitat also occurred at the Effluent, where large numbers of empty gastropod shells occurred in the sediment; however, silt content of Effluent sediments was consistently lower than that of Giants Neck sediments. Although high densities of the cirratulid, Chaetozone spp., occurred at the Effluent in September, silt content was very low (0.1%), thus any strict relationship between the abundance of this species and silt content at this site remains unclear.

The Jordan Cove subtidal station was most affected by variations of the physical environment. Sediment grain size and silt content varied at this site during the year, possibly reflecting seasonal changes in wind direction and sediment transport patterns. An increase in grain size and a decrease in silt content occurred in September when frequent storms and northwesterly winds occurred. This scouring effect was of short duration, and grain size decreased and silt content increased again by December. The changes in sediment composition at Jordan Cove resulted in a benthic fauna that varied in density and composition.

The species assemblage at the Intake station was different from other sites because of the high abundance of suspension feeders and low abundance of deposit-feeders. Strong tidal currents in this area (NUSCO 1976; Stone and Webster 1977), were probably responsible for enhancing the development of a suspension feeding community. The removal of organic material by currents could also inhibit the development of infaunal populations, requiring deposited organic matter (Wildish and Krishmanson 1979) as a food source, and this may explain the low abundance of oligochaetes in this area. Species such as Aricidea catherinae, which ingest sand grains, proliferated at this station despite the strong currents.

Although the subtidal community characteristics of density, biomass, and diversity were within the ranges reported for other East Coast studies (Sanders 1960; Phelps 1964; Orth 1973; Normandeau 1977; Maurer et al. 1978; Maurer, Leathem, Kinner and Tinsman 1979), the species composition was different. Sanders (1956) described a typical benthic community in Western Long Island Sound as being dominated by Nepthys incisa and Yoldia limatula; these species were generally most abundant at depths of 4-30m in areas, where silt-clay content exceeded 25%. McCall (1975) described an additional species assemblage in this area, dominated by Capitella capitata, Streblospio benedicti, and Ampelisca vadorum. He considered these species capable of rapidly re-colonizing areas recently disturbed by physical or biological factors. The differences between the benthic infaunal communities at Millstone stations and those of other researchers in LIS may be related to the lower silt-clay fractions in the Millstone area caused by the strong tidal currents (NUSCO 1976; Stone and Webster 1977). However, the silt-clay component of the sediments cannot alone explain the absence of the Nepthys-Yoldia assemblage at the Giants Neck site, since silt-clay content at this site was considerably higher than that reported by Sanders (1956) as necessary for the development of this type of community. The presence of Mytilus shell in the sediments at this station may be a primary factor preventing the establishment of a population of burrowing deposit feeding species. Several researchers have reported reductions in populations of burrowing deposit feeders when suitable sediment area is reduced by the presence tube dwelling polychaetes (Fager 1964; Rhoads and Young 1970; Woodin 1974), and it is possible that the incorporation of Mytilus shells into the sediments at Giants Neck may act in a similar manner.

Intertidal - Intertidal communities are exposed to more extreme variations in temperature, salinity and wave action. This high energy environment strongly influences the structure of intertidal communities (Sanders 1968; Holland and Dean 1977; Whitlatch 1977). Studies of exposed intertidal sandy beaches have reported high abundances of haustoriid amphipods (Dexter 1969; Croker 1978; Eleftheriou and Nicholson 1975; Croker et al. 1974) while polychaetes and molluscs become abundant in sheltered areas (Whithes and Thorp 1978). The annelid dominated assemblages found at Jordan Cove and Giants Neck were more typical of those found on more sheltered sandy beaches exposed to intermediate wave action.

The range of species diversity at Millstone intertidal sites was similar to that of amphipod dominated communities (Croker 1978; Normandeau 1977; Gray 1974; Croker et al. 1974; Dexter 1969) but much lower than that of polychaete dominated mudflat areas (Sanders et al. 1962). The strong spatial differences in species composition between Millstone intertidal sites is probably a reflection of the contrasting sediment composition of these stations. Sediment composition at Giants Neck was consistent over the year with very low amounts of silt-clay and the infaunal community was dominated by species that ingest sand grains. In contrast, the seasonally varying Jordan Cove sediments, with higher amounts of silt-clay and detritus supported a community dominated by a few highly abundant species that were more dependent on organic detritus.

POWER PLANT INPACTS

During 1979, no changes in the Millstone area subtidal or intertidal infaunal communities coult be attributed to operation of the Millstone Nuclear Power Station. Changes in infaunal density and species composition between 1979 and the previous year were believed to be natural fluctuations, which are characteristic of shallow, subtidal and intertidal communities exposed to the physically unpredictable environment in the Millstone Point area.

LITERATURE CITED

Aller, R. C. 1978. Experimental studies of changes produced by deposit feeders on pore water, sediment, and overlying water chemistry. Am. J. Sci. 278:1185-1234.

Battelle-William F. Clapp Laboratories. 1975. A monitoring program on the ecology of the marine environment of the Millstone Point, Connecticut area. Annual report for the year 1975. Presented to Northeast Utilities Service Company.

Battelle-William F. Clapp Laboratories. 1978. A monitoring program on the ecology of the marine environment of the Millstone Point, Connecticut area. Annual report for the year 1978. Presented to Northeast Utilities Service Company.

Biernbaum, C. K. 1979. Influence of sedimentary factors on the distribution of benthic amphipods of Fishers Island Sound, Connecticut. J. exp. mar. Biol. Ecol. 38:201-223

Boesch, D. F. 1973. Classification and community structure of macrobenthos in the Hampton Roads area, Virginia. Mar. Biol. 21:226-244.

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. E.P.A. Environ. Res. Ser. EPA-600/3-77-033. 155pp.

Cairns, J. Jr. 1976. Heated waste-water effects on aquatic systems. Pages 32-38 in G. W. Esch and R. W. McFarlane, eds. Thermal Ecology II ERDA symposium Ser. (Conf.-750425) Apr. 2-5, 1975. Augusta, Georgia. 404pp.

Clifford, H. T. and W. Stevenson. 1975. An introduction to numerical classification. Academic Press, New York. 229pp.

Coe, W. R. 1956. Fluctuations in populations of littoral marine invertebrates. J. Mar. Res. 15:212-232.

Connell, J. H. 1975. Some mechanisms producing structure in natural communities : A model and evidence from field experiments. Pages 460-490 in M. Cody and J. Diamond, eds. Ecology and evolution of communities. Harvard University Press, Cambridge, Mass.

Croker, R. A. 1978. Macrofauna of Northern New England marine sand: Long-term intertidal structure. Pages 439-450 in B. C. Coull ed. Ecology of marine benthos. Univ. of South Carolina Press, Columbia, S.C. 467pp.

Croker, F. A., R. P. Hager and K. J. Scott. 1974. Macrofauna of Northern New England marine sand. II. Amphipod-dominated intertidal communities. Can. J. Zool. 53:42-51.

Dexter, D. M. 1969. Structure of an intertidal sandy-beach community in North Carolina. Chesapeake Sci. 2:93-99.

Eleftheriou, A. and M. Nicholson. 1975. The effects of exposure on beach fauna. Can. Biol. Mar. 16:695-710.

Fager, E. W. 1964. Marine sediments: Effects of a tube-building polychaete. Science 143:356-359.

Fauchald, K. and P. A. Jumars. 1979. The diet of worms: A study of polychaete feeding guilds. Oceanogr. Mar. Biol. Ann. Rev. 17:193-284.

Folk, D. 1974. Petrology of sedimentary rocks. Hemphill Publishing Company, Texas. 182pp.

Franz, D. 1976. Benthic molluscan assemblages in relation to sediment gradients in northeastern Long Island Sound, Connecticut. Malacologia 15:377-399.

Gray, J. S. 1974. Animal-sediment relationships. Oceanogr. and Mar. Biol. 12:223-262.

Greig-Smith, P. 1964. Quantitative plant ecology, 2nd Ed. Washington Butterworths 265pp.

Holland, A. F. and J. M. Dean. 1977. The community biology of intertidal macrofauna inhabiting sandbars in the north inlet area of South Carolina, U.S.A. Pages 423-437 in B. C. Coull ed. Ecology of marine benthos. Univ. South Carolina Press, Columbia, S.C. 467pp.

Jumars, P. A. 1975. Target species for deep-sea study in ecology, genetics and physiology. Zool. J. Linn. Soc. Lond. 54:101-135.

Magnum, C. P. 1964. Activity patterns in metabolism and ecology of polychaetes. Comp. Biochem. Physiol. 14:239-256.

Maurer, D., L. Watling, P. Kinner, W. Leathem and C. Wethe. 1978. Benthic invertebrate assemblages of Delaware Bay. Mar. Biol. 45:65-78.

Maurer, D., W. Leathem, P. Kinner and J. Tinsman. 1979. Seasonal fluctuations in coastal benthic invertebrates. Estuar. Coastal Mar. Sci. 8:181-193.

Maurer, S., L. Watling, W. Leathem and P. Kinner. 1979. Seasonal changes in feeding types of estuarine benthic assemblages from Delaware Bay. J. exp. mar. Biol. Ecol. 36:125-155.

McCall, P. L. 1975. The influence of disturbance on community patterns and adaptive strategies of the infaunal benthos of central Long Island Sound. Ph D. Thesis Yale Univ. New Haven, Conn. 198pp.

McCloskey, L. R. 1970. The dynamics of the community associated with a marine sclceractinian coral. Intern. Rev. Ges. Hydrobiologie 55:13-81.

Normandeau Associates, Inc. 1977. Seabrook Benthic Report. Tech. Rep. VII-6 for the Public Service Company of New Hampshire, Normandeau Associates Inc., Bedford, New Hampshire. 437pp.

NUSCO 1976. Environmental assessment of the condensor cooling water intake structures (316 b Demonstration), Volumes 1 and 2, submitted by Northeast Utilities to Connecticut Dept. Environmental Protection.

Orth, R. J. 1973. Benthic infauna of eelgrass, Zostera marina, beds. Chesapeake Sci. 14:258-269.

Paine, R. T. 1974. Intertidal Community Structure-Experimental studies on the relationships between a dominant competitor and its principal predator. Oecologia 15:93-120.

Paine, R. T. and R. L. Vadas. 1969. The effects of grazing by sea urchins, Strongylocentrotus spp., on benthic algal populations. Limnol. Oceanogr. 14:710-719.

Peterson, C. C. J. 1918. The sea bottom and its production of fish food. Rept. Dan. Biol. Sta. 62p.

Phelps, D. K. 1964. Functional relationships of benthos in a coastal lagoon. Ph D. Thesis, Univ. of Rhode Island. 146pp.

Pielou, E. C. 1977. Mathematical Ecology. Wiley-Interscience. New York 385 pp.

Reish, D. J. 1960. The use of marine invertebrates as indicators of water quality. Pages 92-103 in E. A. Pearson ed. Proc. 1st Intern. Conf. on Waste Disposal in the Marine Environment. Pergamon Press, Oxford.

Rhoads, D. C. and D. K. Young. 1970. The influence of deposit-feeding organisms on sediment stability and community trophic structure. J. Mar. Res 28:150-178.

Rhoads, D. C., J. Y. Yingst and W. Ullman 1978. Seafloor stability in central Long Island Sound: I. Seasonal changes in erodability of fine-grained sediments, Pages 221-224 in M. Wiley ed., Estuarine Interactions, Academic Press, New York.

Richards, S. W. and G. A. Riley. 1967. The benthic epifauna of Long Island Sound. Bull. Bingham Oceanogr. Coll. 19:89-735.

Sanders, H. L. 1956. Oceanography of Long Island Sound 1952-1954. X. The biology of marine bottom communities. Bull. Bingham Oceanogr. Coll. 15:345-414.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft-bottom community. Limnol. Oceanogr. 5:138-153.

Sanders, H. L. 1968. Marine Benthic diversity: A comparative study. Am. Nat. 102:243-282.

Sanders, H. L., E. M. Gouldsmit, E. L. Mills, and G. E. Hampson. 1962. A study of the intertidal fauna of Barnstable Harbor, Massachusetts. Limnol. Oceanogr. 7:63-79.

Sanders, H. L., R. R. Hessler and G. R. Hampson. 1965. An introduction to the study of deep-sea benthic faunal assemblages along the Gay Head-Bermuda transect. Deep-Sea Res. 12:845-867.

Smith, K. 1971. Structural and functional aspects of a sublittoral community. Ph D. Thesis. Univ. of Georgia. 159pp.

Stone and Webster Engineering Corporation, 1977. Siltation studies -Phase II. Millstone Nuclear Power Station - Unit 3. Nerm-44. 27pp.

Wade, B. A. 1972. A description of a highly diverse soft-bottom community in Kingston Harbour, Jamaica. Mar. Biol. 13:57-69.

Whitlatch, R. B. 1977. Seasonal changes in the communit. structure of the macrobenthos inhabiting the intertidal sand and mud flats of Barnstable Harbor, Massachusetts. Bio. Bull. 152:275-294.

Wildish, D. J. and D. D. Kristmanson. 1979. Tidal energy and sublittoral macrobenthic animals in estuaries. J. Fish. Res. Board Can. 36:1197-1206.

Wilhm, J. L. 1970. Range of diversity index in benthic macroinvertebrate populations. J. Wat. Poll. Control Fed. 42:221-224.

Wilhm, J. L. and T. C. Dorris 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. Am. Midl. Nat. 76:427-449.

Withers, R. G. and C. H. Thorp. 1978. The macrobenthos inhabiting sandbanks in Langstone Harbour, Hampshire. J. Nat. Hist. 12:445-455.

Woodin, S. A. 1974. Polychaete abundance patterns in a marine soft-sediment environment: The importance of biological interactions. Ecol. Monogr. 44:171-187.

Woodin, S. A. 1978. Refuges, Disturbance and Community Structure: A marine soft-bottom example. Ecology 59:274-284.

Yeo, R. K. and M. J. Risk. 1979. Intertidal Catastrophes: Effects of storms and hurricanes on intertidal benthos of Minas Basin, Bay of Fundy. J. Fish. Res. Board Can. 36:667-669.

LOBSTERS

LOBSTER POPULATION DYNAMICS

INTRODUCTION

The American Lobster, Homarus americanus, is an important commercial and sport species of the Millstone Point region. As such, it is necessary to monitor the population characteristics and standing crop to identify any possible impacts by the operation of the Millstone Nuclear Power Station. There are three potential sources of impact attributable to plant operation: impingement of post-larval lobsters on the intake traveling screens, entrainment of larvae through the cooling water intake system, and possible thermal effects of the heated effluent waters (e.g. varying growth rates, aberrant molting or movement patterns).

The lobster population has been monitored with varying degrees of effort since 1969 (Battelle 1978). During the past four years, intensive sampling programs have been conducted to measure population characteristics and estimate population size using tag and recapture techniques. Since 1976, almost 16,000 lobsters have been captured and pertinent measurements taken.

Although the lobster has been extensively studied throughout much of its range, few long-term investigations have been undertaken within Long Island Sound (LIS). Stewart (1972) studied the movements, population dynamics, and ecology of lobsters in a small area of Fisher's Island Sound; Lund, Stewart, and Rathbun (1973) inventoried lobster habitat and gathered data on lobster movements throughout the Sound; Smith (1977) described population characteristics in LIS and socioeconomic aspects of the commercial fishery along the Connecticut coast; Briggs and Mushacke (1979) published results of a three-year study on selected population characteristics of lobsters in western LIS.

If there is significant impact of the Millstone Power Plant on the local lobster population, then this should manifest itself by altering the standing crop and/or population characteristics in the area. Efforts are made to compare population characteristics with those of surrounding areas and identify any temporal changes.

MATERIALS AND METHODS

To effectively sample the area lobster population, three stations were established surrounding Millstone Point: Jordan Cove, east of Millstone Point; Intake, along the western shore of Millstone Point near the power plant intake structures; and Twotree, about 1.6 kilometers offshore near Twotree Island (Fig. 1.). These three stations were chosen because they were dominated by rocky outcroppings and as such were the most suitable lobster habitat in the area.

In May 1979, twenty commercial lobster pots (10 metal and 10 wood) were placed at each station. Wooden lath pots (3-5cm lath spacing) and metal wire pots (2.5cm x 2.5cm mesh) were fished in trawls consisting of 5 pots strung between two marker bouys. For the first half of the study (May through July) each station was fished with two wood pot trawls and

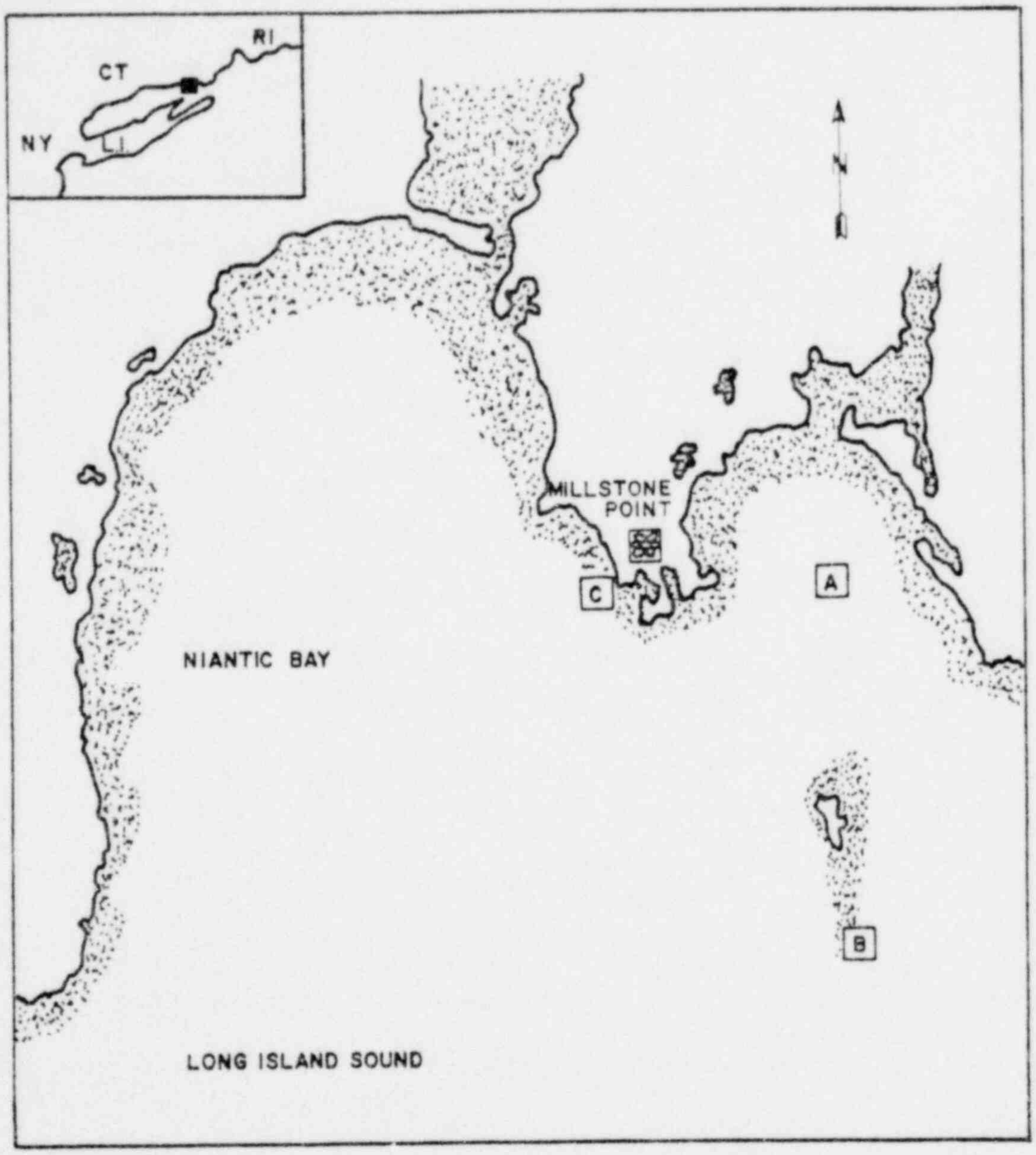

Figure 1. Location of Millstone Nuclear Power Station and the three lobster sampling stations: A=Jordan Cove, B=Twotree, C=Intake.

two metal pot trawls. For the remainder of the study (August through October), wood and metal pots were alternated on each trawl. The trawls were hauled on Monday, Wednesday, and Friday, weather permitting.

At each station, all lobsters were removed from pots, claws restrained with rubber bands, and pots rebaited. To standardize the effect of bait on catchability, flounder carcasses were used throughout the study. Carapace length (CL), sex, presence of eggs (berried), crusher and pincher claw position, missing claws, and molt stage were recorded for all lobsters captured. Criteria of Aiken (1973) were used in determining molt stage. Recaptured tagged lobsters, severely injured individuals, and those less than 55mm CL were returned to the water. All others were taken to the laboratory and held in separate continuous flow saltwater tanks according to station caught and pot type used. Each Friday, all lobsters collected that week were tagged with a numbered, international orange sphyrion tag as described by Scarrett (1970), and returned to the site of capture.

The size of the local lobster population was estimated using the method of Jolly (1965) as modified by Seber (1965). This multiple census method uses tag and recapture data collected from an open population in which recruitment, immigration, mortality, and permanent emigration are operable.

At each station, prior to pots being pulled, surface and bottom water temperatures and salinities were recorded with a Beckman salinometer. General sea and weather conditions were noted.

Methods for collection of lobsters impinged on the intake traveling screens are described in Section 2. Collection of lobster larvae from entrainment samples are described in Section 3.

RESULTS AND DISCUSSION

Physical Measurements

Based on measurements taken during each sampling trip, monthly mean surface temperatures and salinities and mean bottom temperatures and salinities were calculated for each station (Table 1). Bottom water temperatures ranged from about 7°C early in May to over 20°C during the summer months. Surface water temperatures were up to 2.1°C higher than bottom temperatures. Water temperatures at our two shallowest stations, Jordan Cove and Intake (4-6 meters in depth), were similar. Twotree, the deepest station (about 12 meters in depth), consistently had the lowest water temperatures (surface and bottom). Surface water salinities differed slightly from bottom water salinities and neither varied appreciably between stations nor throughout the study. Due to the spring freshwater runoff, salinities were lowest in May and June. These data show a pronounced seasonal change in water temperature throughout the Millstone Point area, but very little change in salinity.

Area Population Characteristics

Catch per Unit Effort - In 1979, 5,031 lobsters were caught in the Millstone Point region. Catch per unit effort (CPUE) was 123 lobsters per 100 pots hauled. In 1978, 4,371 lobsters were caught with a CPUE of 76 lobsters. Monthly CPUE for total catch (lobsters of all sizes) and for legal catch (lobsters greater than 81mm CL) was calculated for each station and for each pot type (Table 2).

Table 1. Monthly mean water temperature (°C) and salinity (0/00) of surface (S) and bottom (B) waters at each station in 1979.

Temperature (°C)

	Jordan Cove		Intake		Twotree	
	S	B	S	B	S	B
May	10.3	9.5	10.5	9.5	9.9	9.2
June	15.0	14.2	15.2	14.4	14.5	13.9
July	19.9	17.8	19.2	18.3	18.3	17.7
August	20.6	19.6	20.2	19.8	19.7	19.2
September	19.8	19.2	19.8	19.3	19.2	18.9
October	17.0	15.9	15.8	15.7	15.6	15.5

Salinity (0/00)

	Jordan Cove		Intake		Twotree	
	S	B	S	B	S	B
May	29.1	29.9	29.2	29.8	29.3	30.0
June	29.2	29.7	29.3	29.5	29.0	30.0
July	30.0	29.9	30.1	30.1	29.8	30.2
August	30.2	30.4	30.5	30.6	30.5	30.7
September	30.8	30.5	30.8	30.7	30.8	31.0
October	30.8	30.9	30.8	30.8	30.9	31.0

Table 2. Monthly catch per unit effort (per 100 pot hauls) for total catch and legal catch (carapace length $\geq$ 81mm) for wood and metal pots at each station in 1979.

JORDAN COVE

	Total Catch		Legal Catch	
	Wood	Metal	Wood	Metal
May	82	124	4	3
June	108	188	21	12
July	134	281	21	36
August	101	227	12	10
September	77	173	7	10
October	70	132	9	10

INTAKE

	Total Catch		Legal Catch	
	Wood	Metal	Wood	Metal
May	59	112	1	6
June	93	194	17	20
July	142	182	30	26
August	129	191	22	18
September	91	181	13	5
October	43	134	4	4

TWOTREE

	Total Catch		Legal Catch	
	Wood	Metal	Wood	Metal
May	117	161	12	8
June	108	166	16	12
July	96	122	19	13
August	55	73	10	9
September	40	100	10	13
October	51	71	13	12

A multiway analysis of variance was performed on these data to test for significant (α=0.5) differences between CPUE for the 6 months sampled, for the three stations, and for the two pot types (Table 3). For total catch, the CPUE varied significantly with month, but the month with the highest CPUE varied with the station. At Jordan Cove and Intake the catch peaked during June through August, while at Twotree catch peaked during May and June. Total catch varied significantly between stations with Jordan Cove having the highest CPUE and Twotree the lowest. Metal pots caught significantly more lobsters than wood pots.

For legal-sized individuals, CPUE varied significantly with month. As with total catch, the legal catch varied significantly between stations. At all three stations, the legal CPUE peaked in July, but it subsequently declined at Jordan Cove and Intake. At Twotree the legal CPUE was more consistent throughout the sampling. There was no significant difference in the legal catch between stations or between metal and wood pots.

The increased catch per unit effort this year over 1978 was most likely due to a reduction in the number of months that sampling occurred and to the increased use of metal pots. In 1978, sampling was conducted from January through November. A change to sampling during the optimal catch months of May through October in 1979 resulted in the observed higher fishing efficiency. Metal pots were only used from August through November in 1978; in 1979 they were used throughout the study. The metal pots with a 2.5cm x 2.5cm mesh prevent the escape of smaller lobsters that are able to escape through the 3-5cm gap in the laths of the wood pots. Similar results were reported by Krouse (1973, 1976) and

Table 3. Multiway analysis of variance on catch per unit effort for total catch and legal catch (carapace length $\geq$ 81mm) for 1979.

TOTAL CATCH

Source of Variation	df	SS	MS	F
Model	20	100171.49	5008.57	11.93**
Month	5	21987.76	4397.55	10.47**
Station	2	12877.80	6438.90	15.34**
Pot Type	1	41227.21	41227.21	98.20**
Month X Station	10	19477.34	1947.73	4.64**
Station X Pot Type	2	4601.37	2300.69	5.48*
Error	15	6297.61	419.84	
Corrected Total	35	106469.10		

LEGAL CATCH

Source of Variation	df	SS	MS	F
Model	20	1770.08	88.50	5.91**
Month	5	1285.23	257.05	17.16**
Station	2	16.00	8.00	0.53
Pot Type	1	5.70	5.70	0.38
Month X Station	10	443.66	44.37	2.96*
Station X Pot Type	2	19.49	9.75	0.65
Error	15	224.70	14.98	
Corrected Total	35	1994.78		

* $P < .05$
** $P < .01$

by Battelle (1978). Krouse (1971) reported that lobsters between 68-70mm CL were fully vulnerable to metal pots while with wood pots only individuals greater than 85mm CL. Although we would expect metal pots to catch more lobsters in the 81-85mm CL range, our data does not support this contention.

The positive relationship between catch and water temperature is well established (McLeese and Wilder 1958; Dow 1966, 1967, 1976, 1977; Cooper and Uzmann 1971; Flowers and Saila 1972; Dow, Bell, and Harriman 1975). Weekly catch per unit effort and mean weekly bottom temperature were plotted together to show their relationship (Fig. 2). At Jordan Cove and Intake a significant positive correlation was found (Spearman rank correlation, $P < .05$). However, at Twotree the catch was significantly negatively correlated with bottom water temperature. In their laboratory experiments McLeese and Wilder (1958) demonstrated that the activity of lobsters in Canada was low at temperatures less than $10^{\circ}C$ and increased at temperatures above $10^{\circ}C$. In our field study, as temperatures increased past $10^{\circ}C$, catch began to increase at Jordan Cove and Intake and peaked at temperatures between $15^{\circ}C$ and $20^{\circ}C$. At Twotree, the peak catches were highest between $7^{\circ}C$ and $15^{\circ}C$. Since catches at Twotree decreased as they increased at Jordan Cove and Intake, the movement of lobsters from Twotree to our inshore stations is a plausible explanation. Our movement data does not, however, support this hypothesis. If lobsters are moving, they are more likely moving offshore. Further examination of the data is needed to support this contention.

Size Frequencies - The size distribution of lobsters caught in the Millstone Point area are presented in Fig. 3. Sizes ranged from 44-100mm CL

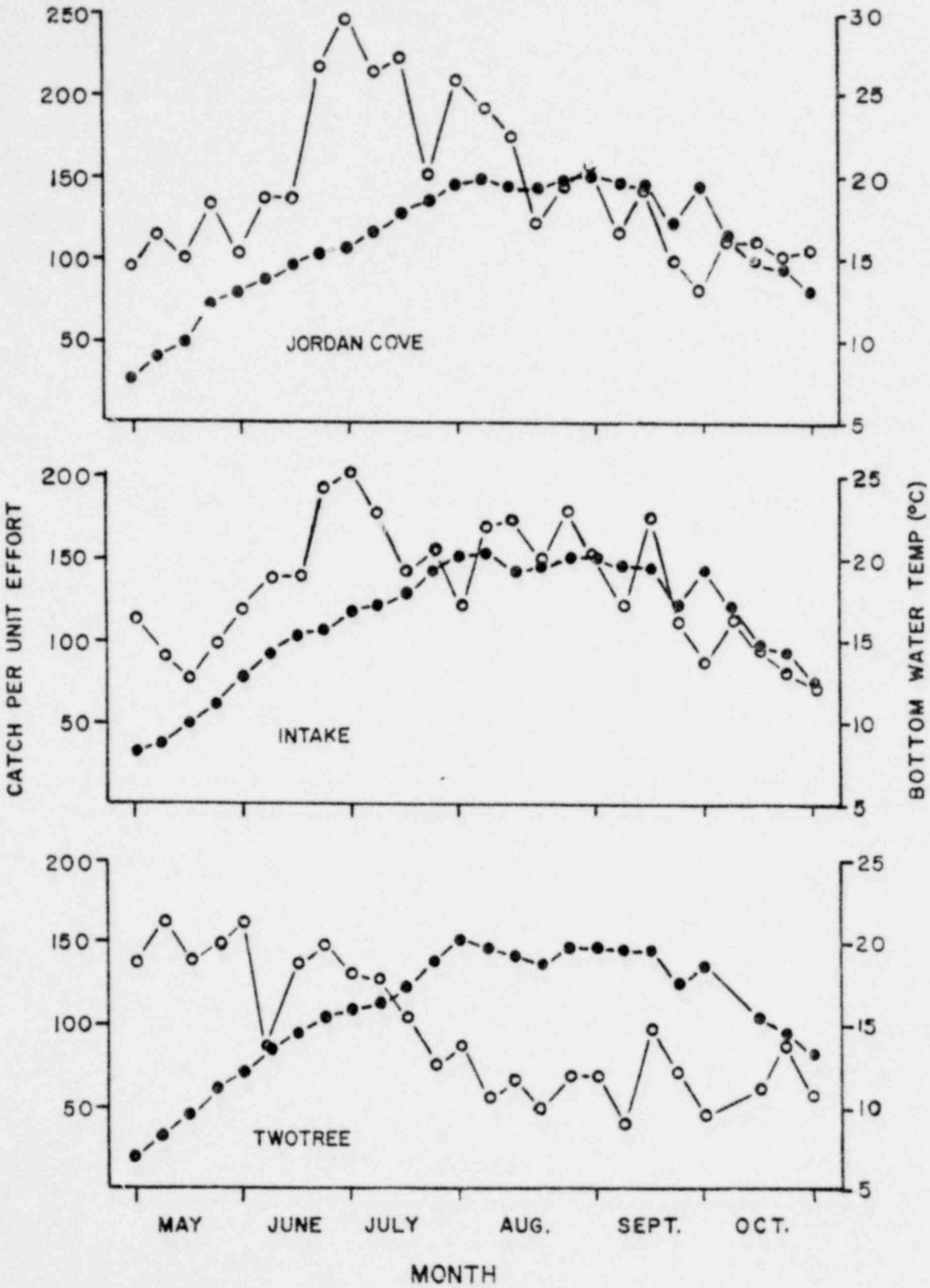

Figure 2. Catch per unit effort (O—O) and bottom water temperature (●—●) by month for each station in 1979.

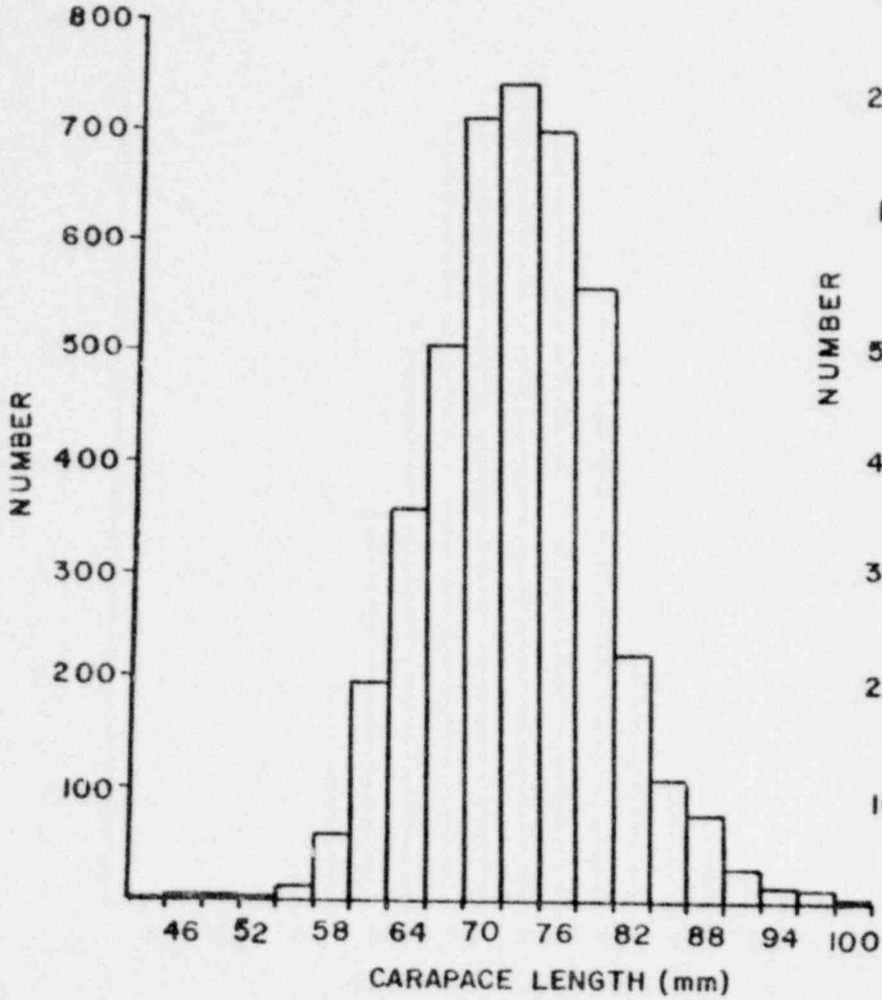

Figure 3. Size distribution for all lobsters caught in 1979.

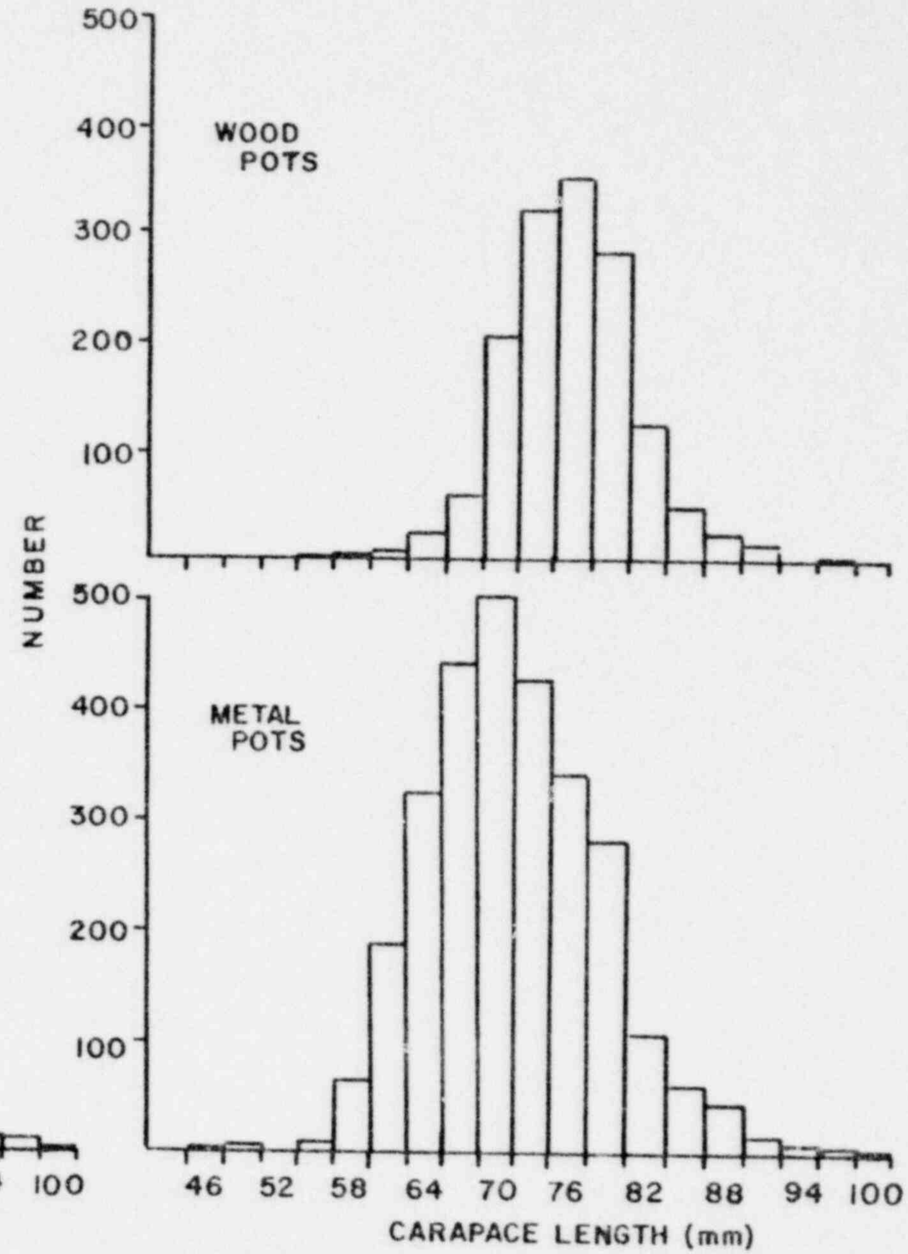

Figure 4. Size distribution of lobsters caught in wood pots and metal pots in 1979.

with a mean CL for all lobsters of 72.7mm. Legal-sized individuals ($\geq$ 81mm CL) comprised 10.7% of the total catch. Assuming a growth per molt of 13% in carapace length, 92% of the legals could have come into the fishery on the previous molt (i.e., newly recruited individuals).

The catch of the two types of sampling gear, wood and metal pots, were of different size distributions (Fig. 4). These differences were significant (Kolmogorov-Smirnov test, $P<.05$), with the metal pots having a greater proportion of smaller lobsters in their catch. The mean CL of lobsters caught in the metal pots was 71.2mm and was 75.6mm in the wood pots.

There were no significant differences in the size distributions of lobsters caught at each station (Fig. 5). At Twotree the mean carapace length was 73.3mm; at Jordan Cove and Intake the means were 72.2 and 72.9, respectively. Twotree had slightly more legal-sized lobsters with 11.6% of the catch, while Intake had 11.1% and Jordan Cove 9.7%.

The size distribution has changed little from the catch of last year (Battelle 1978). This year there were more individuals in the smaller size classes than last year, largely resulting from the increased use of metal pots. Smith (1977) calculated the average carapace length at about 79mm in an area of LIS east of the Connecticut River. Briggs and Mushacke (1979) working in western LIS calculated the average carapace length at about 77mm in the catch they examined. From our wood pots (the type used by Smith and by Briggs and Mushacke) the average was 75.6mm. Marcello, Davis, O'Hara and Hartley (1979) in their investigation

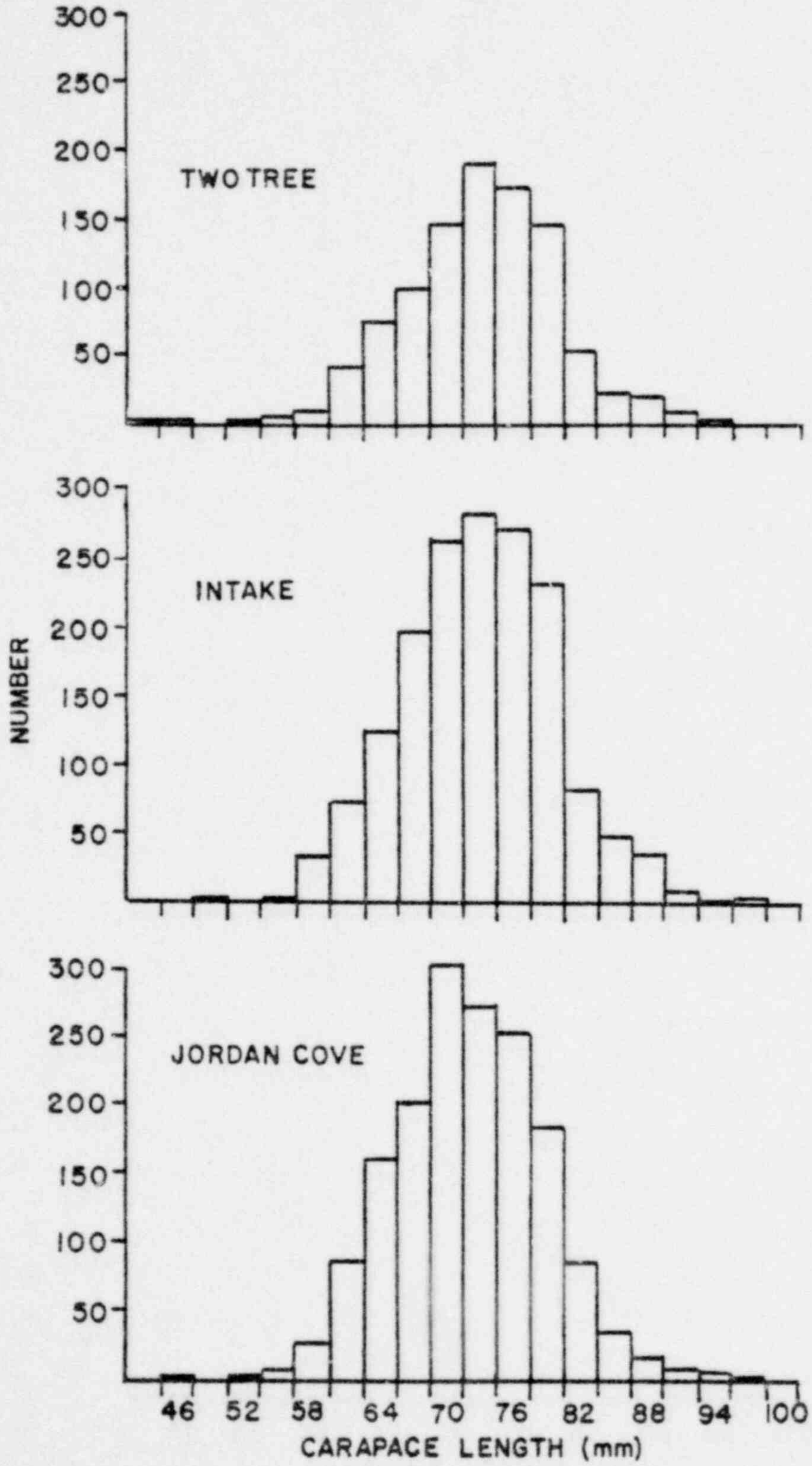

Figure 5. Size distribution of lobsters caught at each station in 1979.

of the lobster population in Block Island Sound calculated an average carapace length of 74.1mm. Although their sampling gear was similar to our metal pots, our average CL was 71.2mm.

The percentage of legal individuals in the catch, 15.4% for wood pots and 8.2% for metal pots, was considerably lower than the 24.6-30% reported by other area investigators (Smith 1977; Briggs and Mushacke 1979; Marcello, et al. 1979). Three possible factors might explain the greater percentage of sublegal lobsters in our catch. First, our nearshore stations (Jordan Cove and Intake) may support smaller lobsters than the deeper water stations of the other studies. We have some evidence of this since our deepest station, Twotree, had slightly larger lobsters and a somewhat higher percent legal. Second the exploitation rate may be greater in our study are than in surrounding areas. Ninety-two percent of our legal catch were newly recruited individuals. This high value attests to the high exploitation rate of lobsters throughout the study area. The third possible explanation was that our sampling from May through October was conducted in a limited study area, in contrast to the larger areas fished by commercial lobstermen.

<u>Sex Ratios</u> - This year 54.2% of the catch were males and 45.8% were females. In the previous three years (1976-1978) males made up 51% of the catch, females 49%. At Jordan Cove 58.8% of the catch was male and at Intake 53.6%. However, Twotree differed with only 47.6% of the catch male. This pattern has been observed since 1976 and was supported by a number of area studies. Briggs and Mushacke (1979) found that in deeper waters, females dominated the catch, while males dominated in shoaler

waters. Smith (1977), Marcello, et al. (1979) and Stewart (1972) working in waters similar in depth to Twotree, reported similar higher percentages of females in their catch.

Berried Females - In 1979 and in 1978 3.1% of all female lobsters caught were carrying external eggs (berried). Twotree has the highest percent of berried females with 5.2%, followed by Intake with 2.8% and Jordan Cove with 1.7%. This trend has been observed in previous years (Battelle 1978). Stewart (1972) reported 2.6% of females were berried off Noank, Connecticut, Smith (1977) found about 8% east of the Connecticut River, and Marcello, et al. (1979) reported 5.2% in Block Island Sound. These values differ considerably from those reported in western LIS where Smith reported 27.3% of females berried and Briggs and Mushacke who found 27.8% berried.

The size distribution of all berried females caught in 1979 is shown in Fig. 6. The overall mean size was 80.6mm CL with the smallest individual 64mm CL. The mean carapace length has not changed from the 80.1mm of 1978. About 54% of the berried females caught this year were of sublegal size. Briggs and Mushacke (1979) reported similar results while Marcello, et al. (1979) and Smith (1977) reported higher values of 83.1mm and 86.6mm, respectively. The smallest berried female caught in 1979 was smaller than reported by most of the area investigators. Briggs and Mushacke (1979) did report a berried female of 64mm CL from western LIS. It appears from available data that female lobsters in LIS and Block Island Sound mature earlier than those off the coast of Maine and the outer shelf which mature at 90mm CL (Skud and Perkins 1969; Krouse 1973; Thomas 1973).

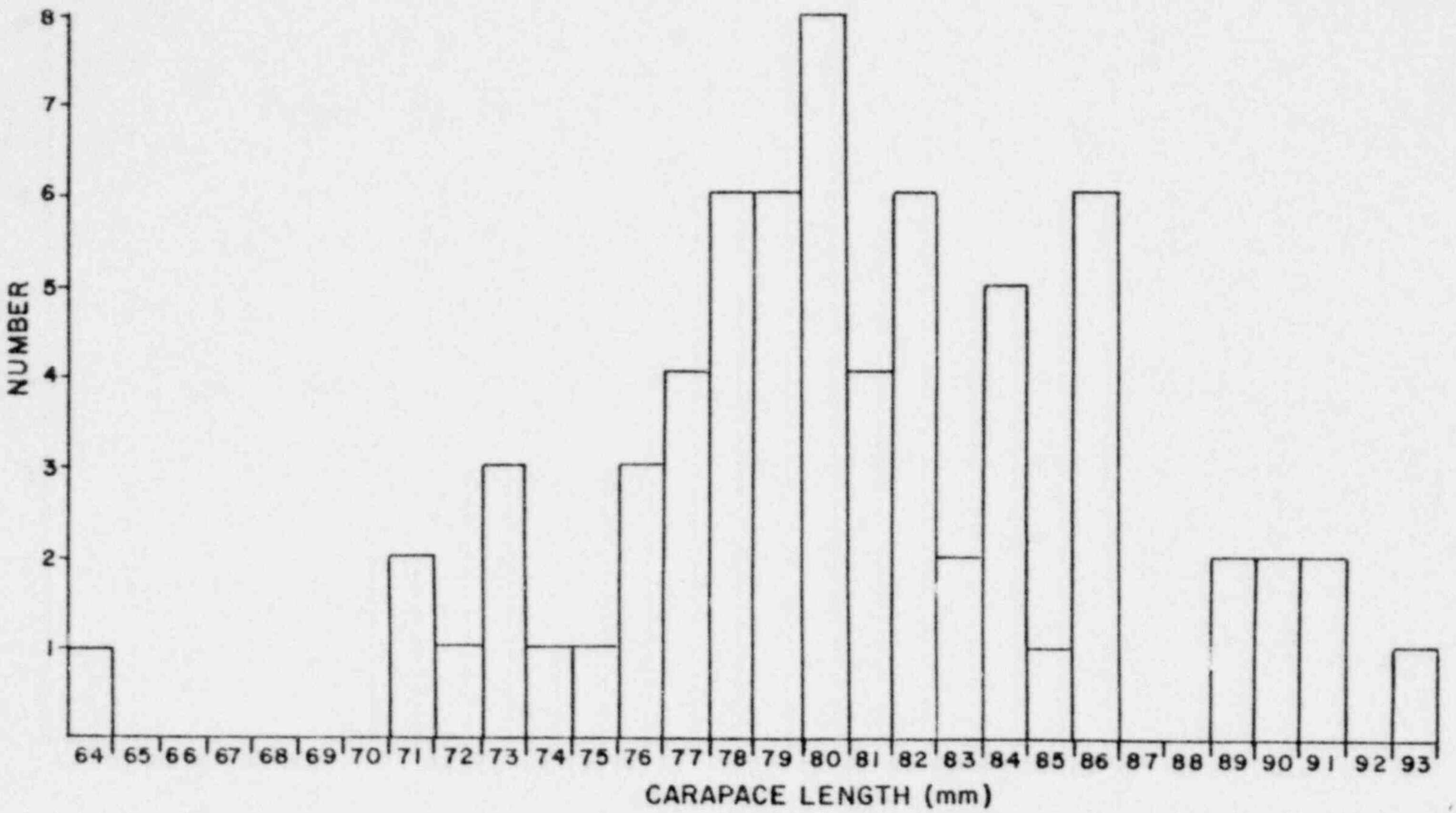

Figure 6. Size distribution of berried females caught in 1979.

There has been a decline in the percent of berried females of sublegal size from the 67.2% of 1978 to 53.7% in 1979. These values are considerably higher than reported by Marcello, et al. (1979) who found 31.5% sublegal and Smith (1977) who reported only 26%.

There is an indication that while the percent berried female in the area has changed little in the past few years, the size at which female lobsters are maturing may be decreasing; however, with such a small sample size, these trends could represent random events.

Claw Loss - In 1979, 16.2% of lobsters caught were missing either one or both claws (culled). Twotree had the lowest percent cull with 9.6% while Intake and Jordan Cove each had about 18%. Legal-sized individuals had a higher percent cull than sublegals, 18.4% and 13.9%, respectively. There was no change in the percent cull in the catch since last year's 16.5%. Smith (1977) reported that sublegal, rather than legal-sized lobsters, as in our study, exhibited the greater claw loss. He also found a percent cull of about 26%. The two principle causes of claw loss are recognized as handling by lobstermen and by aggressive behavior of lobsters in dense populations (Scarrett 1973). Sublegal individuals would be expected to suffer greater claw loss in both cases. The reason for our data differing from the expected results is primarily sampling methodology. Using metal wire pots we catch many smaller lobsters not vulnerable to the commonly used wood pot. These individuals are therefore infrequently handled by lobstermen. However, these smaller lobsters are vulnerable to aggressive behavior of large lobsters in the restricted environment of a metal pot. It therefore appears that handling is more responsible for claw loss than aggressive behavior.

Molting Patterns - During 1979 2.7% of the lobsters caught showed signs of imminent molt (Table 4). The onset of a spring molt appeared in June at all stations, but the appearance of a fall molt was only evident at Jordan Cove. Jordan Cove had the largest percent of molting lobsters with 3.4% of the catch.

Another method employed to detect mass molting behavior is inspection of the percent legal-sized lobsters in the catch. A nadir in the plot of percent legal vs. month (Fig. 7) indicates a depletion of legal-sized lobsters with the subsequent recruitment resulting from molting into legal size. This plot supports the occurrence of a molt in June and another beginning in October.

The correlation between bottom water temperature on molting is shown in Fig. 8. About 98% molted at temperatured between 12°C and 20°C with the peak between 14°C and 16°C.

Although molting lobsters were observed in the catch throughout the sampling, there is good evidence that June and November mass molts described by Lund, Stewart, and Rathbun (1973) in LIS also occurred in the Millstone Point region. The peak molting period coincides with bottom water temperatures of between 14-16°C. The mean bottom water temperature in June was 14.4°C and October 15.5°C. The rise in percent molting in the catch at Jordan Cove in October and the general increase in the number of legal-sized individuals in October is a good indication that the November molt occurred.

Table 4. Monthly percentage of molting lobsters in the catch for each station, 1979.

Month	Station			
	Jordan Cove	Intake	Twotree	All Stations
May	1.0%	0.6%	0.0%	0.5%
June	8.3	6.7	4.8	6.6
July	4.1	1.8	3.1	3.1
Aug.	1.5	1.3	0.6	1.3
Sept.	0.9	1.7	0.9	1.2
Oct.	2.0	0.9	0.0	1.1
TOTAL	3.4	2.4	2.1	2.7

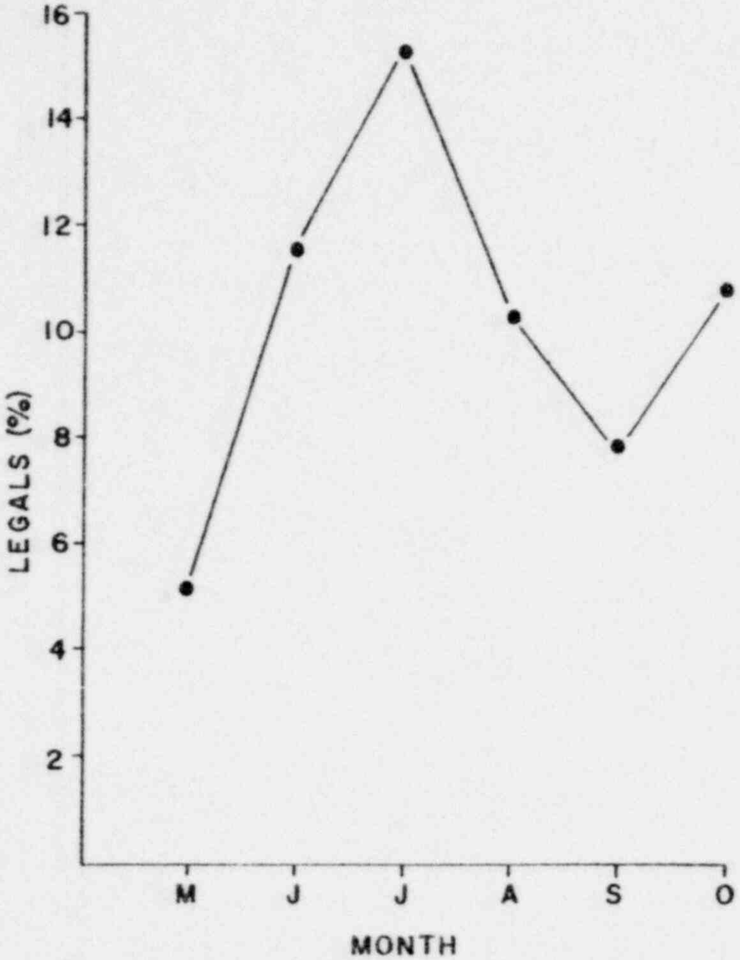

Figure 7. Monthly percent of legal-sized lobsters in the catch in 1979.

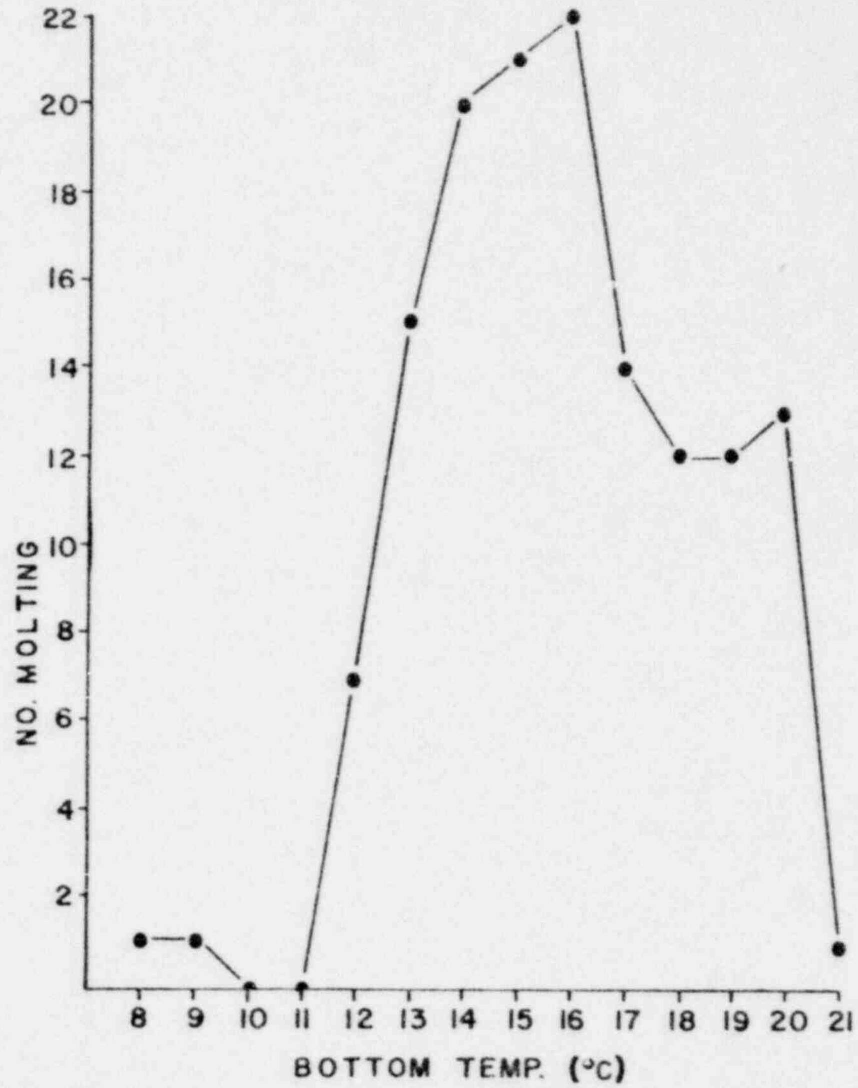

Figure 8. Number of molting lobsters of all sizes vs. bottom water temperature in 1979.

The spring molt was noted by other area investigators (Briggs and Mushacke 1979); Marcello, et al. 1979); neither study sampled into the fall. In Maine and in offshore waters, one period of peak molting has generally been reported (Krouse 1973; Skud and Perkins 1969). Although temperature is strongly implicated as triggering the molting process, Hughes and Matthienssen (1962) additionally suggest a "rapid increase in body tissue resulting from increased feeding activity during the warm summer months" might be responsible for the fall molt.

Tagging Program

Of the 5,031 lobsters caught in 1979, 3,732 were tagged and released; 674 were recaptured individuals. The remainder were either released untagged (caught in October so only examined for tags, less than 55mm CL, injured, or dead) or they were recaptures tagged prior to 1979. The percent recapture in 1979 of 18.1% increased from the 11.8% of 1978. The percent recapture was highly variable in tagging studies by other researchers (5.5%-76%) and seemed to depend on the size of lobster tagged and the site of release (Cooper 1970; Cooper and Uzmann 1971; Dow 1974; Krouse 1977).

Approximately 80% of tagged lobsters caught in our study were recaptured only once; 14% were recaptured twice and 4.8% three times. These values are similar to findings from 1978 (Battelle 1978).

The average time at large for recaptured individuals was 44.8 days. The minimum was 3 days (smallest possible since all tagged lobsters are released on Friday) and the maximum was 434 days for an individual released in 1978.

When lobsters are tagged, they are examined for presence of a scar from a lost tag. This scar is obvious if the individual has not molted. Using the occurrence of these scars, we were able to estimate tag loss at about 14%. This value is the same as reported in 1978. Other investigators using the sphyrion tag estimated non-molt induced tag loss at between 6.2% and 12% (Fair 1977; Stewart 1972). Loss of tags due to molting has been estimated at about 12% (Cooper 1970).

Interstation Movement - During 1979 interstation movement was minimal with only 35 of the 674 recaptures, or 5.2%, having moved from the station where released. At Twotree and Jordan Cove, 99% and 97.5% of the lobsters released there and subsequently recaptured had not moved (Fig. 9). At Intake, 84.1% of the lobsters stayed; 12.7% moved to Jordan Cove and 3.2% moved to Twotree. These data support the conclusions that inshore lobsters tend to form localized populations (Wilder and Murray 1958; Wilder 1963; Cooper 1970; Battelle 1978).

The movement from the Intake station to Jordan Cove and to Twotree support the general trend of eastern movement suggested by Lund, Stewart, and Rathbun (1973). Although the vast majority of tags returned to us came from the study area, we have received tags from as far away as Hudson and Block Canyons on the outer continental shelf.

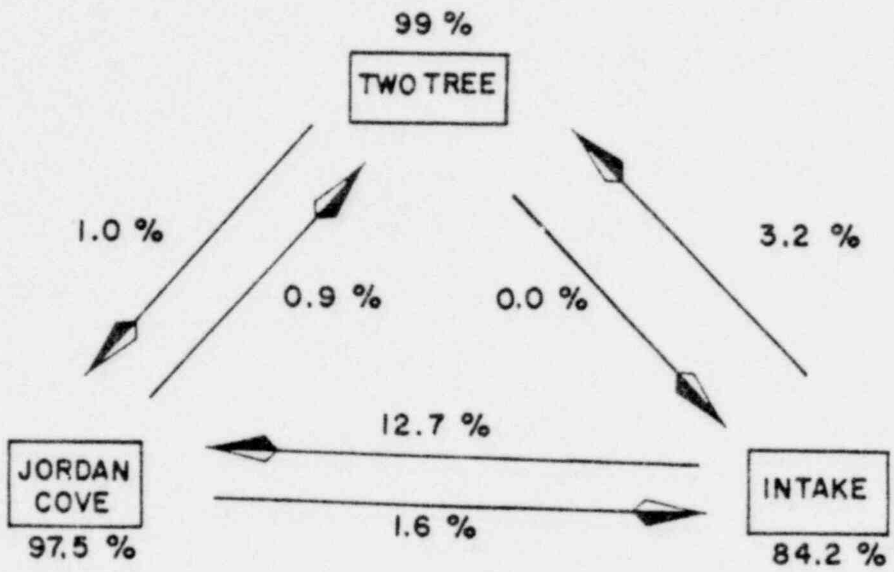

Figure 9. Interstation movement as shown by the percent of recaptured lobsters that moved from the station where released in 1979.

During 1979, local lobster movements were minimal with the exception of those released at the Intake station. In previous years (Battelle 1977), sampling in the Effluent suggested that lobsters do not reside in that area and might move in to feed. The Intake station is close to the effluent which may be an influence on the observed movement to Jordan Cove.

Growth - Of the 674 lobsters recaptured, 85 had molted with an average increase in carapace length of 12.8%. Growth per molt for lobsters caught at Twotree was 13.3%, Intake 12.4%, and at Jordan Cove 11.1%. There was no difference in growth per molt between males and females; males grew an average of 12.3% and females 12.0%. Stewart (1972) reported growth per molt of 15.6% from eastern LIS and Briggs and Mushacke (1979) reported 10.4% from western LIS.

Other researchers have found growth rates of lobsters to be variable (Wilder 1953; Cooper and Uzmann 1971). In northern waters, growth per molt has been reported from 13.3% to 15.7% (Ennis 1972; Fair 1977; Wilder 1953). Cooper and Uzmann (1971) found growth from 17-19% for lobsters caught in deep offshore waters.

Population Estimates - The monthly lobster population estimates in the Millstone Point region are shown in Table 5. The population size ranged from 3,700 to 10,557. The peak abundance was in July with a subsequent decline.

Table 5. Estimated lobster population size, number of recruits, and probability of survival in the Millstone Point area, 1979.

Month	Estimated Population Size, N_i	Standard Deviation of N_i	Estimated # of Recruits, B_i	Standard Deviation of B_i	Estimated Probability of Survival ϕ_i	Standard Deviation of ϕ_i
June	4637	922	7682	1727	.62	.105
July	10557	1959	-334	1084	.63	.101
Aug.	6317	1119	2026	575	.34	.058
Sept.	4174	852	1822	-	.45	.087
Oct.	3700	-	1446	-	.54	-

The estimated recruitment generally follows the trend of population size, with a peak in June corresponding to the peak population size in July. The recuritment of -334 in July with its high standard deviation is hard to explain. The monthly probability of survival averaged about .51 throughout the study.

The 1978 and 1979 lobster population estimates follow the same trend of peak size in July, peak recruitment in June with a decline in both into the fall season. The 1979 monthly population estimate averaged 5,877 lobsters, an increase from the 4,704 of 1978. The present estimates are more precise than those from the preceeding years as shown by the standard deviations between 17-20% of the estimate, while in 1978 they were 18-65% of the estimate. This increase in precision is likely due to the increased percent recapture of 18.1%. The estimated population size generally reflects the trend in CPUE this year. Since the estimates are largely of the sublegal size classes, the depletion in stock size in the later months of the study cannot be adequately explained by fishing pressure. It is more likely caused by a decline in the catchability of lobsters with decreasing temperatures

Impingement

From January to December 1979, an estimated 707 lobsters were impinged at Unit 1 and 2 intakes (Table 6). This number is fairly consistent with the years since 1976. Unit 2 has consistently impinged more individuals than Unit 1 although not always to the same degree. Approximately 64% of these lobsters impinged at Unit 1 survived and were returned to

Table 6. Yearly impingement at Units 1 and 2 and at both units combined 1976-1979.

Year	Unit 1	Unit 2	Both Units
1976*	477	654	1131
1977	308	399	707
1978	261	280	541
1979	303	404	707

* 1976 values are based on 7 days of sampling per week. 1977-1979 values, based on 3 days of sampling per week, are factored up and as such are comparable with 1976.

the water, about 50% survived from Unit 2. In December of 1978, a bottom boom (5 cm chainlink) was set in front of Unit 1 to help reduce the numbers of organisms impinged. A detailed discussion of the bottom boom can be found in the Impingement section this report. While the boom might be responsible for some of the discrepancies between the two units since the boom's installation, further examinations are necessary.

The number of lobserts impinged this year varied seasonally with the peak occurring in July (Table 7). This was a consistent trend at Unit 2, but at Unit 1 there was a peak in April with subsequent oscillations for the remainder of the year. The size distribution of lobsters impinged at Unit 1 and 2 intakes are shown in Fig. 10. The overall mean size at both units was 62.5mm CL. The frequency distribution for Units 1 and 2 were not significantly different (Kolmorgorov-Smirnov test, $P<.05$). The mean carapace length of lobsters impinged at Unit 1 was 62.0mm and 62.9mm at Unit 2.

The increase in number of lobsters impinged during the summer months coincides with increased water temperatures and the June molt, both shown to increase the availability of lobsters. Reasons for the apparent difference in total numbers impinged at Units 1 and 2 and seasonal discrepancies in numbers impinged are unclear.

Entrainment

Presentation of the data concerning the numbers of lobster larvae entrained in 1979 with discussion of the findings are presented in the Entrainment portion of this report (Section 3).

Table 7. Estimated* number of lobsters impinged by month for unit 1 and unit 2 intakes and total impingement for 1979

Month	Unit 1	Unit 2	Both Units
January	7	0	7
February	0	0	0
March	18	0	18
April	75	9	84
May	0	18	18
June	7	77	84
July	49	91	140
August	30	79	110
September	33	63	96
October	47	52	98
November	32	12	44
December	5	3	8
Total	303	404	707

* These values, based on 3 days of sampling per week, are factored up to represent the estimated total number impinged per month.

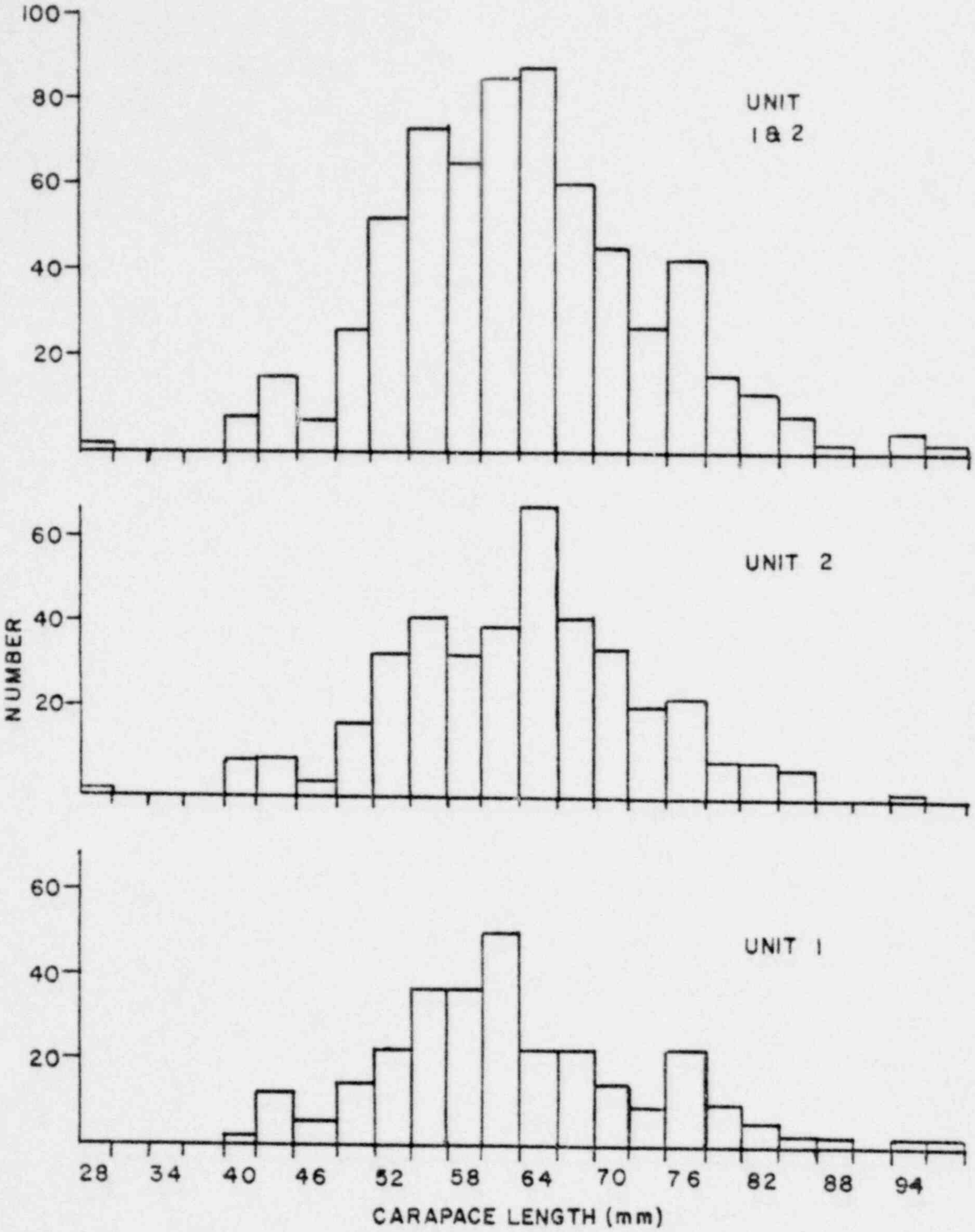

Figure 10. Size distribution of lobsters impinged at unit 1, unit 2, and at both units in 1979.

SUMMARY AND CONCLUSIONS

The total catch per unit effort of lobsters in 1979 was similar to that reported in previous years. Differences in numbers caught are attributable to changes in sampling gear. Seasonal variations in catch were shown to result from the increased activity of lobsters caused by the seasonal increase in water temperature and the occurrence of mass molting in the late spring and fall. The catch at our deepest station, Twotree, did not follow these trends and it appears other factors are involved.

The size distribution was similar to those since 1976 and to those reported from surrounding areas. Inspection of the histograms does reveal that the study area is subject to a high rate of exploitation. The percent of legal-sized lobsters in the catch was generally lower than in surrounding areas.

More than half of the berried females caught were of sublegal size. Either the high exploitation rate is selecting for precocious females or our nearshore stations simply support smaller lobsters. Our deepest station, Twotree, had the highest percent of berried females of the three stations as well as the highest percent of total females.

The spring and fall molts that have been reported to occur in LIS also occurred in the Millstone Point region. The onset of molting appeared to be most affected by water temperatures in the $14^{\circ}C$ to $16^{\circ}C$ range.

Very little movement of lobsters between stations was detected. Most individuals that did move went from the Intake station to the other stations. Although some lobsters moved great distances during the term of the study, most individuals remained in their immediate locale.

The monthly mean population size rose from last year's estimate of 4,704 individuals to 5,877 in 1979. The precision of the estimate also increased over that of 1978. This was likely due to the increased numbers of recaptures.

The number of lobsters impinged on the intake traveling screens in 1979 varied little from previous years. Individuals impinged are smaller ($\bar{x}$ CL=62.5mm) than the individuals caught in pots ($\bar{x}$ CL=72.7mm). The seasonal variation in impingement rate reflected variable activity rates and mass molting behavior. Over half of the lobsters impinged survived and were returned to the surrounding waters.

Characteristics of the lobster population of the Millstone Point region are similar to those of previous years and to those reported from surrounding areas. Based on these findings, we feel that the impact of power plant operation on the local lobster population could not be distinguished from the natural fluctuations in standing crop and the effects of the intense rate of exploitation.

LITERATURE CITED

Aiken, D. E. 1973. Proecdysis, setal development, and molt prediction in the American lobster (Homarus americanus). J. Fish. Res. Board Can. 30:1337-1344.

Battelle-William F. Clapp Laboratories. 1977. Lobster Population Estimates. Pages E1-E26 in the annual report on Ecological and Hydrographic Studies at the Millstone Nuclear Power Station. Northeast Utilities Service Company.

Battelle-William F. Clapp Laboratories. 1978. Lobster Population Estimates. Pages E1-E31 in the annual report on Ecological and Hydrographic Studies at the Millstone Nuclear Power Station. Northeast Utilities Service Company.

Briggs, P. T. and F. M. Mushacke 1979. The American Lobster in Western Long Island Sound. New York Fish and Game J. 26:59-86.

Cooper, R. A. 1970. Retention of marks and their effects on growth, behavior, and migration of the American lobster, Homarus americanus. Trans. Amer. Fish. Soc. 99:409-417.

__________ and J. R. Uzmann. 1971. Migrations and growth of deep-sea lobsters, Homarus americanus. Science 171:288-290.

Dow, R. L. 1966. The use of biological, environmental, and economic data to predict supply and to manage a selcted marine resource. The Amer. Biol. Teacher 28:26-30.

__________, 1967. The influence of temperature on Maine lobster supply. State of Maine Dept. of Sea and Shore Fisheries Res. Bull. No. 30, 22 pp.

__________, 1974. American lobsters tagged by Maine commercial lobstermen, 1957-1959. Fish. Bull. 72:622-623.

__________, 1976. Yield trends of the American lobster resource with increased fishing effort. Mar. Technol. Soc. 10:17-25.

__________, 1977. Relationship of sea surface temperature to American and European lobster landings. J. Cons. Int. Explor. Mer. 37:186-191.

__________, F. W. Bell and D. M.Harriman, 1975. Bioeconomic relationships for the Maine lobster fishery with consideration of alternative management schemes. NOAA Technical Report NMFS SSRF-683, 44 pp.

Ennis, G. P. 1972. Growth per molt of tagged lobsters (Homarus americanus) in Bonavista Bay, Newfoundland. J. Fish. Res. Board Can. 29:143-148.

Fair, J. J., Jr. 1977. Lobster investigations in management area I; southern Gulf of Maine. Massachusetts Division of Marine Fisheries. 7 pp.

Flowers, J M. and S. B. Saila. 1972. An analysis of temperature effects on the inshore lobster fishery. J. Fish. Res. Board Can. 29:1221-1225.

Hughes, J. T. and G. C. Matthiessen. 1962. Observations on the biology of the American lobster, Homarus americanus. Limnol. and Oceanog. 7:414-421.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52:225-247.

Krouse, J. S. 1971. Maturity, sex ratio, and size composition of the natural population of the American lobster (Homarus americanus) along the coast of Maine. Maine Dep. Sea Shore Fish., Completion Rep., Proj. 3-14-R, 17 pp; (Manuscr.) (cited from Thomas, J. C. 1973. An analysis of the commercial lobster (Homarus americanus) fishery along the coast of Maine, August 1966 through December 1970). NOAA Technical Report NMFS SSRF-667. 57 pp.

__________, 1973. Maturity, sex ratio, and size composition of the natural population of American lobster, Homarus americanus, along the Maine coast. Fish. Bull. 71:165-173.

__________, 1976. Incidence of cull lobsters, Homarus americanus, in commercial and research catches off the Maine coast. Fish. Bull. 74:719-724.

__________, 1977. Lobster tagging study. Maine Dep. of Marine Resources, Lobster information leaflet No. 5. 13 pp.

Lund, W. A., Jr., L. L. Stewart and C. J. Rathbun 1973. Investigation on the lobster. National Marine Fisheries Service, Completion Report for Conn. Project 3-130-R Under Commer. Fish. Res. and Devel. Act. 189 pp.

Marcello, R. A., Jr., W. Davis, III, T. O'Hara and J. Hartley 1979. Population statistics and commercial catch rate of American lobster (Homarus americanus) in the Charlestown-Matunuck, Rhode Island region of Block Island Sound. Yankee Atomic Electric Company. Submitted to New England Power Company. YAEC 1175. 40 pp.

McLeese, D. W. and D. G. Wilder. 1958. The activity and catchability of the lobster (Homarus americanus) in relation to temperature. J. Fish. Res. Board Can. 15:1345-1354.

Scarratt, D. J. 1970. Laboratory and field tests of modified sphyrion tags on lobsters (Homarus americanus). J. Fish. Res. Board Can. 27:257-264.

__________, 1973. Claw loss and other wounds in commercially caught lobsters (Homarus americanus). J. Fish. Res. Board Can. 30:1370-1373.

Seber, G. A. F. 1965. A note on the multiple-recapture census. Biometrika 52:249-259.

Skud, B. E. and H. C. Perkins 1969. Size composition, sex ratio, and size at maturity of offshore northern lobsters. U.S. Fish Wildl. Serv. Spec. Sci. Rept. Fish. 598, 10 pp.

Smith, E. M. 1977. Some aspects of catch/effort, biology, and the economics of the Long Island Sound lobster fishery during 1976. NOAA Technical Report NMFS Project No. 3-253-R-1. 97 pp.

Stewart, L. L. 1972. The seasonal movements, population dynamics, and ecology of the lobster, Homarus americanus (Milne-Edwards), off Ram Island, Connecticut. Ph.D. Thesis, University of Connecticut. 112 pp.

Thomas, J. C. 1973. An analysis of the commercial lobster (Homarus americanus) fishery along the coast of Maine, August 1966 through December, 1970. NOAA Technical Report NMFS SSRF-667. 57 pp.

Wilder, D. G. 1953. The growth rate of the American lobster (Homarus americanus). J. Fish. Res. Board Can. 10:371-412.

__________, 1963. Movements, growth, and survival of marked and tagged lobsters liberated in Egmont Bay, Prince Edward Island. J. Fish. Res. Board Can. 20:305-318.

__________ and R. C. Murray. 1958. Do lobsters move offshore and onshore in the fall and spring? Pages 12-15 in Fish. Res. Board Can. Atlantic Prog. Rpt. No. 69.

EXPOSURE PANELS

EXPOSURE PANELS

INTRODUCTION

Early interest in the marine fouling community stemmed from the economic implications associated with the maintenance of ships, buoys, wharves, and other man-made structures. Wooden wharves were weakened from attacks of wood boring molluscs and crustaceans, while ships and buoys, were laden with extra weight. The advent of industrial use of seawater for cooling purposes increased the need for understanding the ecology of fouling communities. Artificial substrata (exposure panels) have been the primary means of monitoring fouling communities and over the years a variety of designs and materials have been employed (WHOI 1952; Frame 1968; Schoener 1974).

Recently, environmental monitoring studies have included exposure panel programs to assess impacts of thermal effluents from steam electric stations. Initially, programs were conducted to gather background information on local fouling communities, which potentially could be impacted by electrical power plant construction and operation (Cory 1967; Frame 1968; Hillman, et al. 1973; NAI 1979). Follow-up studies of thermal effluents described impacts on epifaunal biomass and changes in seasonal growth (Cory and Nauman 1969; Nauman and Cory 1969; Hillman 1975, 1977).

The exposure panel program at Millstone Point was designed to assess potential effects of the construction and operation of the Millstone Nuclear Station on fouling and wood boring organisms in the marine environment. To meet this objective, community composition and species abundances on exposure panels have been monitored over an eleven year period. During 1979, changes in monitoring procedures were made to increase the precision of community assessments and thus allow separation of man-induced fluctuations in species composition from those that occur naturally.

MATERIALS AND METHODS

Exposure Panels and Frames

Each exposure panel consisted of a soft pine (wood) panel 25.4 x 9.5 x 1.9 cm backed by a 25.4 x 9.5 x 0.4 cm panel of transite - a hard, asbestos material. Wood provided a substratum for wood boring organisms, while the asbestos panel allowed settlement of flora and epifauna. Panels were bolted to iron frames in two groups of six panels (Fig. 1). Each frame was suspended vertically to reduce siltation on panel surfaces (Coe and Allen 1937; Fuller 1946). Frames were positioned just below low tide level at dock stations and 30 cm below the surface at floating stations.

The 1979 sampling differed from that in previous years (Battelle 1978). This year panels were submerged for six months at five stations: Effluent, Intake, Fox Island-North, Giants Neck, and White Point (Fig. 2). From 1968-1978, panels were submerged for one and twelve month intervals. More detailed descriptions of earlier programs and location of stations are given by Battelle (1975).

Panels were submerged at each station in November, 1978; February, 1979; and May, 1979. After six months, panels were collected and replaced with a

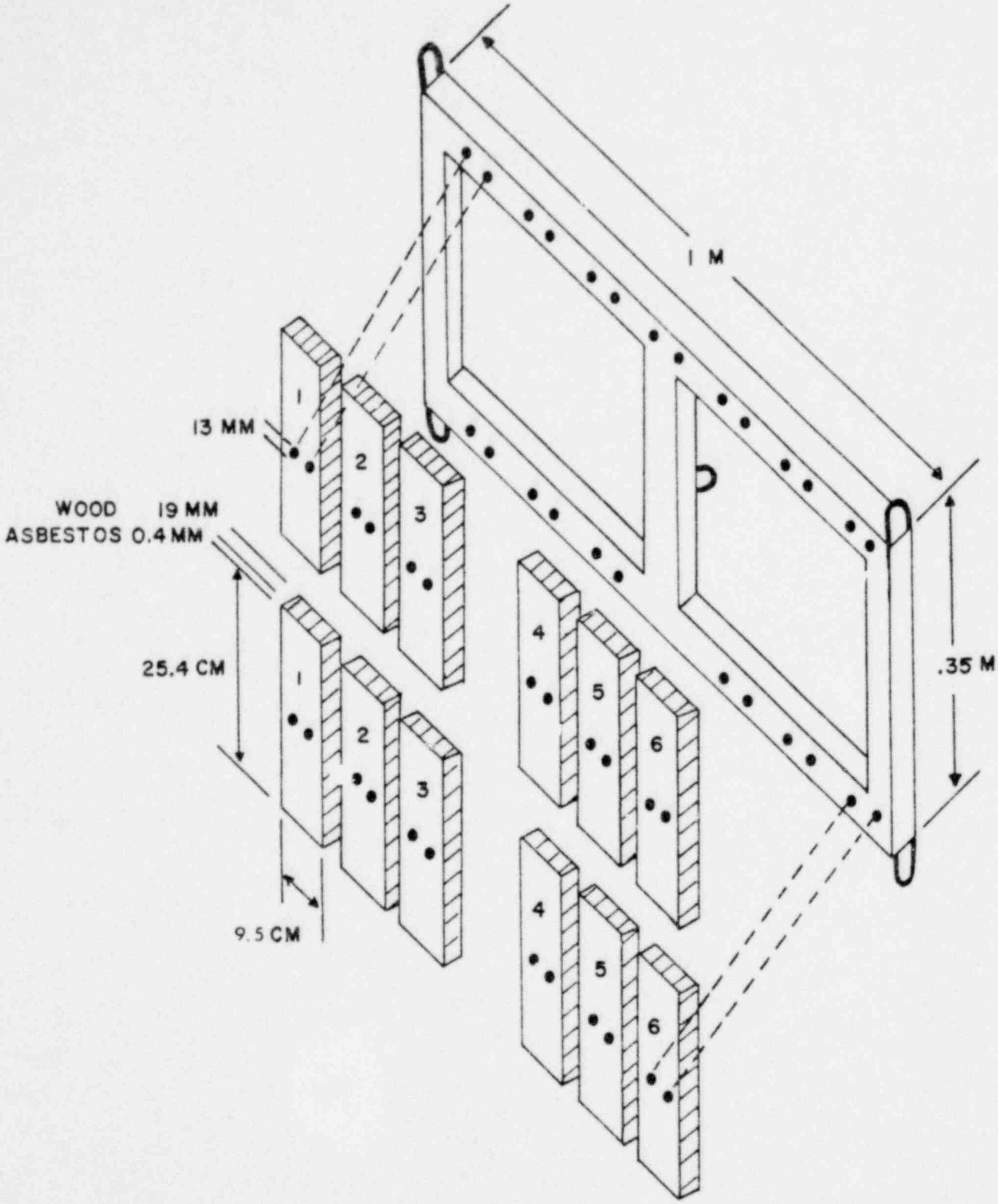

Figure 1. Exposure panel frame and position of panels used for sampling the flora, epifauna and wood borers in the Millstone Point area during 1979.

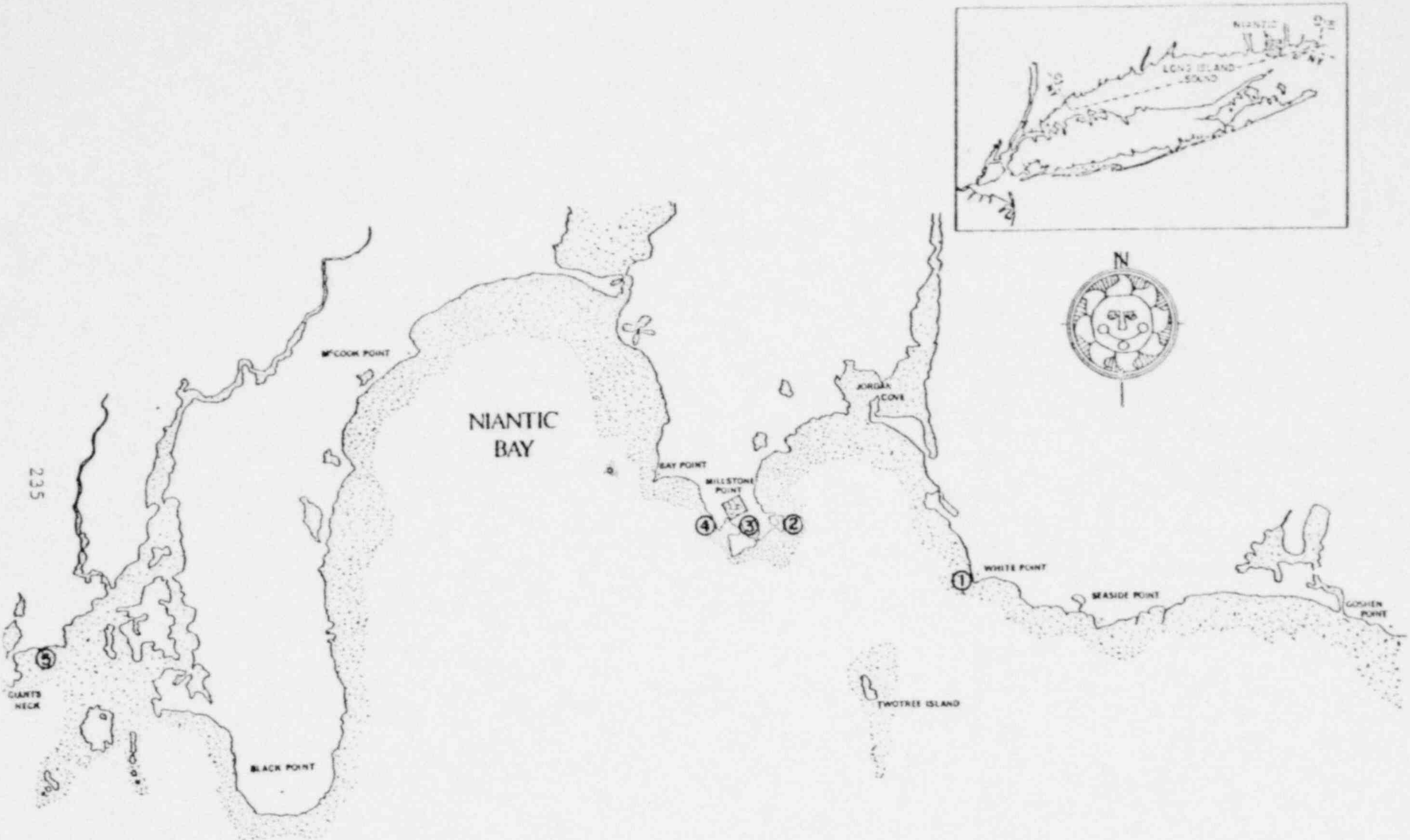

Figure 2. Map of the Millstone Point area showing locations of exposure panel stations (1. White Point, 2. Fox Island-North, 3. Effluent, 4. Intake, 5. Giants Neck).

new set in May, August, and November, 1979. Exposure periods for panels hereafter are referred to by the month in which they were collected. The panels submerged in November, 1978 were placed on the top of the frames and those in February, 1979 on the bottom. This panel orientation was continued in subsequent replacements.

The wood and asbestos panels were separated for analysis. Organisms between the panels were included with the panel they adhered to upon separation.

Individuals were identified to species whenever possible. When species identification was uncertain, the lowest identifiable taxonomic grouping was used. Direct counts of solitary invertebrates on the panels were made when practical. If individuals were numerous, total panel estimates were derived from counting individuals within four to ten, 6.5 cm^2 subsamples. Percent cover estimates on panels were made for colonial and aggregating species. Both counts and percent cover were obtained for barnacles, mussels, wood boring molluscs, spirorbis tubes, serpulid tubes, and solitary tunicates. The abundances of algae and arborescent invertebrates were obtained by estimating the total percent cover of holdfasts.

Diversity, evenness, the Bray-Curtis coefficients, the Jaccard coefficients, and cluster analysis were calculated for wood and asbestos communities using formulas described in the Benthic Infaunal Section of this report. Algae were only included in the calculation of the Jaccard coefficients.

RESULTS

General Community Structure

In 1979, twelve phyla composed of 102 discernable taxa were reported from exposure panels in the vicinity of the Millstone area (Table 1). Of the 12 phyla reported, only White Point had representatives of each. The number of taxa found at each station ranged from 40 at the Effluent to 61 at Giants Neck. The most diverse flora on the panels were red algae (Rhodophyta) followed by greens (Chlorophyta) and browns (Phaeophyta). The most abundant faunal groups were Mollusca and Arthropoda. Porifera, Coelenterata, Platyhelminthes, and Chordata were poorly represented, having only one or two species per phyla.

Highest numerical abundance on wood panels occurred at Giants Neck and the lowest at the Effluent (Table 2). Counts on asbestos panels were the highest at the Intake and lowest at White Point. Differences in numerical abundances between wood and asbestos panels at the Effluent and the Intake were less than 6%, but greater than 50% at Giants Neck and White Point. Percent cover estimates were greatest at the Effluent and the Intake on both panel types (Table 3). Generally, differences in percent cover between wood and asbestos panels were less than those for counts.

During the year, eleven species occurred at every station during one or more exposure periods. Of these "ubiquitous" species *Balanus* spp. were the most common occurring on both panel types in every exposure period and at every station. The wood boring mollusc, *Teredo navalis*, occurred at every station during August and November. The remaining species were *Ceramium rubrum*,

Table 1. Number of species within major taxa collected from exposure panels at each station in the Millstone Point area during 1979.

Taxa	Station[a] EF	IN	FN	GN	WP	Total
Chrysophyta	0	0	2	2	2	2
Chlorophyta	1	3	3	9	6	12
Phaeophyta	0	4	4	2	6	8
Rhodophyta	5	12	8	14	13	23
Porifera	0	1	1	1	1	1
Coelenterata	2	1	1	0	1	2
Platyhelminthes	1	1	0	1	1	1
Bryozoa	4	4	4	3	3	9
Annelida	4	6	6	6	5	8
Mollusca	7	10	9	11	10	14
Arthropoda	16	9	10	9	10	19
Chordata	0	0	0	3	1	3
Total	40	51	48	61	59	102

[a] EF = Effluent GN = Giants Neck
IN = Intake WP = White Point
FN = Fox Island-North

Table 2. Average counts of individuals per exposure period collected on asbestos and wood panels in the Millstone Point area during 1979.

TAXA	STATION[a] EF A	EF W	IN A	IN W	FN A	FN W	GN A	GN W	WP A	WP W
Platyhelminthes										
Stylochus ellipticus	< 1	<1	11	18	-	-	1	2	3	3
Annelida										
Polycheata										
Sedentaria										
Amphitrite spp.	-[b]	-	-	-	< 1	1	-	1	-	-
Sabella microphthalma	-	-	-	< 1	15	9	27	22	7	7
serpulid tubes	14	3	2	1	19	1	72	16	15	2
spirorbis tubes	159	2	-	-	129	29	15	9	2	-
Errantia										
Harmothoe imbricata	-	-	-	< 1	-	-	-	-	-	-
Lepidonotus squamatus	1	2	-	-	1	< 1	4	3	1	2
Nereis succinea	5	5	1	2	1	2	3	1	-	1
Polynoidae	-	-	1	-	-	-	-	-	-	-
Mollusca										
Gastropada										
Anachis avara	-	-	< 1	< 1	-	-	-	< 1	-	1
Crepidula fornicata	1	< 1	< 1	-	-	-	2	< 1	< 1	-
Crepidula plana	-	-	1	1	1	-	1	-	1	1
Crepidula spp.	< 1	-	-	-	< 1	-	-	-	< 1	-
Littorina littorea	-	-	-	-	-	-	-	< 1	-	-
Littorina obtusata	-	-	-	1	3	2	7	3	5	4
Mitrella lunata	-	-	23	19	[illegible]	1	6	9	37	37
Urosalpinx cinerea	-	-	-	-	1	-	-	2	< 1	-
Bivalvia										
Anadara spp.	-	-	-	1	-	-	-	-	-	-
Anomia simplex	< 1	< 1	8	1	1	1	4	2	2	1
Mytilus edulis	44	23	57	75	3	2	1	< 1	2	3
Teredinidae	-	55	-	4	-	61	-	220	-	-
Teredo bartschi	-	6	-	-	-	-	-	-	-	-
Teredo navalis	-	39	-	16	-	78	-	672	-	75
Arthropoda										
Crustacea										
Amphipoda										
Caprella geometrica	1	-	-	1	1	1	3	6	-	-
Caprella linearis	2	1	-	-	-	-	-	-	-	-
Chelura terebrans	-	-	-	-	-	-	-	-	-	647
Corophium acherusicum	1	1	-	-	-	-	-	-	-	-
Corophium acutum	< 1	2	-	-	-	<1	-	-	-	-
Corophium insidiosum	17	21	223	219	34	37	223	262	84	76
Corophium sp.	13	10	-	-	-	-	-	-	-	-
Gammarus laurencianus	100	189	.	-	3	4	-	-	-	-
Jassa falcata	< 1	-	7	6	1	-	-	-	-	-
Stenothoe minuta	< 1	-	-	-	-	-	-	-	-	-
Isopoda										
Idotea balthica	2	6	1	3	-	-	-	-	< 1	1
Limnoria lignorum	-	-	-	-	-	-	-	2501	-	230
Limnoria tripunctata	-	59	-	-	-	1281	-	1	-	2680
Thoracica										
Balanus amphitrite	-	-	-	-	<1	-	5	2	< 1	-
Balanus crenatus	78	21	8	9	191	26	243	77	31	53
Balanus eburneus	66	106	28	35	4	3	52	53	85	60
Balanus improvisus	566	583	1787	1285	9	6	30	24	36	28
Balanus spp.	958	1050	1776	1861	1783	1261	635	373	202	177
Cumacea sp.	<1	-	-	-	-	-	-	-	-	-
Cordata										
Ciona intestinalis	-	-	-	-	-	-	-	1	<1	<1
Molgula manhattensis	-	-	-	-	-	-	1	2	-	-
Molgula spp.	-	-	-	-	-	-	-	1	-	-
Total counts	2030	2184	3934	3555	2202	2805	1334	4266	513	4087

[a] EF = Effluent; IN = Intake; FN = Fox Island-North; GN = Giants Neck; WP = White Point; A = Asbestos; W = Wood

[b] Species not present during 1979.

Table 3. Average percent cover of species collected on asbestos and wood exposure panels in the Millstone Point area during 1979.

TAXA	STATION[a] EF A	EF W	IN A	IN W	FN A	FN W	GN A	GN W	WP A	WP W
Bacillariophyceae spp.	--[b]	--	--	--	--	0.1[b]	0.2	0.1	0.2	0.1
Navicula spp.	--	--	--	--	0.2	0.2	0.1	0.1	0.1	--
Chlorophyta										
Bryopsis plumosa	--	--	--	--	--	--	0.2	0.1	--	--
Chaetomorpha linum	--	--	--	--	--	--	--	--	--	0.1
Codium fragile	--	--	--	--	0.1	--	0.2	0.2	0.1	--
Enteromorpha compressa	--	--	--	--	--	--	--	--	0.1	--
Enteromorpha intestinalis	--	--	--	--	--	--	0.1	--	--	--
Enteromorpha linza	--	--	--	--	--	--	0.1	0.2	--	0.1
Enteromorpha spp.	--	--	0.1	0.1	--	--	0.1	--	0.1	--
Monostroma spp.	--	--	--	0.1	--	--	0.1	--	0.1	--
Siphonales protonema	--	--	--	0.2	0.1	--	0.1	--	--	--
Spongomorpha arcta	--	0.1	--	--	--	--	--	--	--	--
Spongomorpha spp.	--	--	--	--	--	--	0.1	--	--	--
Ulva lactuca	--	--	0.4	0.4	--	0.1	0.5	0.2	0.5	0.2
Phaeophyta										
Chordaria flagelliformis	--	--	0.2	0.2	0.1	--	--	--	0.1	0.1
Ectocarpus spp.	--	--	0.1	0.1	--	--	--	--	--	--
Fucus spp.	--	--	--	--	--	--	--	--	0.1	--
Laminaria agardhii	--	--	9.4	12.2	--	--	0.4	0.5	0.2	1.1
Laminaria spp.	--	--	--	--	0.8	0.3	--	--	--	0.1
Pilayella littoralis	--	--	0.1	0.8	0.1	--	0.1	--	--	--
Scytosiphonaceae	--	--	--	--	--	--	--	--	0.1	--
Sphacelaria spp.	--	--	--	--	0.1	--	--	--	0.1	--
Rhodophyta										
Antithamnion cruciatum	0.2	0.1	--	--	0.1	0.1	0.3	0.3	0.2	0.2
Callithamnion hookeri	0.2	0.1	--	0.1	0.3	--	0.5	0.4	0.1	0.1
Callithamnion roseum	--	--	--	--	--	--	--	--	--	0.1
Callithamnion tetragonum	--	--	0.2	0.2	--	--	--	--	0.1	--
Ceramium rubrum	0.1	0.1	0.6	0.7	--	0.1	0.4	0.3	0.3	0.3
Ceramium spp.	--	--	--	--	0.1	--	0.2	--	0.1	0.1
Champia parvula	--	--	--	--	--	--	0.1	--	0.1	0.1
Cystoclonium purpureum	0.1	--	--	--	--	--	0.1	0.1	--	--
Dasya ballouviana	--	--	--	--	0.1	0.1	0.1	0.1	--	0.1
Goniotrichum alsidii	--	--	--	0.1	--	--	--	--	--	--
Grinnellia americana	--	--	--	--	--	--	--	--	0.1	--
Lomentaria orcadensis	--	--	--	--	--	--	0.1	--	--	--
Lomentaria baileyana	--	--	--	--	--	--	0.1	0.1	--	--
Palmaria palmata	--	--	0.1	0.2	--	--	--	--	--	--
Polysiphonia denudata	--	--	--	--	--	--	0.1	--	--	--
Polysiphonia elongata	--	--	0.1	0.1	--	--	--	--	--	--
Polysiphonia fribrillosa	--	--	0.2	0.2	--	--	--	--	--	--
Polysiphonia nigra	--	--	0.4	0.2	--	--	--	--	0.1	--
Polysiphonia nigrescens	--	--	0.6	0.6	0.6	0.4	0.6	0.3	0.4	0.3
Polysiphonia spp.	--	--	0.2	0.1	0.1	--	0.1	0.2	0.2	0.2
Rhodomela spp.	--	--	0.2	0.2	--	--	--	--	--	--
Spermothamnione repens	0.1	--	0.1	--	0.1	0.1	0.3	0.2	0.4	0.4
Spyrida filamentosa	--	--	--	--	--	--	--	0.1	--	--
Porifera										
Halichondria bowerbankia	--	--	--	0.1	0.2	0.1	3.8	1.2	2.1	0.5
Coelenterata										
Hydrozoa spp.	0.3	0.3	0.2	0.2	0.4	0.3	--	--	0.4	0.4
Tubularia spp.	4.6	4.6	--	--	--	--	--	--	--	--

Table 3. (cont.)

TAXA	STATION									
	EF		IN		FN		GN		WP	
	A	W	A	W	A	W	A	W	A	W
Bryozoa										
Alcyonidium spp.	--	8.2	--	--	--	--	--	--	--	--
Bugula simplex	--	--	--	--	0.6	0.4	--	0.1	--	--
Bugula turrita	0.3	0.3	--	--	0.4	0.3	0.7	0.7	1.2	1.1
Bugula spp.	--	--	--	--	0.3	0.3	--	--	--	0.1
Callopora aurita	--	0.2	--	--	--	--	--	--	--	--
Cryptosula pallasiana	0.6	0.7	0.4	0.5	31.4	18.0	3.3	4.8	13.4	7.9
Electra crustulenta	--	--	0.1	0.3	--	--	--	--	--	--
Electra monostachys	--	--	0.3	0.2	--	--	--	--	--	--
Tubulipora liliacea	--	--	0.1	--	--	--	--	--	--	--
Annelida										
Polychaeta										
Sedentaria										
Serpulid tubes	0.3	0.2	0.2	0.1	0.5	0.2	0.9	0.6	0.4	0.3
Spirorbis tubes	1.0	0.2	--	--	0.7	0.4	0.4	0.3	--	--
Bivalvia										
Teredinidae	--	0.9	--	0.3	--	0.5	--	0.7	--	--
Teredo bartschi	--	0.4	--	--	--	--	--	--	--	--
Teredo navalis	--	6.8	--	4.3	--	7.4	--	33.8	--	21.4
Arthropoda										
Thoracica										
Balanus amphitrite	--	--	--	--	0.1	--	0.3	0.2	0.1	--
Balanus crenatus	10.7	2.6	0.6	0.5	10.0	1.5	11.6	3.8	1.1	2.1
Balanus eburneus	7.3	10.2	4.7	4.6	0.7	0.4	5.3	6.8	6.5	7.3
Balanus improvisus	24.0	20.6	34.9	26.1	0.4	0.3	2.4	1.6	3.4	1.4
Balanus spp.	21.4	17.4	22.3	25.3	10.5	5.4	7.8	5.2	4.7	3.5
Cordata										
Botryllus schlosseri	--	--	--	--	3.7	0.3	2.0	2.8	1.8	2.4
Ciona intestinalis	--	--	--	--	--	--	--	0.2	0.1	0.1
Molgula manhattensis	--	--	--	--	--	--	0.2	0.3	--	--
Molgula spp.	--	--	--	--	--	--	--	0.1	--	--
Total percent cover	71.0	74.0	76.8	79.3	62.8	37.3	44.0	66.7	39.1	52.2

[a] EF=Effluent GN=Giants Neck A=Asbestos
IN=Intake WP=White Point W=Wood
FN=Fox Island-North

[b] Species not present during 1979.

Spermothamnion repens, Cryptosula pallasiana, Nereis succinea, Anomia simplex, Mytilus edulis, Corophium insidiosum, Balanus crenatus, and *Balanus improvisus*.

Eight additional taxa were collected at all stations except the Effluent. These were: *Ulva lactuca, Polysiphonia nigrescens, Polysiphonia* spp., *Mitrella lunata, Halichondia bowerbankia, Sabella microphthalma, Crepidula plana*, and *Littorina obtusata*.

The following taxa were unique to the Effluent: *Spongomorpa artica, Tubularia* spp., *Alcyonidium* spp., *Callopora aurita, Teredo bartschi, Caprella linearis, Corophium acherusicum, Corophium acutum, Corophium* spp., *Stenothoe minuta*, and *Cumacea* spp.

Twenty five of the 102 taxa reported for 1979 were only found on a single panel. Twenty-one of these were algae which comprised 50% of the taxa reported for the divisions Chlorophyta, Phaeophyta, and Rhodophyta. The remaining four taxa include two species of bryozoans and two taxa of tunicates.

The five most abundant species at each station accounted for 86-98% of the counts, and 72-92% of the percent cover (Table 4). Generally, asbestos panels were dominated by *Balanus*, while wood panels were dominated by *Limnoria*. At the Effluent and the Intake, counts and percent cover on both panel types were highest for *Balanus*. In general, percent cover estimates at Fox Island-North, Giants Neck and White Point were dominated by either *Cryptosula pallasiana* or *Teredo navalis*.

Table 4. Average counts ($\bar{x}$), percent cover ($\bar{x}$), and the percent contribution of the five most dominant organisms on asbestos and wood exposure panels collected from the Millstone Point area during 1979.

EFFLUENT COUNT:

Asbestos Panels				Wood Panels			
Species	$\bar{x}$	%	Cummulative %	Species	$\bar{x}$	%	Cummulative %
Balanus spp.	958	47	47	*Balanus* spp.	1050	48	48
Balanus improvisus	567	28	75	*Balanus improvisus*	583	27	75
Spirorbis tubes	159	8	83	*Gammarus lawrencianus*	189	9	84
Gammarus lawrencianus	100	5	88	*Balanus eburneus*	106	5	89
Balanus crenatus	78	4	92	*Limnoria tripunctata*	59	3	92

EFFLUENT PERCENT COVER:

Asbestos Panels				Wood Panels			
Species	$\bar{x}$	%	Cummulative %	Species	$\bar{x}$	%	Cummulative %
Balanus improvisus	24	32	32	*Balanus improvisus*	21	28	28
Balanus spp.	21	28	60	*Balanus* spp.	17	22	50
Balanus crenatus	10	13	73	*Balanus eburneus*	10	13	63
Balanus eburneus	7	9	82	*Alcyonidium* sp.	8	11	74
Mytilus edulis	5	7	89	*Teredo navalis*	7	9	83

INTAKE COUNT:

Asbestos Panels				Wood Panels			
Species	$\bar{x}$	%	Cummulative %	Species	$\bar{x}$	%	Cummulative %
Balanus improvisus	1787	45	45	*Balanus* spp.	1861	52	52
Balanus spp.	1776	45	90	*Balanus improvisus*	1285	36	88
Chorophium insidiosum	223	6	96	*Chorophium insidiosum*	219	6	94
Mytilus edulis	56	1	97	*Mytilus edulis*	75	2	96
Balanus eburneus	28	1	98	*Balanus eburneus*	35	1	97

INTAKE PERCENT COVER:

Asbestos Panels				Wood Panels			
Species	$\bar{x}$	%	Cummulative %	Species	$\bar{x}$	%	Cummulative %
Balanus improvisus	35	43	43	*Balanus improvisus*	26	31	31
Balanus spp.	22	27	70	*Balanus* spp.	25	30	61
Laminaria agardhii	9	11	81	*Laminaria agardhii*	12	14	75
Balanus eburneus	5	6	87	*Mytilus edulis*	5	6	81
Mytilus edulis	4	5	92	*Balanus eburneus*	5	6	87

Table 4 (cont.)

FOX ISLAND - NORTH COUNT:

Asbestos Panels				Wood Panels			
			Cummulative				Cummulative
Species	$\bar{x}$	%	%	Species	$\bar{x}$	%	%
Balanus spp.	1783	81	81	*Limnoria tripunctata*	1281	47	47
Balanus crenatus	191	9	90	*Balanus* spp.	1261	46	93
Spirorbis tubes	129	6	96	*Teredo navalis*	78	3	96
Corophium insidiosum	34	1	97	*Corophium insidiosum*	37	1	97
Serpulid tubes	19	1	97	Spirorbis tubes	29	1	98

FOX ISLAND - NORTH PERCENT COVER:

Asbestos Panels				Wood Panels			
			Cummulative				Cummulative
Species	$\bar{x}$	%	%	Species	$\bar{x}$	%	%
Cryptosula pallasiana	31	49	49	*Cryptosula pallasiana*	18	48	48
Balanus spp.	10	16	65	*Teredo navalis*	7	19	67
Balanus crenatus	10	16	81	*Balanus* spp.	5	13	86
Botryllus schlosseri	4	6	87	*Balanus crenatus*	2	5	91
Laminaria spp.	1	2	88	*Balanus eburneus*	<1	1	92

GIANTS NECK COUNT:

Asbestos Panels				Wood Panels			
			Cummulative				Cummulative
Species	$\bar{x}$	%	%	Species	$\bar{x}$	%	%
Balanus spp.	635	47	47	*Limnoria lignorum*	2501	62	62
Balanus crenatus	243	18	65	*Teredo navalis*	672	17	79
Corophium insidiosum	223	17	82	*Balanus* spp.	323	8	87
Serpulid tubes	72	5	87	*Corophium insidiosum*	262	6	93
Balanus eburneus	52	4	91	*Balanus crenatus*	77	2	95

GIANTS NECK PERCENT COVER:

Asbestos Panels				Wood Panels			
			Cummulative				Cummulative
Species	$\bar{x}$	%	%	Species	$\bar{x}$	%	%
Balanus crenatus	12	27	27	*Teredo navalis*	34	52	52
Balanus spp.	8	18	45	*Balanus eburneus*	7	11	63
Balanus eburneus	5	11	56	*Balanus* spp.	5	8	71
Halichondria bowerbankia	4	9	65	*Cryptosula pallasiana*	5	8	79
Cryptosula pallasiana	3	7	72	*Balanus crenatus*	4	6	85

Table 4. (cont.)

WHITE POINT COUNT:	Asbestos Panels				Wood Panels		
			Cummulative				Cummulative
Species	$\bar{x}$	%	%	Species	$\bar{x}$	%	%
Balanus spp.	202	39	39	*Limnoria tripunctata*	2680	66	66
Balanus eburneus	85	17	56	*Chelura terebrans*	647	16	82
Chorophium insidiosum	84	16	72	*Limnoria lignorum*	230	6	88
Mitrella lunata	37	7	79	*Balanus* spp.	177	4	92
Balanus improvisus	36	7	86	*Corophium insidiosum*	76	2	94

WHITE POINT PERCENT COVER:	Asbestos Panels				Wood Panels		
			Cummulative				Cummulative
Species	$\bar{x}$	%	%	Species	$\bar{x}$	%	%
Cryptosula pallasiana	13	33	33	*Teredo navalis*	24	46	46
Balanus eburneus	6	15	48	*Cryptosula pallasiana*	8	15	61
Balanus spp.	5	13	61	*Balanus eburneus*	7	13	74
Balanus improvisus	3	8	69	*Balanus* spp.	4	8	82
Halichondria bowerbankia	2	5	74	*Botryllus schlosseri*	2	4	86

Wood borers were dominant components of the fauna at Fox Island-North, Giants Neck and White Point; generally, these organisms accounted for differences in abundance between panel types (Table 5 and 6). At the Intake and the Effluent, where the abundance of wood borers were lowest, the abundance of fouling organisms on wood and asbestos panels was similar.

Species Diversity

In general, diversity for both types of panels increased from May to November except at the Effluent where the inverse was observed (Table 7). Highest diversity on asbestos panels occurred in May at the Effluent and lowest in May at Giants Neck. On wood panels at Fox Island, the highest diversity at all stations was attained in November, while the lowest occurred in May. Evenness for both panel types was similar throughout the year. The number of species increased from May to November, except at the Effluent where the reverse occurred (Fig. 3). The number of species were generally similar in August and November at all stations but White Point, where November values were nearly twice those of August.

Species area curves revealed the effectiveness with which six replicate panels sampled the available species pool. After three replicate panels at each station and exposure period, 80% of the wood panels and 40% of the asbestos panels had attained 80% of their total replicate floral and faunal species found on six panels. Four panels were needed to achieve 80% sampling proficiency for all stations and exposure periods.

Table 5. Average counts ($\bar{x}$) and standard deviations (STD) of the marine borers, *Limnoria* and *Chelura*, in wood panels collected during 1979.

Station	Exposure Period					
	November-May		February-August		May-November	
	$\bar{x}$ Count	STD [a]	$\bar{x}$ Count	STD	$\bar{x}$ Count	STD
Effluent						
Limnoria lignorum	-- [b]	--	--	--	--	--
Limnoria tripunctata	0.8	1.2	26.2	20.2	2.3	3.9
Limnoria tunnels	1.2	1.6	36.7	25.7	7.0	11.8
Intake						
Limnoria lignorum	--	--	--	--	--	--
Limnoria tripunctata	--	--	--	--	--	--
Limnoria tunnels	--	--	--	--	--	--
Fox Island-North						
Limnoria lignorum	--	--	--	--	--	--
Limnoria tripunctata	0.3	0.5	466.7	86.9	173.3	81.2
Limnoria tunnels	0.5	0.8	386.7	75.0	242.5	88.5
Giants Neck						
Limnoria lignorum	489.2	221.9	675.0	112.6	86.2	49.9
Limnoria tripunctata	--	--	--	--	0.7	1.6
Limnoria tunnels	290.0	131.0	620.8	111.6	134.3	63.2
White Point						
Limnoria lignorum	40.7	33.8	74.2	14.29	--	--
Limnoria tripunctata	--	--	641.7	64.6	69[illegible].3	88.6
Limnoria tunnels	49.3	33.7	651.7	73.6	1116.7	136.6
Chelura telebrans	--	--	8.7	5.7	315.0	47.6

[a] STD = Standard Deviation

[b] Species not found

Table 6. Average counts ($\bar{x}$) and percent cover ($\bar{x}$) on wood exposure panels, of *Teredo* collected from the Millstone Point area in 1979.

Station	November-May				February-August				May-November			
	$\bar{x}$ Percent Cover	STD[a]	$\bar{x}$ Count	STD	$\bar{x}$ Percent Cover	STD	$\bar{x}$ Count	STD	$\bar{x}$ Percent Cover	STD	$\bar{x}$ Count	STD
Effluent												
Teredinidae	0.7	0.5	1.2	1.2	1.0	0.0	2.3	1.8	1.2	0.4	23.8	25.7
Teredo bartschi	0.2	0.4	0.2	0.4	--	--	--	--	1.0	0.9	3.0	2.8
Teredo navalis	0.2	0.4	0.2	0.4	0.2	0.4	0.5	1.2	20.0	4.5	18.8	6.2
Intake												
Teredinidae	--[b]	--	--	--	1.0	0.0	1.8	1.6	--	--	--	--
Teredo navalis	--	--	--	--	0.7	0.5	1.0	0.9	12.2	3.2	7.0	2.5
Fox Island-North												
Teredinidae	--	--	--	--	1.5	0.5	30.5	18.4	--	--	--	--
Teredo navalis	--	--	--	--	1.8	1.0	20.8	7.6	20.3	5.7	18.3	9.2
Giants Neck												
Teredinidae	--	--	--	--	2.2	1.2	110.0	31.1	--	--	--	--
Teredo navalis	--	--	--	--	3.7	2.7	39.3	17.4	97.7	1.0	296.7	26.6
White Point												
Teredinidae	--	--	--	--	--	--	--	--	--	--	--	--
Teredo navalis	--	--	--	--	1.0	0.0	2.0	0.9	63.3	22.7	35.3	11.9

[a] STD=Standard Deviation

[b] Species not found

Table 7. Species diversity for asbestos (A) and wood (W) exposure panels collected from the Millstone Point area in 1979.

Station		Exposure Period					
		November-May		February-August		May-November	
		A	W	A	W	A	W
EFFLUENT	H' [a]	2.95	2.58	1.77	1.97	1.56	1.49
	J	0.74	0.65	0.76	0.62	0.47	0.45
	S	16	16	5	9	10	10
	N	1482	1108	1334	1076	3272	4196
INTAKE	H'	1.89	1.82	1.30	1.25	2.08	2.33
	J	0.94	0.91	0.37	0.36	0.55	0.55
	S	4	4	11	11	14	19
	N	12	18	8062	6982	3756	3692
FOX ISLAND - NORTH	H'	0.59	0.33	2.01	3.32	2.64	3.81
	J	0.21	0.10	0.52	0.27	0.69	0.46
	S	7	9	16	10	14	14
	N	5182	3608	808	3156	616	1472
GIANTS NECK	H'	0.46	0.90	2.61	1.62	2.76	2.29
	J	0.23	0.35	0.62	0.36	0.69	0.54
	S	4	6	18	22	16	19
	N	1218	3590	1722	5384	1060	2572
WHITES POINT	H'	1.43	1.85	2.34	1.17	3.00	1.79
	J	0.62	0.66	0.68	0.30	0.69	0.44
	S	5	7	11	15	20	17
	N	106	511	516	4716	916	7032

a H'=Diversity S=Number of Species
J=Evenness N=Number of Individuals

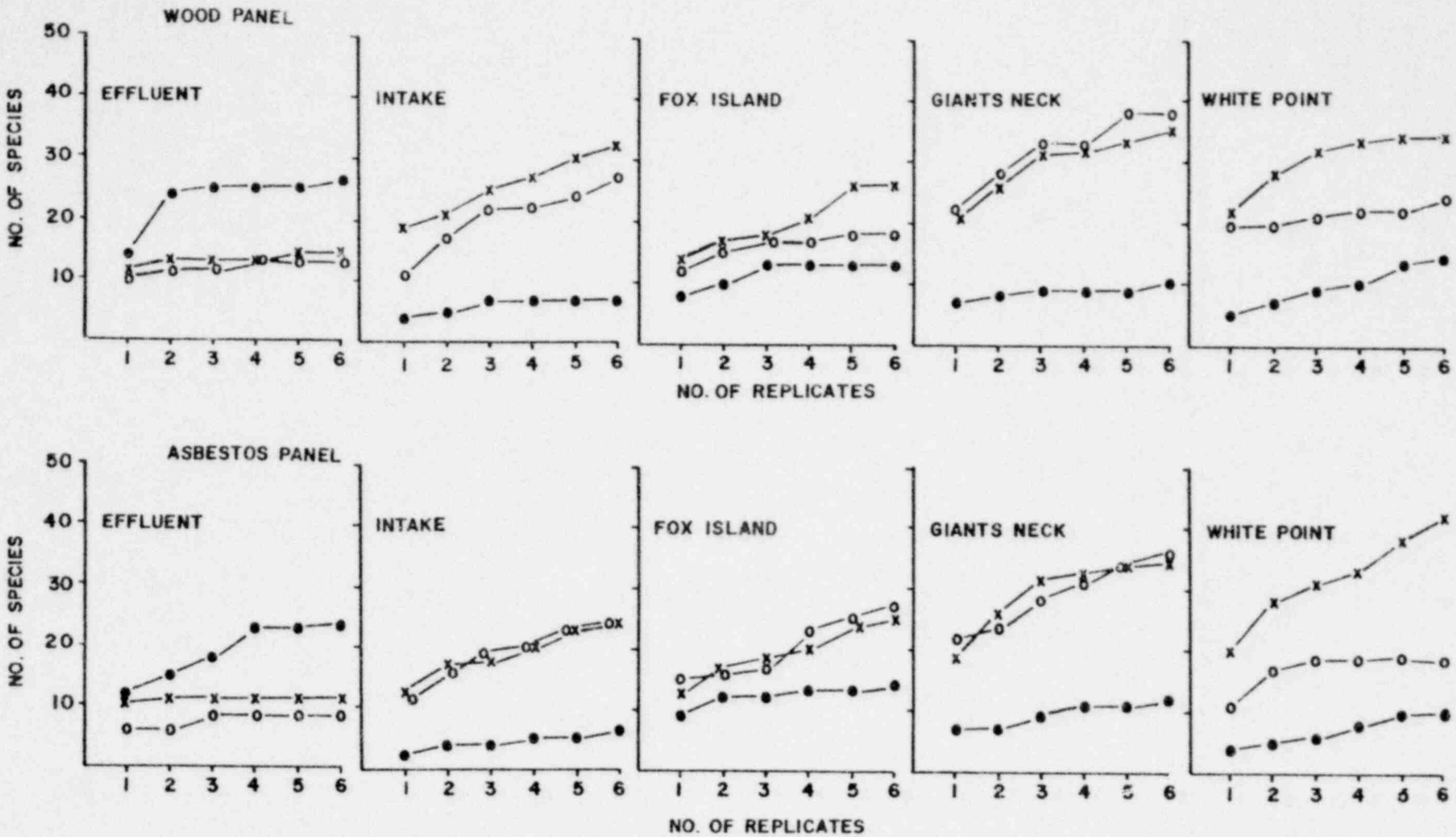

Figure 3. Species area curves for the six replicate exposure panels collected in the Millstone Point area during 1979.

Cluster Analysis

Numerical classification of stations based on the Bray-Curtis similarity coefficients was performed to compare faunal species abundances between stations and exposure periods (Fig. 4). The asbestos panels clustered into two groups. The May Intake assemblage (group I) was most unique because of low faunal abundance relative to other collections. Group II consisted of three subgroups: A, B, and C. Group A was a temporal grouping composed of panels collected in May, but also included White Point in August. Group B comprised Giants Neck, White Point, and Fox Island-North in November and Giants Neck in August. Group C was a spatial grouping composed of Effluent panels from all exposure periods, Intake panels from August and November, and Fox Island-North in August.

The wood panels generally clustered into similar groups as the asbestos panels. White Point and Fox Island-North in August were the only collections that clustered into different groups (Fig. 5). The dominance of borers on wood panels contributed to the within-station similarities observed in Group B.

The affinity of the stations based on the Jaccard coefficients are presented as trellis diagrams in the Tables 8 and 9. The highest affinities, 50-60%, were found in August and November between the Fox Island-North, Giants Neck, and White Point comparisons. In contrast, the highest similarity value at the Effluent station was with itself during August and November. These trends were similar for both panel types.

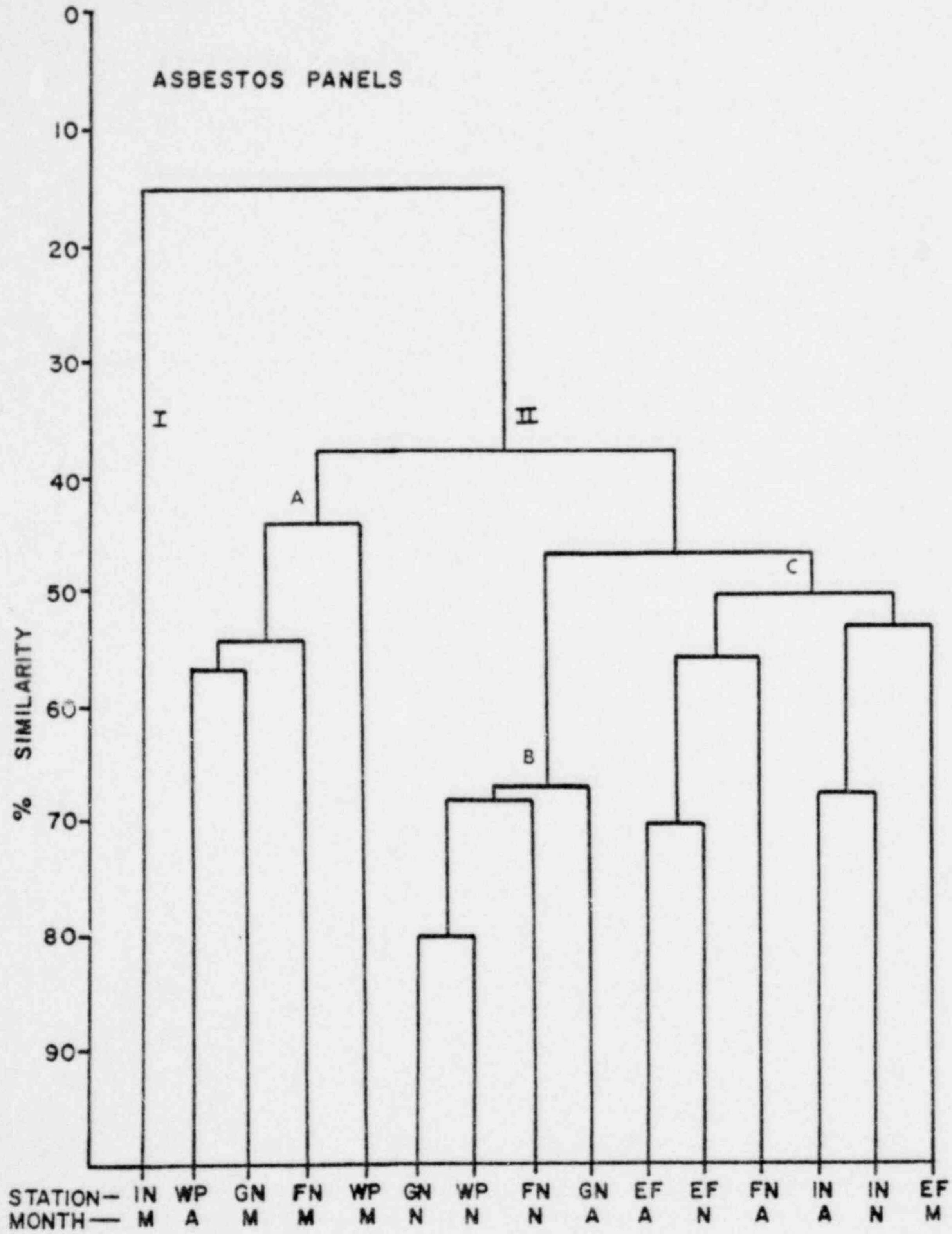

Figure 4. Dendrogram of similarities between the faunal abundances on asbestos panels collected at the Effluent (EF), Intake (IN), Fox Island-North (FN), Giants Neck (GN), and White Point (WP) in May (M), August (A), and November (N), 1979.

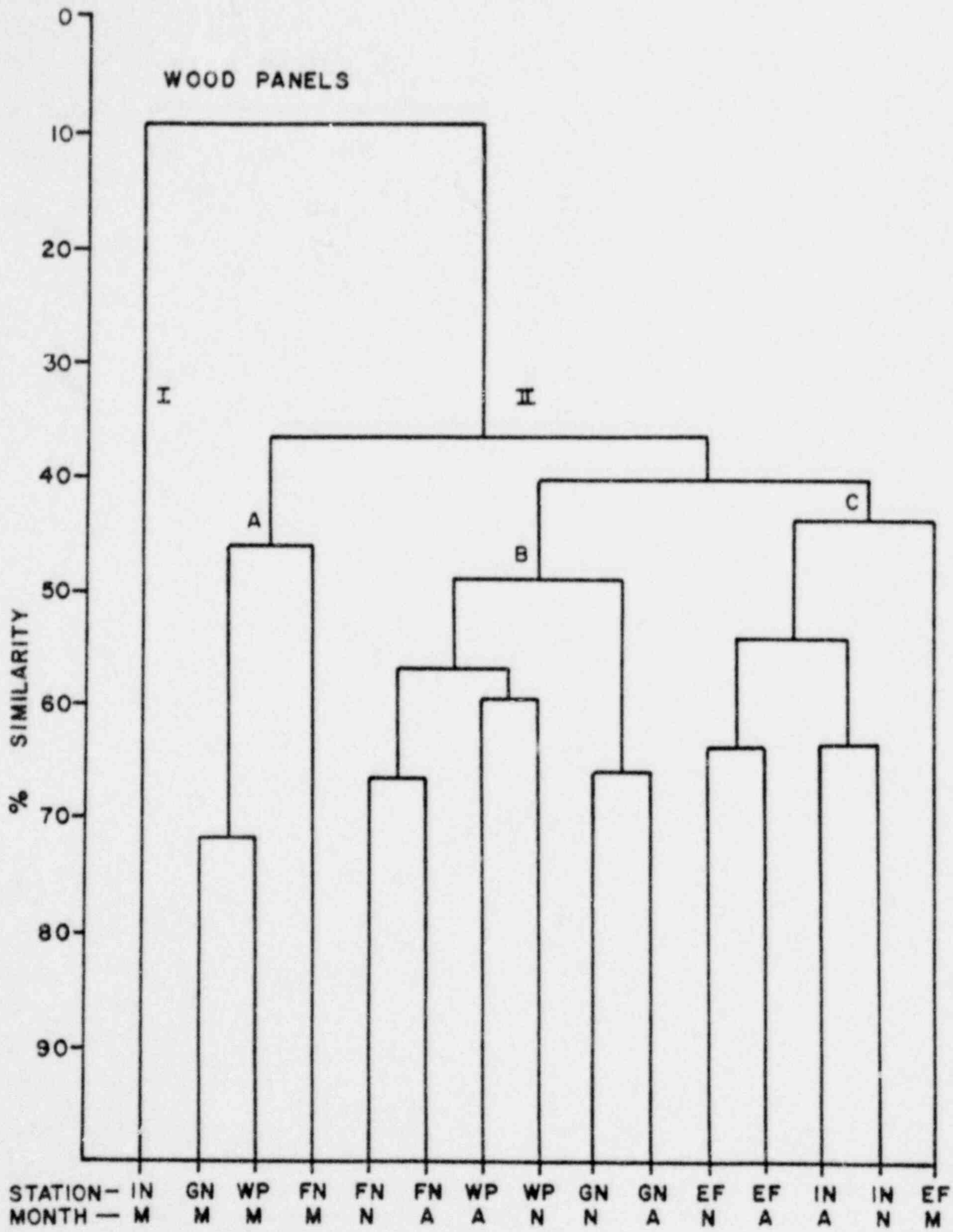

Figure 5. Dendrogram of the similarities between faunal abundances on wood panels collected at the Effluent (EF), Intake (IN), Fox Island-North (FN), Giants Neck (GN), and White Point (WP) in May (M), August (A) and November (N), 1979.

Table 8. Jaccard similarity coefficients for asbestos exposure panels from the Millstone Point area in 1979.

		May					August					November				
		EF	FN	GN	IN	WP	EF	FN	GN	IN	WP	EF	FN	GN	IN	WP
May	EF		23	12	16	15	18	24	25[a]	17	22	13	20	23	21	22
	FN			14	20	35	10	21	14	19	23	9	8	12	14	8
	GN				21	37	5	15	14	16	19	4	16	10	15	8
	IN					27	8	10	8	12	14	7	7	5	14	7
	WP						5	17	19	27	27	9	8	14	17	12
August	EF							17	16	14	17	27	18	20	13	16
	FN								50	24	53	22	40	42	32	47
	GN									28	49	15	39	59	31	50
	IN										34	21	20	26	38	24
	WP											20	38	43	35	36
November	EF												24	22	22	18
	FN													51	30	40
	GN														39	55
	IN															38
	WP															

[a] Numbers underlined indicate the highest similarities between each station-time couplet.

EF=Effluent
FN=Fox Island-North
GN=Giants Neck
IN=Intake
WP=White Point

Table 9. Jaccard similarity coefficients for wood exposure panels collected in the Millstone Point area in 1979.

		May					August					November				
		EF	FN	GN	IN	WP	EF	FN	GN	IN	WP	EF	FN	GN	IN	WP
May	EF		23	10	10	18	23	<u>27</u>[a]	26	24	23	<u>27</u>	22	25	19	23
	FN			24	19	<u>37</u>	9	21	14	15	25	14	12	10	13	7
	GN				14	<u>28</u>	5	8	10	9	14	5	10	10	11	8
	IN					<u>24</u>	6	9	7	10	11	5	3	2	8	5
	WP						8	19	24	28	28	13	11	14	18	12
August	EF							32	26	18	21	<u>47</u>	23	24	16	22
	FN								<u>42</u>	26	38	20	31	34	26	32
	GN									33	43	16	41	<u>54</u>	35	43
	IN										28	21	27	27	<u>40</u>	25
	WP											24	37	42	28	37
November	EF												19	20	18	18
	FN													<u>55</u>	32	49
	GN														35	<u>56</u>
	IN															<u>41</u>
	WP															

[a] Numbers underlined indicate the highest similarities between each station-time couplet.

EF=Effluent
FN=Fox Island-North
GN=Giants Neck
IN=Intake
WP=White Point

DISCUSSION

Distribution of Communities on Exposure Panels

Community structure of exposure panels remained consistent from 1978 to 1979 with the same 12 phyla found in both years. A total of 119 taxa were collected in 1978 and 102 in 1979. The total percentages of fauna and flora for each station during 1979 were approximately equal to that reported over the previous ten years (Battelle 1978).

The similarity of 1979 results to those of previous years indicated that present sampling methods (using six month panels) were as representative of community structure as prior schemes (12 months). This agreed closely with Brown and Moore (1977), who worked with data gathered at Millstone Point from 1968 to 1974. They concluded that species found on 12 month panels could be obtained after exposure periods of only seven to nine months.

Temporal and Spatial Distribution of Species

Differences in temporal distributions of exposure panel communities were evident in species area curves, species diversities, Bray-Curtis similarities, and Jaccard similarities. At the Intake, Fox Island-North, Giants Neck, and White Point, the lowest number of species and diversity occurred on panels collected in May. These low values may be related to the low water temperature that occurs during winter. This seasonal pattern of reduced colonization in winter has also been reported by Coe and Allen (1937), Schoener (1974), Osman (1977), Sutherland and Karlson (1977), Brown and Moore (1977), Schoener et al. (1978), and Field (1979).

The Effluent station, due to location, was most affected by the thermal discharge of the Millstone plant. This thermal effect caused the species diversity and total number of species to decrease from May to November at the Effluent, while these parameters increased during the same period at the Intake, Fox Island-North, Giants Neck, and White Point. The Effluent site also differed from others because the wood boring species, *Teredo bartschi*, has only been collected at this station since 1975.

The differences in species composition and abundance at the Intake station from those at Fox Island-North, Giants Neck, and White Point were probably associated with its location. The latter three stations were located in shallow areas that were protected by jetties, while the Intake station was more influenced by wave and tidal currents. The presence of *Mytilus edulis* and *Laminaria agardhii*, in greatest abundance at the Intake, were probably reflective of this higher energy environment.

Wood Versus Asbestos

Wood borers were primarily responsible for differences in abundance between wood and asbestos panels. At the Intake and the Effluent, where populations of wood borers were low or totally absent, differences in total abundance between wood and asbestos panels were less than 6%. At Giants Neck and White Point, where wood boring species were abundant, differences were greater than 50%. These results indicated that one species or group of species could affect comparisons between stations. At Fox Island-North, the percent cover of *Cryptosula pallasiana* on asbestos panels was primarily responsible for the differences observed in total abundance between panel types. Other researchers have shown that certain species can have a disproportionate influence on community structure (Sutherland and Karlson 1977; Osman 1977).

Throughout this study (1968-1979), wood panels have provided information on the variability in distribution and abundance of wood boring species. Asbestos panels provided an alternate type of substratum, which was not affected by borers.

Panel Variability

Qualitative sampling could be achieved using fewer than six replicates, because variability between replicate panels was low. However, the new sampling strategy will increase the precision of quantitative estimates, and will better allow us to discern between natural and man-induced fluctuations in wood boring and fouling community composition and abundance.

SUMMARY AND CONCLUSIONS

1) In 1979, community composition and structure of fouling and wood boring organisms were similar to those of previous years. Changes in sampling methods were initiated to improve the precision of community estimates.

2) Differences in abundance between wood and asbestos panels were attributed to the presence of large numbers of one or a few dominant species, usually wood borers.

3) Temporal variations wer indicated by a steady increase in species (flora and fauna) abundance and diversity between the May and November exposure periods.

4) Spatial differences in species composition between the Intake and the remaining sites were probably due tc physical factors, e.g. increased wave action and tidal currents, rather than thermal stress.

5) However, spatial differences in species composition and abundance between the Effluent and other sites were a direct result of the thermal effluent.

LITERATURE CITED

Battelle-William F. Clapp Laboratories. 1975. A monitoring program on the ecology of the marine environment of Millstone Point, Connecticut area. Annual Report for the year 1975. Presented to Northeast Utilities Service Company.

Battelle-William F. Clapp Laboratories. 1978. A monitoring program on the ecology of the marine environment of Millstone Point, Connecticut area. Annual Report for the year 1978. Presented to Northeast Utilities Service Company.

Brown, R.T. and S.F. Moore. 1977. An analysis of exposure panel data collected at Millstone Point, Connecticut. MIT, Cambridge, MA. Rep. No. MIT-EL 77-015. 119 pp.

Coe, W.R. and W.E. Allen. 1937. Growth of sedentary marine organisms on experimental blocks and plates for nine successive years at the pier of the Scripps Institute of Oceanography. Scripps Inst. Oceanog. Bull. Scripps Inst. Oceanog. Tech. Ser. 4: 101-135.

Cory, R.L. 1967. Epifauna of the Patuxent River estuary, Maryland, for 1963 and 1964. Chesapeake Sci. 8: 71-89.

Cory, R.L. and J.W. Nauman. 1969. Epifauna and thermal additions in the upper Patuxent River estuary. Chesapeake Sci. 10: 210-217.

Field, B.D. 1979. A structural analysis of fouling community development in Damariscotta River estuary, Maine. M.S. Thesis, Univ. of ME, Orono. 195 pp.

Frame, D.W. 1968. Epibiota attached to wooden panels on the Cape Cod Canal, Sandwich, Massachusetts. M.S. Thesis, Univ. of MA., Amherst. 146 pp.

Fuller, J.L. 1946. Season of attachment and growth of sedentary marine organisms at Lamoine, Maine. Ecology 27: 150-158.

Hillman, R.E. 1975. Environment monitoring through the use of exposure panels. Pages 55-76 in S. B. Saila ed. Fisheries and energy production. Lexington Books, D.C. Heath Co., Lexington, MA.

Hillman, R.E. 1977. Techniques for monitoring reproduction and growth of fouling organisms at power plant intakes. Pages 5-9 in L.D. Jensen ed. Biofouling control procedures, technology and ecological effects. Marcel Dekker, Inc., New York.

Hillman, R.E., N.W. Davis, and R.W. Cote. 1973. A monitoring program on the ecology of the marine environment of the Millstone Point, Connecticut area, with special attention to key indicator organisms - pre-operational phase. Summary Report to Northeast Utilities Service Company, Battelle-Columbus Laboratories, William F. Clapp Laboratories, Duxbury, MA.

NAI. 1979. Seabrook ecological studies 1976-1977. Estuarine panel studies. Coastal panel studies. Tech. Rep. VII-5: 311-436 prepared for Public Service Company of New Hampshire by Normandeau Associates, Inc., Bedford, N.H.

Nauman, J.W. and R.L. Cory. 1969. Thermal additions and epifaunal organisms at Chalk Point, Maryland. Chesapeake Sci. 10: 218-226.

Osman, R.W. 1977. The establishment and development of a marine epifaunal community. Ecol. Monogr. 47: 37-63.

Schoener, A. 1974. Colonization curves for planar marine islands. Ecology 55: 818-827.

Schoener, A., E.R. Long, J.R. DePalma. 1978. Geographic variation in artificial island colonization curves. Ecology 59: 367-382.

Sutherland, J.P. and R.H. Karlson. 1977. Development and stability of the fouling community at Beaufort, North Carolina. Ecol. Monogr. 47: 425-446.

Woods Hole Oceanographic Institution. 1952. Marine fouling and its prevention. Contribution, 580. U.S. Naval Inst., Annapolis, MD. 388 pp.

FISH ECOLOGY

FISH ECOLOGY

INTRODUCTION

Finfish in the area of the three-unit electric generating station located at Millstone Point, Connecticut, in eastern Long Island Sound have been studied since 1969 as part of an ecological program designed to evaluate the effects of construction and operation of the power plants on the marine environment in their vicinity. Shore-zone fish have been sampled with beach seines since May, 1969, pelagic fish since December, 1971 with gill nets and ground fish since April, 1973, using otter trawls. Unit 1 became operational in December, 1970, Unit 2 in October, 1975, and Unit 3 is under construction. Therefore, both preoperational and operational data bases exist for comparative analyses.

The significance of shore-zone, pelagic and demersal fish to estuarine ecology as well as to the commercial and sport fisheries of the Mid-Atlantic Bight region has been emphasized by various authors. Clark (1967) outlined the dependence of sport and commercial fish on the Mid-Atlantic coastal region and Saila and Pratt (1973) summarized the distribution of commercially important fish in this region. The relationship of shore-zone fish to coastal and estuarine ecology has been indicated by several authors (Warfel and Merriman 1944; June and Reintjes 1957; Gunter 1958; de Sylva, Kalber and Shuster 1962; Perlmutter 1971; Hillman, Davis and Wennemer 1977; Carr and Giesel 1975). The importance of demersal fish has been emphasized by Richards (1963), Oviatt and Nixon (1973), McErlean et al. (1973), Jeffries and Johnson (1974) and Bradbury (1978). However, few investigators have considered the ecology of the shore-zone, pelagic and demersal fish together (Massman, Ladd and McCutcheon 1952; McErlean et al. 1973).

The distributions of fish in Long Island Sound have been presented primarily in summaries of marine resources (Baird 1873; Bean 1903; Merriman and Warfel 1948; McHugh 1972; Saila and Pratt 1973). Additionally, reports have focused on fish ecology in estuaries of Long Island Sound (Greenley 1938; Pearcy and Richards 1962; Briggs 1975; Dey and Baumann Texas Instrument manuscript; Pease, Savage and Schmidtt 1979), and in the Sound proper (Warfel and Merriman 1944; Richards 1963; Perlmutter 1971; Hillman et al. 1975; Austin and Amish 1974). Few have studied any populations for more than two consecutive years.

The overall objective of the monitoring program at Millstone is to determine the impacts of construction and operation of the power plants on local fish communities. These impacts have been defined as power-plant related changes in the occurrence, distribution and abundance of fish species which would affect the community structure and ecology of the region. This report summarizes such fluctuations in the Millstone area over several years some of which were prior to the startup of the power plants, and relates these changes to the ecology of the area.

MATERIALS AND METHODS

Shore-zone Fish

Beginning in May, 1969, three beach seine hauls were made within the two-hour period preceding high tide using a 9.2m x 1.2m knotless nylon seine with 1.3m mesh drawn parallel to the beach. The person inshore hauled the full length of the tow, 30m, and the person offshore arched into the beach at the end of the tow. Hauls were made each February, May, July, September and December through 1972 at Giants Neck (GN), Bay Point (BP), Jordan Cove (JC), and White Point (WP) (Fig. 1). In February, 1973, two additional stations were added: Seaside Point (SS) and Crescent Beach (CB). In 1974, the sampling frequency was increased to include collections during June, August and October. During 1975, one additional station, Sandy Point (SP), was sampled. Fish in each tow were identified to lowest practical taxon, counted and measured (standard length) to the nearest millimeter. When expressed as catch per unit effort, shore-zone fish abundances were standardized to a 30m haul.

Pelagic Fish

Beginning in December, 1971, gill nets were set overnight near Twotree Island (TT) and Bay Point (BP) on a quarterly basis (Fig. 1). In June, 1973, sampling sites were added near Black Point (BLP) and in Jordan Cove (JC), and the sampling frequency increased to bimonthly beginning with the July, 1973 sample. In January, 1974, the sampling frequency was increased to monthly.

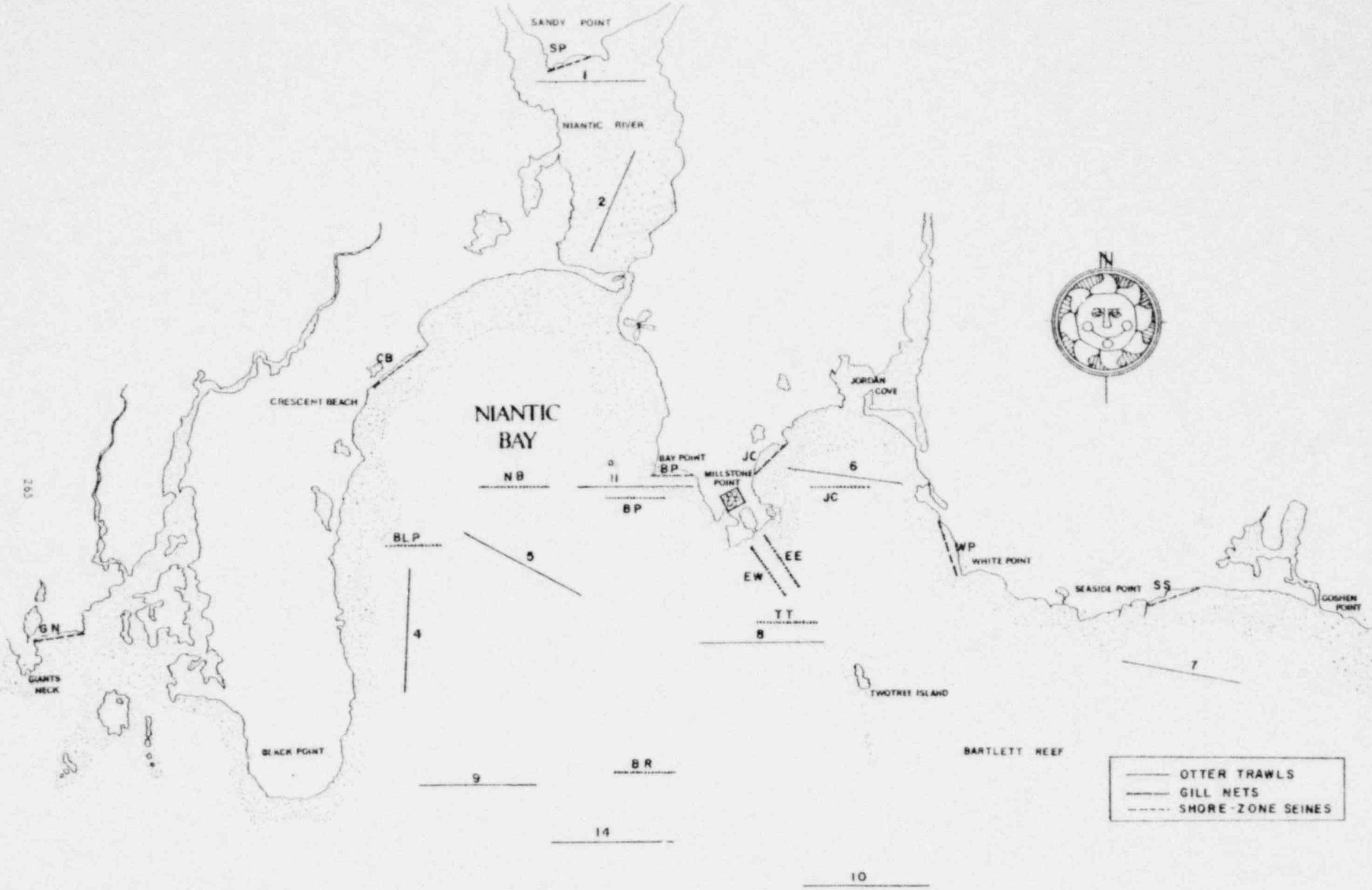

Figure 1. Location of shore-zone (seines), pelagic (gill net) and demersal (trawl) sampling sites.

Standard monofilament experimental nets from Sterling Marine Products made up of six 7.6m panels, 1.83m deep, with a stretch mesh of 5.1, 3.2, 2.5, 1.9, 3.8 and 6.4cm were used during the period from December, 1971, through January, 1975. They were placed perpendicular to the prevailing currents and set so that the float line was approximately 0.6m below the surface at low tide.

In February, 1975, the number of sites was increased and nets were set both at the surface and approximately 0.5m off the bottom at some sites. Surface and bottom nets were set at Twotree, Bartlett Reef (BR), Niantic Bay (NB), and Bay Point. A surface net was set west of the effluent plume (EW) and a bottom net was set east of the effluent (EE). A surface net was also set at the Jordon Cove and Black Point sites. In May, 1975, the nets were changed to a multifilament net from the Nylon Net Company, made up of eight 7.6m panels, 1.83m deep, with a stretch mesh of 10.1, 6.4, 5.1, 1.9, 2.5, 3.8, 7.6 and 12.7 cm.

In February, 1976, surface and bottom sets were replaced with mid-water sets at all stations. From October, 1977, to present, monthly midwater gill nets were set overnight at eight stations (Fig. 1). Throughout the program, fish were identified to the lowest practical taxon and counted. Standard lengths to the nearest millimeter were recorded for Petromysoniformes (lamprey eel) and Chondrichthyes (sharks). When expressed as catch per unit effort, pelagic fish abundances were standardized to an 18 hour set.

Demersal Fish

Beginning in April, 1973, the demersal fish were sampled biweekly using a 9.2m Wilcox otter trawl with a 0.6cm mesh cod-end liner. The trawl was towed at 1.5 to 2 knots at each station for 15 minutes. Initially, one tow was taken at Stations 1, 4, 6, 7, 8, 9 and 10 (Fig. 1). Station 11 was added in September, 1974, Station 5 in February, 1975, Station 2 in June, 1975, and Station 14 in February, 1976. Single tows were taken at each station in every sample period until June, 1974, when two tows were made at one randomly chosen station in a sample period. In August, three tows were taken at one randomly chosen station each sample period. In September, 1974, duplicate tows were taken at Stations 8, 10 and 11. In February, 1975, duplicate tows were begun at Station 5. For the remainder of the stations, one tow per sampling period was taken plus one randomly chosen tow. Beginning in February, 1976, triplicate tows were made at Stations 2, 5, 6, 8, 11 and 14, and single tows at Stations 1, 4, 7, 9 and 10. Stations 1, 4, 7, 9 and 10 were deleted in January, 1977. Beginning in October, 1977, the duration of the tow was the length of time required to cover a fixed distance of 0.69 km over the bottom. Throughout the study, fish from each haul were identified to lowest practical taxon, counted and measured (total length) to the nearest millimeter. When expressed as catch per unit effort, demersal fish abundances were standardized to a 15 minute tow.

Analyses

Preliminary evaluations using the Shapiro-Wilk W-statistic (Shapiro and Wilk 1965) and the Kolmogorov Smirnov D-statistic (Stephens 1974) tests for normality, indicated that the $\log_e$ (CPUE+1) transformation could be assumed to normalize the trawl data for analyses of variance, while no transformation could adequately normalize the seine or gill net data. For consistency, all abundance graphs were prepared using the $\log_e$ transformation. However, analyses of variance of the shore-zone and pelagic fish data utilized the nonparametric procedure of Kruskal and Wallis (1952) that is based on ranks. All significance levels were at $\alpha = .05$.

In order to evaluate the fishery data as a time series, the observations had to be equally spaced in time. For this reason, and to maximize the use of the available data, the observations from the shore-zone and pelagic fish data were grouped together on a quarterly basis, while the demersal fish observations were considered on a monthly basis. The mid-points of these intervals were used on all graphics that considered time as the independent variable. Quarters were designated by the center month, e.g., the quarter that included January, February and March was referred to as the February quarter. Abundance estimates were plotted as the $\log_e$ (CPUE+1) where CPUE was the mean catch per unit effort of all data points in a time interval. As an indication of richness, the total number of species recorded from each time period was also considered against time, and subjected to analyses of variance.

Graphics and statistical analyses were completed using the SAS79 (Helwig and Council 1979) statistical package on an IBM System 3033 computer.

RESULTS AND DISCUSSION

Overview of Fish in Greater Millstone Bight

Species composition. From May, 1969, through December, 1979, a total of 291,470 individuals representing at least 86 species of shore-zone, pelagic and ground fish was recorded from 4,637 samples collected around Millstone Point. Of these, 175,890 fish including 41 species were collected from 1,168 seine samples yielding 151 fish per sample. A total of 6,581 individuals representing 46 species was collected from 582 gill net sets yielding 11 fish per sample. The 2,887 trawl collections averaged 38 fish per sample based on 108,999 representatives of 70 species. In this respect, the seines provided the most data per sampling event and the gill nets the least.

In terms of actual abundance, 95% of all fish caught were represented by 20 species (Table 1). Silversides (*Menidia* spp.) were the most abundant fish captured, making up almost half of the total species composition. They were also the most important shore-zone fish collected, making up 76.8% of this group. The winter flounder (*Pseudopleuronectes americanus*) and scup (*Stenotomus chrysops*) were the second and third most abundant fish overall, making up 15.4% and 6.4% of the catch respectively, and were the first and second most abundant demersal fish collected, their combined catch contributing over half to the trawl catch. The most abundant pelagic fish, the Atlantic herring (*Clupea harengus*) was only the 13th most abundant fish overall.

Table 1. Actual abundance and percent species composition of fish collected with seines, gill nets, and trawls in Long Island Sound near the Millstone Power Station, 1969-1979.

Species	All Gear		Seines		Gill Nets		Trawls	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Menidia spp.	142,375	48.85	135,137	76.83	17	0.26	7,221	6.62
Pseudopleuronectes americanus	44,876	15.40	52	0.03	15	0.23	44,809	41.11
Stenotomus chrysops	18,729	6.43	0	----	133	2.02	18,596	17.06
Ammodytes americanus	9,842	3.38	9,645	5.48	0	----	197	0.18
Fundulus heteroclitus	8,742	3.00	8,742	4.97	0	----	0	----
Scopthalmus aquosus	8,529	2.93	4	0.00	7	0.11	8,518	7.81
Fundulus majalis	7,921	2.72	7,921	4.50	0	----	0	0.00
Tautogolabrus adspersus	5,960	2.04	5	0.00	357	5.42	5,598	5.14
Brevoortia tyrannus	5,836	2.00	4,477	2.55	1,328	20.18	31	0.03
Raja spp.	4,685	1.61	0	----	14	0.21	4,671	4.29
Apeltes quadracus	4,670	1.60	3,963	2.25	0	----	707	0.65
Anchoa spp.	3,912	1.34	0	0.00	0	----	3,912	3.59
Clupea harengus	3,016	1.03	156	0.09	2,826	42.94	34	0.03
Prionotus spp.	2,004	0.69	0	----	177	2.69	1,827	1.68
Merluccius bilinearis	1,707	0.59	0	----	46	0.70	1,661	1.52
Myoxocephalus aenaeus	1,610	0.55	23	0.01	5	0.08	1,582	1.45
Tautoga onitis	1,514	0.52	7	0.00	29	0.44	1,478	1.36
Cyprinodon variegatus	1,379	0.47	1,379	0.78	0	0.00	0	----
Alosa aestivalis	1,342	0.46	548	0.31	384	5.83	410	0.38
Peprilus triacanthus	1,268	0.44	2	0.00	548	8.33	718	0.66
Fundulus spp.	1,218	0.42	1,205	0.69	0	----	13	0.01
Gasterosteus aculeatus	1,060	0.36	654	0.37	0	----	406	0.37
Urophycis spp.	1,032	0.35	11	0.01	24	0.36	997	0.91
Gadidae family	995	0.34	86	0.05	15	0.23	894	0.82
Paralichthys dentatus	850	0.29	0	----	2	0.03	848	0.78
Pungitius pungitius	804	0.28	804	0.46	0	----	0	----
Syngnathus fuscus	636	0.22	289	0.16	1	0.02	346	0.32
Osmerus mordax	590	0.20	25	0.01	28	0.43	537	0.49
Alosa pseudoharengus	467	0.16	3	0.00	145	2.20	319	0.29
Pholis gunnellus	375	0.13	0	0.00	1	0.02	374	0.34
Anchoa mitchilli	340	0.12	14	0.01	4	0.06	322	0.30
Anguilla rostrata	336	0.12	228	0.13	1	0.02	107	0.10
Mugil cephalus	320	0.11	319	0.18	1	0.02	0	----
Hemitripterus americanus	274	0.09	0	----	0	----	274	0.25
Myoxocephalus octodecemspinosus	276	0.09	0	----	3	0.05	273	0.25
Etropus microstomus	198	0.07	0	----	0	----	198	0.18
Pomatomus saltatrix	209	0.07	53	0.03	150	2.28	6	0.01
Morone americanus	174	0.06	9	0.01	10	0.15	155	0.14
Opsanus tau	188	0.06	0	----	0	----	188	0.17
Mustelis canis	129	0.04	0	----	57	0.87	72	0.07
Alosa sapidissima	100	0.03	1	0.00	19	0.29	80	0.07
Centropristis striata	92	0.03	0	----	1	0.02	91	0.08
Paralichthys oblongus	91	0.03	0	----	0	----	91	0.08
Squalus acanthias	92	0.03	0	----	91	1.38	1	0.00
Cyclopterus lumpus	64	0.02	0	----	0	----	64	0.06
Cynoscion regalis	66	0.02	0	----	16	0.24	50	0.05
Liparis spp.	68	0.02	0	----	0	----	68	0.06
Scomber scombrus	49	0.02	0	----	47	0.71	2	0.00
Sphaeroides maculatus	56	0.02	16	0.01	0	----	40	0.04
Anchoa hepsetus	37	0.01	0	----	37	0.56	0	----

Table 1. (continued)

Species	All Species Number	All Species Percent	Seines Number	Seines Percent	Gill Nets Number	Gill Nets Percent	Trawls Number	Trawls Percent
Caranx crysos	16	0.01	11	0.01	5	0.08	0	----
Clupeidae	17	0.01	6	0.00	0	----	11	0.01
Gobiidae	29	0.01	6	0.00	0	----	23	0.02
Limanda ferruginea	20	0.01	0	----	0	----	20	0.02
Macrozoarces americanus	24	0.01	0	----	0	----	24	0.02
Menticirrhus saxatilis	43	0.01	35	0.02	1	0.02	7	0.01
Monacanthus hispidus	32	0.01	0	----	0	----	32	0.03
Strongylura marina	16	0.01	16	0.01	0	----	0	----
Alosa mediocris	7	0.00*	0	----	6	0.09	1	0.00
Aluterus schoepfi	5	0.00	0	----	0	----	5	0.00
Aulostomus maculatus	1	0.00	0	----	0	----	1	0.00
Caranx hippos	6	0.00	1	0.00	5	0.08	0	----
Conger oceanicus	1	0.00	0	----	0	----	1	0.00
Dactylopterus volitans	6	0.00	0	----	0	----	6	0.01
Enchelyopus cimbrius	1	0.00	0	----	0	----	1	0.00
Etrumeus teres	5	0.00	0	----	5	0.08	0	----
Fistularia tabacaria	5	0.00	0	----	0	----	5	0.00
Fundulus diaphanus	4	0.00	4	0.00	0	----	0	----
Gasterosteidae	3	0.00	0	----	0	----	3	0.00
Hippocampus spp.	7	0.00	0	----	0	----	7	0.01
Leiostomus xanthurus	12	0.00	0	----	1	0.02	11	0.01
Lophius americanus	9	0.00	0	----	1	0.02	8	0.01
Lucania parva	10	0.00	10	0.01	0	----	0	----
Morone saxatilis	13	0.00	1	0.00	9	0.14	3	0.00
Mugil curema	3	0.00	2	0.00	0	----	1	0.00
Mullus auratus	1	0.00	0	----	0	----	1	0.00
Myoxocephalus spp.	13	0.00	0	----	0	----	13	0.01
Petromyzon marinus	1	0.00	0	----	1	0.02	0	----
Pristigenys alta	3	0.00	0	----	0	----	3	0.00
Scomber japonicus	7	0.00	0	----	7	0.11	0	----
Scomberesox saurus	6	0.00	6	0.00	0	----	0	----
Scyliorhinus retifer	1	0.00	0	----	0	----	1	0.00
Selene vomer	3	0.00	0	----	0	----	3	0.00
Seriola zonata	1	0.00	0	----	1	0.02	0	----
Synodus foetens	5	0.00	0	----	0	----	5	0.00
Trachinotus falcatus	12	0.00	12	0.01	0	----	0	----
Trachurus lathami	3	0.00	0	----	0	----	3	0.00
Trinectes maculatus	9	0.00	0	----	0	----	9	0.01
Tylosaurus marinus	1	0.00	1	0.00	0	----	0	----
Ulvaria subbifurcata	4	0.00	0	----	0	----	4	0.00
Specimen not identified	1	0.00	1	0.00	0	----	0	----
Vomer setapinnis	1	0.00	0	----	0	----	1	0.00
Totals	291,470	100.00	175,890	100.00	6,581	100.00	108,999	100.00
No. of samples	4,637		1,168		582		2,887	

* <0.01%

Distribution of total catches. For summary purposes, the geographically proximate sampling stations indicated in Fig. 1 were considered together in the regions listed below:

Trawl 1, 2, Seine SP	Niantic River
Trawl 4, 5, Seine CB, Gill Net BLP, NB	Niantic Bay
Trawl 11, Seine BP, Gill Net BP	Intake
Gill Net EW, EE	Effluent
Trawl 8, Gill Net TT	Twotree
Trawl 6, Seine JC, WP, Gill Net JC	Jordan Cove
Trawl 7, Seine SS	Seaside
Trawl 9, 10, 14, Gill Net BR	Bartlett Reef
Seine GN	Giants Neck

The distribution of catch and sampling effort in these regions since 1969 was summarized in Table 2. Fish were most numerous in the Jordan Cove region where the most collections were made. The resulting 170 fish collected per sampling episode was almost twice the catch in the next highest region, 88 fish per sample at Giants Neck. These numbers probably reflect the high proportion of seine samples collected in both regions. The Niantic Bay and Intake regions had the next most numerous catches at 29,240 and 25,398 fish respectively, representing 37 and 36 fish per sample. However, the Niantic River, with 22,817 fish in 479 samples, actually had more fish per sampling event, 48. The least productive region in terms of fish per sampling episode was the Effluent region sampled only by gill nets, which produced 8 fish per collection.

Table 2. Yearly abundance of all fish species in each sampling region in Long Island Sound near the Millstone Power Station: 1969-1979.

	Bartlett Reef		Effluent		Giants Neck		Intake		Jordan Cove		Niantic Bay		Niantic River		Seaside		Twotree		Totals	
	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows
1969																				
Trawls	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Seines	.	.	.	.	860	12	26	12	6,011	24	.	.	.	.	.	.	.	.	6,897	48
Gill Nets	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All Gear	.	.	.	.	860	12	26	12	6,011	24	.	.	.	.	.	.	.	.	6,897	48
1970																				
Trawls	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Seines					801	15	1,302	15	5,186	30					.	.	.	.	7,289	60
Gill Nets	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All Gear	.	.	.	.	801	15	1,302	15	5,186	30	.	.	.	.	.	.	.	.	7,289	60
1971																				
Trawls	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Seines	.	.	.	.	2,926	15	140	15	30,065	30	.	.	.	.	.	.	.	.	33,131	60
Gill Nets	.	.	.	.	.	.	7	1	.	.	.	.	.	.	.	.	31	1	38	2
All Gear	.	.	.	.	2,926	15	147	16	30,065	30	.	.	.	.	.	.	31	1	33,169	62
1972																				
Trawls	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Seines	.	.	.	.	1,307	15	596	15	5,927	30	.	.	.	.	.	.	.	.	7,830	60
Gill Nets	.	.	.	.	.	.	166	4	.	.	.	.	.	.	.	.	157	4	323	8
All Gear	.	.	.	.	1,307	15	762	19	5,927	30	.	.	.	.	.	.	157	4	8,153	68
1973																				
Trawls	2,319	31	.	.	.	.	.	.	527	15	1,060	16	499	14	283	14	610	16	5,298	106
Seines	.	.	.	.	682	15	144	15	5,913	30	74	12	.	.	180	15	.	.	6,993	87
Gill Nets	.	.	.	.	.	.	72	5	105	5	81	5	.	.	.	.	140	5	398	20
All Gear	2,319	31	.	.	682	15	216	20	6,545	50	1,215	33	499	14	463	29	750	21	12,689	213
1974																				
Trawls	3,032	62	.	.	.	.	709	16	1,144	33	830	30	1,310	29	423	22	998	35	8,446	227
Seines	.	.	.	.	2,488	24	156	21	8,832	48	280	24	.	.	64	24	.	.	11,820	141
Gill Nets	.	.	.	.	.	.	288	12	309	13	525	12	.	.	.	.	234	11	1,356	48
All Gear	3,032	62	.	.	2,488	24	1,153	49	10,285	94	1,635	66	1,310	29	487	46	1,232	46	21,622	416

Table 2. (continued)

	Bartlett Reef		Effluent		Giants Neck		Intake		Jordan Cove		Niantic Bay		Niantic River		Seaside		Twotree		Totals	
	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows	#Fish	#Tows
1975																				
Trawls	2,983	120	.	.	.	.	2,627	89	1,160	32	5,582	112	2,192	59	713	34	1,732	89	16,989	535
Seines	.	.	.	.	2,130	24	7	7	9,518	48	142	24	6,617	21	314	21	.	.	18,728	145
Gill Nets	74	22	200	22	.	.	265	21	297	13	388	34	.	.	.	.	280	23	1,504	135
All Gear	3,057	142	200	22	2,130	24	2,899	117	10,975	93	6,112	170	8,809	80	1,027	55	2,012	112	37,221	815
1976																				
Trawls	3,334	130	.	.	.	.	4,041	78	3,564	77	4,085	104	5,836	122	318	26	1,780	78	22,958	615
Seines	.	.	.	.	2,707	21	114	21	39,797	45	499	24	.	.	5,805	24	.	.	48,922	135
Gill Nets	12	11	185	24	.	.	104	13	171	12	106	14	.	.	.	.	37	13	615	87
All Gear	3,346	141	185	24	2,707	21	4,259	112	43,532	134	4,690	142	5,836	122	6,123	50	1,817	91	72,495	837
1977																				
Trawls	2,645	78	.	.	.	.	4,648	78	2,037	78	3,412	78	2,165	78	.	.	1,715	78	16,622	468
Seines	.	.	.	.	2,198	24	118	24	19,126	48	209	24	.	.	120	24	.	.	21,771	144
Gill Nets	18	12	85	25	.	.	64	12	117	12	54	16	.	.	.	.	21	12	359	89
All Gear	2,663	90	85	25	2,198	24	4,830	114	21,280	138	3,675	118	2,165	78	120	24	1,736	90	38,752	701
1978																				
Trawls	2,121	78	.	.	.	.	4,081	78	1,943	78	5,057	78	1,428	78	.	.	1,525	78	16,155	468
Seines	.	.	.	.	1,126	24	346	24	2,978	48	168	24	.	.	323	24	.	.	4,941	144
Gill Nets	55	12	248	25	.	.	117	12	198	12	168	24	.	.	.	.	66	12	852	97
All Gear	2,176	90	248	25	1,126	24	4,544	114	5,119	138	5,393	126	1,428	78	323	24	1,591	90	21,948	709
1979																				
Trawls	2,389	78	.	.	.	.	4,720	78	3,125	78	5,959	78	2,770	78	.	.	3,568	78	22,531	468
Seines	.	.	.	.	1,554	24	442	24	5,089	48	149	24	.	.	334	24	.	.	7,568	144
Gill Nets	25	12	292	24	.	.	98	12	278	12	412	24	.	.	.	.	31	12	1,136	96
All Gear	2,414	90	292	24	1,554	24	5,260	114	8,492	138	6,520	126	2,770	78	334	24	3,599	90	31,235	708
All Years																				
Trawls	18,823	577	.	.	.	.	20,826	417	13,500	391	25,985	496	16,200	458	1,737	96	11,928	452	108,999	2,887
Seines	.	.	.	.	18,779	213	3,391	193	138,442	429	1,521	156	6,617	21	7,140	156	.	.	175,890	1,168
Gill Nets	184	69	1,010	120	.	.	1,181	92	1,475	79	1,734	129	.	.	.	.	997	93	6,581	582
All Gear	19,007	646	1,010	120	18,779	213	25,398	702	153,417	890	29,240	781	22,817	479	8,877	252	12,925	545	291,470	4,637

The greatest number of fish in a single year (72,495) was collected in 1976. This was the most intensively studied year with 837 collections. The highest density of fish per sample (535) was reported in 1971. The earlier years (1969-1972), in general, had higher catches per collection, ranging from 120 in 1972 to 535 in 1971. In 1973, when the trawl collections began and the gill net program intensified, the number of fish collected per sample dropped precipitously because, as pointed out previously, trawls and gill nets did not collect as many fish as seines. While the sampling effort over the last three years was fairly constant (700 collections per year), the total number of fish caught ranged from 21,948 in 1978 to 38,752 in 1977. The fewest number of fish per collection (31) occurred in 1978.

Regional distribution of selected species. The regional abundances in terms of catch per unit of effort (CPUE) of species contributing at least 1% to any of the fishery catches, were summarized in Tables 3-5. Silversides were the most abundant shore-zone fish caught in five of the seven regions sampled by seines (Table 3), being highest in abundance at Jordan Cove and lowest at Seaside.

Sandlance (*Ammodytes americanus*) was the most abundant shore-zone fish collected from Seaside and was at its highest abundance there. Fourspine stickleback (*Apeltes quadracus*), mummichog (*Fundulus heteroclitus*) and killifish (*Fundulus majalis*) were found at their greatest abundances in the Niantic River, while menhaden (*Brevoortia tyrannus*) and silversides were most abundant in Jordan Cove. The very large CPUE of silversides from Jordan Cove was partially attributable to unusually large catches of juveniles ($>$5,000 per haul) in the summer of 1971 and again in 1976.

Table 3. Regional distribution of selected* species' mean catch (number per 30 meter haul) using seines, 1969-1979

Species	Bartlett Reef	Effluent	Giants Neck	Intake	Jordan Cove	Niantic Bay	Niantic River	Seaside	Twotree
Ammodytes americanus	NS**	NS	1.52	0.08	8.27	0.15	0.19	36.03	NS
Apeltes quadracus	NS	NS	0.06	0.04	8.55	0.04	11.62	0.18	NS
Brevoortia tyrannus	NS	NS	0.45	6.57	6.70	0.01	0.00	0.01	NS
Fundulus heteroclitus	NS	NS	3.45	0.05	14.62	1.01	73.71	0.06	NS
Fundulus majalis	NS	NS	1.46	0.10	15.81	0.03	37.57	0.09	NS
Menidia spp.	NS	NS	74.60	8.28	259.56	7.60	186.52	5.69	NS

Table 4. Regional distribution of selected species' mean catch (number per 18 hour set) using gill nets, 1971-1979

Species	Bartlett Reef	Effluent	Giants Neck	Intake	Jordan Cove	Niantic Bay	Niantic River	Seaside	Twotree
Alosa aestivalis	0.21	0.70	NS	0.38	2.86	0.85	NS	NS	0.03
Alosa pseudoharengus	0.04	0.67	NS	0.10	0.76	0.35	NS	NS	0.59
Brevooria tyrannus	0.46	2.04	NS	2.94	4.56	4.21	NS	NS	0.59
Clupea harengus	0.84	2.24	NS	5.53	4.83	3.56	NS	NS	7.18
Peprilus triacanthus	0.00	0.43	NS	0.51	2.50	2.06	NS	NS	0.06
Pomatomus saltatrix	0.04	0.53	NS	0.25	1.79	0.31	NS	NS	0.00
Prionotus spp.	0.34	0.19	NS	0.94	0.16	0.26	NS	NS	1.49
Squalus acanthias	0.19	0.01	NS	0.23	0.03	0.44	NS	NS	0.62
Stenotomus chrysops	0.05	0.12	NS	1.37	0.36	0.11	NS	NS	0.97
Tautogolabrus adspersus	0.02	1.67	NS	0.28	0.11	0.22	NS	NS	2.17

Table 5. Regional distribution of selected species' mean catch (number per 15 minute tow) using trawls, 1973-1979

Species	Bartlett Reef	Effluent	Giants Neck	Intake	Jordan Cove	Niantic Bay	Niantic River	Seaside	Twotree
Anchoa spp.	0.01	NS	NS	2.88	1.02	5.31	0.63	0.00	0.80
Menidia spp.	0.64	NS	NS	6.26	4.24	1.92	5.19	0.09	0.90
Merluccius bilinearis	1.58	NS	NS	0.78	0.24	0.49	0.01	0.17	0.58
Myoxocephalus aenaeus	1.10	NS	NS	0.76	0.99	0.28	0.56	0.26	0.46
Prionotus	1.21	NS	NS	0.51	0.19	0.57	0.59	0.08	0.90
Pseudopleuronectes americanus	11.09	NS	NS	18.73	17.77	20.81	29.95	7.18	14.61
Raja spp.	3.34	NS	NS	1.89	0.96	1.90	0.01	0.68	2.23
Scophthalmus aquosus	7.65	NS	NS	2.86	1.71	2.89	1.20	1.11	2.46
Stenotomus chrysops	4.08	NS	NS	9.35	3.63	23.12	0.52	0.94	5.41
Tautoga onitis	0.36	NS	NS	0.97	0.97	0.38	0.91	0.49	0.32
Tautogolabrus adspersus	0.76	NS	NS	8.69	1.96	0.66	0.93	5.08	0.63

* Those fish that made up at least 1% of the species composition.
** Not sampled.

Atlantic herring were the most abundant fish caught in all but one of the six regions sampled by gill nets (Table 4), being most abundant at Twotree and least abundant at Bartlett Reef. Menhaden were the most abundant fish caught in Niantic Bay. Blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), menhaden, butterfish (Peprilus triacanthus) and bluefish (Pomatomus saltatrix) were at their greatest abundances in Jordan Cove, while Atlantic herring, searobins (Prionotus spp.) and spiny dogfish (Squalus acanthias) were most abundant at Twotree. Scup were found in their highest abundance in the Intake region.

Winter flounder was, numerically, the most important fish collected by bottom trawls from all regions but Niantic Bay (Table 5). Highest catches were recorded from the Niantic River and lowest catches off Seaside. Scup was the dominant species collected from Niantic Bay. Silverhake (Merluccius bilinearis), searobins, skates (Raja spp.) and windowpane flounder (Scophthalmus aquosus) were found in their highest abundance in the Bartlett Reef area, while silversides and cunner (Tautogalabrus adspersus) were found to be most abundant in the Intake region and anchovies (Anchoa spp.) and scup in Niantic Bay. The grubby (Myoxocephalus aenaeus) was found in its highest abundance at Bartlett Reef and Jordan Cove. Blackfish (Tautoga onitis) were evenly distributed, but were most abundant in the Intake area and Jordan Cove.

Annual distribution for selected species. Silversides were the most abundant shore-zone fish collected by seines in ten of the 11 years sampled since the beginning of the program, and were particularly abundant in 1971 and 1976 due to large catches of juveniles in Jordan Cove (Table 6). Killifish was the most abundant species collected in 1969. Menhaden, caught primarily as juveniles in the seines (personal observation) seem to have decreased considerably from the earlier years in the shore-zone catches. Sandlance, killifish and silversides also had catch ranges that varied as widely as the menhaden and the decrease may reflect either a normal long term fluctuation or a patchy distribution in time and space.

Of the pelagic species, Atlantic herring was the most abundant fish collected in five of the nine years sampled with gill nets (Table 7). Searobins, menhaden (primarily adults), blueback herring and butterfish dominated the 1973, 1976, 1977 and 1979 catches respectively. Four of the ten selected pelagic species (alewife, menhaden, butterfish and bluefish) recorded their maximum average abundances in 1974. Atlantic herring, scup and cunner were most abundant in 1972. While 1971, 1973 and 1978 were the best years for spiny dogfish, searobins and blueback herring respectively.

Winter flounder was the numerically dominant demersal fish in all years of the study and was notably most abundant, along with blackfish and cunner, in 1979 (Table 8). The remaining species had peak occurrences in other years: anchovies and grubby in 1978, and silversides in 1976 (also a year it was very abundant in shore-zone seines). Silverhake, windowpane flounder and scup were most abundant in 1975, skates in 1974 and searobins in 1973 (the year in which they were most abundant in gill net catches).

Table 6. Annual distribution of selected* species' mean catch (number per 30 meter haul) using seines, 1969-1979

Species	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Ammodytes americanus	3.27	0.00	0.03	0.00	2.90	0.15	18.14	41.37	3.75	0.13	0.90
Apeltes quadracus	4.52	1.90	1.23	4.07	0.09	2.16	5.74	3.31	4.24	3.66	3.39
Brevoortia tyrannus	32.31	30.37	12.62	2.98	0.00	0.03	0.01	0.00	0.00	0.14	0.00
Fundulus heteroclitus	3.33	7.75	9.42	7.98	17.71	2.90	12.69	10.01	6.11	4.02	1.74
Fundulus majalis	51.81	7.08	6.87	5.50	3.37	3.16	9.46	3.09	2.10	4.15	4.72
Menidia spp.	37.92	71.70	508.97	94.32	53.15	73.67	59.51	303.47	128.69	20.25	38.72

Table 7. Annual distribution of selected species' mean catch (number per 18 hour set) using gill nets, 1971-1979

Species	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Alosa aestivalis	NS**	NS	0.00	0.00	0.00	0.53	0.28	0.76	1.82	1.98	0.87
Alosa pseudoharengus	NS	NS	0.31	0.20	0.29	1.07	0.54	0.25	0.04	0.74	0.27
Brevoortia tyrannus	NS	NS	0.00	0.39	2.53	6.39	2.04	3.05	1.09	2.95	3.03
Clupea harengus	NS	NS	8.02	13.21	3.97	12.78	4.08	2.05	0.78	4.01	1.06
Peprilus triacanthus	NS	NS	0.00	0.61	0.00	1.23	0.31	0.21	0.13	0.45	4.80
Pomatomus saltatrix	NS	NS	0.00	0.12	0.23	2.26	0.91	0.14	0.05	0.29	0.06
Prionotus spp.	NS	NS	0.00	0.69	4.55	0.36	0.50	0.14	0.13	0.04	0.08
Squalus acanthias	NS	NS	2.92	1.23	0.56	0.77	0.25	0.02	0.06	0.03	0.08
Stenotomus chrysops	NS	NS	0.00	11.42	0.75	0.07	0.17	0.15	0.07	0.06	0.07
Tautogolabrus adspersus	NS	NS	0.52	5.59	2.95	0.00	0.15	0.38	0.01	0.27	1.89

Table 8. Annual distribution of selected species' mean catch (number per 15 minute tow) using trawls, 1973-1979

Species	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Anchoa spp.	NS	NS	NS	NS	0.00	0.00	0.06	1.87	1.70	5.49	0.04
Menidia spp.	NS	NS	NS	NS	0.59	1.89	0.39	4.02	3.68	2.86	3.93
Merluccius bilinearis	NS	NS	NS	NS	0.03	0.43	1.72	0.86	0.36	0.28	0.30
Myoxocephalus aenaeus	NS	NS	NS	NS	0.00	0.23	0.36	0.36	0.68	1.65	0.77
Prionotus spp.	NS	NS	NS	NS	1.41	0.73	0.49	0.79	0.73	0.25	0.81
Pseudopleuronectes americanus	NS	NS	NS	NS	17.32	19.55	18.06	16.36	14.21	15.76	27.23
Raja spp.	NS	NS	NS	NS	1.15	3.78	2.99	1.79	1.26	1.06	0.92
Scophthalmus aquosus	NS	NS	NS	NS	2.91	3.93	4.12	3.62	2.96	1.82	3.48
Stenotomus chrysops	NS	NS	NS	NS	1.53	1.69	12.90	4.16	8.83	6.72	10.80
Tautoga onitis	NS	NS	NS	NS	0.40	0.62	0.61	0.56	0.67	0.62	0.74
Tautogolabrus adspersus	NS	NS	NS	NS	2.02	1.94	2.49	2.06	2.22	0.87	3.57

* Those fish that made up at least 1% of the species composition.

** Not sampled.

Seasonal distribution of selected species. The abundances of many of these selected species were also seen to vary seasonally. Silversides were the most abundant species in all but one of the months sampled by seines June, when mummichog was dominant (Table 9). Although the average monthly abundances varied widely and peaked in the August quarter, none of the shore-zone fish except silversides, exhibited a strong seasonal progression, increasing and then decreasing from month to month.

The most abundant pelagic species, Atlantic herring, exhibited a seasonal pattern (Table 10). Not only was it most abundant in the winter-spring months (December-April), but was also the numerical dominant collected from gill nets during this period as well. Cunner peaked in June and searobins and butterfish in July and August respectively. Menhaden exhibited semiannual peaks in May and again September through November.

Among the demersal fish, winter flounder was the dominant recorded from January through July (Table 11) and from October and November samples. Scup was most abundant in August and September, and silversides in December trawls. All of the demersal species exhibited some seasonality in their catches over the months. Skates could be considered aseasonal in their occurrence as they were caught in similar amounts year round with several relative minima and maxima. Two demersal species were found to be bimodal in their annual cycle of abundances. Winter flounder had maximal average monthly abundances six months apart (May and November). Windowpane flounder, on the other hand, had two separate peaks in the late summer and late fall. Distinct seasonal maxima were observed for grubby (February), cunner (June), searobins (August) and silverhake

Table 9. Seasonal distribution of selected* species' mean catch (number per 30 meter haul) using seines, 1969-1979

Species	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ammodytes americanus	NS**	0.01	NS	NS	0.09	0.09	55.69	0.14	0.33	1.83	NS	0.03
Apeltes quadracus	NS	0.18	NS	NS	1.05	0.14	6.26	7.29	4.94	6.84	NS	1.51
Brevoortia tyrannus	NS	0.01	NS	NS	0.00	0.00	21.37	0.05	4.11	0.02	NS	0.05
Fundulus heteroclitus	NS	0.04	NS	NS	2.29	6.24	20.10	4.30	7.96	20.34	NS	0.98
Fundulus majalis	NS	0.00	NS	NS	1.82	3.21	7.44	5.54	25.55	7.10	NS	0.50
Menidia spp.	NS	0.21	NS	NS	2.79	4.13	572.09	153.77	73.93	37.24	NS	21.22

Table 10. Seasonal distribution of selected species' mean catch (number per 18 hour set) using gill nets, 1971-1979

Species	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alosa aestivalis	0.00	0.00	0.00	0.06	0.73	2.03	1.46	0.84	1.74	1.18	0.41	0.53
Alosa pseudoharengus	0.17	0.11	0.17	0.06	0.17	0.27	0.80	0.76	0.70	0.34	0.30	0.84
Brevoortia tyrannus	0.06	0.04	1.40	3.29	4.02	2.03	1.74	3.86	3.04	6.16	3.92	1.59
Clupea harengus	19.63	10.70	7.90	6.08	1.09	0.08	0.22	0.00	0.07	0.01	2.93	12.57
Peprilus triacanthus	0.00	0.00	0.00	0.00	0.07	0.29	0.01	7.70	1.49	0.89	0.13	0.05
Pomatomus saltatrix	0.00	0.00	0.00	0.00	0.00	0.01	0.91	1.52	1.69	0.84	0.02	0.00
Prionotus spp.	0.00	0.00	0.00	0.15	0.59	1.64	2.43	0.34	0.20	0.00	0.00	0.03
Squalus acanthias	0.00	0.00	0.00	0.00	0.05	0.64	0.15	0.00	0.01	0.50	0.91	0.38
Stenotomus chrysops	0.00	0.00	0.00	0.00	0.14	0.10	0.59	0.10	2.83	0.10	0.04	0.00
Tautogolabrus adspersus	0.00	0.02	0.00	0.23	1.40	3.75	1.40	0.72	0.24	0.14	0.15	0.13

Table 11. Seasonal distribution of selected species' mean catch (number per 15 minute tow) using trawls, 1973-1979

Species	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Anchoa spp.	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.04	12.52	6.33	0.13	0.30
Menidia spp.	8.19	1.40	0.80	0.11	0.00	0.00	0.00	0.15	0.19	0.92	3.10	20.57
Merluccius bilinearis	0.97	0.28	0.04	0.04	0.04	0.06	0.01	0.07	0.07	0.46	3.23	2.30
Myoxocephalus aenaeus	1.65	2.39	1.11	1.17	0.60	0.11	0.04	0.04	0.05	0.04	0.24	1.16
Prionotus	0.00	0.00	0.00	0.20	0.88	1.12	1.61	1.86	1.34	0.31	0.12	0.03
Pseudopleuronectes americanus	9.78	8.28	14.86	19.20	24.70	24.34	23.11	17.24	17.37	18.09	23.30	18.82
Raja spp.	2.47	1.21	1.62	1.76	1.68	1.19	1.00	2.06	1.24	1.32	2.41	2.85
Scophthalmus aquosus	2.46	1.40	1.18	1.53	1.83	2.94	3.04	5.66	4.08	3.44	5.61	4.62
Stenotomus chrysops	0.00	0.00	0.00	0.00	1.79	10.57	12.53	26.73	21.91	7.37	0.75	0.02
Tautoga onitis	0.16	0.02	0.04	0.10	0.61	1.43	1.58	1.36	0.77	0.60	0.24	0.28
Tautogolabrus adspersus	0.08	0.08	0.08	0.30	4.53	10.33	5.72	2.97	0.88	0.51	0.37	0.24

* Those fish that made up at least 1% of the species composition.

** Not sampled.

(November). Large seasonal abundance variations were exhibited by scup (August), anchovies (September) and silversides (December).

Taken together, these summaries suggest that certain species were permanent residents during all life stages of the shore-zone, pelagic and bottom communities of the greater Millstone bight, while others migrated between these communities or in and out of the area completely, in differing frequencies. Winter flounder, skates, windowpane flounder, grubby and blackfish could be considered permanent residents of the demersal community--they have been present in varying degrees in all regions and all months (with some seasonal variation) since the beginning of the trawl program. Alewives and menhaden could be considered the most pe manent residents of the pelagic community in the area. While Atlantic herring were dominant in the winter gill net catches, their absence during some seasons suggested they migrated completely out of the area during late summer. Seasonal out-migrations were also implicated for blueback herring, butterfish and spiny dogfish by their complete absence during certain months. All of the shore-zone fish were recorded in lowest numbers in February, and their abundance varied widely from year to year and region to region. While sandlance, fourspine stickleback, killifish, and mummichog were recorded only from seines, menhaden at different stages appeared equally in the shore-zone and pelagic communities and silversides appeared to migrate between the shore-zone and demersal communities. Juvenile menhaden were most abundant in the July seines and were abundant periodically as adults throughout the summer from the trawls. Silversides, however, exhibited an inverse seasonality in the shore-zone and demersal communities. Juveniles were most abundant in the shore-zone in July and adults most abundant in demersal collections in December. These data support the idea presented by Bayliff (1950) that silversides move to deeper water when the water temperature drops. Anchovies and silverhake were only present over a period of several months in the demersal community, suggesting that these species migrate into the area periodically. While anchovies were caught exclusively in trawls, they are not generally considered part of the demersal community (Bigelow and Schreoder 1953). It seemed that when they were in the area, they occurred in great enough numbers to be caught in the trawls. Finally, searobins, scup and cunner appeared to be seasonal residents of both the demersal and pelagic communities--when they were in the area, both gill nets and trawls captured them.

Assessment of Potential Power Plant Impact on Fish in Greater Millstone Bight

The power plant would have the greatest effect on those fish populations subject to impingement or entrainment losses. Therefore, to put the numbers of impinged and entrained fish in the perspective of those caught in the fish program, those species whose abundances contributed 1% or more to either impingement, entrainment, seine, gill net, or trawl collections were considered together in Table 12.

Of the 16 most commonly impinged species, ten were also found in seine, gill net or trawl collections and of the seven most common entrained larval species, four were represented in the fish samples. These eleven species included winter flounder, silversides, grubby, anchovies, cunner,

Table 12. Comparison of species representing at least 1% of fish collected from impingement, entrainment, seine, gill net, and trawl samples, 1969-1979.

Species	Impingement (Unit 1 & Unit 2) 1972-1979			Entrainment (Unit 1 & Unit 2) 1979			Seines 1969-1979			Gill Nets 1971-1979			Trawls 1973-1979		
	Rank	Total	%	Rank	$\#/m^3$	%	Rank	Total	%	Rank	Total	%	Rank	Total	%
Pseudopleuronectes americanus	1	57,871	27	3	.195	6							1	44,809	41
Menidia spp.	2	30,391	14				1	135,137	77				4	7,221	7
Gasterosteus aculeatus	3	26,367	12												
Myoxocephalus aenaeus	4	18,939	9	5	.065	2							10	1,582	2
Anchoa spp.	5	11,236	5	1	1.829	72							7	3,912	4
Tautogolabrus adspersus	6	9,790	5							5	357	5	5	5,598	5
Tautog onitis	7	5,847	3										11	1,478	1
Merluccius bilinearis	8	5,368	3										9	1,661	2
Scophthalmus aquosus	9	5,182	2										3	8,518	8
Microgadus tomcod	10	5,020	2												
Morone americana	11	4,516	2												
Syngnathus fuscus	12	4,374	2	7	.026	1									
Brevoortia tyrannus	13	3,082	1				5	4,477	3	2	1,328	20			
Alosa aestivalis	14	3,069	1							4	384	6			
Osmerus mordax	15	2,389	1												
Cyclopterus lumpus	16	2,106	1												
Ammodytes americanus				2	.234	10	2	9,645	6						
Pholis gunnellus				6	.048	1									
Unidentified				4	.044	2									
Fundulus heteroclitus							3	8,742	5						
Fundulus majalis							4	7,921	5						
Apeltes quadracus							6	3,963	2						
Clupea harengus										1	2,826	43			
Peprilus triacanthus										3	548	8			
Prionotus spp.										6	177	3	8	1,827	2
Pomatomus saltatrix										7	150	2			
Alosa eudoharengus										8	145	2			
Ste omus chrysops										9	133	2	2	18,596	17
qualus acanthias										10	91	1			
Raja spp.													6	4,671	4

blackfish, silverhake, windowpane flounder, menhaden, blueback herring and sandlance. Seven potentially impacted species including threespine stickleback (Gasterosteus aculeatus), tomcod (Microgadus tomcod), white perch (Morone americana), pipefish (Syngnathus fuscus), smelt (Osmerus mordax), lumpfish (Cyclopterus lumpus) and rock gunnel (Pholis gunnellus) did not contribute 1% to any of the fish collections. Eleven other species contributed 1% only to the fishery samples and included mummichog, striped killifish, fourspine stickleback, Atlantic herring, butterfish, searobins, bluefish, alewife, scup, spiny dogfish and skates.

The potential impact of power plant operations on shore-zone, pelagic and demersal fish was considered by way of graphical interpretations of changes in the total catch and numbers of species. Temporal and spatial distributions of selected species abundances were also graphically evaluated. To support interpretations of shore-zone and pelagic graphs, separate nonparametric one-way analyses of variance were performed using as single factors year, station and quarter. The evaluation of the trawl abundance and numbers of species graphs were supplemented with analyses of variance using year, quarter and station as combined effects and a Duncan's multiple range test on the main effects.

Shore-zone fish. The total catch of shore-zone fish exhibited extreme seasonal fluctuations at all stations, but did not experience any obvious net change over time (Fig. 2, arrows indicate startup of Units I and II). Even though the two peaks representing a $\log_e$ (CPUE+1) greater than 8.0 for Jordan Cove in both 1971 and 1976 might suggest that these years were significantly different from the others, the counts in the

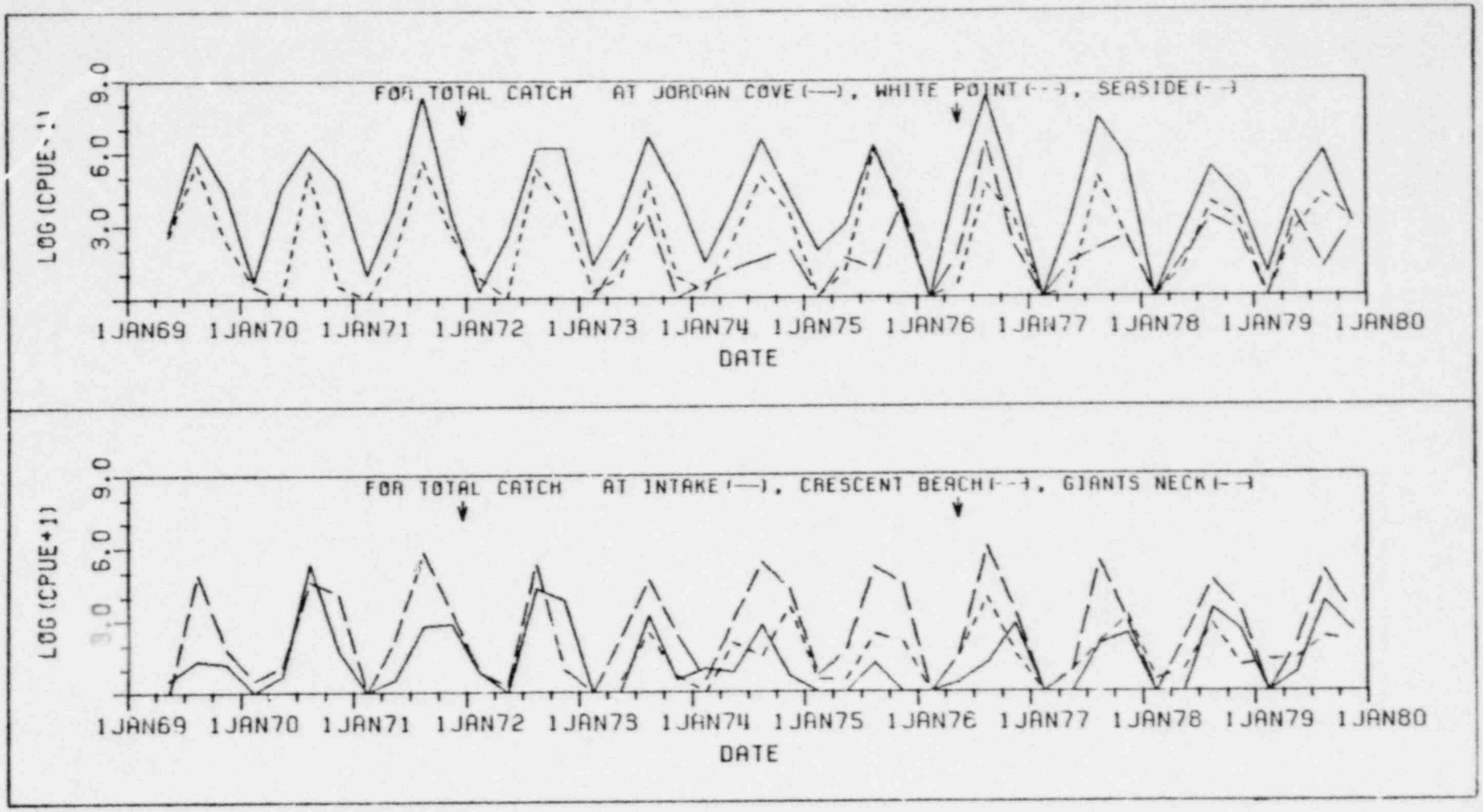

Figure 2. Total shore-zone catch per 30 meter seine haul at each station.

other quarters of those years were sufficiently low to prevent the overall annual abundance over all stations from being significantly different from the remaining years. The results of the nonparametric one-way analysis of variance on the ranks of the total catch indicated no significant effect due to year (Table 13). Seasonally, minimal abundances occurred in the first quarter of every year at all stations and maxima in the second and third quarter. Nonparametric analysis of variance indicated that significant differences existed between the catches in each quarter with the August quarter highest and the February quarter lowest. In general, abundances recorded from Jordan Cove appeared higher than those from the remaining stations, and the nonparametric AOV indicated that there was a significant effect due to station. Jordan Cove had the highest mean abundance for total shore-zone fish catch and Bay Point the lowest.

The number of species recorded each quarter also varied seasonally (Fig. 3), ranging from an average high (7.0) in the August quarter through 3.3 species in the November quarter to a low of <1 in the February quarter and then to 4.1 species in the May quarter. There appeared to be no net increase or decrease in the number of species with time and Jordan Cove was seen to have the highest number of species at all times. An analysis of variance with quarter, year and station in combination as factors, indicated that significantly more species were caught in the August quarter but there was no significant difference in the average number of species collected (3.8) each year. Jordan Cove catches had significantly higher numbers of species (6.6) than all other stations.

Table 13. Kruskal-Wallis nonparametric analysis of variance on shore-zone seine data using quarter, year and region as single factors. If a significant effect existed, the value of the class variable in which the maximum mean abundance and minimum mean abundance occurred is listed under each class variable.

	Quarter*		Year		Station**	
Dependent variable	Max.	Min.	Max.	Min.	Max.	Min.
Total catch	8	2	NSD***		JC	IN
Menidia spp.	8	2	NSD		JC	SS
A. americanus	8	2	NSD		NSD	
F. heteroclitus	8	2	NSD		JC	IN
F. majalis	8	2	NSD		JC	CB
B. tyrannus	8	5	NSD		NSD	
A. quadracus	8	2	NSD		JC	IN

* 2 = February quarter
5 = May quarter
8 = August quarter
11 = November quarter

** JC = Jordan Cove
SS = Seaside
IN = Intake
CB = Crescent beach

*** NSD = No significant difference

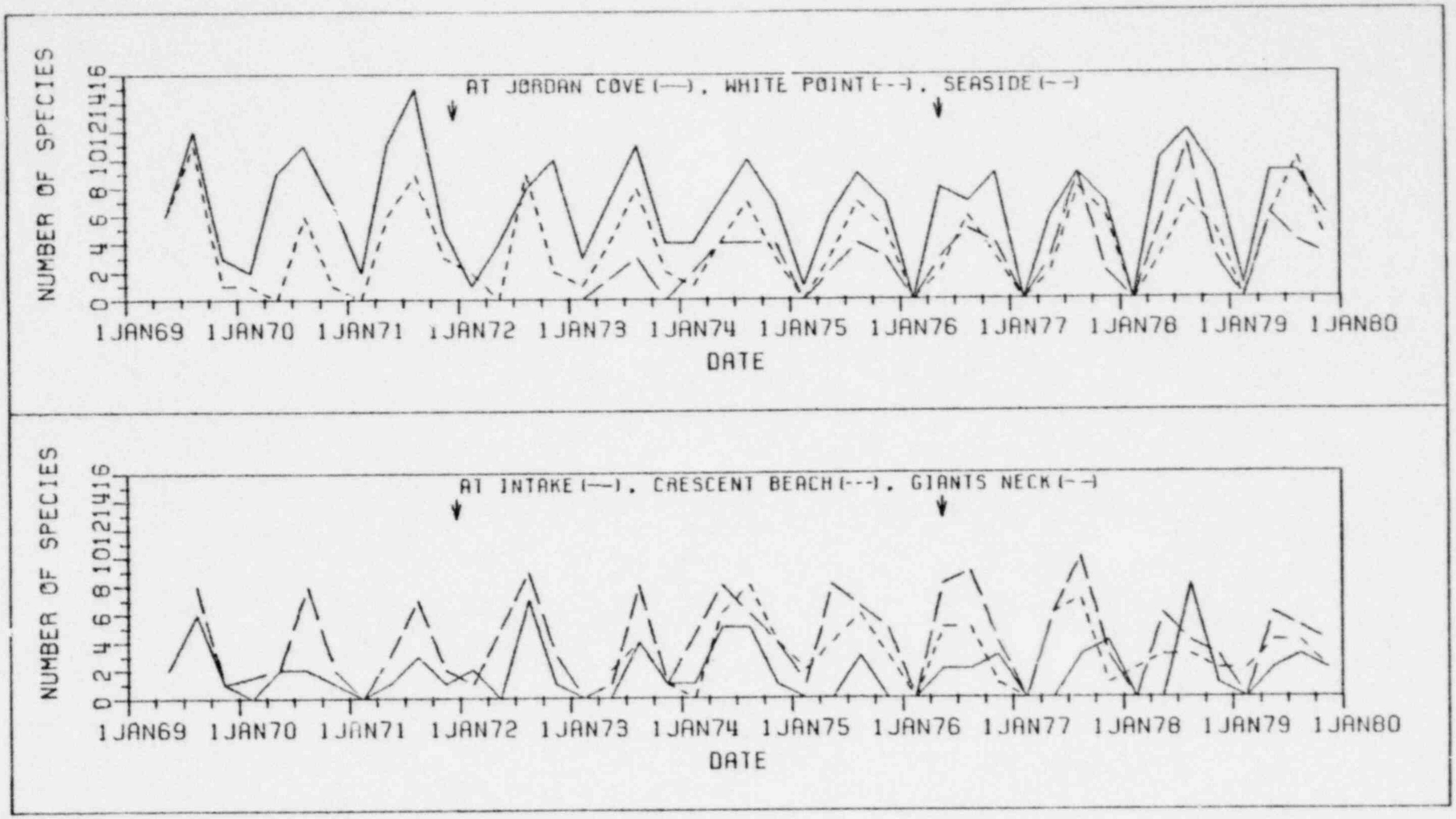

Figure 3. Number of shore-zone fish species caught at each station.

Even though silversides, mummichog, killifish and stickleback did not exhibit strong seasonal progressions from month to month (Table 9), the seasonality of these species was quite apparent at least at some stations on a quarterly basis (Fig. 4-7). Silversides abundances could be seen to vary seasonally at all stations (Fig. 4). All of the selected shore-zone species experienced a significant effect due to quarter (Table 13). Highest abundances were recorded from the August quarter and lowest abundances from the February quarter except for menhaden whose lowest mean abundance occurred in the May quarter. Except for the large peaks of silversides in 1971 and 1976, none of the selected species experienced any apparent change in annual abundance (Fig. 4). The analysis of variance indicated no significant differences in annual abundances for any of the species (Table 13). Again lower than average values in the other three quarters of 1971 and 1976 kept the annual mean abundance for those years from being significantly different from the other years.

All four of the graphically depicted shore-zone fish abundances varied from station to station (Figs. 4-7). The effect due to station was significant for these four species. Silversides were most abundant at Jordan Cove and least abundant at Seaside (Table 13). Mummichog and killifish were also most abundant in Jordan Cove and, except for White Point, made only sporadic appearances at the remaining stations (Figs. 5-6). The fourspine stickleback was found almost exclusively at the Jordan Cove site (Fig. 7). Menhaden and sandlance abundances were not significantly affected by station (Table 13).

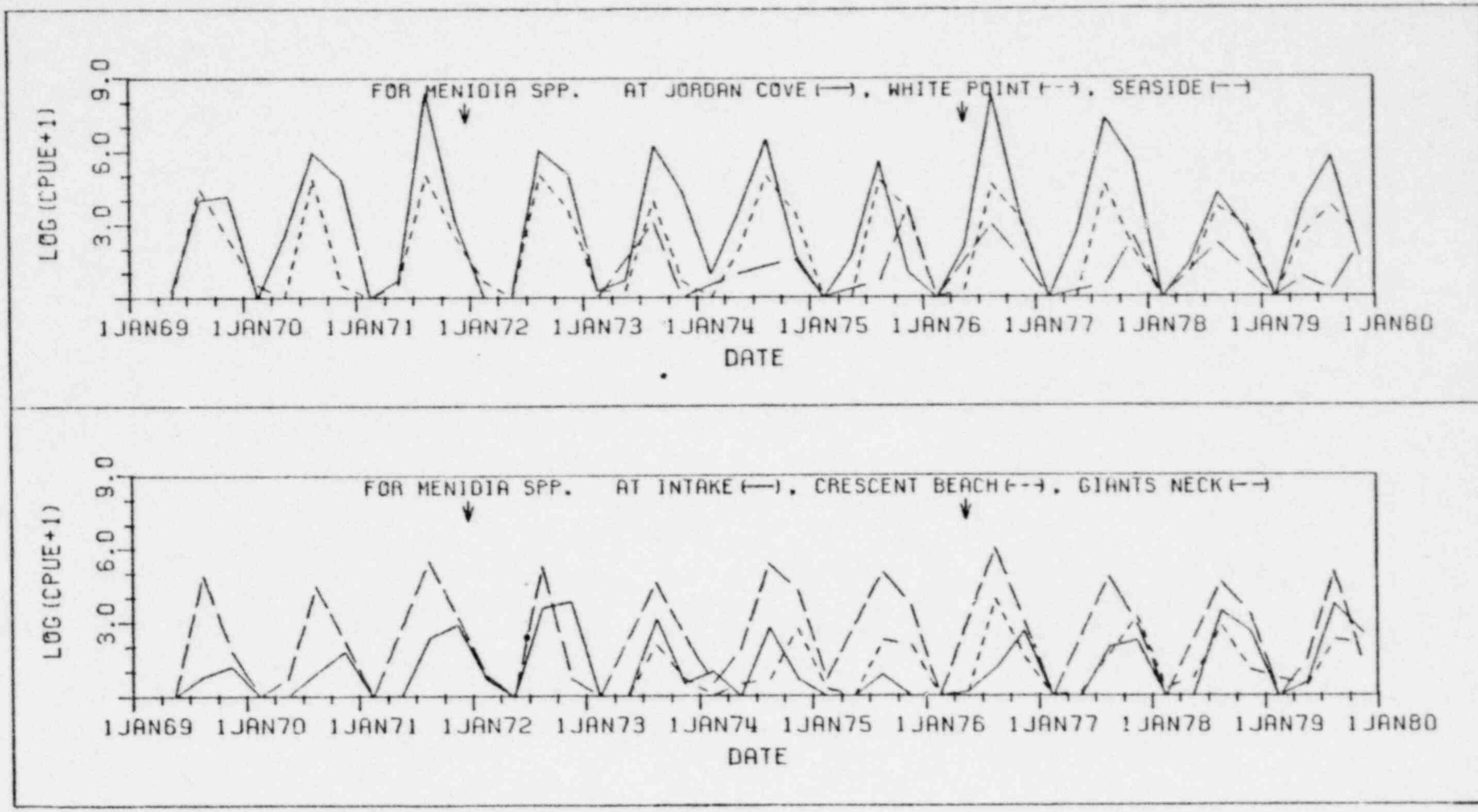

Figure 4. Total catch of silversides per 30 meter seine haul at each station.

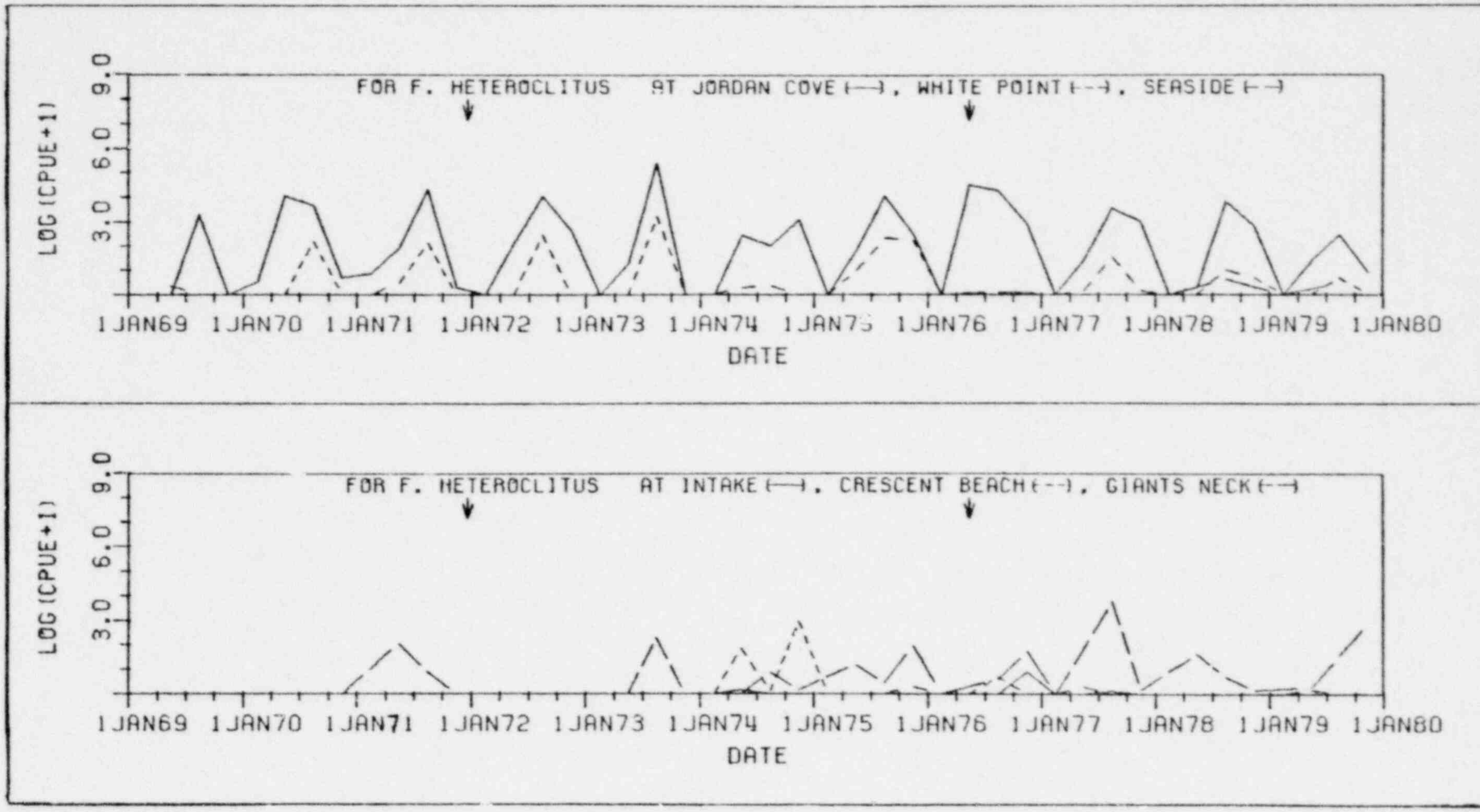

Figure 5. Total catch of mummichog per 30 meter seine haul at each station.

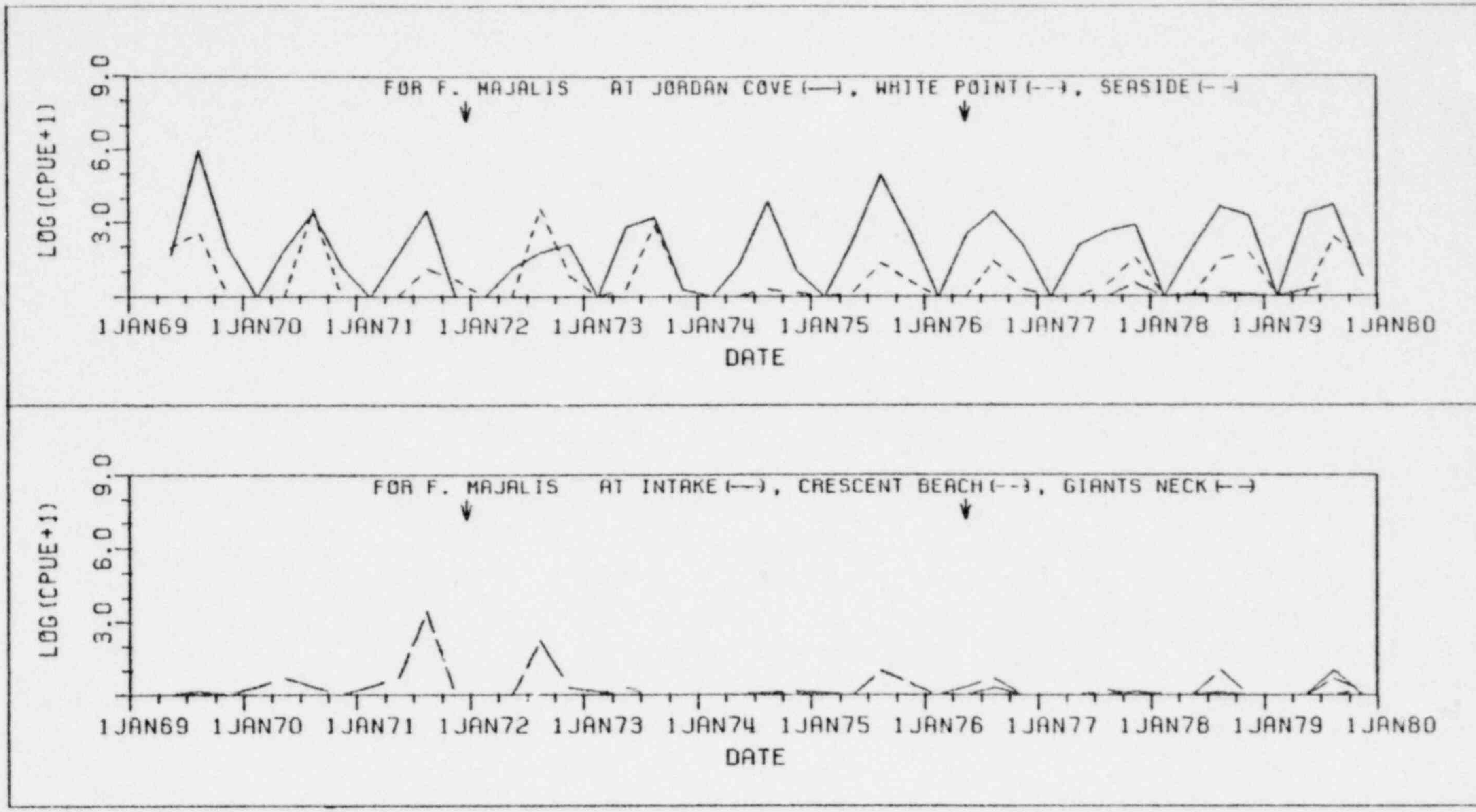

Figure 6. Total catch of killifish per 30 meter seine haul at each station.

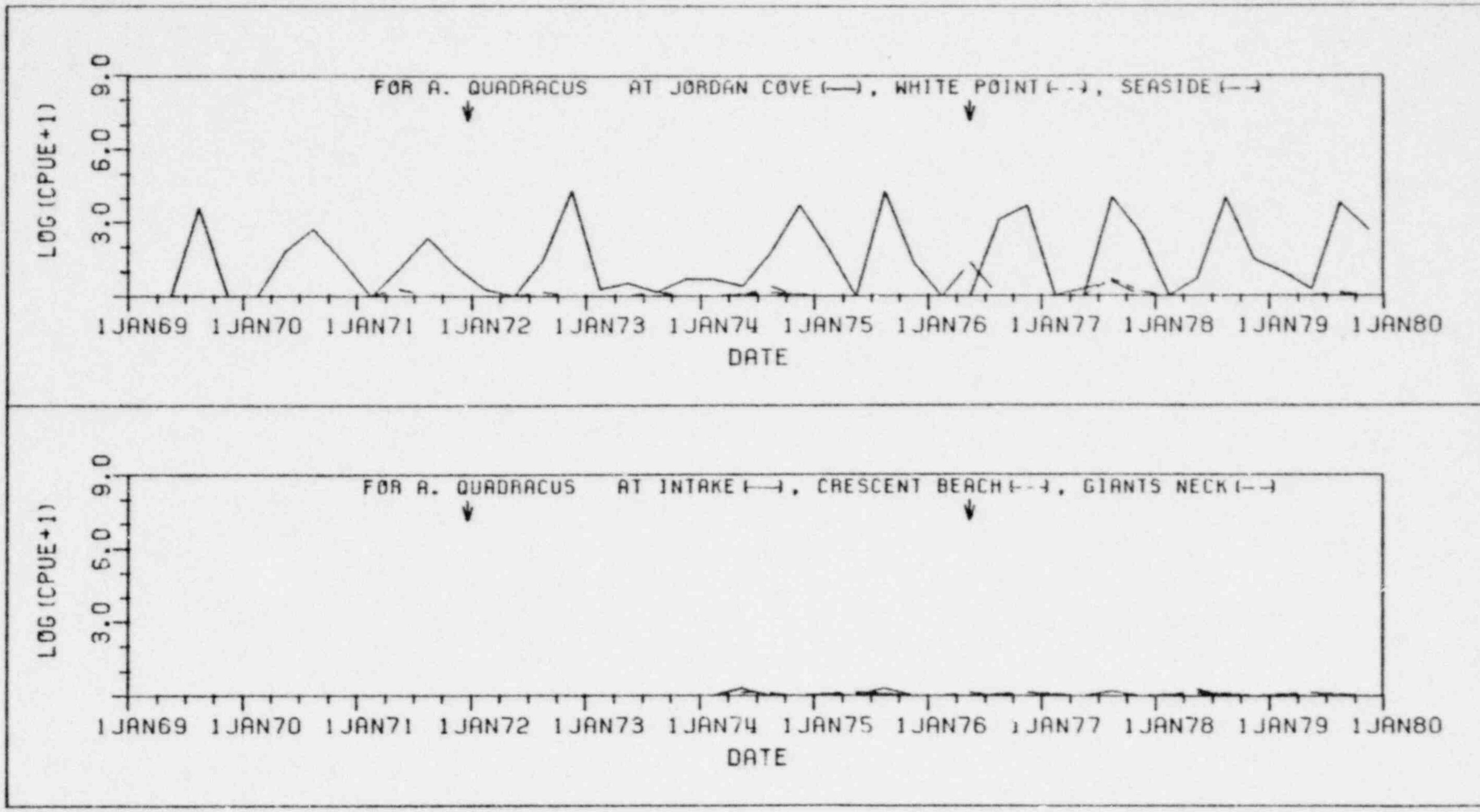

Figure 7. Total catch of four spine stickleback per 30 meter seine haul at each station.

Pelagic fish. The total catch of pelagic fish did not exhibit the seasonal fluctuations so characteristic of the total shore-zone fish catch (Fig. 8). There were no significant differences between the mean catch in the quarters as determined by the nonparametric analysis of variance (Table 14). At all stations except Twotree, there did not seem to be any increasing or decreasing trend over the years (Fig. 8). However, the analysis of variance indicated a significant effect due to year with 1974 recording the highest mean abundance over all stations and quarters and 19.7 the lowest (Table 14). The low value in 1977 may be partially attributable to sampling problems (ice) in the February quarter due to the extremely cold weather that year. The total pelagic catch also exhibited a significant effect due to station (Table 14). Average catches were highest at Jordan Cove and lowest at Bartlett Reef.

The average number of pelagic species (2) was lower in the February quarter than in all other quarters, the strong seasonal pattern characteristic of the number of shore-zone species was not apparent graphically (Fig. 9). Neither was a decreasing or increasing trend over time indicated (Fig. 9). Niantic Bay appeared to consistently have the most number of species present. An analysis of variance using quarter, year and station in combination and a Duncan's multiple range test indicated all three factors had a significant effect on the number of species. The February quarter had significantly fewer species than all other quarters. The highest annual number of species was recorded from 1975 (5.9) and lowest from 1977 (3.1).

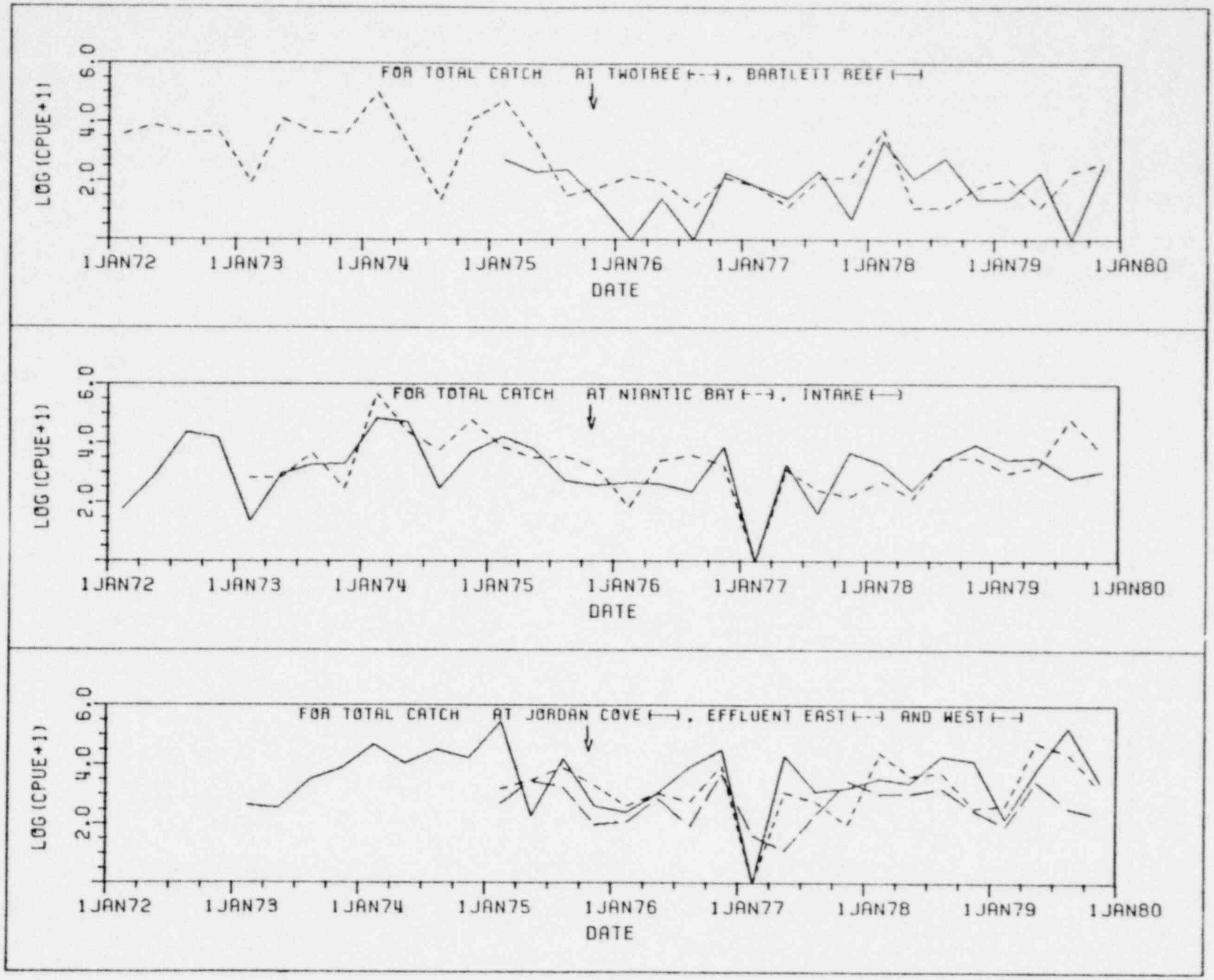

Figure 8. Total pelagic catch per 18 hour gill net set at each station.

Table 14. Kruskal-Wallis nonparametric analysis of variance on gill net data using quarter, year and region as single factors. If a significant effect existed, the value of the class variable in which the maximum mean abundance and minimum mean abundance occurred is listed under each class variable.

	Quarter*		Year		Station**	
Dependent variable	Max.	Min.	Max.	Min.	Max.	Min.
Total catch	NSD***		74	77	JC	BR
C. harengus	2	8	NSD		NSD	
B. tyrannus	11	2	74	72	JC	BR
P. triacanthus	8	2	NSD		NB	BR
A. aestivalis	8	2	NSD		JC	TT
T. adspersus	5	2	72	74	NSD	
Prionotus spp.	5	2	NSD		NSD	
P. saltatrix	8	2	NSD		NSD	
A. pseudoharengus	NSD		NSD		EW	BR
S. chrysops	8	2	NSD		NSD	
S. acar'hias	NSD		NSD		NSD	

* 2 = February quarter
5 = May quarter
8 = August quarter
11 = November quarter

** JC = Jordan Cove
BR = Bartlett Reef
NB = Niantic Bay
TT = Twotree
EW = Effluent West

*** NSD = No significant difference

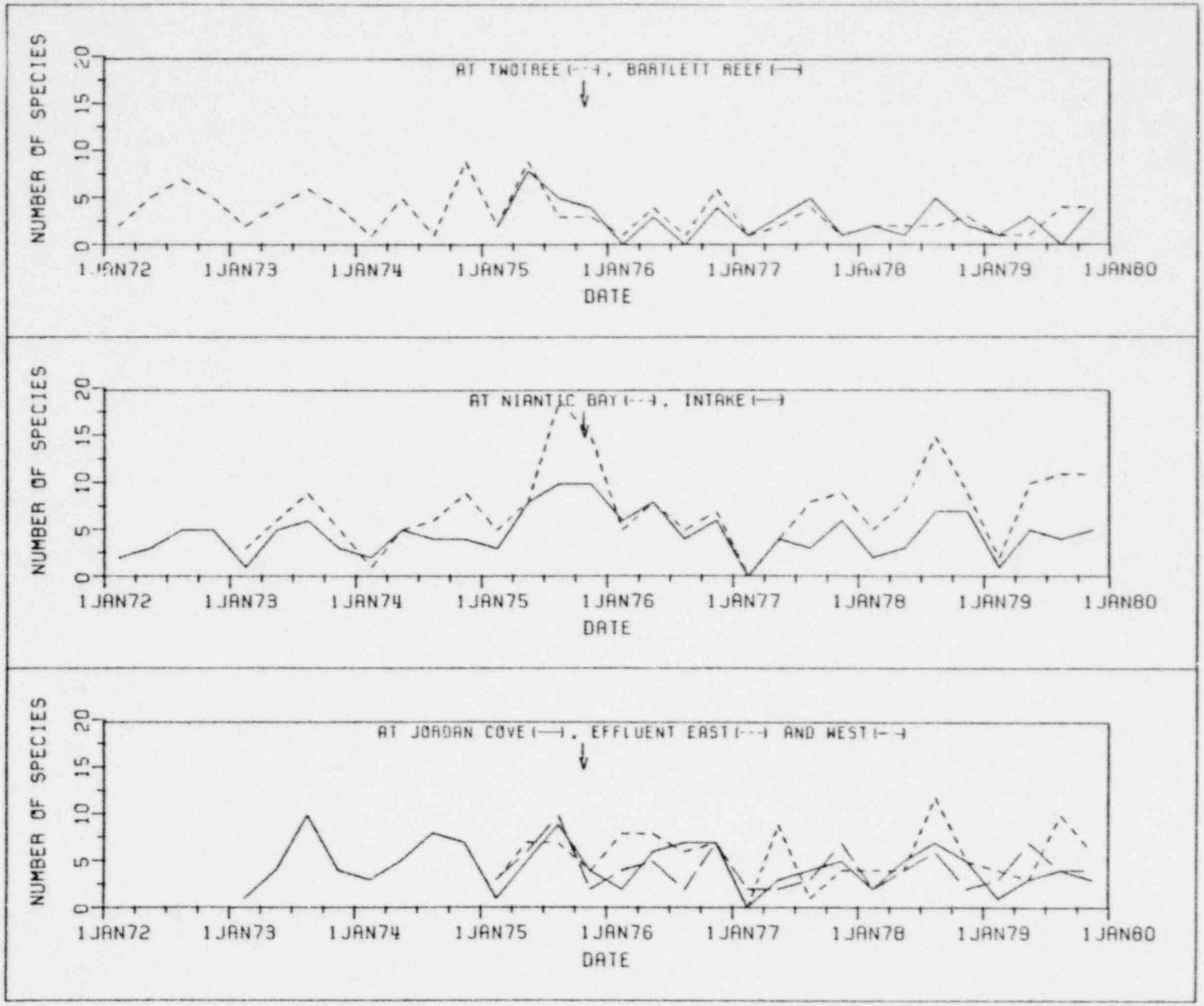

Figure 9. Number of pelagic fish species caught at each station.

Atlantic herring, menhaden, blueback herring, searobins, butterfish and cunner abundances versus time were depicted in Figs. 10-15. While all of the species except alewife and spiny dogfish had a significant quarterly effect (Table 14), the seasonal pattern was not as apparent graphically at all locations as in the shore-zone fish data. Atlantic herring showed the most obvious pattern (Fig. 10), but this species, along th menhaden (Fig. 11) in contrast to all other selected species, both had peak occurrences in the colder quarters. Menhaden was most abundant in the November quarter and the Atlantic herring peaked in the February quarter, when all other selected pelagic and shore-zone species abundances were at a minimum (Table 14). The menhaden cycle was frequently bimodal within a year (Fig. 11). Butterfish, blueback herring, bluefish and scup were most abundant in the August quarters, and searobins and cunner most abundant in the May quarter (Table 14).

Only, two of the selected species abundances were significantly effected by year (Table 14). Mehaden were most abundant in 1974 and least abundant in 1972, and cunner were most abundant in 1972 and least abundant in 1974. The remaining species considered were not significantly affected by year.

Unlike the shore-zone fish, all of which had a significant effect due to station and were most abundant in Jordan Cove, only menhaden, butterfish, alewife, blueback herring and butterfish had a significant station effect. Menhaden and blueback herring were most abundant in Jordan Cove while butterfish were most abundant in Niantic Bay and alewife west of the effluent (Table 14). All other species appeared equally abundant at

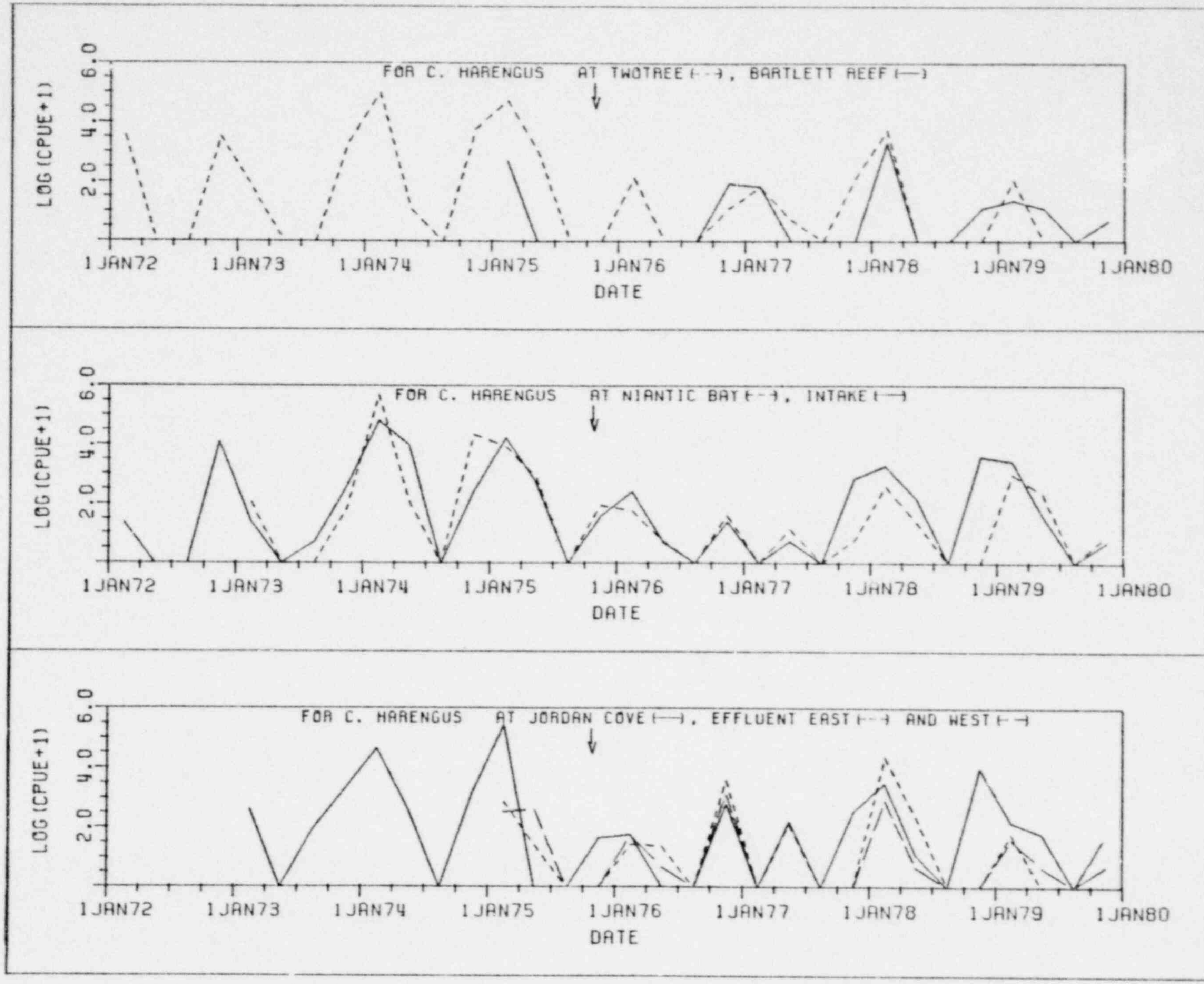

Figure 10. Total catch of Atlantic herring per 18 hour gill net set at each station.

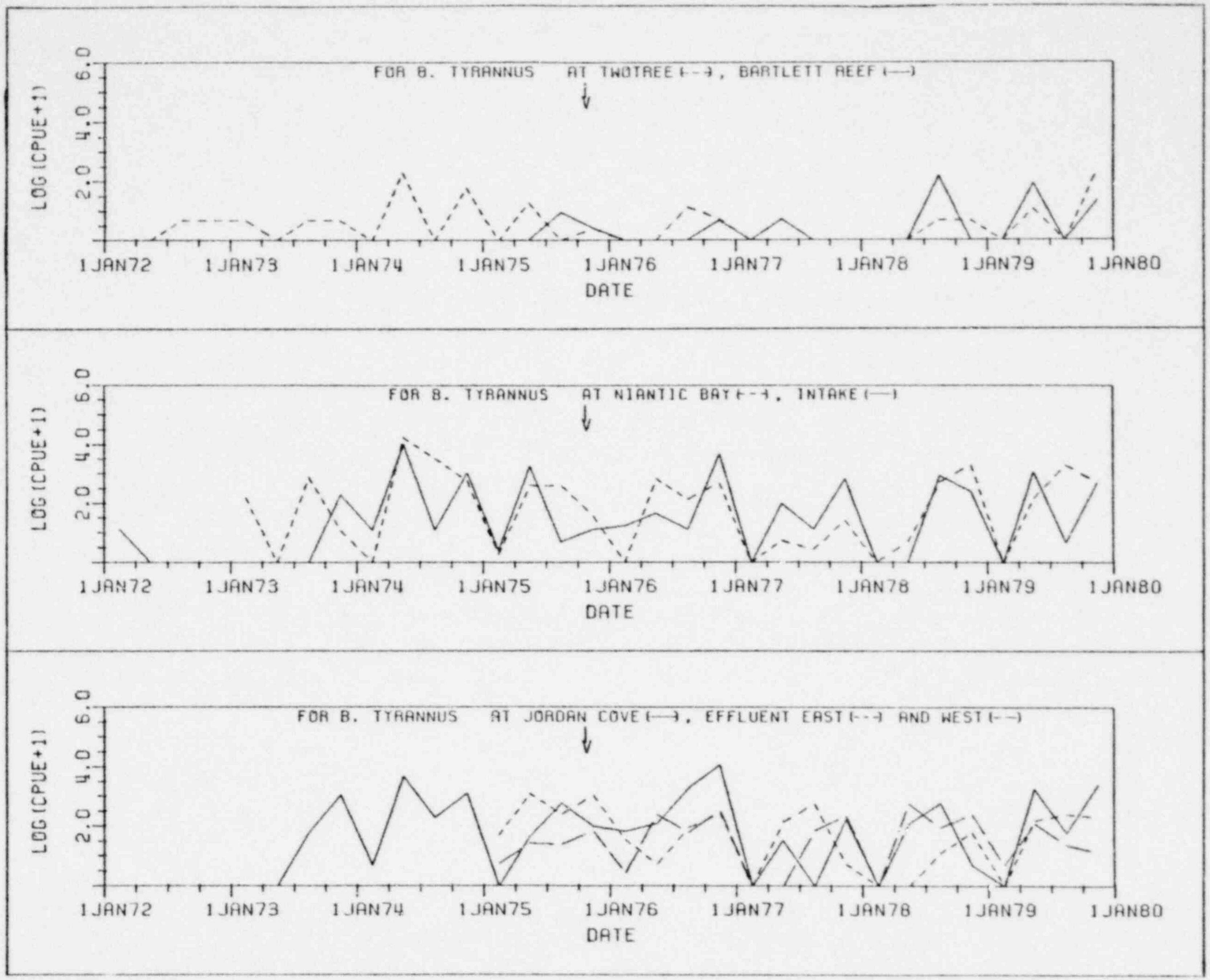

Figure 11. Total catch of menhaden per 18 hour gill net set at each station.

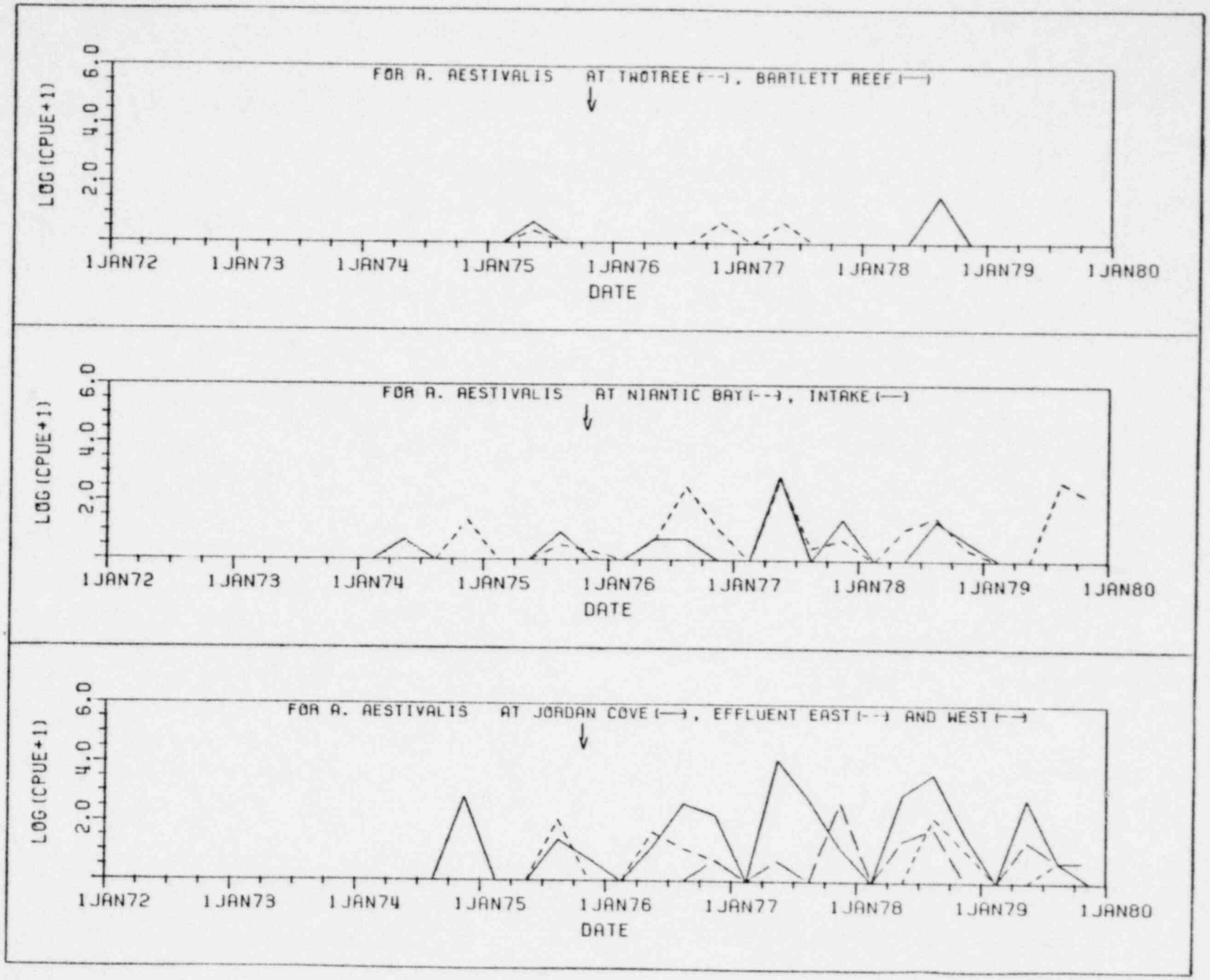

Figure 12. Total catch of blueback herring per 18 hour gill net set at each station.

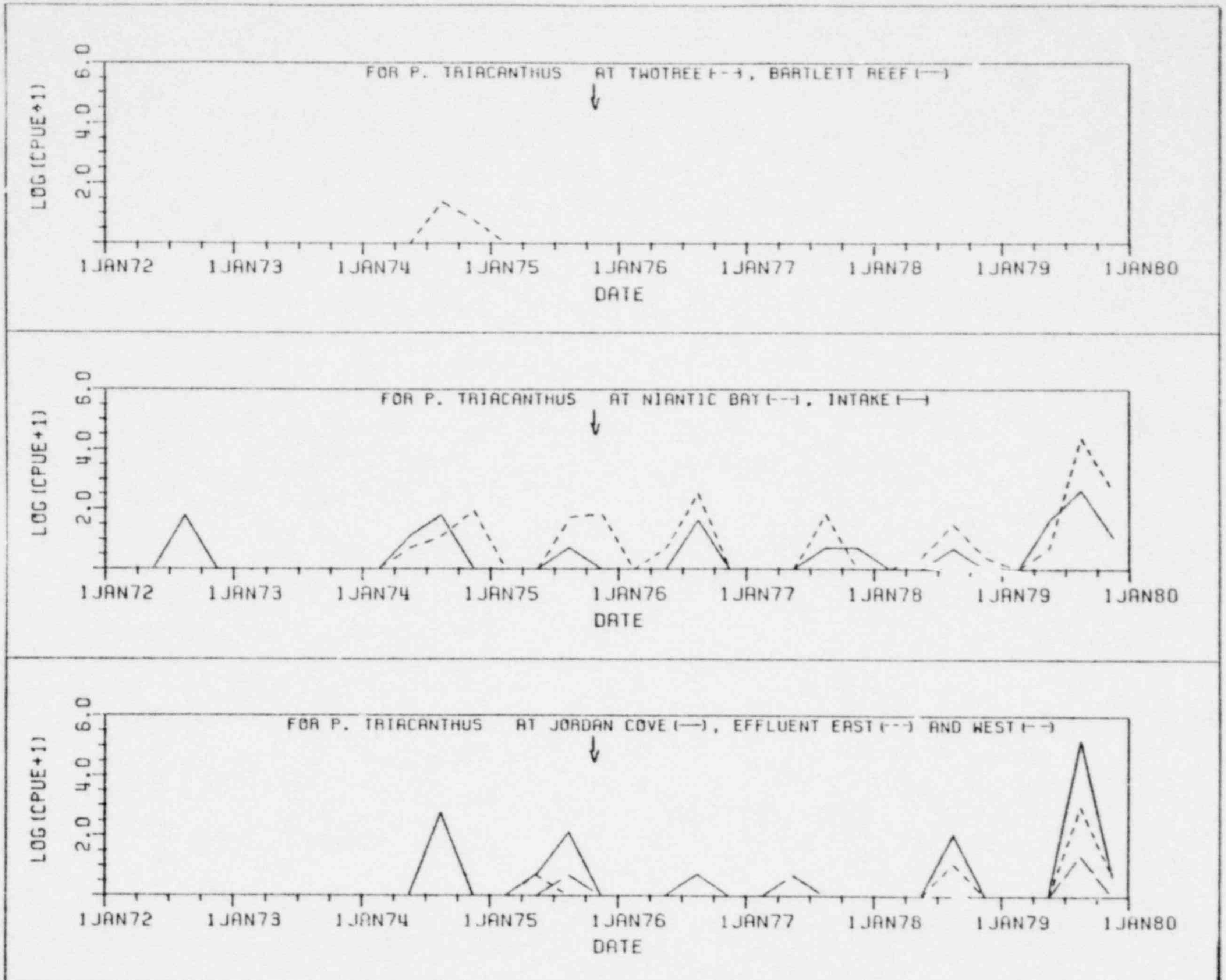

Figure 13. Total catch of butterfish per 18 hour gill net set at each station.

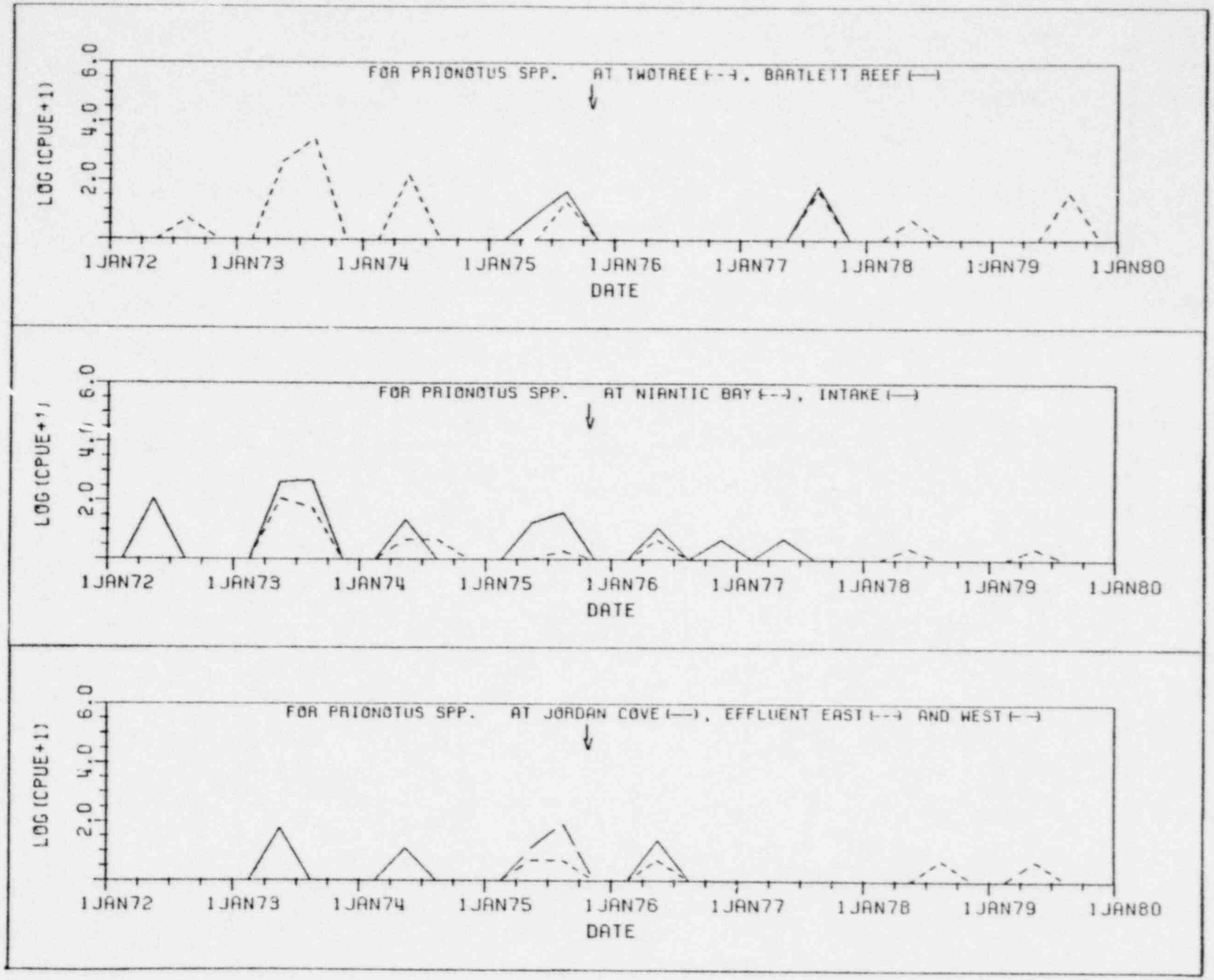

Figure 14. Total catch of searobins per 18 hour gill net set at each station.

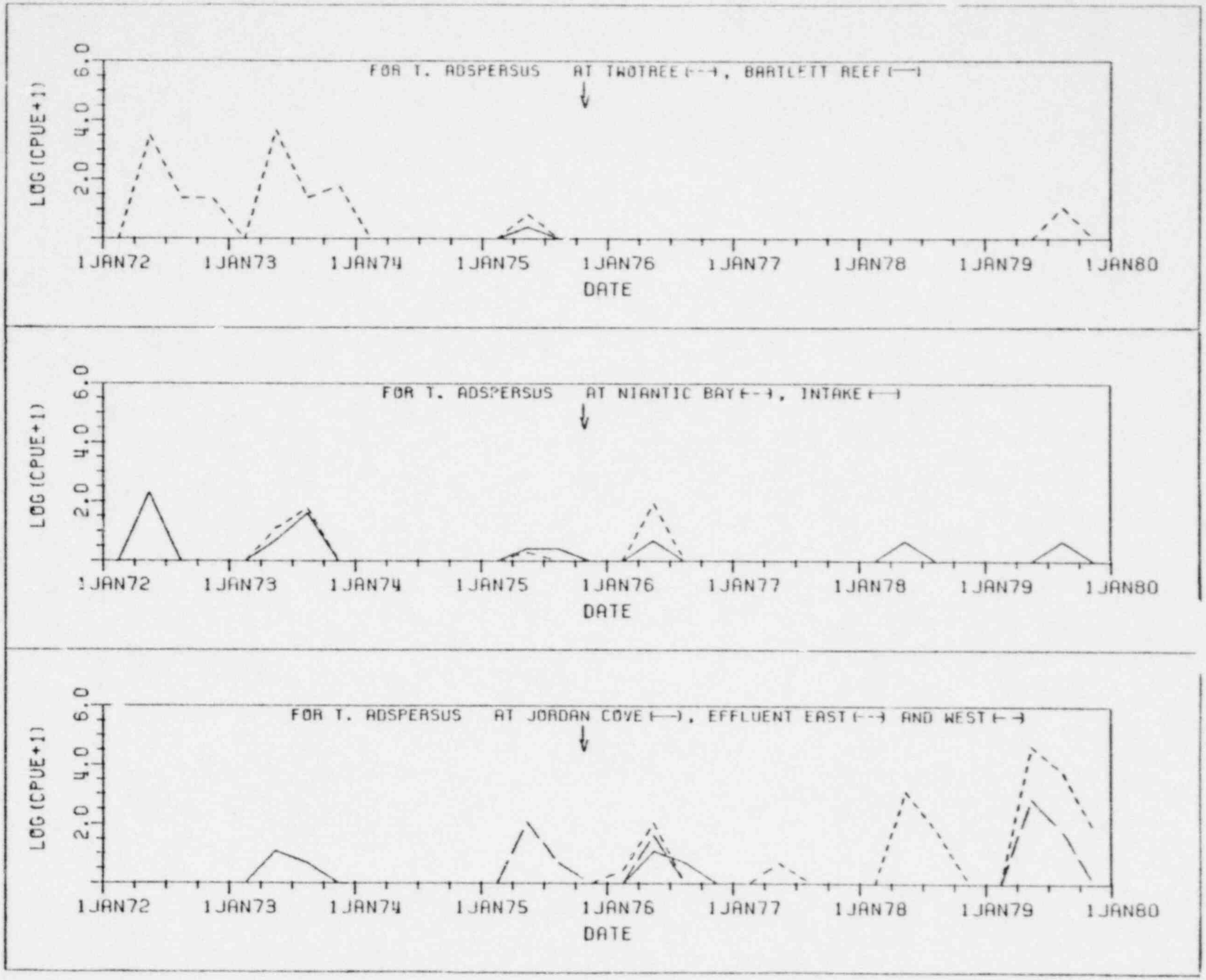

Figure 15. Total catch of cunner per 18 hour gill net set at each station.

the various stations. Even though cunner had no significant differences due to station, an interesting pattern emerged (Fig. 15). In the earlier years (1972-1974), cunner was more abundant at Twotree than in recent years. Cunner has been increasing at the effluent stations since 1975 when the sites were first sampled. Since cunner prefer a rocky reef habitat (Olla, Bejda and Martin 1975) they may be attracted to the rip rap now present near the effluent.

Demersal fish. A periodicity, characteristic of the total shore-zone catch, was not readily apparent in the total demersal catch (Fig. 16). However, analyses of variance on the log transformed total catch per effort data indicated that the mean catch in the August quarter was significantly higher than the catch from all other quarters and the catch in the February quarter was lowest (Table 15). The mean annual catches did not exhibit any notable trends, but some years were significantly different from others. Mean total catch for 1973 was significantly lower than all subsequent years and 1979 was higher than all previous years, but not significantly greater than catches in 1974 or 1975. Regionally, the total catch was highest at the Intake and Niantic Bay and lowest at Twotree and Seaside (Table 15).

The number of species varied over time and space, but without a graphically apparent pattern (Fig. 17). A significant difference between the mean number of species in each quarter, however, was indicated (Table 15). The most species were found in the August quarter and the fewest in the February quarter similar to mean total catch. Since the beginning of the study, the most species were found in 1975, but not significantly

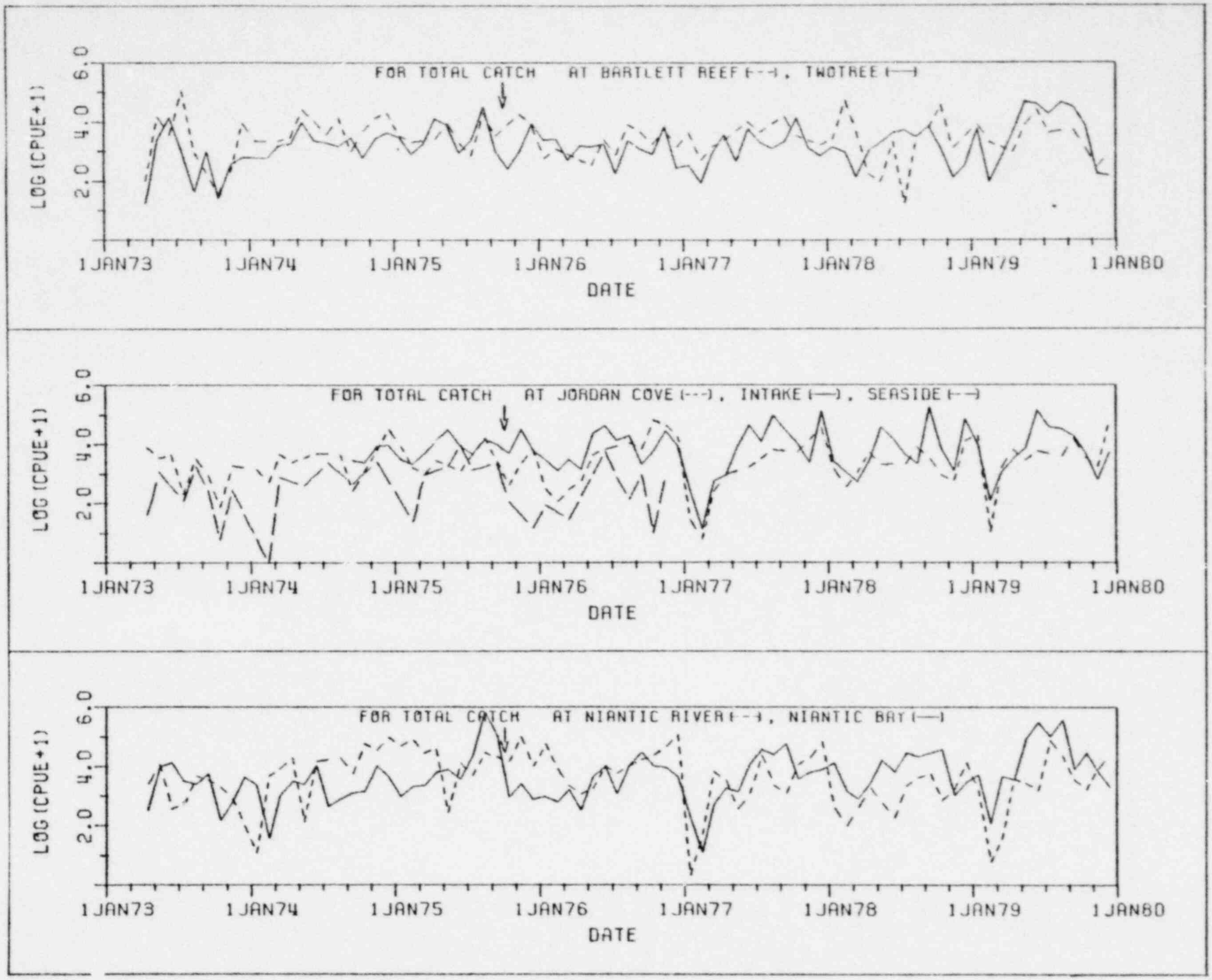

Figure 16. Total catch of demersal fish per 15 minute trawl in each region.

Table 15. Duncan's Multiple Range Test of significance for the means of total catch $\log_e$ (CPUE+1), number of species, and means of selected species catch ($\log_e$ (CPUE+1)) in various classes. Class values connected by a line had means that were not significantly different. Mean values within a class decrease from left to right.

Dependent variable	Class variables: Quarter*	Year	Region**
Total catch	8 11 5 2	79 75 74 76 78 77 73	IN NB NR JC BR TT SS
Number of species	8 5 11 2	75 76 74 79 77 78 73	IN BR JC NB TT NR SS
P. americanus	5 11 8 2	79 74 75 78 76 77 73	NR NB IN JC TT BR SS
S. hrysops	8 5 11 2	79 75 77 78 76 74 73	NB IN TT BR JC SS NR
S. aquosus	11 8 5 2	74 75 76 79 77 73 78	BR NB IN TT JC NR SS
Menidia spp.	11 2 8 5	79 78 76 77 74 75 73	JC IN NB NR TT BR SS
T. adspersus	5 8 11 2	73 74 75 79 76 77 78	SS IN JC BR NB NR TT
Raja spp.	11 2 5 8	74 75 76 73 77 78 79	BR TT NB IN JC SS NR
Anchoa spp.	11 5 8 2	77 76 78 79 75 73 74	NB IN JC NR TT BR SS
Prionotus spp.	8 5 11 2	73 76 74 79 77 75 78	BR TT NB IN NR JC SS
M. bilinearis	11 2 8 5	75 76 74 77 79 78 73	BR IN NB TT JC SS NR
M. aenaeus	2 5 11 8	78 79 77 75 76 74 73	JC IN NR BR TT NB SS
T. onitis	8 5 11 2	No significant difference	IN JR NR SS NB BR TT

* 2 = February quarter
5 = May quarter
8 = August quarter
11 = November quarter

** IN = Intake
NB = Niantic Bay
NR = Niantic River
JC = Jordan Cove
BR = Bartlett Reef
TT = Twotree
SS = Seaside

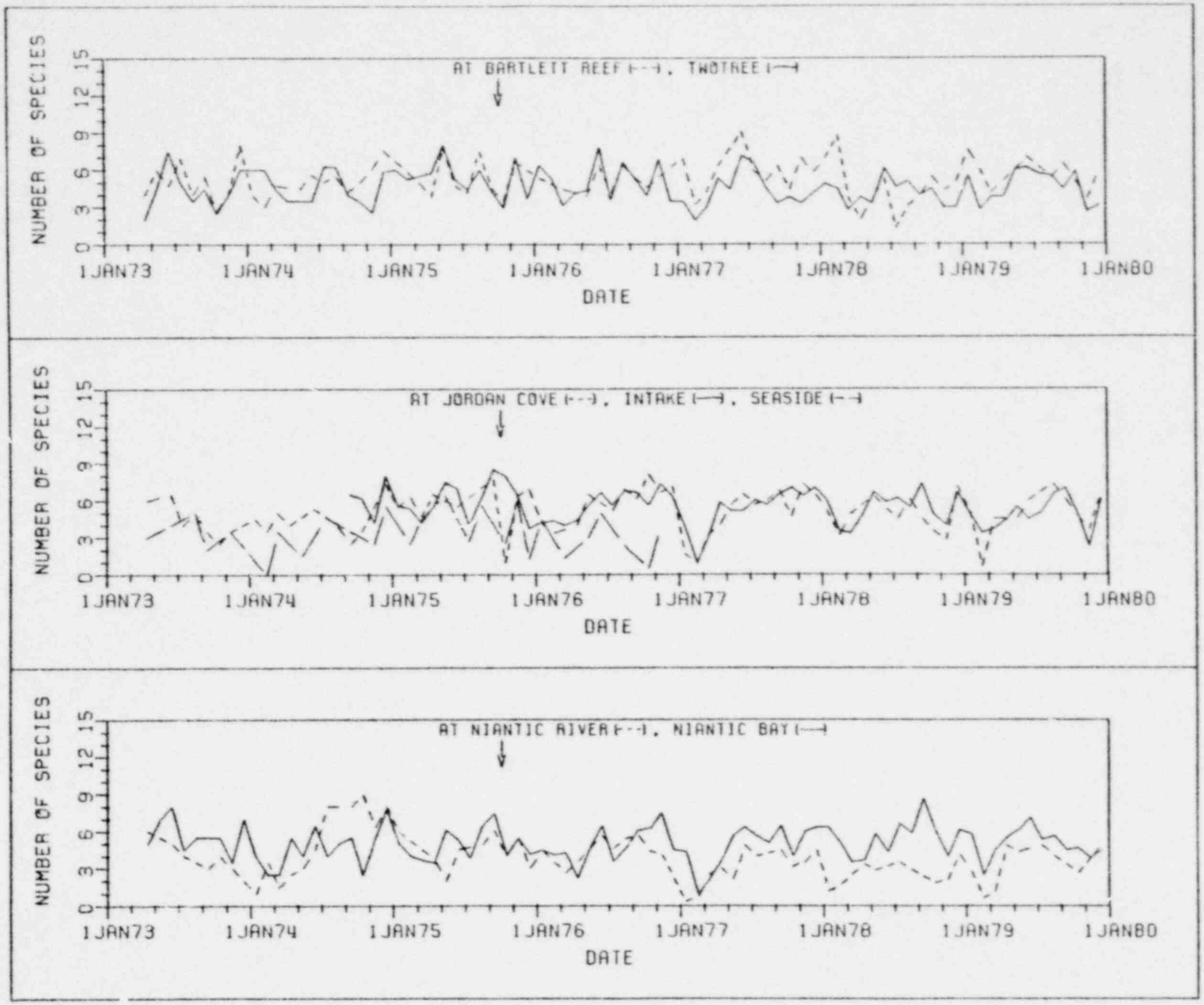

Figure 17. Number of demersal fish species caught in each region.

more than in 1976 or 1974 (Table 15). There were no significant differences among the mean numbers of species found in the remaining years. Regionally, the most species have been found at the Intake and Barlett Reef and the fewest at Seaside and the Niantic River.

The abundances of many of the frequently caught and abundant species such as winter flounder, scup, windowpane flounder, silversides, cunner, skates, silverhake and searobins appeared to fluctuate in recurring patterns at most stations (Fig. 18-25). All of the selected demersal species were significantly affected by quarter (Table 15), but in different ways. Grubby abundance peaked in the February quarter and winter flounder and cunner in the May quarter (Table 15). Grubby spawn all winter (December through March) in this area (Lund and Marcy 1975) and cunner from May through July (Johansen 1925; Dew 1976). These species would be more concentrated during these periods and might be more susceptible to capture. Even though winter flounder spawn from February through April (see Winter Flounder Population Dynamics section), they were caught in highest abundances as spent adults when they were believed to be feeding in Niantic Bay. Scup (Fig. 19), searobins (Fig. 24) and blackfish (Table 15) were most abundant in the summer, again corresponding to their approximate spawning periods (Bigelow and Schroeder 1953). The remaining species, windowpane, flounder (Fig. 20), silversides (Fig. 21), skates (Fig. 23), silverhake (Fig. 25) and anchovies had significantly higher abundances in the November quarter than in the spring or summer (Table 15). In the case of the skates, this period corresponds to one of the spawning periods of the little skate, *Raja erinacea*, (Richards et al. 1963). However, in the case of the other species and winter flounder

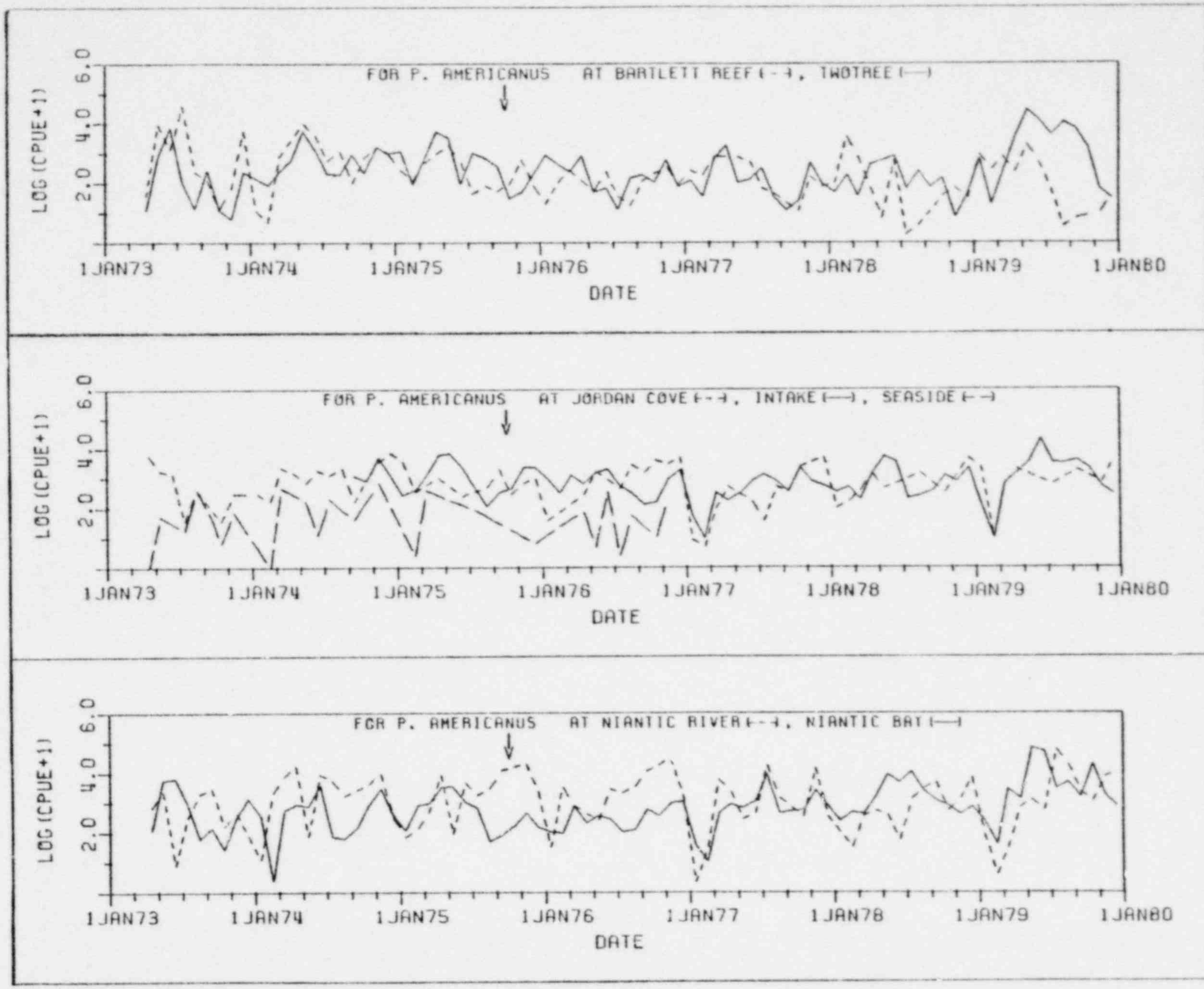

Figure 18. Total catch of winter flounder per 15 minute trawl in each region.

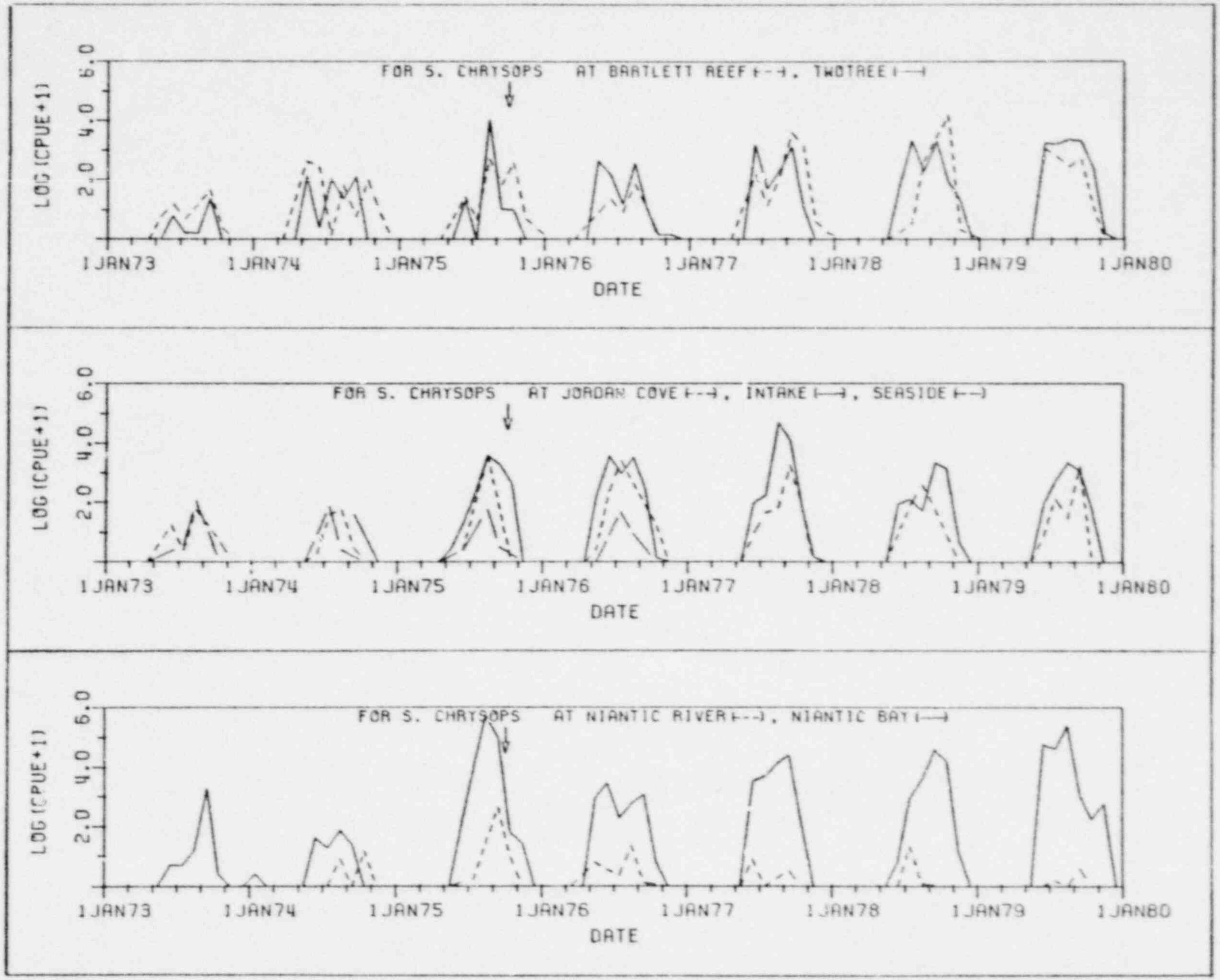

Figure 19. Total catch of scup per 15 minute trawl in each region.

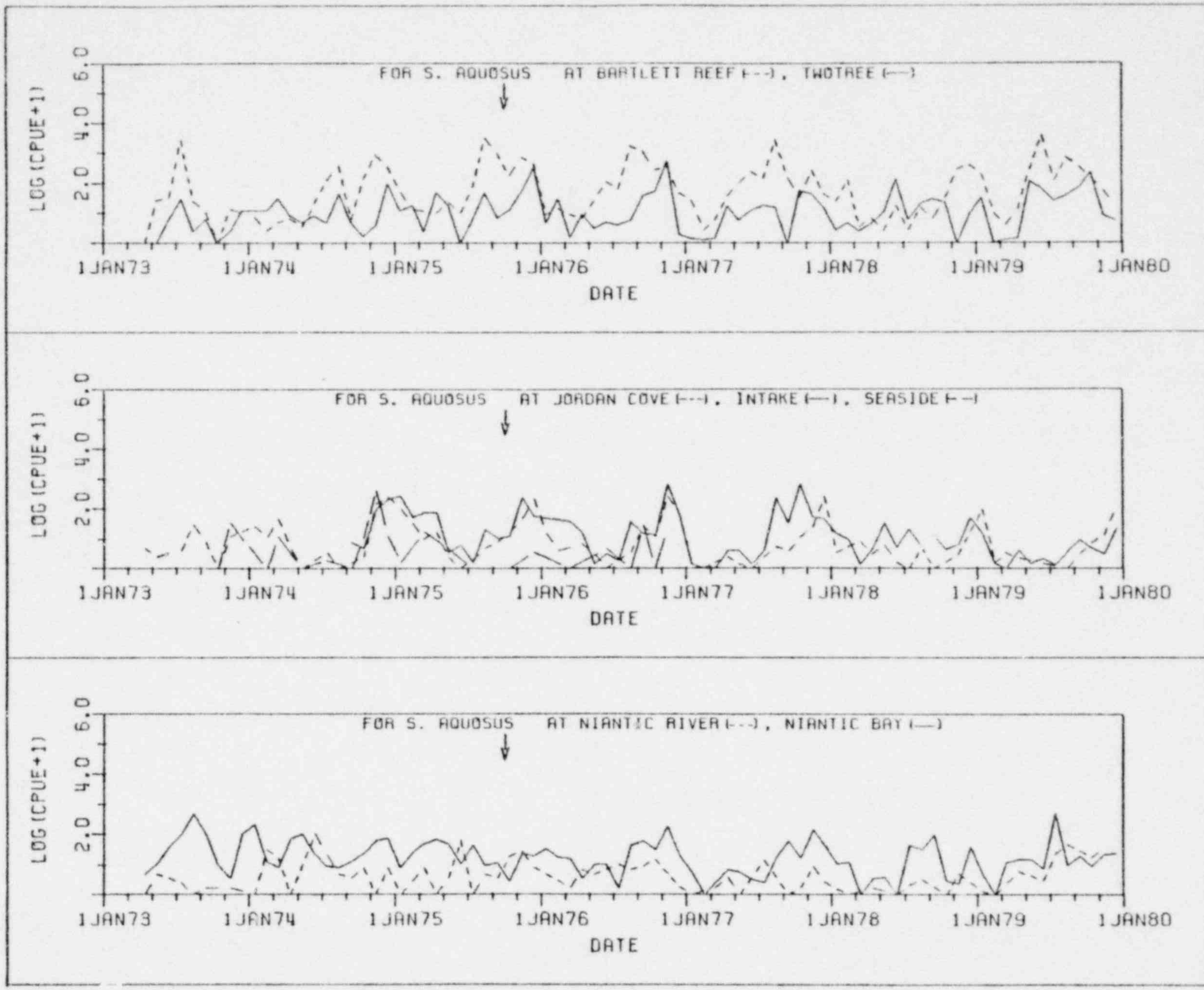

Figure 20. Total catch of windowpane flounder per 15 minute trawl in each region.

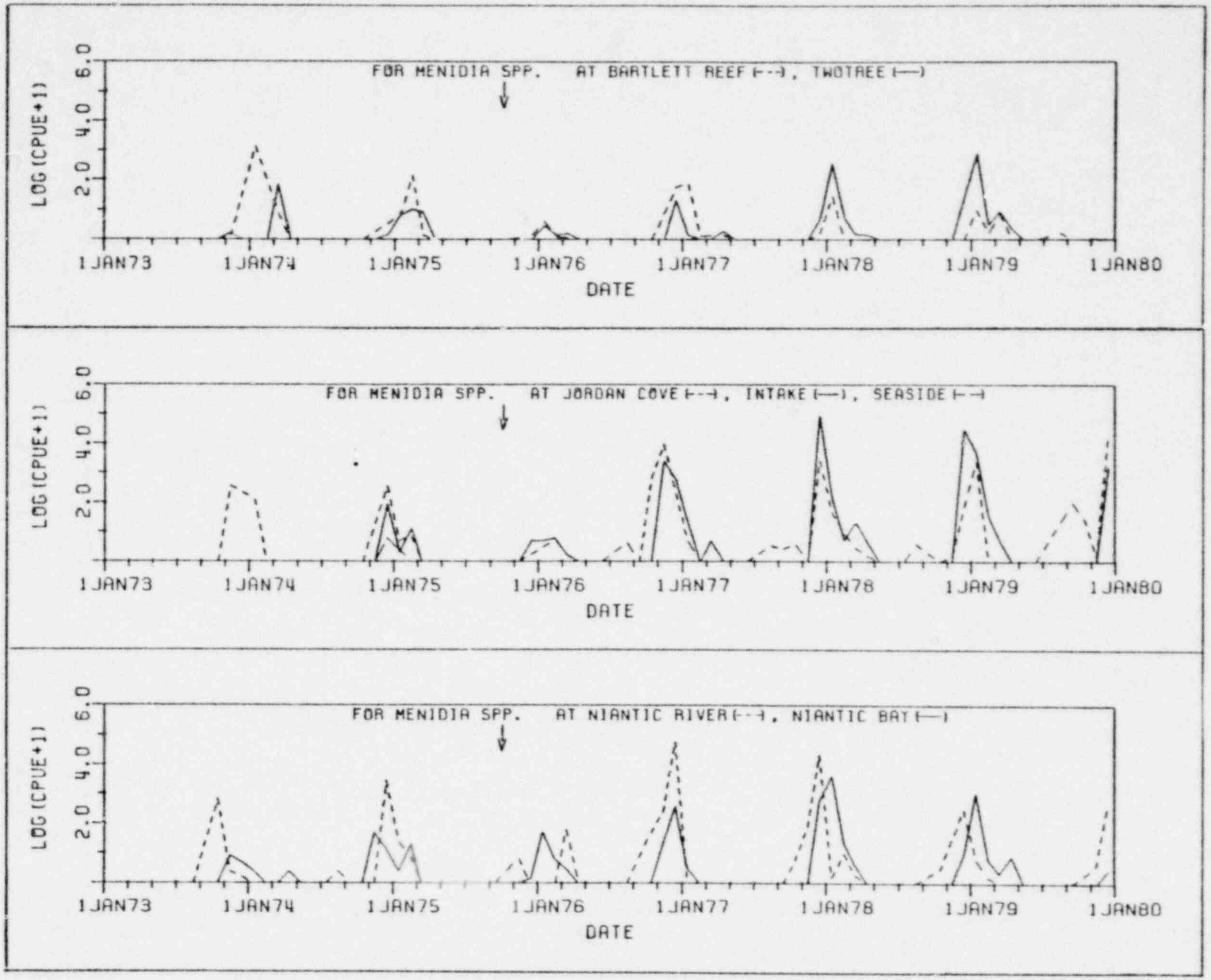

Figure 21. Total catch of silversides per 15 minute trawl in each region.

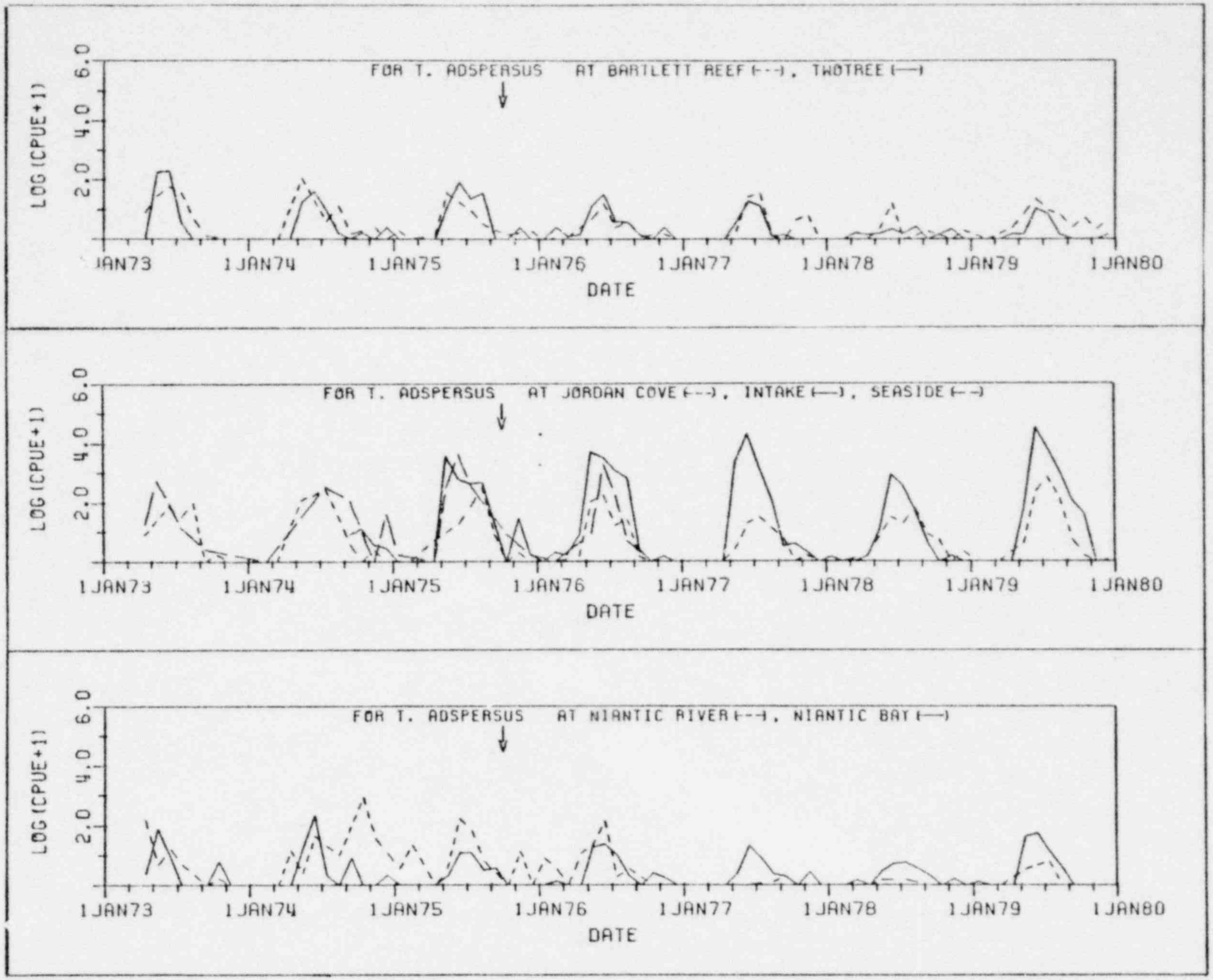

Figure 22. Total catch of cunner per 15 minute trawl in each region..

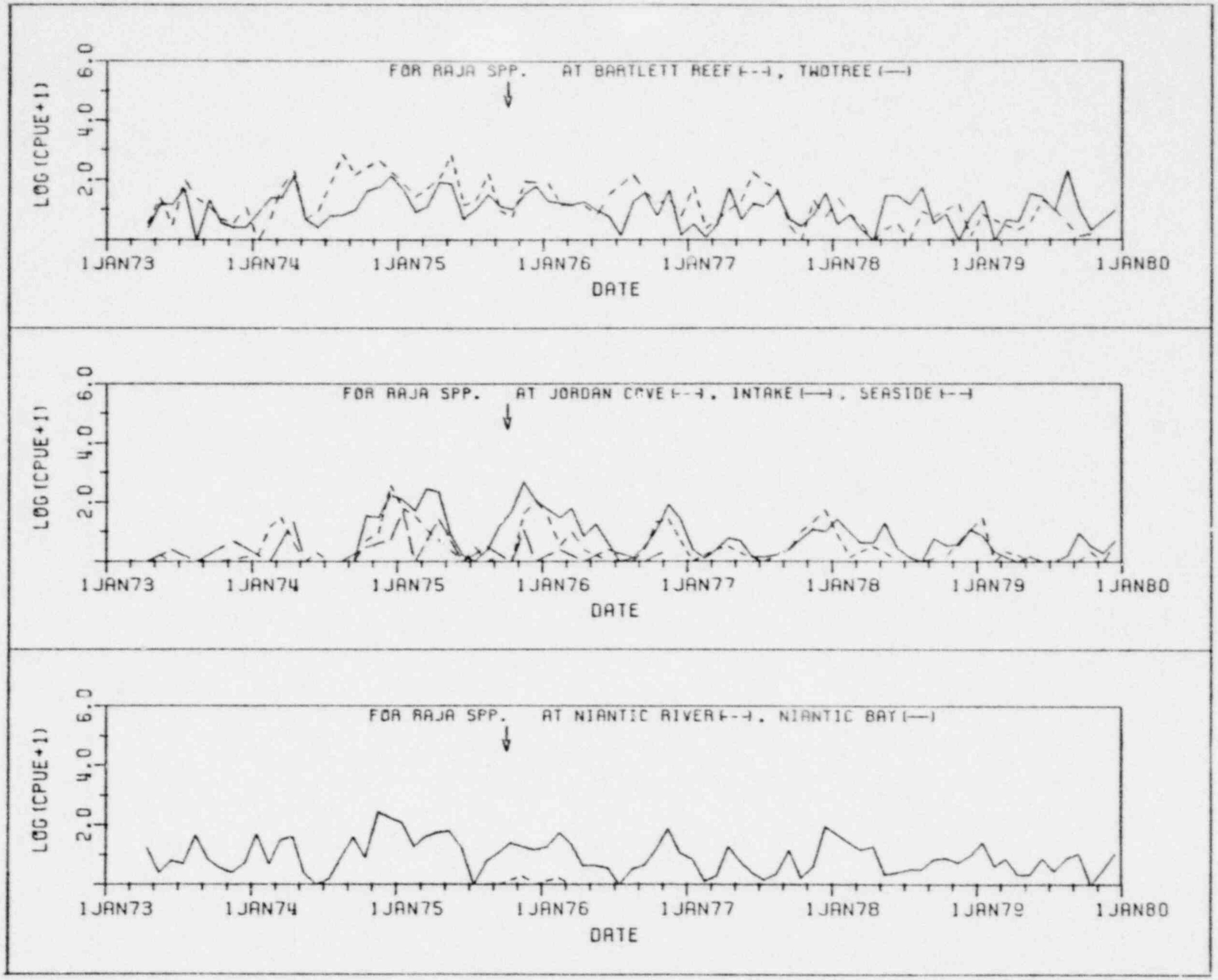

Figure 23. Total catch of skates per 15 minute trawl in each region.

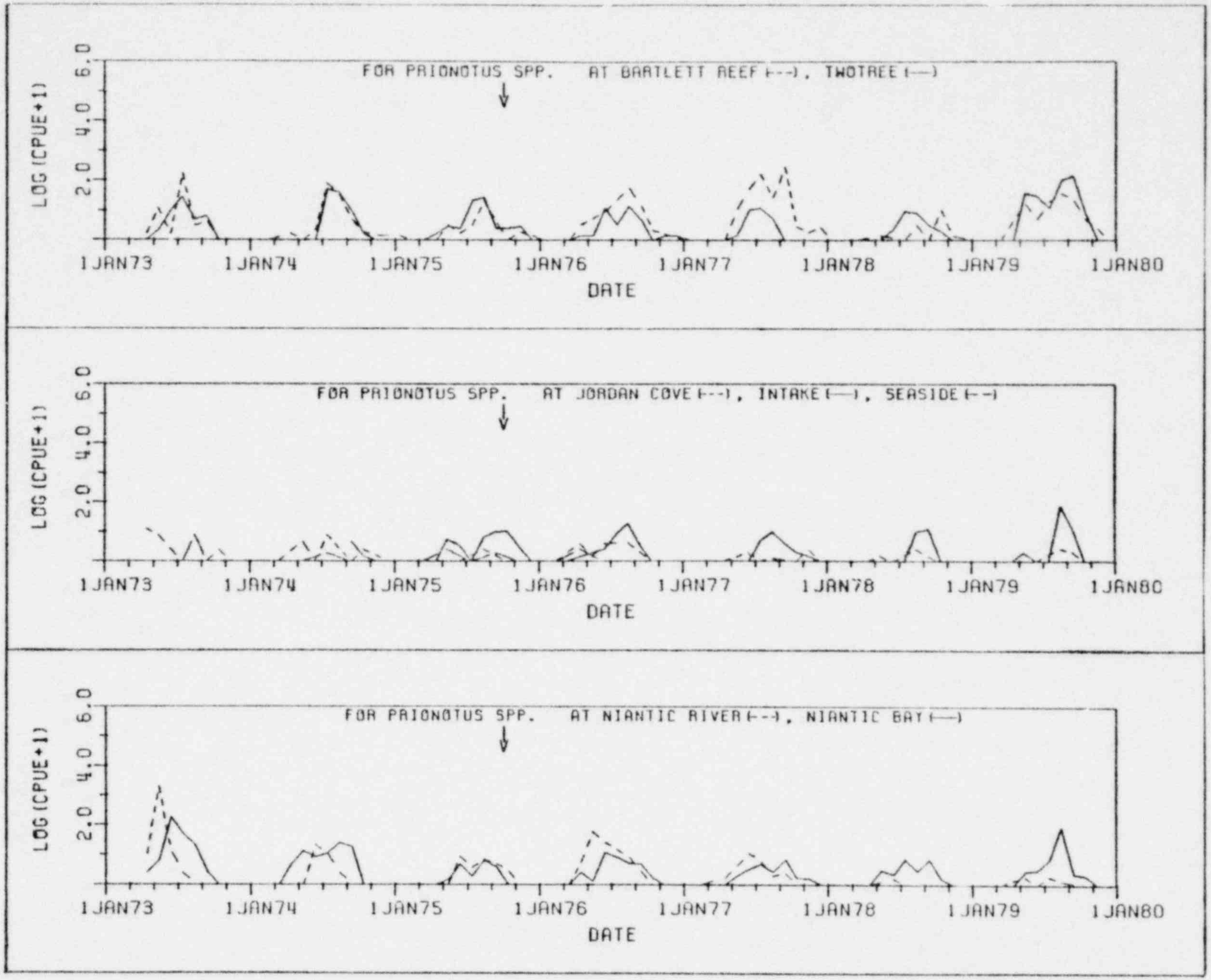

Figure 24. Total catch of searobins per 15 minute trawl in each region.

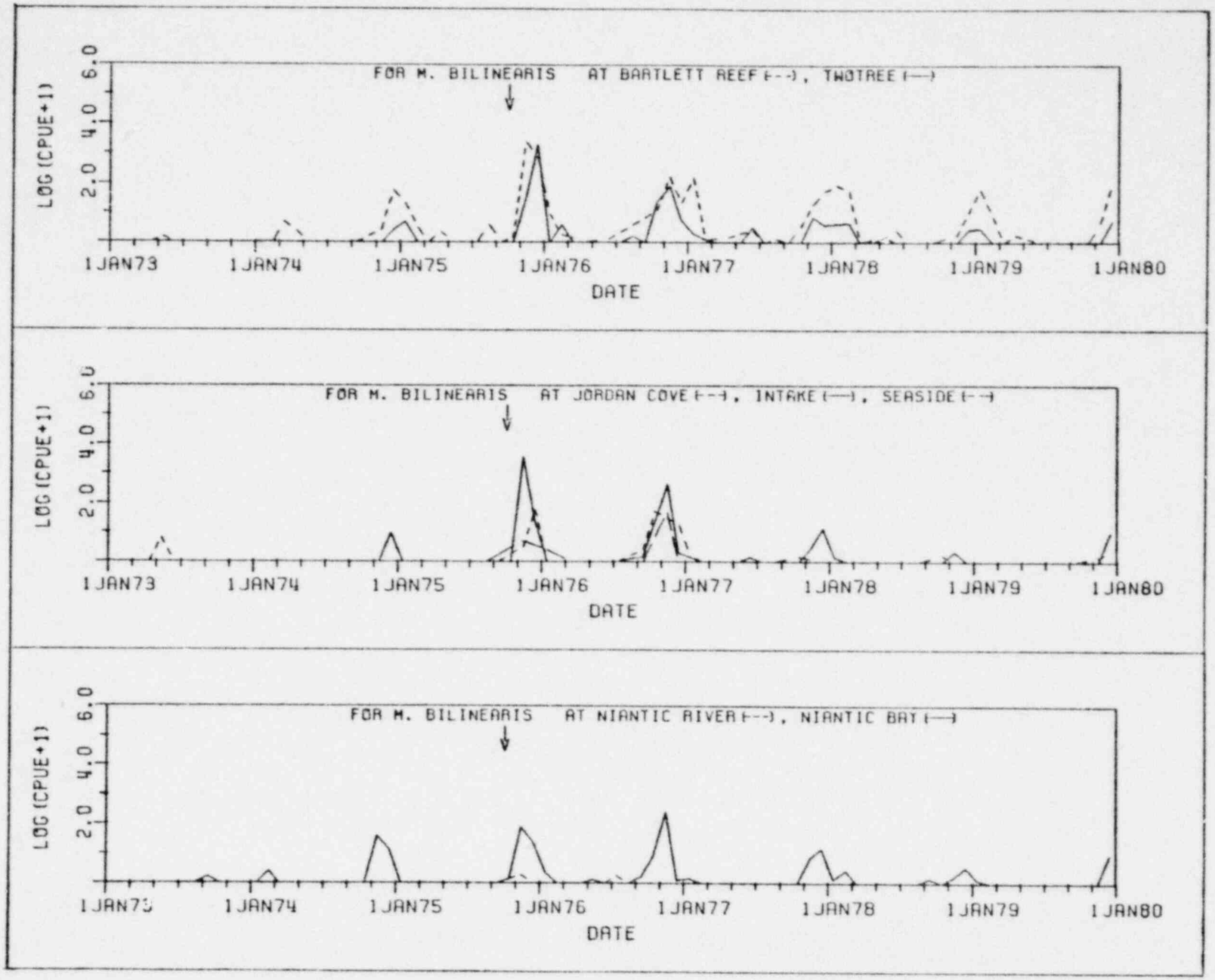

Figure 25. Total catch of silverhake per 15 minute trawl in each region.

which exhibited a secondary peak during this period (Fig. 18), these peak abundances may be the result of migratory patterns or other factors. The fact that individual species abundances peaked at different times of the year may contribute to the lack of an apparent seasonal cycle in total catch.

All of the selected species had mean annual abundances that were significantly affected by year (Table 15), even though most of the graphs (Figs. 18-25) did not show any consistent increases or decreases. The large catches of winter flounder from May through December 1979, in certain regions (Niantic Bay and Twotree) (Fig. 18), were responsible for the significantly increased abundance in 1979 over all other years except 1974. Searobins (Fig. 24), skates (Fig. 23) and windowpane flounder (Fig. 20), on the other hand, were significantly more abundant in the early years of the study than 1979 (Table 15). Scup and silversides had mean catches that were highest in 1979 and lowest in 1973 (Table 15). Grubby mean catch for 1979 fell off from its peak value in 1978. Anchovies mean catch was highest in 1977 and was significantly lower in 1979 than in the three previous years. In 1975 and 1976, the mean catch of silver-hake was significantly higher than all other years while cunner had its highest catch in 1973.

The selected demersal species were distributed geographically in different ways with some being caught in greater abundance at offshore locations and others at inshore regions. Even though the mean total catch was highest at the Intake, only blackfish were more abundant there (Table 15). Many of the other species were found in their second or third greatest abundances at the Intake, thus contributing to the large total catch there. Historically, the prime area for catch of winter flounder was the Niantic River, but in early 1978 this shifted to the Niantic Bay and remained there for most of the months since (Fig. 18). The reasons for this apparent shift were unclear. However, since 1974 there have been increases in bottom coverage by eelgrass (Zostera marina) and red and blue-green algae in the river. This may be an indication of changes in the River habitat. Windowpane flounder, skates, searobins and silverhake were significantly more abundant at the offshore stations in the Bartlett Reef region (Table 15). However, while windowpane flounder and searobins were present (although in reduced abundance) in the Niantic River (Figs. 20 and 24), skates and silverhake w virtually absent from this region (Figs. 23 and 25). Silversides and grubby were significantly more abundant in Jordan Cove and the Intake regions, while significantly more scup and anchovies were found in Niantic Bay. Cunner was the only fish that had its highest mean catch at Seaside (Table 15).

Summary and Conclusions

Fish populations in the Greater Millstone Bight have not experienced any detectable adverse change due to the operation and construction of power plants on Millstone Point. Ten years of shore-zone seine, eight years of gill net and six years of trawl data provided the bases for this conclusion. While total catch and numbers of species of shore-zone, pelagic and demersal fish were seen to vary periodically, no net change in these parameters was detected. Neither was any adverse change detected in any of the selected species also subject to impingement or entrainment losses. Winter flounder, potentially affected by both impingement and larval entrainment, were most abundant during 1979. A shift in the area of dominant catch from Niantic River to Niantic Bay occurred and was throught to be more a reflection of ecological changes in the river than power plant influence in the Bay. Silversides, the second most important impinged fish, were caught in highest numbers by seines in Jordan Cove. They apparently undergo a migration to deeper water in the colder months, similar to that reported in the literature, where they were subsequently caught by trawls. Annual catches of silversides were not significantly different in either trawls or seines before and after the power plants became operational. Windowpane flounder abundances as estimated by trawls remained stable both temporally and spacially. Adult menhaden catches decreased in the gill net collections since 1971, but juvenile abundances as estimated by seines, did not change detectably. Blueback herring, the least impinged species also represented in the fish collections, has not exhibited any detectable change attributable to the power plant.

Grubby, anchovies, cunner, blackfish and silverhake represent species that were subject to entrainment/impingement losses but may not be quantitatively sampled by trawls. Grubby prefer dense eelgrass beds (Bigelow and Schroeder 1953) and cunner and blackfish rocky 'reef' type habitats (Olla et al. 1975), neither of which are trawled with high efficiency. Schooling fish like anchovies and silverhake, neither of which are bottom fish (Bigelow and Schroeder 1953) had catches that were seen to vary as much as four times from tow to tow within a set of triplicates (personal observation). This variability, suggestive of a patchy distribution, would contribute uncertainty to absolute abundance estimates as determined from trawls. Even so, assuming the gear samples these populations in a consistent way, relative comparisons indicated no detectable change in the abundances of grubby, anchovies, blackfish or silverhake. Cunner, as sampled by gill nets have become increasingly abundant at two near shore locations, the Intake and Effluent where rip rap may be providing added habitat.

LITERATURE CITED

Austin, H. and R. Amish. 1974. Preoperational ecological monitoring program of the marine environs at the LILCO, Shoreham Nuclear Power Station, Shoreham, Long Island, New York. Vol. 3 : Fish Ecology.

Baird, S. F. 1873. Natural history of some of the more important food fishes of the south shore of New England. Rept. U.S. Comm. Fish and Fisheries of 1871-1872, p. 228-252.

Bayliff, W. H., Jr. 1950. The life history of the silverside Menidia menidia (Tinnaeus). Md. Board Natur. Resour. Publ. 90:1-27.

Bean, T. H. 1903. The food and game fishes of New York: Note on their common names, distribution, habitats and mode of capture. State of N.Y. Forest, Fish and Game Comm., pp. 247-460.

Bigelow, H. B., and W. C. Schroeder. 1953. Fishes of the Gulf of Maine, Fish. Bull. of the Fish and Wildl. Ser. 53.

Briggs, P. T. 1975. Shore-zone fishes of the vicinity of Fire Island Inlet, Great South Bay, New York. N.Y. Fish. and Game J. 22:1-12.

Bradbury, R. H. 1978. Complex systems in simple environments: A demersal fish community. Mar. Bio. 50:17-28.

Carr, W. E. S., and J. T. Giesel. 1975. Impact of thermal effluent from a steam-electric station on a marshland nursery area during the hot season. Fish. Bull. 73:67-80.

Clark, J. 1967. Fish and man. Littoral Soc. Spec. Pub. No. 5: 1-78.

de Sylva, D. P., F. A. Kalber, Jr. and C. N. Shuster, Jr. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary, with notes on other species collected in deeper waters. Univ. Delaware Mar. Lab. Inf. Ser. No. 5.

Dew, C. B. 1976. A contribution of the life history of the cunner, Tautogolabrus adspersus, in Fishers Island Sound, Connecticut. Chesapeake Sci. 17:101-113.

Greenley, J. R. 1938. Fishes and habitat conditions of the shore zone based upon July and August seining investigations. Section II, pages 72-91 in A Biological Survey of the Saltwaters of Long Island, Pt. II N.Y. Conserv. Dept.

Gunter, G. 1958. Population studies of the shallow water fishes of an outer beach in south Texas. Pub. Inst. Mar. Sci. 5:186-193.

Helwig, J. T. and K. A. Council, editors. 1979. SAS users guide, SAS Institute Inc., Raleigh, North Carolina, USA.

Hillman, R. E., N. W. Davis and J. Wennemer. 1977. Abundance, diversity and stability in shore zone fish communities in an area of Long Island Sound affected by the thermal discharges of a nuclear power plant. Est. and Coast. Mar. Sci. 5:355-381.

Jeffries, H. P. and W. C. Johnson. 1974. Seasonal distributions of bottom fishes in the Narragansett Bay area: Seven-year variations in the abundance of winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Can. 31:1057-1066.

Johansen, F. 1925. Natural history of the cunner, Tautogolabrus adspersus (Walbaum). Contrib. Canad. Biol. 2:423-268.

June, F. C. and J. S. Reintjes. 1957. Survey of the ocean fisheries off Delaware Bay. Dept. Inst. Fish. and Wildl. Serv., Spec. Sci. Rept. No. 222.

Kruskal, W. H. and W. A. Wallis. 1952. Use of ranks on one-criterion variance analysis. Jour. of the Amer. Stat. Assoc. 47:583-621. Addendum: ibid. 1953, 907-911.

Lund, W. A. and B. C. Marcy, Jr. 1975. Early development of the grubby, Myoxocephalus aenaeus (Mitchill). Biol. Bull. 149:373-383.

Massman, W. H., E. C. Ladd and H. W. McCutcheon. 1952. A biological survey of the Rappahannock River. Virginia Fisheries Laboratory, Spec. Scientific Report 6, 2 vols.

McErlean, A. J., S. G. O'Connor, H. A. Mihurski and G. I. Gibson. 1973. Abundance, diversity and seasonal patterns of estuarine fish populations. Est. and Coast. Mar. Sci. 1:19-36.

McHugh, J. L. 1972. Marine fisheries of New York State. Fish. Bull. 70:585-610.

Merriman, D. and H. E. Warfel. 1948. Studies of the marine resources of southern New England. VII Analysis of a fish population. Bull. Bing. Oceanogr. Coll. 11:131-164.

Olla, B. L., A. J. Bejda, and A. D. Martin. 1975. Activity, movements and feeding behavior of the cunner, Tautogolabrus adspersus, and comparison of food habits with young Tautoga onitis, off Long Island, New York. Fish. Bull. 73:895-900.

Oviatt, C. A. and S. W. Nixon. 1973. The demersal fish of Narragansett Bay: An analysis of community structure, distribution and abundance. Estuar. and Coastal Mr. Sci. 1:361-378.

Pearcy, W. and S. W. Richards. 1962. Distribution and ecology of fishes of the Mystic River estuary, Connecticut. Ecology 43:248-259.

Pease, D. N., N. B. Savage and C. J. Schmitt. 1979. New Haven Ecological Studies Summary Report, 1979. Section 11 in A. J. McCusker and W. S. Bosworth, editors. New Haven Harbor Ecological Studies Summary Report, 1970-1977. Normanteau Associates, Inc. Bedford, New Hampshire.

Perlmutter, A. 1971. Ecological study of the aquatic environs of the proposed nuclear power stations of the Long Island Lighting Company at Shoreham: 1970-1971 and summary, 1968-1971. Long Island Lighting Company, 158 pp.

Richards, S. W. 1963. The demersal fish population of Long Island Sound. I. Species composition and relative abundance in two localities, 1956-1957. Bull. Bingham Oceanogr. Coll. 18:5-31.

Saila, S. B. and S. D. Pratt. 1973. Mid Atlantic bight fisheries. Pages 6-1 to 6-125 in Coastal and Offshore Environmental Inventory. Univ. of R. I. Mar. Pub. Ser.

Shapiro, S. S. and M. B. Wilk. 1965. An analysis of variance test for normality (complete samples), Biometrika 52: 591-611.

Stephens, M. A. 1974. Use of Kolmogorov-Smirnov, Cramer-VonMises and related statistics without extensive tables. J. Amer. Stat. Assoc. 69:730.

Warfel, H. E. and D. Merriman. 1944. Studies on the marine resources of southern New England. I. An analysis of the fish population of the shore zone. Bull. Bing. Oceanogr. Coll. 9:1-53.

WINTER FLOUNDER

WINTER FLOUNDER POPULATION DYNAMICS

INTRODUCTION

Winter flounder (Pseudopleuronectes americanus) is one of the most common demersal fish species in northeastern coastal waters. Its range is known to encompass nearly the entire eastern coast of North America (Bigelow and Schroeder 1953). It is the most abundant fish in trawl samples in the Millstone Point area of Long Island Sound.

Peak abundance of flounder usually occurs during the spring and late fall, although they are present during all seasons. Late summer or early fall are the only seasons when other fishes (scup, anchovies, and cunner) have been caught in greater abundance.

Spawning of flounder usually occurs during late February through early April. In the Millstone Bight, males mature at age two and females mature at age three. This is not true for all northeast Atlantic coastal areas. MacPhee (1978) states that maturity may be related to size rather than age, since northern flounder mature at an older age than southern fish, but are the same size at maturity. Male flounder are usually ripe by December when the abdomen of females is just beginning to enlarge from egg development. Most female flounder are not ripe until late February through March.

Flounder ranged in size from 2cm (age zero) to 45cm (age ten or older). Mean size by age during March through May for 1977 through 1979 was age one - 8.3cm, age two - 18.7cm, age three - 26.3cm, and age three plus - 32.8cm. The yearly mean size by age has varied significantly (p=.05) over the period of 1977 to 1979. The variation in size may have been due to changes in temperature and/or food quantity or tvpe (Kurtz 1975).

Winter flounder were caught in all areas of the Millstone Point sampling area, from the intertidal zone to a depth of 20 meters and on rock, sand and weed bottoms. A few flounder have also been caught in overnight gill net sets.

Winter flounder congregate in the Niantic River each winter and early spring to spawn. Special emphasis has been placed on understanding the dynamics of this population because of the proximity of the Millstone Power Station and because the contribution of the spawning product to the greater Millstone Bight is uncertain. Studies initiated in 1973 included development of a predictive mathematical population dynamics model (Sissenwine et al. 1975 and Saila 1976) and a program of monitoring the Niantic River winter flounder population size. Field studies were expanded in 1977 to include age structure and fecundity estimates in order to verify model parameters and to develop a time series of information for assessments independent of the model.

This report summarizes results of the Niantic River winter flounder study for 1979 and includes comparison with earlier years. Age structure, length distribution, survival coefficients, and fecundity estimates are reported and compared with those used in the population dynamics model (Saila 1976). Length frequency distributions for winter flounder in standard trawl catches are also included.

An evaluation of the Jolly-Seber method of population size estimation is presented as part of a continuing effort to insure that the methods used provide the most representative data. Results follow the winter flounder population dynamics section.

MATERIALS AND METHODS

An outline of the winter flounder studies from 1973 through 1979 is shown in Table 1. Additional details regarding earlier study techniques can be found in NUSCO (1975 1978 and 1979).

The 1979 population study was carried out from the week of March 12 through May 14. The Niantic River was divided into eight sampling stations. Stations 1, 2 and 4 were located in the channel and Stations 3 and 5-8 were located outside the channel (Fig. 1).

During 1979, mark-and-recapture sampling was conducted two days each week, usually Monday and Tuesday. To maximize the catch, two boats were used for trawling. Each boat towed a 9.1 meter Wilcox biological otter trawl with a 6.4mm bar mesh cod-end liner. The majority of tows was taken at the stations of best catch per unit effort. Tow duration varied between 5 to 20 minutes according to conditions such as the size of the area to be towed, expected catch, or the amount of clogging of nets with eel grass and algae. All flounder over 15cm were marked by using a freeze-branding method. A 15.9mm brass letter (week code) and number (station code) cooled in a container of liquid nitrogen was used to brand the fish on the pigmented side, midway between the dorsal fin and the lateral line. All recaptured fish were recorded and then remarked with the brand designating the week and station of recapture. Each week approximately 100 to 200 fish were measured to the nearest millimeter (total length). Upon completion of the processing, all fish were returned to the general area of capture.

Table 1. Outline of Niantic River Winter Flounder population studies from 1973 through 1979.

Year	Number of Fish Marked	Size of Fish Marked	Marking Method	Method of Population Estimation	Types of Studies	Comments
1973	2,000	≥ 25cm	Floy Anchor Tags	None	Population study of the total Millstone Bight.	Only 1000 fish marked in the Niantic River. Insufficient number of fish marked for a satisfactory population estimate.
1974	2,600	≥ 20cm	Floy Anchor Tags	Jolly (1965)	Population study of the Niantic River and Jordan Cove.	All except 300 marked in the Niantic River; Insufficient number of fish marked for a satisfactory population estimate.
1975	10,633	≥ 15cm	Fin Clipping	Triple Trellis, Ricker(1958) and Jolly (1965)	Population study of the Niantic River.	Study set up for triple trellis method of population estimation. Marking method changed to increase number of fish that could be marked.
1976	10,693	≥ 15cm	Fin Clipping	Jolly (1965)	Population study of the Niantic River.	Study set up for Jolly method to give improved population estimate results.
1977	7,358	≥ 15cm	Freeze Branding	Jolly (1965)	Population, fecundity, age (scales-otoliths), sex ratio, and length-weight studies of Niantic River	Used freeze branding to improve the method of marking and to increase the variety of marks that could be used, other studies done to supply field data to be used in the URI model.
1978	8,283	≥ 15cm	Freeze Branding	Jolly (1965)	Population, age (scales-otoliths, and scales alone) sex ratio, and length-weight studies of Niantic River.	Aging by scales and otoliths and scales alone, to compare aging methods.
1979	8,104	≥ 15cm	Freeze Branding	Jolly (1965)	Population, age (scales), sex ratio, and survival from age 2 to 3 fish studies of Niantic River.	Scales were a satisfactory method of aging if all fish over 3 years old were combined as 3+ year old fish.

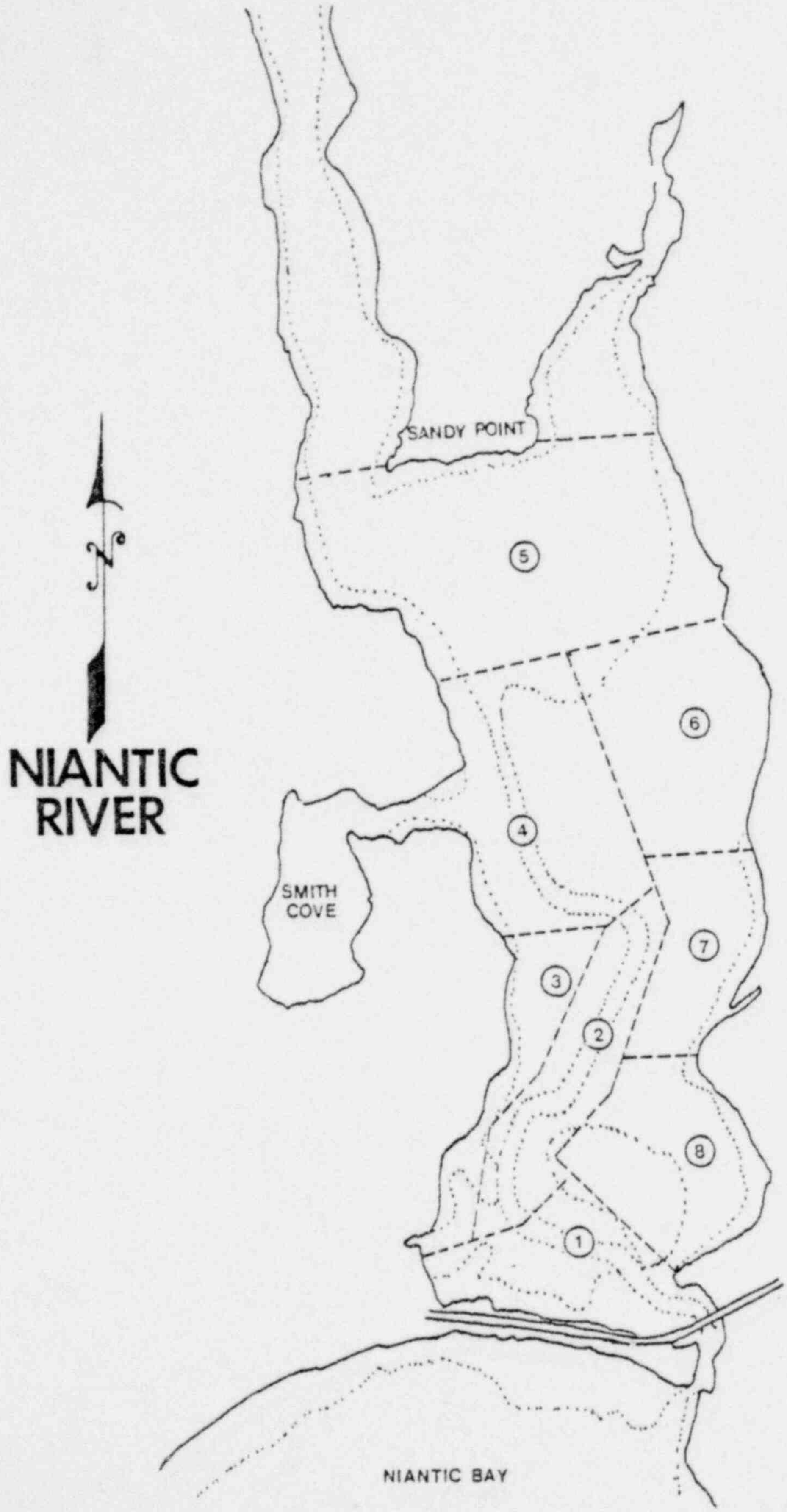

Figure 1. Location of Niantic River winter flounder sampling stations.

Population estimates were calculated using the Jolly (1965) method. Data were analyzed by computer using the population estimating program outlined by Davies (1971) with a modification. The Fortran DO loop where R(I) was defined, was changed so that the initial I value was 1 instead of 2. Total population estimates were obtained by starting with an estimate of the initial population and then adding the total number of fish that were recruited during subsequent weeks. The estimated population of fish less than 15cm was determined from the following proportion:

$$\frac{\text{population of fish} < 15 \text{ cm}}{\text{total catch of fish} < 15 \text{ cm}} = \frac{\text{population of fish} \geq 15 \text{ cm}}{\text{total catch of fish} \geq 15 \text{ cm}}$$

The sex of all winter flounder over 24cm was determined by sexual dimorphism as described by Smigielski (1975). The Massachusetts Department of Natural Resources, from 1963 to 1964, found that of 518 fish examined, 90 percent agreement was made on scales versus gonads in sex determination. Most disagreement occurred when attempting to sex immature males.

Scales from 762 fish, chosen randomly, were removed from the dark side midway between the head and the caudal peduncle and midway between the dorsal fin and the lateral line. Four or five scales from each fish were cleaned and mounted on a slide with plastic resin and a cover slip. Ages were read from scales using a Bausch and Lomb trisimplex projector with a 5 cmf lens and a 5x extension tube. An image of the scales was projected onto a white screen, which was placed approximately 1.4 meters from the projector, giving an approximate magnification of 60x. The scales were read by two people. When no agreement could be made on an age, the estimated age of the fish was determined by its length.

The aging techniques using otoliths and scales were both satisfactory if all fish over three years were categorized as three plus year fish due to the difficulty of aging older fish. Berry (1959), Landers (1941) and Kurtz (1975) also had difficulty in aging fish older than three years. They used otoliths and found scales unsatisfactory for aging. This may have been due to the use of scale impressions rather than the actual scales. The main advantage of scales over otoliths was that the fish did not have to be sacrificed.

The age distribution, as a percent of fish < 15cm and $\geq$ 15cm, was determined from the 762 aged fish. The number of two year old fish was the sum of the number of age two fish < 15cm and the number $\geq$ 15 cm.

The percent length frequency of flounder by 2cm intervals was determined by age and year for the Niantic River winter flounder population and by year and station for winter flounder caught in standard trawls. An analysis of variance was used to compare differences of mean length per age between years.

The total number of spawning females was considered to be all females three years and older in the estimated spawning population. The population during the spawning period for 1976 through 1978 was obtained from the population estimates from the beginning of the population study through the first week of April. The 1975 spawning population was estimated by comparing the 1975 catch per unit effort data at Stations 1 and 2 to the 1976 data. The ratio of unit-effort data of 1975 to 1976 was used to determine the 1975 spawning population. Survival from age two to age three was determined by dividing the number of age three fish in year x by the number of age two fish in year x-1.

Total and mean fecundity by age for 1979 were derived by applying a known length-fecundity relationship, $\log_{10}$ (fecundity)=0.6366 + 3.3703 Log_{10} (total length in cm) (NUSCO 1978), to the lengths of all female flounder measuring over 23 cm.

RESULTS AND DISCUSSION

Results from 1973 through 1978, are summarized in NUSCO (1975, 1978 and 1979). During 1979, there were 19,177 winter flounder caught over the ten weeks studied, and of these 8,104 fish over 15 centimeters were marked. A total of 492 (6.1%) of the marked fish was recaptured. Of the fish marked in 1973 through 1978, 40 were recaptured in 1979 (Table 2). The numbers of flounder marked and recaptured from 1975 through 1979 are listed in Table 3. The number marked and the percent recaptures has not varied greatly between years.

The 1979 data from weeks 1, 2 and 3 were combined and weeks 9 and 10 were combined because of the small number of fish marked and the lack of recaptures during those periods. The 1978 and 1979 population estimates indicated that more than 700 fish per week are needed for satisfactory results.

Estimates of the instantaneous weekly populations ranged from 36,237 to 131,217 during 1975; 23,827 to 51,381 during 1976; 5,798 to 54,019 during 1977; 13,332 to 24,660 during 1978 and 9,892 to 34,111 during 1979. The total population of winter flounder over 15cm in total length in the Niantic River during 1979 was estimated to be 53,643 (standard error, S.E., 10,700)(Tables 4 and 5). There was a large decrease in population size from 1975 to 1976. Smaller decreases occurred each year thereafter but estimates were all within the bounds of the 95 percent confidence interval.

Table 2 . Weekly catch data used for determining population estimates of Niantic River winter flounder during 1979.

Week No.	Date (week of)	Total Caught	Number Unmarked	Number Marked	Number Removed	Number Examined	Recap. 1975-1976	Recap. 1977	Recap. 1978	1979 Recaptures (week Marked) 1	2	3	4	5	6	7	8	9	Total Recap. 1979
1	3-12	381	163	218	0	218	0	2	3	-									-
2	3-14	1,172	613	556	3	559	1	2	10	2	-								2
3	3-26	2,781	1,735	1,046	0	1,046	0	2	4	2	4	-							6
4	4-2	2,983	1,674	1,308	1	1,309	1	1	1	2	5	43	-						50
5	4-9	3,317	2,379	938	0	938	0	0	4	3	5	27	51	-					86
6	4-16	1,383	713	668	2	670	0	3	1	1	1	20	26	50	-				98
7	4-23	2,715	1,272	1,443	0	1,443	0	1	1	1	2	15	15	45	41	-			119
8	4-30	1,928	973	954	1	955	0	2	0	0	2	7	3	4	7	45	-		68
9	5-7	1,758	784	973	1	974	2	0	1	0	1	4	0	3	2	7	16	-	33
10	5-14	759	547	0	0	212	0	0	0	0	0	2	0	1	2	4	6	15	30
Total		19,177	10,853	8,104	8	8,324	4	11	25	11	20	118	95	103	52	56	22	15	492

Table 3. Yearly mark and recapture data of Niantic River winter flounder ≥15 cm in length.

Year	Number of Weeks Sampled	Number Marked	Number Recaptured	Percent Recaptured	Number Recaptured From previous years
1975	6	10,633	547	5.1	--
1976	10	10,693	674	6.3	155
1977	10	7,358	616	8.4	47
1978	11	8,283	689	8.3	95
1979	10	8,104	492	6.1	40

Table 4. Yearly population, spawning, and fecundity data of Niantic River winter flounder ≥15 cm in length.

Year	Total Population Estimates ($X 10^3$)	Standard Error ($X 10^3$)	Number of Weeks of Population Estimates	Spawning Population ($X 10^3$)	Percent Females	Spawning Females ($X 10^3$)	Total Fecundity ($X 10^9$)	Mean Fecundity ($X 10^5$)
1975	160	19	4	55	--	14	4.8	3.2
1976	91	15	9	51	--	12	4.3	3.5
1977	74	20	8	37	53.3	12	5.9	4.4
1978	56	9	6	19	71.4	11	6.8	6.0
1979	54	11	5	34	53.8	13	6.7	5.2

Table 5 . Niantic River winter flounder population estimates (Jolly Method), 1979.

Date (week of)	Total Number (N)	Probability of Survival (PHI)	Number Joining (calculated) (B)	Number Joining (actual)	S.E. (N)	S.E. (PHI)	S.E. (B)
3/12/79 to 3/26/79		0.7183		34,110.61		0.0981	
4/2/79	34,110.61	0.3892	-2,404.25	0.00	6,556.86	0.0551	2,317.26
4/9/79	10,870.76	0.7826	1,383.84	1,383.84	1,696.97	0.1297	1,330.99
4/16/79	9,891.70	0.5445	7,931.60	7,931.60	1,748.30	0.1168	1,908.22
4/23/79	13,316.57	0.4935	10,216.78	10,216.78	2,685.06	0.1398	3,462.68
4/30/79	16,789.10				4,918.30		
Total Population				53,642.83			
			S.E.	10,700.11			

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

MICROCOPY RESOLUTION TEST CHART

Abundance, as measured by routine trawls, was somewhat different. Catches of flounder increased from a low point in 1977 to a peak in 1979. The increase was greatest at Niantic Bay indicating a shift in the area of dominant catch (see Fish Ecology Section).

Annual trends in catch of winter flounder at Millstone appear to reflect those reported regionally for the last decade. Fig. 2, updated from MRI and NEP (1978), shows a generalized decline in winter flounder catch through 1976 and a leveling off thereafter or very slight increases.

There were two distinct periods of winter flounder occurrence in the Niantic River during each tag and recapture study period. The first week of April appeared to be the dividing point between the two periods. During the first period when spawning occurred, most of the flounder were caught in the lower part of the river. During 1975 through 1979, the number of the spawning females remained fairly constant (Table 4). The second period was assumed to be the "feeding" period because very few ripe females were caught and there was an increase in stomach content. During this latter period, most fish moved into the shallower parts of the river (Station 6 and 7). The major decrease in numbers of winter flounder from 1975 to 1976 occurred after the spawning period.

The percentage of females in the total population (Table 4) varied between years from 53% to 71%. This suggests that the percentage of males found in the Niantic River during the spawning season is not a true percentage for the entire population during other periods of the year. During the spawning season males and females behave differently

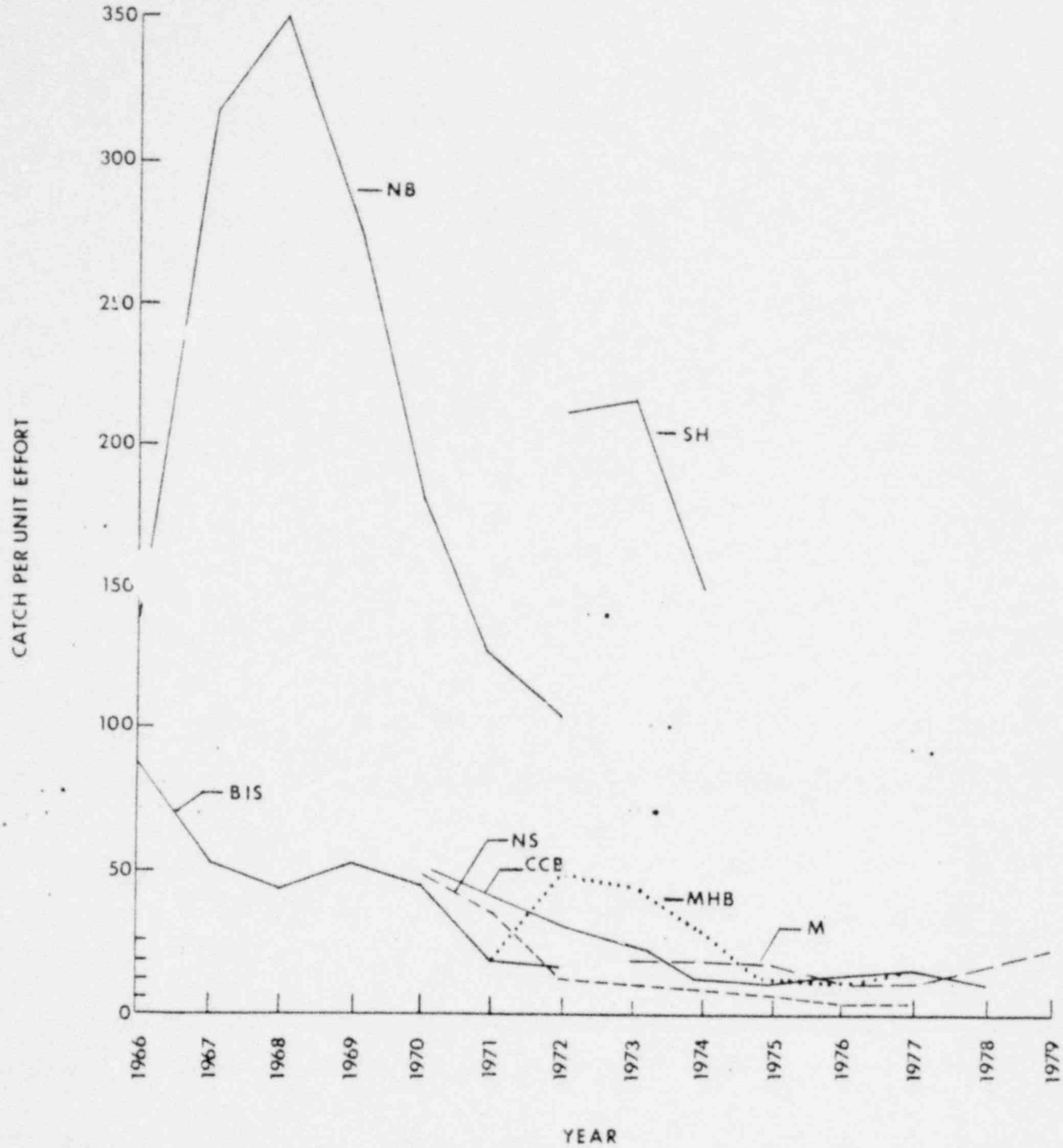

Figure 2. Winter flounder catch per unit effort during 1966-1979 at Narragansett Bay (NB), Salem Harbor (SH), Block Island Sound (BIS), Nantucket Sound (NS), Cape Cod Bay (CCB), Mount Hope Bay (MHB), and Millstone (M) (revised from Marine Research, Inc. and New England Power Company, 1978).

and tend to congregate in different areas. During the 1978 spawning period, more females were caught in the lower channel stations (1 and 2) of the Niantic River and more males were caught in the upper stations (4 and 5) of the Niantic River. Since the majority of fish caught in 1978 were in the lower stations of the Niantic River, the percentage of females was larger than in 1977 and 1979 when the distribution by sex was approximately the same for all areas sampled in the river.

The 1977 through 1979 populations are broken down by number of flounder per age group in Table 6 and percentage of flounder per size group per age in Fig. 3. There was a slight increase in numbers of one and two year old flounder and a slight decrease in numbers of three and three plus year old flounder. This may have been due to higher 1977 and 1978 total fecundity and lower 1975 and 1976 total fecundity (Table 4).

Length distribution by age is shown in Figs. 3 and 4. Yearly mean lengths and ranges of length distributions per age varied each year. Duncan Analysis (Table 7) indicated there was a significant decrease in mean size of one and two year olds in 1978 as compared to the mean size in 1977 and of two and three year olds in 1979 as compared to the mean sizes in 1977 and 1978. The decrease in mean length followed through a complete year class (Table 7 and Fig. 3). This suggests that the decrease in size may have had its origin during the zero age groups of 1976 and 1977, rather than the adult stages, and continued to be expressed in subsequent years.

Table 6. Niantic River winter flounder population estimates by age including survival from age two to age three.

1977 Age	1977 Population	1977 Survival	1978 Age	1978 Population	1978 Survival	1979 Age	1979 Population
						1	60,000
			1	42,000		2	37,000
1	51,000		2	28,000	.3856	3	11,000
2	37,000	.3491	3	13,000		3+	13,000
3	25,000		3+	18,000			
3+	12,000						

Mean survival from two to three years of age for 1977-1978 and 1978-1979 = .3674

Table 7. Duncan analysis showing differences in winter flounder mean lengths by year and age.

AGE					
1	Sample Year/Year Class	1976/1975	1979/1978	1977/1976	1978/1977
	Mean Length (cm)	10.1 (2)	8.7	8.6	7.5
	Group 1				
2	Sample Year/Year Class	1977/1975	1978/1976	1979/1977	
	Mean Length (cm)	20.0	18.7	17.4	
	Group				
3	Sample Year/Year Class	1977	1978/1975	1979/1976	
	Mean Length (cm)	27.2	27.0	24.7	
	Group				
3+	Sample Year	1978	1977	1979	
	Mean Length (cm)	33.0	32.9	32.6	
	Group				

(1) Group - Means connected by a line are not significantly different.

(2) Mean of approximate length groups per age.

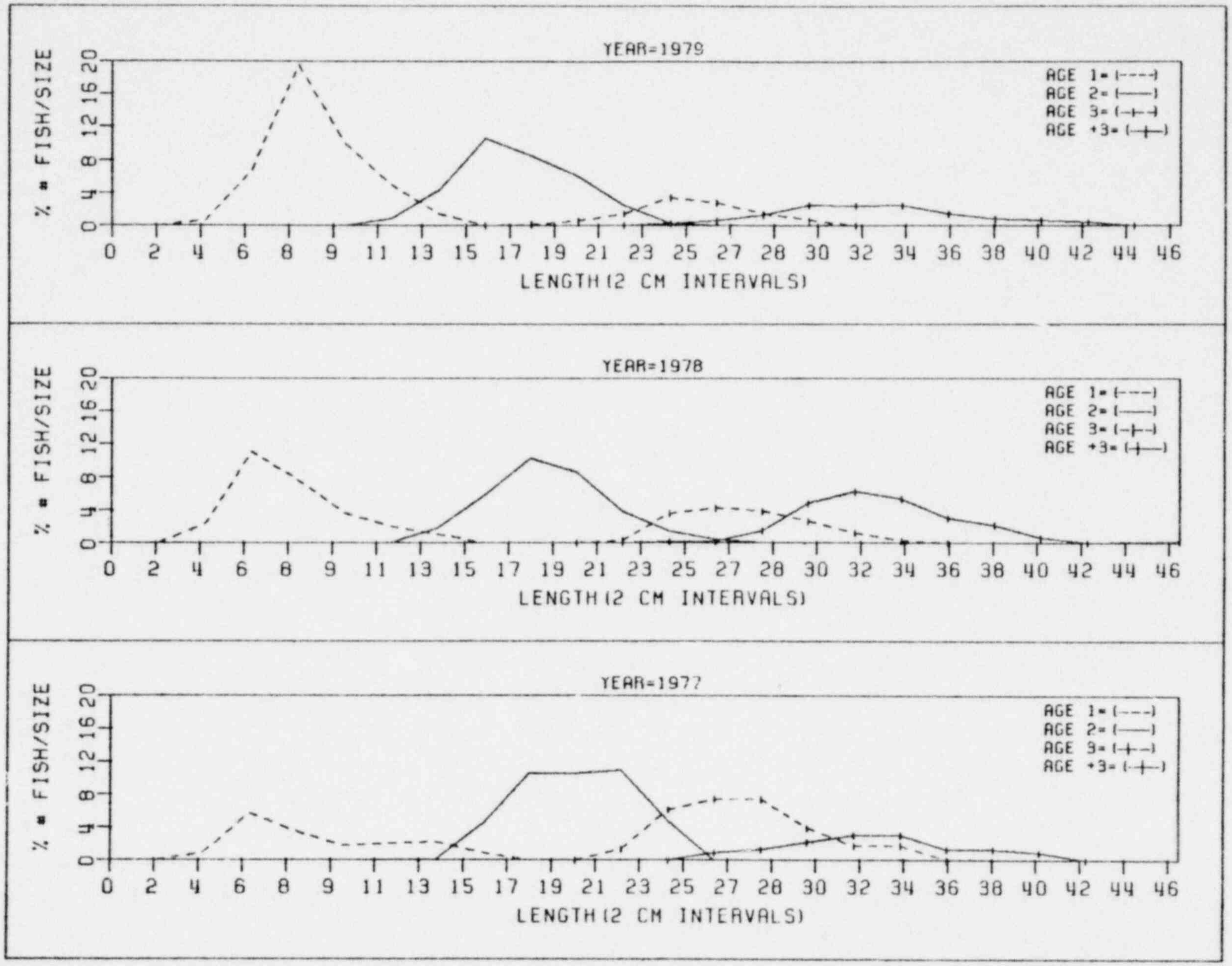

Figure 3. Percent number of Niantic River winter flounder during March-May per 2 cm length intervals, age, and year.

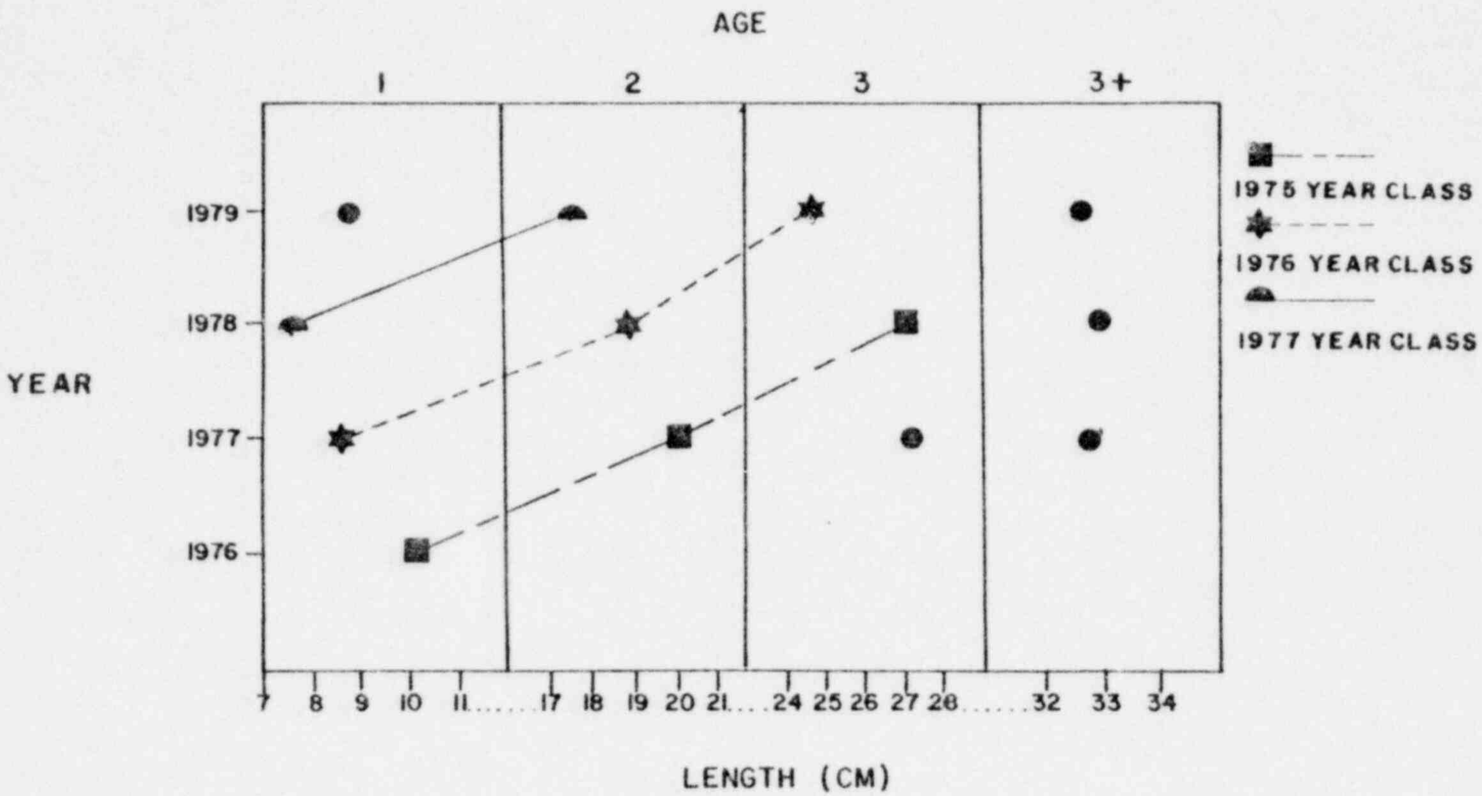

Figure 4. Mean length of Niantic River winter flounder by age, year, and year class during 1976 through 1979 (1976 age 1 mean length is an estimate obtained from length distribution data and not age-length data).

Changes in length distribution of winter flounder caught in the otter trawl study were also evaluated. Length distributions for March through May per station are shown in Figs. 5-10. This period of time was chosen so that the lengths could be compared to those measured and aged during the Niantic River winter flounder study.

Flounder caught during the routine trawl survey were not aged, and their lengths could not be broken down into ages due to the overlap of age length ranges. In order to clarify changes in length distribution by age, approximate ranges (obtained from Fig. 4) of age one fish were 0 to 14cm, age two were 14 to 23cm, age three were 23 to 30cm and age three plus were greater than 30cm.

Significant ($p = .05$) differences (analysis of variance) occurred in winter flounder mean lengths between years. These differences reflected changes in both mean length and percent catch by age (Figs. 5-10). The major changes in length (age) distribution of trawled fish occurred after 1974 when there was an increase in total percentage of age one fish and a decrease of age two and three fish.

Annually, the winter flounder length distribution was most constant for those fish collected in Jordan Cove (Fig. 5). The only notable change was a decrease of two year old fish in 1979. There was a higher percentage of three and three plus year old fish in Jordan Cove and in Niantic River, compared to other stations, indicating that both areas were probably spawning grounds for winter flounder. Previous trawl collections of juvenile winter flounder in Jordan Cove and Jordan River support this.

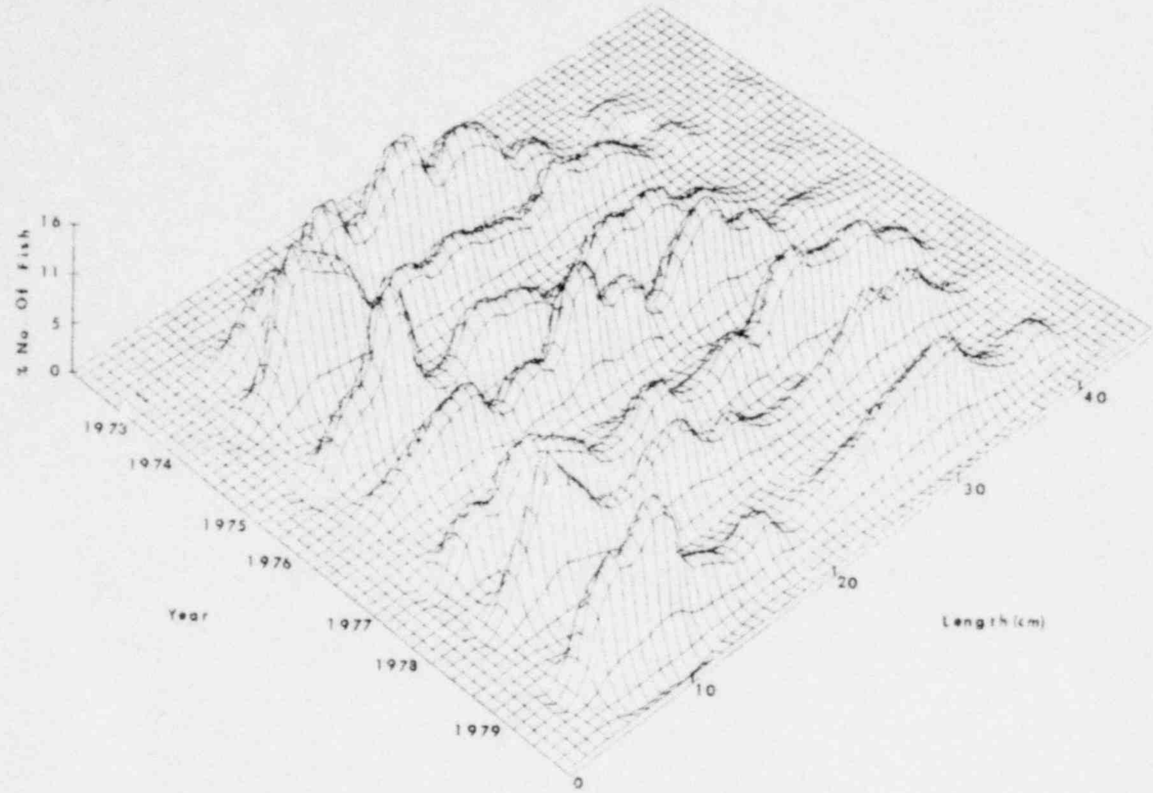

Figure 5. Winter flounder length distribution during March-May per 2 cm length intervals and year for standard trawls in Jordan Cove.

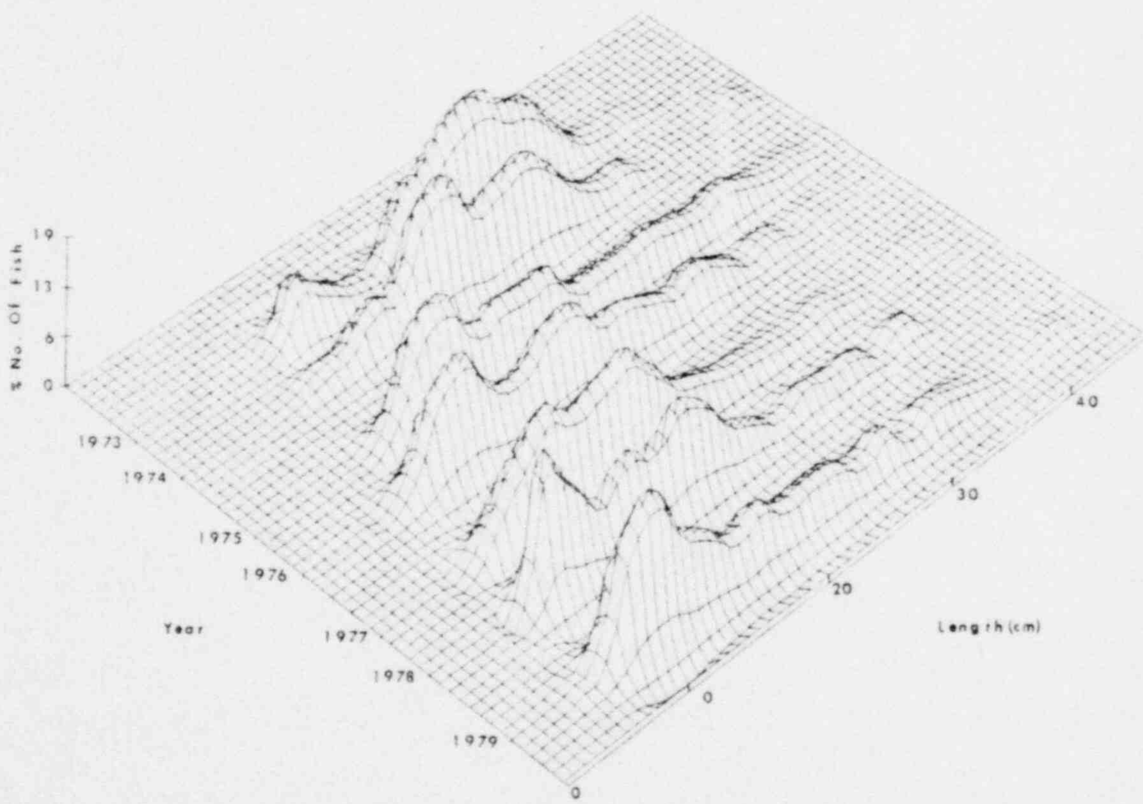

Figure 6. Winter flounder length distribution during March-May per 2 cm length intervals and year for standard trawls in Bartlett Reef.

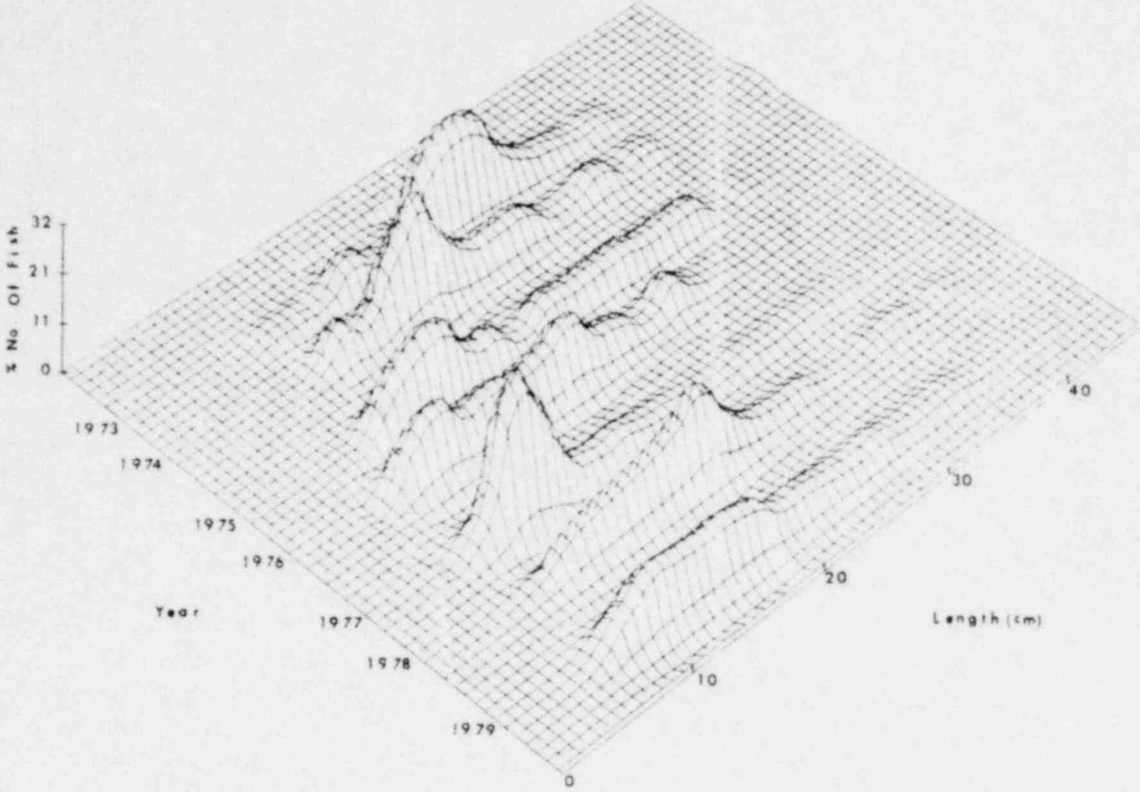

Figure 7. Winter flounder length distribution during March-May per 2 cm length intervals and year for standard trawls in Twotree.

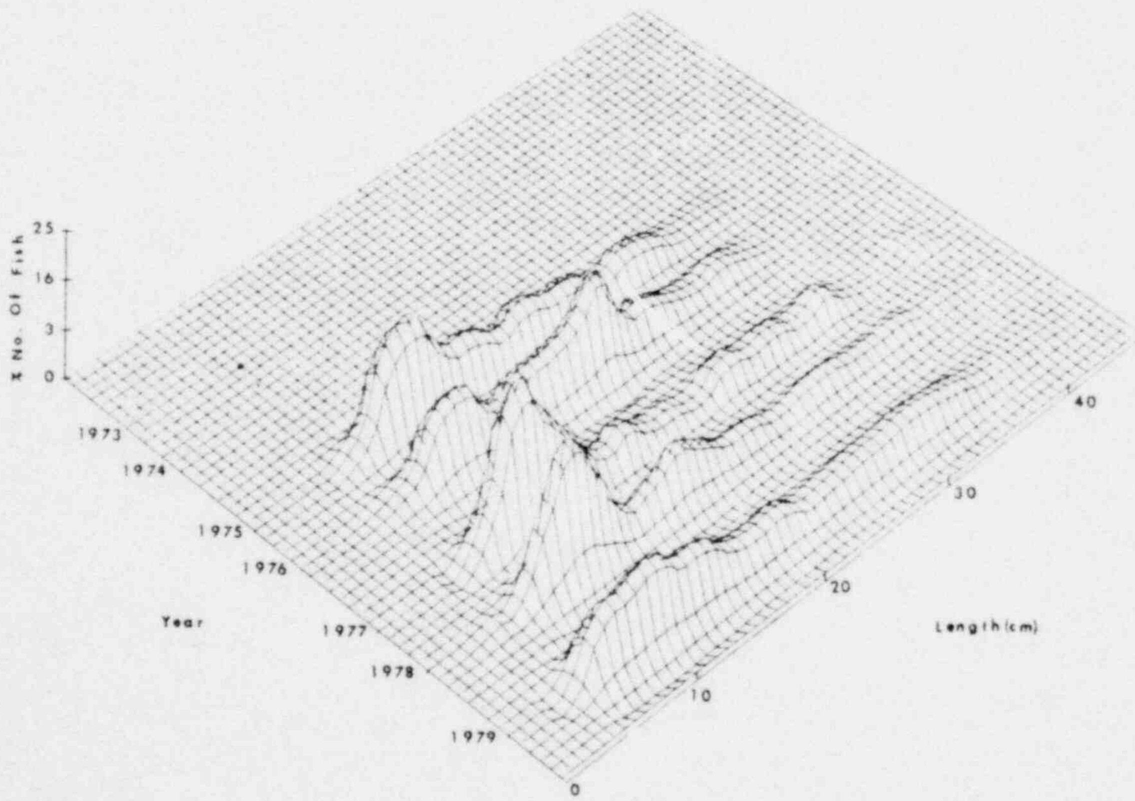

Figure 8. Winter flounder length distribution during March-May per 2 cm length intervals and year for standard trawls in Intake.

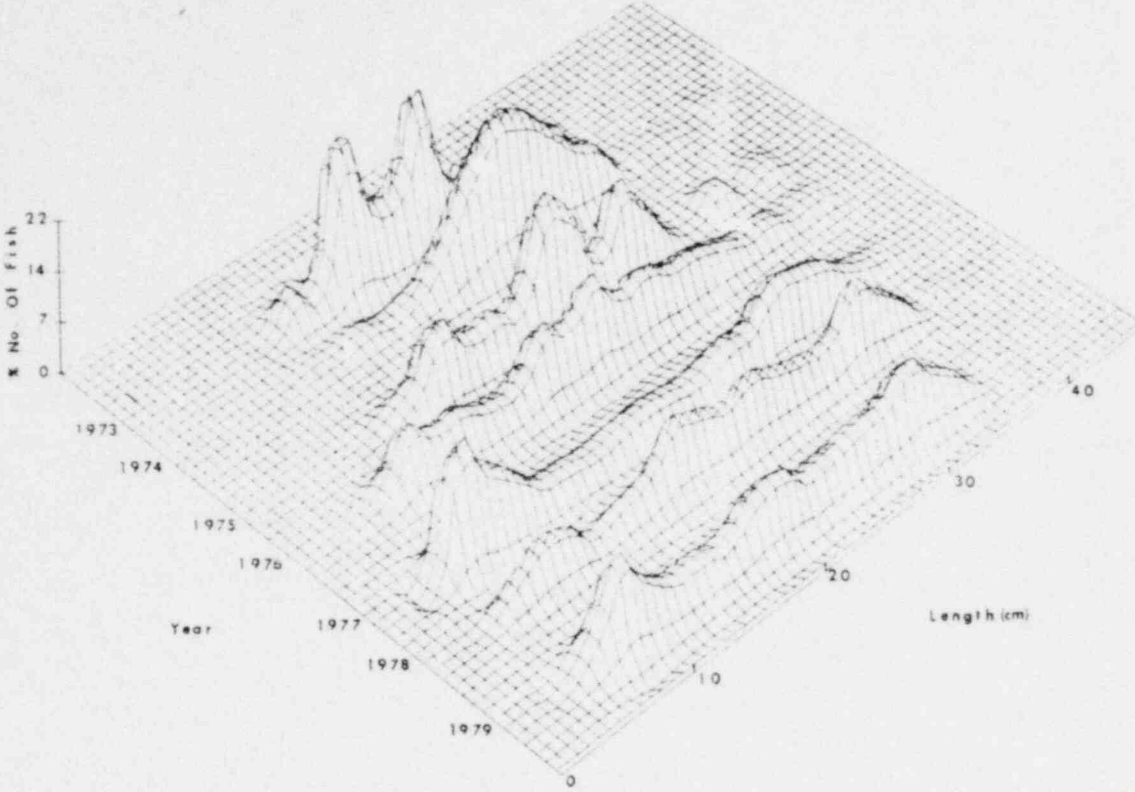

Figure 9. Winter flounder length distribution during March-May per 2 cm length intervals and year for standard trawls in Niantic River.

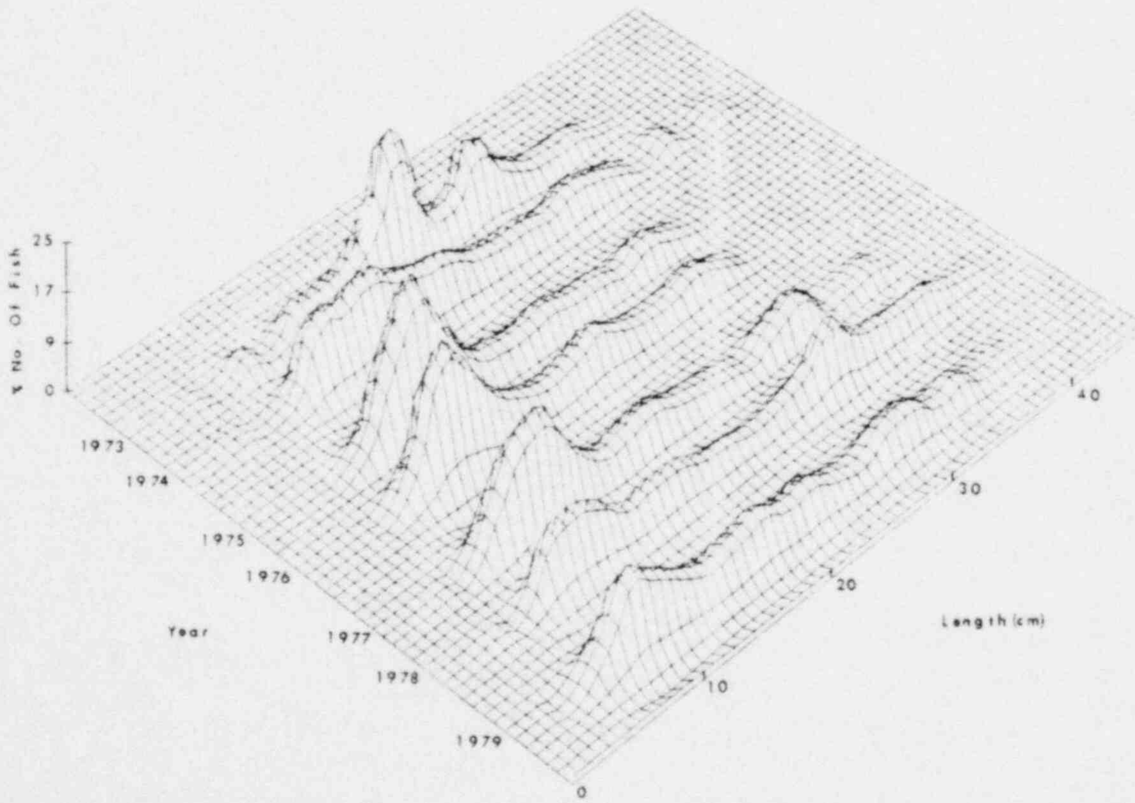

Figure 10. Winter flounder length distribution during March-May per 2 cm length intervals and year for standard trawls in Niantic Bay.

Flounder less than 25cm were the primary size group caught at the Bartlett Reef, Twotree, and Intake stations (Figs. 6-8). This size class, representing ages one and two, was also the major group observed in impingement samples.

After 1975, when percent abundance of age one flounder in Niantic River had increased and the percent of older fish had leveled off, the length distribution of the flounder caught in the river and Niantic Bay were similar (Figs. 9-10). The similarity suggests that winter flounder in both areas may represent the same subpopulation (race). Electrophoritic analyses are presently underway to examine this possibility.

The yearly total and the mean fecundity by age for the Niantic River population are listed in Tables 4 and 8. The 1978 and 1979 total fecundity increased over previous years. The mean length, which is the mean for 1977 through 1979 combined and mean fecundity per age are listed in Table 8.

The field data (Tables 4, 6 and 8), when compared to the simulated data used in the mathematical population dynamics model (Sissenwine, Hess and Saila 1974), were similar. Survival from age two to age three was estimated for 1977 to 1978 and 1978 to 1979 (Table 6). The mean survival from age 2 to age 3 was .3674 as compared to .3333 (the mean of the survival rate obtained by Berry, Saila and Horton 1965 and Poole 1965) used in the model. The age length-weight, and fecundity relationships compared very closely to that used in the model (from Saila 1961 and Berry, Saila and Horton 1965) (Table 8). The major differences were the

Table 8. Female winter flounder mean size and mean fecundity comparing the Niantic River data during 1977-1979 to that used in the mathematical populations dynamics model (Saila 1976).

Age	Mean Size of Females (cm)		Mean Fecundity ($X\ 10^5$)	
	Niantic River	Model	Niantic River	Model
1	8.2	13.5	-	-
2	18.3	21.5	-	-
3	27.7	27.4	3.2	2.6
4	31.7	31.8	4.9	4.4
5	33.5	35.2	6.0	6.4
6	35.7	37.7	7.4	8.1
7	37.6	39.6	8.8	9.7
8	39.8	40.1	10.6	11.1
9	40.7	42.2	11.5	12.2
10	42.3	43.0	13.2	13.0
11	44.0	43.6	15.0	13.7
12	45.6	44.1	16.9	14.2

percent females, a mean of 60%, as compared to 70% (Saila 1976) used in the model, and the total fecundity, 3 to 6 x 10^9 eggs as compared to 1 x 10^9 used in the initial model run (Sissenwine, Hess and Saila 1974) and 13 x 10^9 used in a revised model run (Saila 1976). Changes in mean fecundity and population size have little effect on the final outcome of the mathematical population dynamics model since the population is assumed to be in a state of equilibrium.

SUMMARY AND CONCLUSION

Tag and recapture information was used in the Jolly-Seber formulation to estimate winter flounder population size in the Niantic River during March through May, 1975-1979. The estimated population decreased from a peak of 160,000 fish in 1975 to much lower but near constant levels (91,000 to 54,000) from 1976 through 1979. The number of spawning females ranged more uniformly between 11,000 and 14,000.

Trends in winter flounder abundance in the greater Millstone area were monitored through the use of otter trawls taken repetitively over several years, 1973-1979. Catch per unit effort in otter trawls decreased in 1976 compared to 1975. Abundance over all stations increased in 1978 and peaked in 1979. Observed trends in winter flounder abundance at Millstone were comparable to those reported regionally from Long Island Sound to Cape Cod Bay.

Various population parameters including age structure, survival, fecundity and length distribution were determined. Age structure based on otolith and scale readings since 1977 were uniform. Survival coefficients between age two and three and fecundity estimates were within the ranges reported in the literature. Length frequencies of tagged winter flounder changed annually. Mean length by age was found to decrease from the 1975 year class through the 1977 year class but reflected events operating in the larval and juvenile stages in Niantic River.

Based on regional trends and various population parameters discussed above, it is concluded that the operation and construction of power plants at Millstone have not had a detrimental impact on the Millstone Point area winter flounder population.

JOLLY-SEBER EVALUATION

The Niantic River winter flounder population is an open population subject to immigration, emmigration, natural death, and removal by fishermen. The Jolly method of population estimation was chosen because it is the least complicated, uses all the information provided by the experiment, and provides the most valid results (Cormack 1968). Although Seber's (1965) population estimation method is almost identical to the Jolly method, the Jolly method was used because it is more general and allows for the removal (deliberately or accidentally) of animals caught in any sample. The Jolly (or Jolly-Seber) method has been used extensively. Others that have used it are DeLong (1966); Lidicker (1966); Parker (1968); Williamson, Cameron and Carter (1977); Schweigert, Ward and Clayton (1977); and Siniff, DeMaster, Hofman, and Eberhardt (1977).

In order to use the Jolly method to estimate the winter flounder population in the Niantic River the following conditions or assumptions had to be made: (1) a marked fish had an equal chance of being caught as an unmarked fish; (2) there was no mark lost or mark-related mortality during the study period; (3) the complete capture history of all recaptured fish had to be known; and (4) fish that emmigrated from the study area would not return during the study period. In order to meet the first assumption a period of at least 4 (usually 5) nonmarking days separated each marking period and all marked fish were returned to the approximate area of capture. The second assumption was met by using the freeze-brand marking method which was chosen (by observing marked fish in captivity) to have little effect on the fish after a period of at least three months. The third assumption was met by using a different mark for each marking period and by remarking all recaptured fish. The fourth assumption of the Jolly-Seber method of analyzing tag and recapture data is that tagged animals do not migrate outside the population being studied and then immigrate during the course of the sampling. If this assumption is not met, then animals which do temporarily out-migrate are not subject to the same probabilities of survival and capture as those remaining in the population for the duration of sampling. Further, the estimates of the survival and capture probabilities would be biased if there were significant numbers of tagged animals that temporarily out-migrate. The estimate $\hat{\emptyset}_i$ of survival from time i to time (i+1) is an overestimate of $\emptyset_i$ if temporary out-migration occurs.

In order to consider this assumption further, a test was developed for determining whether non permanent emmigration is operating in the Niantic River winter flounder population. Results are summarized below.

The quantities used in the maximum-likelihood estimation of the parameters $\emptyset_i$, the probability of a marked animal surviving from i to i+1, and pi, the probability of capture in sample i, were as follows:

n_i = number of animals caught in sample i.

m_i = number of marked animals caught in sample j.

m_{i_j} = number of marked animals caught in sample i that were last caught in sample j.

r_j = number of animals released at sample j that are subsequently recaptured.

z_i = number of animals captured prior to time i, not caught at i, but are caught subsequently.

In tabular form, these quantities are:

		Week of Capture					
		2	3	4	5	6	r_j
Week of release	1	m_{21}	m_{31}	m_{41}	m_{51}	m_{61}	r_1
	2		m_{32}	m_{42}	m_{52}	m_{62}	r_2
	3			m_{43}	m_{53}	m_{63}	r_3
	4				m_{54}	m_{64}	r_4
	.					.	.
	.					.	.
	.					.	.
Totals m_i		m_2	m_3	m_4	m_5	$m_6 \cdots$	

The z_i are obtained from:

$$z_{i+1} = z_i + r_i - m_{i+1}\ , \qquad z_1 = 0.$$

If we let ξ_{ij} be the probability a marked animal survives from time i to time j and is not recaptured between i and j, then if no temporary out-migration occurs,

$$\xi_{ij} = \phi_i q_{i+1} \phi_{i+1} q_{i+2} \cdots q_j \phi_j .$$

where $q_i = 1 - p_i$. If temporary out-migration does occur between i and j then

$$\xi_{ij} > \phi_i q_{i+1} \cdots\cdots q_j \phi_j$$

Under the assumption that temporary out-migration does not occur, then the parameters ϕ_i, p_i can be estimated from the set of random variables

$$\{n_i, m_i, r_i, z_i\}$$

in the following way:

Let $\hat{M}_i = \frac{n_i z_i}{r_i} + m_i$ = estimated number of marked animals in the population at time i.

Then $\hat{\phi}_i = \frac{\hat{M}_{i}+1}{\hat{M}_i - m_i + n_i}$

and $\hat{p}_i = \frac{m_i}{\hat{M}_i}$.

Note that if temporary out-migration does occur, then $\hat{M}_i$ is not a valid estimate of the number of marked animals in the population at time i, since z_i may in`ude animals marked prior to i, not captured at i because they are not in the population, but are recaptured subsequently.

If temporary out-migration does occur, then we can estimate the set of parameters $\{\xi_{ij}, p_i\}$ using the complete set of returns $\{m_{ij}\}$. It can be shown that the probability distribution of $\{m_{ij} | \{m_i, r_i\}\}$ is multi-hypergeometric and therefore a test of the hypothesis of no temporary out-migration is possible. The test is of the form of a sequence of single degree of freedom chi-squared statistics.

The above method of testing for temporary out-migration was applied to winter flounder tag and recapture data for the tagging seasons of 1976, 1977, 1978, and 1979. The results are presented in table (9). The interpretation of the table is as follows: The 6, 7, 8, 9 in the ij-th cell indicate that for the years 1976, 7, 8 and 9 respectively, a significant degree of temporary out-migration occurred for the animals released at time (1, 2, .., i), between time i and time j, $j \geq i+2$. Note that the number of weeks of sampling were:

1976	11 weeks
1977	10 weeks
1978	8 weeks
1979	9 weeks

From the table a number of conclusions can be drawn. First, it is apparent that any marked animals released on or after the sixth week of sampling do not appear to temporarily out-migrate. This would indicate that the population of winter flounder in the Niantic River appears to stabilize sometime around mid-April, and that there is a more mobile population prior to this time. The second major conclusion is that temporary out-migration seems to occur mainly as a two-week phenomenon, i.e. most temporary out-migrations occur between weeks i and i+2, for i = 1, 2, 3, 4, 5.

Table 9. Results of Niantic River winter flounder data on temporary out-migration by week of recapture - week of release per year (197_).

Week of Release	Week of Recapture 3	4	5	6	7	8	9	10	11
1	6 7	7	7		7				
2		8 9	9	9				6	
3			6 7 8	7 9	7				
4				8		6	7		
5					6 7 8 9				
6									
7									
8									
9									
10									

The recommendation from this study of the migration pattern of marked winter flounder are:

1. A significant degree of temporary out-migration does occur;

2. The Jolly-Seber estimates of survival probability are therefore too high;

3. Modifications to the estimation procedure accounting for nonpermanent emmigration would improve the estimates of the population size of winter flounder in the Niantic River.

LITERATURE CITED

Berry, R. J. 1959 Critical growth studies of winter flounder, Pseudopleuronectes americanus, (Walbaum). in Rhode Island waters. Master Thesis, University of Rhode Island. 52 pp.

Berry, R. J., S. B. Saila and D. B. Horton. 1965. Growth studies of winter flounder, Pseudopleuronectes americanus, (Walbaum), in Rhode Island. Trans. Am. Fish. Soc. 94:259-264.

Davies, R. G. 1971. Computer programming in quantitative biology. Academic Press, New York, N.Y.

Delong, K. T. 1966. Population ecology of feral house mice: Interference by Microtus. Ecology, 47:481-483.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with death and immigration scholastic model. Biometrika, 52:225-247.

Kurtz, R. J. 1975. Stomach content analysis in growth rate of winter flounder, Pseudopleuronectes americanus, from two Long Island bays. Master Thesis, Long Island University, C. W. Post College. 49 pp.

Landers, W. S. 1941. Age determination of the winter flounder of Narragansett Bay by otolith analysis. Master Thesis, University of Rhode Island. 44 pp.

Lidicker, W. Z. 1966. Feral mouse population declining to extinction. Ecological Monographs, 36:30-31.

MacPhee, G. K. 1978. Synopsi . biological data for the winter flounder, Pseudopleuronectes americanus (Walbaum). NOAA Tech. Cir. #414. 190 pp.

Massachusetts Division of Marine Fisheries. 1964. Annual Report, fiscal year July 1, 1963 - June 30, 1964. 82 pp.

Marine Research, Inc. and New England Power Company. 1978. Brayton Point Generating Station, supporting document for cooling water discharge of temperature up to 95°F. 249 pp.

NUSCO, 1975. Summary report, ecological and hydrographic studies. May, 1966 through December 1974, Millstone Nuclear Power Station. 2.13.1-2.13.6.

NUSCO, 1978. Annual report, 1977, ecological and hydrographic studies, Millstone Point Nuclear Power Station. F1-F48.

NUSCO, 1979. Annual report, 1978 Ecological and Hydrographic Studies, Millstone Point Nuclear Power Station. F1-F28.

Parker, R. R. 1968. Marine mortality schedules of pink salmon of the Bella Coola River, Central British Columbia. J. Fish. Res. Bd. Canada, 25:757-794.

Poole, J. D. 1966. Growth and age of winter flounder in four bays of Long Island, N.Y. Fish. Game J. 13:206-220.

Ricker, W. E. 1958. Handbook of computation for biological statistics of fish populations. J. Fish. Res. Bd. Canada 119:1-300.

Saila, S. B. 1976. Effects of power plant entrainment on winter flounder populations near Millstone Point, Connecticut. U.R.I.-NUSCO Rep. No. 5, 134 pp.

Schweigert, J. F., F. J. Ward, and J. W. Clayton. 1977. Effects of fry and fingerling introduction on walleye, Stizostedion vitrem vitrem, production in West Blue Lake, Manitoba. J. Fish. Res. Bd. Canada, 34:2142-2150.

Seber, G. A. F. 1973. The estimation of animal abundance and related parameters. Hafner Press, New York, N.Y., 196-208.

Siniff, D. B., D. P. DeMaster, R. J. Hofman and L. L. Eberhardt. 1977. An analysis of the dynamics of a Weddell seal population. Ecological Monograph. 47:319-335.

Sissenwine, M. B., K. W. Hess and S. B. Saila. 1975. Evaluating the effect of power plant entrainment of population near Millstone Point, Connecticut. MES-NUSCO Rep. 197pp.

Smigielski, A. S. 1975. Hormonal-induced ovulation of the winter flounder, Pseudopleuronectes americanus, Fish. Bull. 73: 431-438.

HEAVY METALS

HEAVY METAL ANALYSIS

INTRODUCTION

The objective of heavy metal analyses of seawater, oyster (*Crassostrea virginica*), and mussel (*Mytilus edulis*) tissue is to determine if there is any detectable contribution by the Millstone Power Station to heavy metal concentrations of adjacent Long Island Sound (LIS). The study of heavy metals associated with power plant operations began in September, 1971. Metals selected were copper, zinc, iron, chromium and lead in seawater, and the same with the exception of lead in oyster and mussel tissue.

MATERIALS AND METHODS

Sample Collection

One gallon of seawater was collected immediately below the surface, at each of four stations in LIS in the power plant vicinity during February, May, July, September and December. The Effluent, Twotree and the Intake were chosen because of their close proximity to the power station. Giants Neck was chosen as a control. Water samples were collected approximately two hours before low tide.

Samples of oyster and mussel tissue were collected on the same schedule as was seawater. The oysters were taken from trays suspended at the Millstone Environmental Lab dock, White Point, Effluent and Giants Neck (Fig. 1). Oysters growing naturally in the quarry were also sampled. The 2 to 3 year old oysters were placed in the trays each February. At

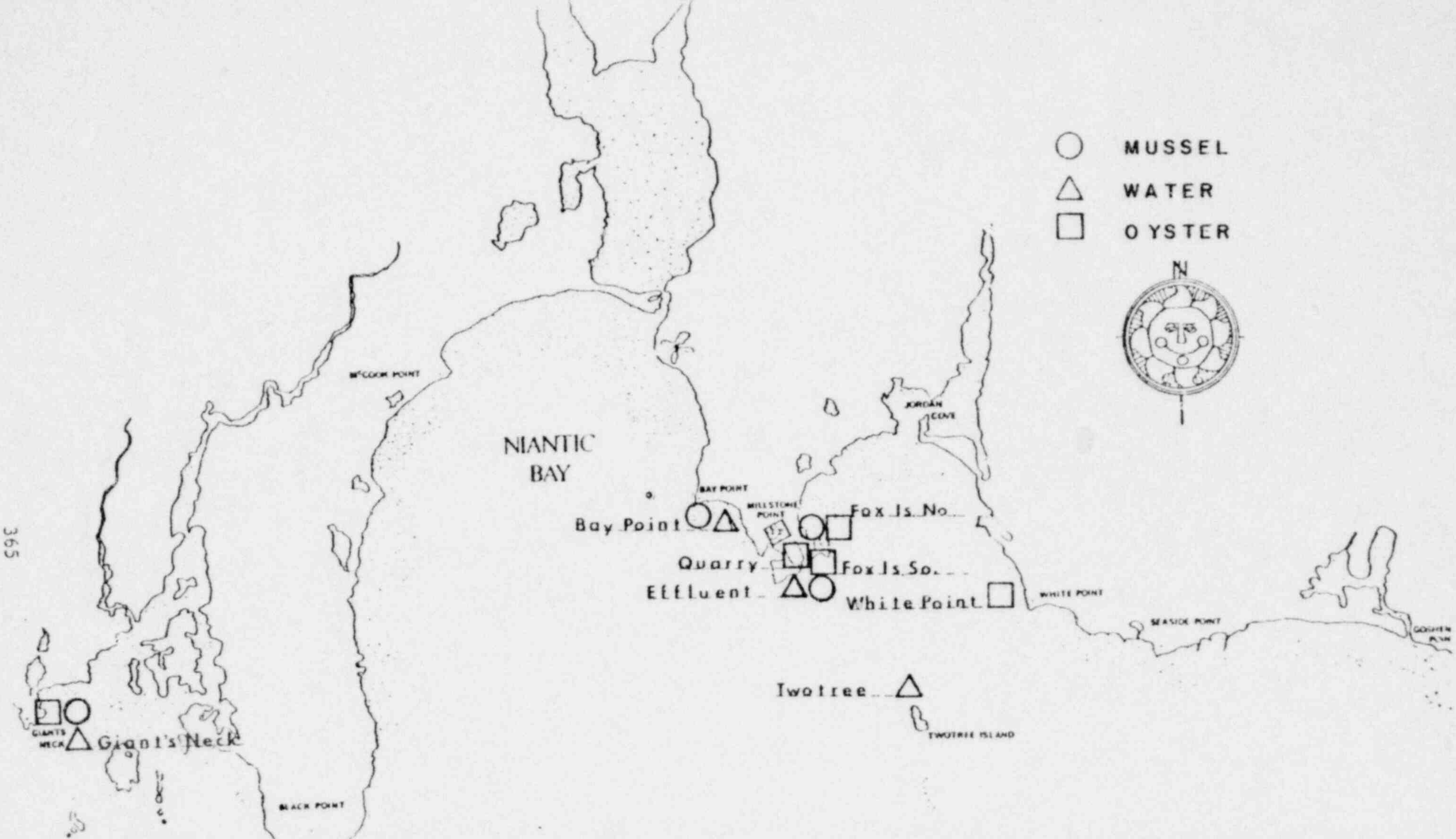

Figure 1.-Location of sampling sites for trace metal analysis.

this time tissue of ten individuals was analyzed for ambient levels of heavy metals. Mussels were collected from the rocky shore at Fox Island-South in the influence of the thermal effluent, White Point, Fox Island-North, and Giants Neck.

Oyster and mussel tissue was collected to provide five grams of pooled tissue of each species at each site. The organisms were kept cool while in transport to the lab where they were shucked and their tissue frozen. The samples were usually analyzed within one day of collection by Battelle, Columbus Laboratories.

Laboratory Analysis

Determination of copper, zinc, iron, chromium and lead in seawater and in oyster and mussel tissue followed the methods of Mansell and Emmel (1969), Mulford (1966), and Brooks et al (1967). For additional methodological detail, see Battelle (1978).

RESULTS

Heavy metal concentrations in seawater, oyster and mussel tissue collected during 1979 are shown in Table 1.

Annual means and ranges are given in Tables 2 through 6.

Table 1. Concentrations of copper, zinc, iron, chromium, and lead in seawater and in oyster and mussel tissue collected from Long Island Sound waters near Millstone Point, Waterford, Connecticut, 1979.

	Cu					Zn					Fe					Cr					Pb					
	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Site
Seawater Soluble (ppb)	1.4	1.4	0.9	1.8	1.0	1.7	3.8	2.9	1.8	7.6	<0.5	0.5	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0	<1.0	1.3	0.5	2.7	1.0	<1.0	Intake
	1.5	2.4	1.7	1.8	1.6	2.9	3.1	4.0	2.4	2.6	<0.5	<0.5	2.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0	<1.0	<0.5	1.1	<1.0	<1.0	<1.0	Effluent
	1.9	1.3	1.4	1.4	1.4	2.5	1.9	4.9	1.4	2.6	<0.5	<0.5	<1.0	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0	<1.0	<0.5	1.1	<1.0	1.2	<1.0	Giants Neck
	1.1	0.9	0.9	1.6	1.4	2.8	2.2	4.4	3.8	2.8	<0.5	<0.5	3.1	<1.0	<1.0	<0.5	<1.0	<1.0	<1.0	<1.0	1.5	0.6	<1.0	<1.0	<1.0	Two Tree
	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	
Seawater Insoluble (ppb)	0.5	<0.5	3.0	0.9	<0.4	1.2	<0.5	6.3	3.8	2.1	130.	75.	100.	120.	101.	<0.5	<1.0	<1.0	<0.5	<0.5	0.8	<0.5	<1.0	1.0	1.0	Intake
	0.5	1.5	3.3	1.0	<0.4	0.8	1.0	4.4	3.2	0.8	130.	92.	110.	94.	25.	<0.5	<1.0	<1.0	<0.5	0.6	0.6	<0.5	<1.0	1.0	2.1	Effluent
	1.1	<0.5	3.0	0.4	0.4	1.2	1.8	5.5	2.4	1.3	160.	75.	87.	250.	254.	<0.5	<1.0	<1.0	<0.5	0.5	1.1	<0.5	<1.0	1.6	1.2	Giants Neck
	0.4	<0.5	2.9	0.4	<0.4	1.7	<0.5	5.2	2.4	1.3	120.	53.	56.	130.	132.	<0.5	<1.0	<1.0	<0.5	<0.5	0.6	<0.5	<1.0	1.0	1.0	Two Tree
	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	
Oysters (tray-held) (ppm)	105.	70.	67.	82.	74.	1300	1040	1030	1290	1360	41.	52.	91.	100.	54.	0.4	<1.0	0.9	0.8	0.2						Giants Neck
	97.	88.	91.	80.	78.	1740	1290	1440	1220	1360	40.	35.	80.	67.	54.	0.5	<1.0	0.9	0.7	0.2						Fox Island
	114.	46.	97.	100.	83.	1410	980	1200	[illegible]	1300	29.	36.	57.	51.	52.	0.5	<1.0	0.7	0.8	0.2						White Point
	293.	69.	220.	320.	335.	1720	860	1500	1620	2320	109.	37.	270.	97.	115.	0.7	<1.0	1.4	0.7	0.4						Effluent
	395.	390.	590.	590.	505.	1940	1730	3690	3320	2660	72.	63.	370.	140.	92.	0.7		1.9	1.5	0.3						Quarry
	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	Feb.	May	July	Sept.	Dec.	
Mussels (ppm)	2.0	2.1	1.9	2.0	2.5	29	32	35	27	56	107	55	89	65	114	0.6	<1.0	1.0	1.1	1.4						Giants Neck
	2.3	2.5	2.0	2.1	2.1	29	34	32	39	67	65	61	72	62	106	0.6	<1.0	1.0	1.1	0.7						Bay Point
	1.8	2.8	3.4	1.8	2.1	16	34	35	30	58	56	63	90	65	95	0.4	<1.0	1.0	0.6	0.9						Fox Island No.
	1.7	2.4	2.5	2.0	2.4	18	44	47	41	65	64	60	68	63	96	0.5	<1.0	1.1	0.9	0.7						Fox Island So.

Table 2. Mean annual copper concentrations in seawater and in oyster and mussel tissue collected from Long Island Sound waters near Millstone Point, Waterford, Connecticut, 1972-1979.

	1972		1973		1974		1975		1976		1977		1978		1979		Site
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Seawater Soluble (ppb)	4-28	14	6-18	10	3-12	6	2.5-12	6	2.10	4.6	1.4-4.8	3.1	2.9-6.0	4.6	1.5-2.4	1.8	Quarry
	3-70	23	7-9	8	1-15	6	1.1-8.9	6	1.5-12	5.5	2.0-5.7	3.8	1.1-3.6	2.6	0.9-1.6	1.1	Twotree
	3-28	11	3-6	5	3-10	5	1.7-8	4	2.4-20	8.5	2.0-32	8.3	1.9-3.3	2.3	0.9-1.8	1.3	Intake
	4-32	11	3-7	5	2-12	8	1.7-12	5	2.7-16	6.5	2.4-5.0	3.2	1.3-4.0	3.1	1.3-1.9	1.4	Giants Neck
Seawater Insoluble (ppb)	<1-11	4	1-27	8	<1-6	2	<0.5-<1	0.7	<0.5-2.8	1.0	<0.5-4.1	1.5	<0.5-3.9	1.4	<0.4-3.3	1.3	Quarry
	<1-16	5.4	1.6	4	<1-4	2	<0.5-<1	0.7	<0.5-3.2	1.0	<0.5-4.1	1.5	<0.5-0.7	<0.5	<0.4-2.9	0.9	Twotree
	<1-6	3	<1-3	2	<1-5	2	<0.5-<1	0.7	<0.5-4.5	1.8	<0.5-7.6	2.2	<0.5-3.6	1.3	<0.4-3.0	1.1	Intake
	2-23	8	1-5	2	2-6	4	<0.4-<1	0.7	<0.5-7.9	1.2	<0.5-13	3.2	<0.5-2.4	1.3	<0.4-3.0	1.1	Giants Neck
Oysters (trayheld) (ppm)					100(a)			39(a)	75(a)	59(b)	151(a)	82(c)	115(a)		65(a)	67(f)	
	205-525	365	202-470	368	100-357	280	39-386	276	292-497	354	79-708	499	505-720	623	390-590	494.0	Quarry
		155	75-159	123	67-110	84	39-190	101	51-130	100.8	63-100	81.6	92-160	120	78-97	86.8	Fox Island-North
		75	95-130	110		(c)	39-145	93(d)	59-53	55	99-180	135	80-166	111	67-105	79.6	Giants Neck
					41-110	98	39-	(c)	53-117	66.4	80-151	113	69-145	101	46-114	88.0	White Point(e)
									125-859	356.4	275-519	405		(d)	69-335	247.4	Effluent
Mussels (ppm)	2-2	2	3-3	4	2-4	3	2.8-7	4	2.3-3.2	2.8	1.7-3.0	2.5	2.1-2.7	2.4	1.7-2.5	2.2	Fox Island-South
	2-3	2	2-3	2	2-3	2	1.9-3.5	3	2.1-3.2	2.6	1.8-2.6	2.1	2.4-3.5	3.1	1.8-3.4	2.3	Fox Island-North
	2.3	2	2-3	2	2-2	2	2-3	2	2.1-3.1	2.6	1.8-2.4	2.2	1.9-2.8	2.3	1.9-2.5	2.1	Giants Neck
									1.9-2.4	2.6	1.8-2.4	2.2	2.1-2.9	2.4	2.0-2.5	2.2	Bay Point

(a) Ambient levels in oysters at start of year.
(b) Ambient level in oysters, new stock set out in May at White Point and Giants Neck, original new stock lost, vandalism.
(c) Tray missing by May.
(d) Tray missing in December.
(e) Ambient levels in oysters, new stock set in May at White Point and Giants Neck, original new stock lost, vandalism.
(f) Ambient levels in new oyster stock December 1979.

Table 3. Mean annual zinc concentrations in seawater and in oyster and mussel tissue collected from Long Island Sound waters near Millstone Point, Waterford, Connecticut, 1972-1979.

	1972		1973		1974		1975		1976		1977		1978		1979		Site
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
	5-22	11	2-11	7	5-15	9	1.9-15	9	4-20	10.3	1.3-8.4	3.8	2.4-16.5	7.4	[illegible].6-4.0	3.0	Quarry
Seawater	7-20	12	4-73	19	4-8	6	2.3-24	11	3.5-39	15.7	1.9-11.0	5.7	2.7-11.8	6.5	2.2-4.4	3.2	Twotree
Soluble	9-133	37	4-8	6	6-13	7	4.0-26	12	6-26	12.2	3.5-6.9	5.2	2.2-15.4	9.4	1.7-7.6	3.6	Intake
(ppb)	5-24	15	6-14	10	5-11	8	6-28	12	2.9-35	14.0	<1.0-10.0	4.8	2.1-29.0	12.7	1.4-4.9	2.6	Giants Neck
	<1-3	2	1-4	2	<1-7	4	<0.5-4	2	<0.5-5.3	2.7	1.5-4.5	2.4	0.7-1.5	1.1	0.8-4.4	2.0	Quarry
Seawater	<1-3	2	<1-5	3	<1-3	1	<0.5-6.4	3	<0.5-4.3	2.0	1.1-5.2	2.9	0.9-1.5	1.2	<0.5-5.2	[illegible].2	Twotree
Insoluble	<1-9	3	2.4	3	<1-4	2	<0.5-18	6	<0.5-2.7	1.5	0.8-4.7	2.4	<0.5-1.7	1.4	<0.5-6.3	2.8	Intake
(ppb)	<1-47	17	2-9	3	2-5	3	<0.5-5.9	2	<0.5-22	5.8	1.3-24.0	6.3	0.7-5.3	3.9	1.2-5.5	2.4	Giants Neck
					1770 (a)		1010(a)		940(a)	1040(b)	1370(a)	1720(e)	1473(a)		1130(a)	[illegible](g)	
Oysters	1595-1870	1732	1430-2150	1770	1645-2440	1893	1010-3160	2732	1160-2030	1618	960-287[illegible]	2109	2230-3610	2854	1730-3690	2668	Quarry
(trayheld)		2440	890-2283	1631	1080-2050	1293	1010-2140	1744	940-1960	1348	1030-1730	1300	1160-2190	1723	1220-1740	1410	Fox Island-North
(ppm)		1240	1090-1650	1323		(c)	1010-2250	1530(d)	1040-1430	1235	852-2330	1604	1050-2040	1540	1030-1360	1204	Giants Neck
					1130-1770	1300	1010-	(c)	1030-1560	1020	962-1740	1310	1300-2510	1680	980-1410	1244	White Point
									1370-2200	1866	1440-1868	1682		(f)	860-2320	1604	Effluent
	30-79	50	29-72	51	20-68	43	48-197	94	27-47	37	27-157	58.6	30-48	39.5	18-65	43.0	Fox Island-South
Mussels	27-48	38	22-45	32	18-50	36	34-170	75	24-39	33.20	24-86	39.4	22-49	38.8	16-58	34.6	Fox Island-North
(ppm)	26-36	31	28-65	41	21-47	36	41-169	82	24-43	34.2	22-100	40.0	21-30	23.8	27-56	35.8	Giants Neck
									25-45	35.2	15-60	36.0	23-46	32.8	29-67	40.2	Bay Point

(a) Ambient level in oysters at start of the year.
(b) Ambient level in oysters, new stock set out in May at White Point and Giants Neck, original new stock lost, vandalism.
(c) Tray missing by May.
(d) Tray missing in December.
(e) Ambient level in new oyster stock at effluent in July.
(f) Sufficient data not available for calculations at this time.
(g) Ambient level in new oyster stock in December.

Table 4. Mean annual iron concentrations in seawater and in oyster and mussel tissue collected from Long Island Sound waters near Millstone Point, Waterford, Connecticut, 1972-1979.

	1972		1973		1974		1975		1976		1977		1978		1979		Site
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Seawater Soluble (ppb)	1-43	13	1-6	3	<1-7	3	<1-10.5	3.2	<0.5-2.4	1.6	<0.5-3.2	1.3	0.5-0.9	0.7	<0.5-2.0	<1.0	Quarry
	<1-61	17	<1-18	7	<1-5	2	<1-1.7	1.2	0.8-8.9	3.4	<0.5-1.1	0.8	0.5-1.7	0.9	<0.5-3.1	<1.0	Twotree
	2-19	7	1-13	4	<1-3	2	<1-1.6	1.3	<0.5-2.4	1.6	<0.5-1.7	1.2	0.5-3.7	1.4	<0.5-<1.0	<1.0	Intake
	2-43	13	2-10	5	<1-7	3	<1-1.6	1.1	0.8-3.5	1.8	<0.5-3.1	1.2	0.5-1.3	0.8	<0.5-<1.0	<1.0	Giants Neck
Seawater Insoluble (ppb)	11-227	88	33-720	204	43-196	116	15-101	56	49-195	132	55-400	151	71-133	99	92-130	104.0	Quarry
	11-347	128	67-[illegible]47	194	51-240	125	33-146	70	85-251	153	48-310	142	57-128	101	53-132	98.2	Twotree
	27-296	108	55-120	81	37-170	101	21-148	75	44-195	106	53-490	157	38-105	66	75-130	105.2	Intake
	83-6200	1350	216-533	352	67-193	141	19-88	60	61-300	143.2	43-3800	855	124-413	209	75-254	165.2	Giants Neck
Oysters (trayheld) (ppm)						23(a)		37(a)	31(a)	80(b)	33(a)	83(c)**	34(a)		35(a)	34(e)	
	53-58	56	43-112	81	23-170	88	37-178	121	27-243	134.8	39-423	167	134-395	252	63-370	147.4	Quarry
		45	37-62	48	23-60	39	37-86	62	31-90	65.2	42-129	65	36-71	49	35-80	55.2	Fox Island-North
		50	35-50	45		(c)	36-73	44(d)	80-103	91.5*	40-70	51	30-84	56	41-100	67.6	Giants Neck
		-			23-71	51	37-	(c)	42-73	44.2	27-134	71	34-49	43	29-57	45.0	White Point(b)
									73-175	119.4	99-214	155***		(d)	37-270	125.6	Effluent
Mussels (ppm)	64-90	77	44-190	104	54-188	94	84-302	152	102-198	125.4	84-127	110	69-140	97.3	60-96	70.2	Fox Island-South
	86-133	110	51-93	72	45-138	80	78-175	129	65-137	101	42-121	78	81-100	89.3	56-95	73.8	Fox Island-North
	54-125	90	54-104	70	71-158	110	66-126	95	108-151	135	57-137	86	59-100	74.0	55-114	86.0	Giants Neck
									72-112	86.2	54-122	81	49-140	92.5	61-106	73.2	Bay Point

(a) Ambient level in oysters at start of year.
(b) Ambient level in oysters, new stock set out at White Point and Giants Neck, original new stock lost, vandalism.
(c) Tray missing by May.
(d) Tray missing in December.
* Oysters missing from tray in February.
** New stock set out in September, concentration 83.0 ppm.
*** Oysters missing from tray in May.
(e) Ambient level in new oyster stock in December.

Table 5. Mean annual chromium concentrations in seawater and in oyster and mussel tissue collected from Long Island Sound waters near Millstone Point, Waterford, Connecticut, 1972-1979.

	1972		1973		1974		1975		1976		1977		1978		1979		Site
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Seawater Soluble (ppb)	<1-<1	<1	<1-<1	<1	<1-<1	<1	<0.5-<1	0.7	<1-2.4(a)	1.3	<0.5-<1	<1	<2-<2	<2	<0.5-<1.0	0.9	Quarry
	<1-<1	<1	<1-<1	<1	<1-<1	<1	<0.5-<1	0.7	<1.5(a)	1.8	<0.5-<1	<1	<2-<2	<2	<0.5-<1.0	0.9	Twotree
	<1-<1	<1	<1-<1	<1	<1-<1	<1	<0.5-<1	0.7	<1-<1	<1	<0.5-<1	<1	<2-<2	<2	<0.5-<1.0	0.9	Intake
	<1-<1	<1	<1-<1	<1	<1-<1	<1	<0.5-<1	0.7	<1-<1	<1	<0.5-<1	<1	<2-<2	<2	<0.5-<1.0	0.9	Giants Neck
Seawater Insoluble (ppb)	<1-<1	<1	<1-3	1	<1-2	1	<0.5-2	1	<1-<1	<1	<0.5-<1	<1	<2-<2	<2	<0.5-<1.0	0.7	Quarry
	<1-<1	<1	<1-4	1	<1-1	<1	<0.5-2.7	1	<1-<1	<1	<0.5-<1	<1	<2-<2	<2	<0.5-<1.0	0.7	Twotree
	<1-<1	<1	<1-3	1	<1-5	1	<0.5-2	1	<1-<1	<1	<0.5-<1	<1	<2-<2	<2	<0.5-<1.0	0.7	Intake
	<1-2	1	<1-7	2	<1-3	1	<0.5-2	1	<1-<1	<1	<0.5-10.0	<2	<2-<2	<2	<0.5-<1.0	0.7	Giants Neck
						1(b)		2(b)	1(b)	0.6(c)	0.4(a)	0.5(g)**	0.2(a)		0.4(b)	0.2(i)	
Oysters (trayheld) (ppm)	<1-<1	<1	<1-2	1	1-5	3	2-4	3	0.1-1.1	0.7	<0.2-0.7	0.6	<2-<2	<2	0.3-1.9	1.1	Quarry
	<1		<1-2	1	1-5	3	1-4	2	<1-0.8	0.6	0.1-0.6	0.3	<2-<2	<2	0.2-<1.0	0.7	Fox Island-North
	<1		<1-1	<1	1?	(d)	1-4	2(e)	0.4-0.6	0.5*	<0.2-0.6	0.3	<2-<2	<2	0.2-<1.0	0.7	Giants Neck
					1-4	3(f)	2	(c)	0.2-0.6	0.4	0.1-2.4	0.8	<2-<2	<2	0.2-<1.0	0.7	White Point
									<1-1	0.8	0.2-0.8	0.6***		(h)	0.4-1.4	0.8	Effluent
	<1-1	<1	<1-5	2	1-14	7	<3-30	13	<1-1.2	1.0	0.5-1.1	0.8	0.9-<2	<2	0.5-1.1	0.8	Fox Island-South
	<1-1	<1	<1-2	1	1-8	4	3-10	6	<1-0.9	0.8	0.2-0.9	0.6	0.6-<2	<2	0.4-1.0	0.8	Fox Island-North
	<1-1	<1	<1-2	1	2-8	4	3-10	6	<1-1.6	1.2	0.4-1.1	0.7	0.5-<2	<2	0.6-1.4	1.0	Giants Neck
					9		2-4	3									White Point
									<1-1.5	1.2	0.4-0.9	0.8	0.8-<2	<2	0.6-1.1	0.9	Bay Point

(a) February sample contaminated in transit to the laboratory.
(b) Ambient level in oysters at start of year.
(c) Ambient levels in oysters, new stock set out in May at White Point and Giants Neck, original new stock lost, vandalism.
(d) Tray missing in May.
(e) Tray missing in December.
(f) No February sample - oysters missing.
* Oysters missing from tray in February.
** New stock set out in September, concentration 0.5 ppm.
*** Effluent oysters missing in May
(g) Ambient levels in new oyster stock in July.
(h) Sufficient data not available for calculations at this time.
(i) Ambient levels in new oyster stock in December.

Table 6. Mean annual lead concentrations in seawater collected from Long Island Sound waters near Millstone Point, Waterford, Connecticut, 1972-1979.

	1972		1973		1974		1975		1976		1977		1978		1979		
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Seawater Soluble (ppb)	2-4	3	<1-5	2	<1-4	2	1-1	1	<1-14(b)	3.6	<0.5-<1	0.7	<0.5-1.5	1.1	<0.5-1.1	0.9	Quarry
	2-32	10	<1-4	2	<1-3	2	1-1	1	<1-13(b)	3.4	<0.5-1.9	<1	<0.5-2.0	1.2	0.6-1.5	1.0	Twotree
	3-30	9	<1-7	4	<1-2	1	1-2	1	<1-1.3	1	<0.5-3.6	1.6	<0.5-8.0	3.0	<1.0-2.7	1.3	Intake
	<1-7	3	<1-3	1	<1-5	2	1-3	1	<1-1	1	<0.5-2.4	1.0	<0.5-1.2	0.8	<0.5-1.2	0.9	Giants Neck
Seawater Insoluble (ppb)	<1-<1	<1	<1-14	4	<1-<2	<1	1-1	1	<1-12	2.5	<0.5-3.0	1.2	<0.5-11	3.3	<0.5-2.1	1.0	Quarry
	<1-2	<1.2	<1-2	<1.4	<1-<2	<1.4	1-1	1	<1-21	5	<0.5-4.0	1.3	<0.5-<1	0.6	<0.5-<1.0	0.8	Twotree
	<1-<1	<1	<1-1	<1	<1-<2	<1.4	1-1	1	<1-6.7	2.1	<0.5-3.3	1.2	<0.1-<1	0.7	<0.5-<1.0	0.8	Intake
	<1-13	3	<1-3	2	<1-3	<1.4	1-6	2	<1-8.3	2.5	<0.5-1.0	0.8	0.5-6.7	2.6	<0.5-1.6	1.1	Giants Neck

(a) December data available for calculations.
(b) February sample may have been contaminated in transit to the laboratory.

Copper

Concentrations of soluble copper in 1979 ranged between 2.4 ppb at the Quarry and 0.9 ppb at the Twotree and Intake sites. Differences between the months sampled were usually small with the monthly means ranging between 1.2 ppb in July and 1.6 ppb in September.

Annual soluble copper concentrations in seawater declined steadily since 1972. The constant trend towards lower values is undoubtedly the result of constantly improved methodology to reduce contamination in every stage of the sampling, storage, processing and analytical processes. The highest annual mean during the eight years of study was 23.0 ppb at Twotree Channel in 1972 while the lowest, 1.1 ppb, occurred at Twotree Channel in 1979. At the effluent station values were generally higher in 1978 and 1979. Because of the variability associated with these measurements, it has not been possible to discern any consistent relationship in the long-term ranking of sites.

Insoluble copper concentrations in seawater were also highest in 1972. Insoluble copper has fluctuated from year to year with no one site consistently higher than the others. During July 1979, insoluble copper was found at levels about 2.2 ppb above other months for all sites. A low for all sites of $<$ 0.4 ppb was recorded in December.

Annual copper concentrations in oysters during 1979 showed a general decrease for the first time since 1976. Consistent with previous years, the annual means for oysters in the Quarry (494ppm) and at the Effluent

(247ppm) were higher than all other sites. During 1979 annual mean concentrations at Fox Island, Giants Neck and White Point were very consistent ranging between 79.6 ppm (Giants Neck) and 88.0 ppm (White Point).

Copper concentrations in mussel tissue continued at comparatively low levels in 1979. Annual means from 1972 through 1975 were within a range of two to four ppm and have not risen past 3.1 ppm since 1976.

Zinc

Annual concentrations of soluble zinc in seawater fluctuated between sites and years. Concentrations during 1979 were the lowest recorded during eight years of study, ranging between 3.6 ppb at the Intake and 2.6 ppb at Giants Neck. The largest monthly mean, 3.8 ppb, occurred in December, and the lowest mean, 2.4 ppb, in September. The December Intake concentration, 7.6 ppb, was the largest recorded during 1979.

Insoluble zinc concentration in seawater during 1979 were consistent with other years except 1978 when values were only slightly l[illegible]. No obvious trends have been established. Highest values at all stations during 1979 were found in July, with the maximum of 6.3 ppb at the Intake. Concentrations ranged to a low of 0.5 ppb at both the Intake and Twotree sites in May.

Annual mean zinc levels in oysters during 1979 were highest at the Quarry and Effluent sites with values of 2668 ppm and 1604 ppm respectively. The elevation of zinc in quarry oysters is a trend observed as early as 1973. Concentrations were highest at the Quarry in July with a value of 3690 ppm and lowest at Effluent in May at 860 ppm. There appears to be a seasonal relationship showing a progressive uptake of zinc after the spawning period and as water temperatures increase.

Zinc concentrations in mussels have remained relatively constant for all years except 1975. When compared to previous years, the 1979 values show little increase or decrease. Fox Island-South had the highest mean value of 43.0 ppm during 1979. Elevated levels have been observed at Fox Island-South since 1972 and may be related to the proximity of the station to the effluent. Zinc concentrations in mussels during 1979 were highest in December at Bay Point (67 ppm) and lowest in February at Fox Island-North (16 ppm).

Iron

Soluble iron concentrations in seawater were highest in 1972. The peak value of 61.0 ppb was found at Twotree Channel. Since 1972, iron concentrations have generally declined and for 1979, were among the lowest observed, ranging between 3.1 ppb and $<$0.5 ppb. Seasonally, concentrations were generally higher in July when the monthly mean was 118 ppb.

Insoluble iron concentrations were highest in both 1972 and 1977, when values ranged upward of 6200 ppb and 3800 ppb respectively. Among the stations, Giants Neck has had consistently higher insoluble iron levels except in 1975. In 1979, the annual mean at Giants Neck (1652 ppb) continued to be higher than other stations although the value represented a five fold reduction compared to 1977. Seasonal low concentrations occurred in May, but levels continued to be varied among the other months.

Compared to previous years, mean concentrations of iron in oyster tissue remained essentially the same in 1979. Oysters collected from the Quarry and Effluent sites continued at higher concentrations with values of 147.4 ppm and 125.6 ppm respectively. Seasonal values ranged from a high of 370.0 ppm in July at the Quarry to 29.0 ppm in February at White Point.

No trends have been observed in the iron concentrations in mussel tissue. The highest mean recorded was at Fox Island-South in 1975 (152 ppm) and the lowest at Fox Island-South in 1979 (70.2 ppm).

Chromium

Soluble chromium concentrations in seawater have fluctuated little since 1972 and were uniform from site to site. Throughout the study, concentrations have never risen above 2.0 ppb and in 1979 the values remained less than 1.0 ppb. Chromium concentrations have not changed appreciably in oysters or in mussels.

Lead

The highest annual values for soluble lead in seawater were recorded at Twotree (10.0 ppb) and the Intake (9.0 ppb) in 1972. Since then, no means have exceeded 4.0 ppb. In 1979, the Intake had the largest mean of 1.3 ppb and also had the single highest value for 1979 of 2.7 ppb in July.

Insoluble lead concentrations in 1979 showed no distinguishing trends and the values remained essentially the same as in previous years. September had the highest concentrations at Giants Neck (1.6 ppb) with the lowest levels in May at all sites ($<$0.5 ppb).

DISCUSSION

Of the five metals studied, copper, zinc and iron were found in the largest concentrations in seawater with chromium and lead in very small amounts. The values for soluble and insoluble trace metals in 1979 showed a general decline over previous years, however, it is probable that the long term fluctuations in the data reflect more an analytical improvement than actual decreases in concentrations.

The values of heavy metals in oysters in 1979 showed the same pattern as previous years, with only slight decreases at some sites. The oysters collected at the Millstone Power Station effluent (tray-held) and the naturally occurring oysters in the Quarry continued to have the highest levels of heavy metals. It has been shown that the rate of uptake of heavy metals by a marine organism is dependent upon the rate of respiration (Galtsoff 1928, Feng 1965). The maximum pumping rate for C. virginica was reported to occur at 25°C. Below this temperature, pumping rates decrease until a temperature of 7.6°C was reached at which time pumping ceased (Galtsoff 1928). This being the case, the Quarry and Effluent oysters would tend to concentrate heavy metals faster.

There also appears to be a seasonal trend in the concentrations of heavy metals in oysters. Since the ripe oyster gonad may comprise 31-41% of total body weight (Galtsoff 1964), the Quarry sample collected in May would reflect high body weight and lower concentrations of heavy metals. After the weight loss due to spawning, concentrations of heavy metals would appear to double. This trend was apparent at almost all sites for all metals in 1979 although the timing was different for control stations.

Concentrations of heavy metals in mussels showed no significant increase or decrease for values reported in 1979 compared to previous years. The fluctuations between sampling periods and sites obscured any trends.

In summary, continuing heavy metal analysis at Millstone have shown a decline in seawater concentrations over the entire study period. This decline is thought to reflect improvements in analytical techniques rather than actual decreases in concentrations.

Higher concentrations of heavy metals, particularly copper and zinc were found in oyster and mussel tissue at Millstone Quarry. However, there has been no noticeable long term increase in heavy metals in seawater or indicator molluscs in the surrounding waters.

LITERATURE CITED

Battelle. 1978. A monitoring program of the ecology of the marine environment of Millstone Point, Connecticut area. Annual Report for 1977 to Northeast Utilities Service Company. Report No. 14820. Battelle Columbus Laboratories, William F. Clapp Laboratories, Inc., Duxbury, MA.

Brooks, R. R., B. J. Presley and I. R. Kaplan. A.P.D.C.-MTBK Extraction System for the determination of Trace Elements in saline waters by Atomic absorptions spectrophotometry. 14, pp. 809-816 (1967).

Feng, S. Y. and G. M. Ruddy. 1974. Zinc, copper, cadmium, maganese and mercury in oysters along the Connecticut coast. In investigations on Concentrations, Distributions and Fates of Heavy Metal Waste in Parts of Long Island Sound. pp. 132-158. University of Connecticut, Groton, Connecticut.

Galtsoff, P. S. 1928. The effects of temperature on the mechanical activity of the gills of the oyster. J. Gen. Physiol., 11: 415-431.

Galtsoff, P. S. 1964. The American Oyster Crassostrea virginica Gmelin Fishery Bull. U.S. Fish Wildl. Serv., 64: 1-480.

Mansell, R. E. and H. W. Emmel. Trace metal extractions from brine with APDC and Oxine. Atomic Absorption Newsletter, 4, pp. 365-366 (1969).

Mulford, C. E. Solvent extraction techniques for atomic absorption spectroscopy. Atomic Absorption Newsletter, 5, pp. 88-90 (1966).

OSPREY

The osprey, Pandion haliaetus carolenensis, or fish hawk, is a fish eating migratory bird of prey that has been victimized by pollution. Due to PCB's, dieldrin and especially DDT contamination of our coastal waters, ospreys have suffered a severe decrease in productivity, resulting in its classification as an endangered species in Connecticut (Wiemeyer 1975). Once numerous along the Connecticut coast with nests numbering over a thousand, the osprey population dwindled to a nadir of nine active nests in 1974 (Spitzer 1979a). DDT use was limited by law in 1965 and the osprey is beginning to repopulate the Connecticut shoreline.

Millstone Point, historically, has been an osprey nesting site. In 1967, an artificial nesting platform was provided for the birds by Northeast Utilities to substitute for an unused derrick dismantled during the construction of Millstone 1. Another site was erected in 1974 in the wildlife preserve area of the Millstone site. These nests have been very successful, fledging a total of 23 ospreys since 1969. In 1979 another nesting site was erected on Fox Island, adjacent to the NUSCO Millstone Environmental Lab. It is hoped that this site will also attract active, reproductively mature birds in the near future.

The history of the Millstone area nests is presented in Table 1. From 1971 through 1975, from 30 to 50% of the fledglings born in Connecticut originated from this site. Since 1969, 18% of Connecticut osprey fledglings have come from Millstone Point.

During the 1979 breeding season visual observations of the osprey nests were made. Following are the reports from these surveys:

March 27

The first sighting of ospreys in area was on this date. Two adults were seen in the wildlife preservation area near Jordan Cove. Nest rebuilding commenced within a few days.

April 25

Another osprey pair were observed at the nest behind the Millstone Environmental lab. This nest was not successful and was subsequently abandoned in mid-May. Spitzer (1979b) notes that young ospreys often engage in housekeeping activities a year prior to actual breeding.

June 14

First observation of nestlings. Two juvenile ospreys were seen in the nest being fed.

July 16

Nestlings fledged by this date. Osprey were noted either feeding in the nest or perched in the vicinity of the nesting site after fledging.

August 30

Nest was abandoned.

October 5

Last day ospreys seen in the Millstone area for the year.

It is anticipated that the young housekeeping osprey pair will return next year along with the original pair, thus doubling Millstone's osprey productivity and further enhancing the limited but resurgent osprey population.

Table 1. Number of Active Nests and Number of Fledglings Produced in Connecticut and Millstone Point

Year		Millstone Point		Connecticut	
		Active Nests	Fledglings	Active Nests	Fledglings
1969		1	0	16	10
1970		1	0	13	8
1971		1	3	12	8
1972		1	3	10	9
1973		1	2	10	4
1974		1	2	9	7
1975		1	2	9	10
1976		1	3	10	14
1977		1	3	14	20
1978		1	3	15	15
1979		1	2	15	25
	Totals		23		130

LITERATURE CITED

Wiemeyer, Stanley, N. 1975. Effects of environmental pollutants on Connecticut and Maryland Ospreys. J. Wildl. MANAGE. 39 (1): 124139.

Spitzer, Paul R., 1979a. Dynamics of a discrete coastal breeding population of ospreys (Pandion haliaetus) in the northeastern United States during a period of decline and recovery, 1969-1978. Ph.D. Thesis, Cornell University.

Spitzer, Paul R., 1979b. Personal communication to Gary Doughty, Manager, Systems Nuclear Information, NUSCO Langmuir Laboratory, Cornell University.

ETS REQUIREMENTS

SECTION 12

POWER PLANT OPERATIONAL MONITORING REQUIREMENTS

SECTION 12

POWER PLANT OPERATIONAL MONITORING REQUIREMENTS

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ETS SECTION 1

INTRODUCTION

1.1 Background

The Environmental Technical Specifications (ETS) for Millstone Nuclear Power Station Units 1 and 2 require annual operating reports on environmental surveillance. This report covers those nonradiological surveillance activities, as specified in Section 5.6.1.a, which were conducted in 1979. Included are results of activities related to Limiting Conditions for Operation (Section 2), Environmental Surveillance (Section 3) and Special Surveillance, Research or Study activities (Section 4).

The ETS was issued on December 19, 1975 for Millstone Unit 1 and on August 1, 1975 for Millstone Unit 2. Nineteen hundred and seventy-nine (1979) therefore, was the fourth full year during which both units operated under ETS requirements.

ETS SECTION 2

LIMITING CONDITIONS FOR OPERATION

2.1 Thermal

2.1.1 Maximum ΔT Across the Condenser and Maximum Discharge Temperature

Monitoring

Water temperature is continuously monitored by sensing units located in front of the intake structure and at the quarry cut. The continuous output of the sensors is reduced to digital form using a Data General Model 1220 Nova minicomputer and recorded every 15 minutes. At the end of each hour, a host computer system at Northeast Utilities Service Company telephones the field computer and logs the data on disc storage. The data is examined twice daily, edited as necessary on a monthly basis, and transferred to magnetic tape for permanent storage. If the field computer is not called for a period of two hours, it automatically prints out the data on its teletype and punches a paper tape for later incorporation into the data record.

The output of the above sensors is also recorded in the control rooms at the plant. The ΔT is determined by continuously differentiating the intake and quarry cut temperatures and is also recorded, as is the change in discharge temperature from the previous hour. Alarms are provided when discharge temperature, ΔT, or rate of change of discharge temperature exceed the limits of Environmental Technical Specifications, Section 2.1. This analog record is used to fill in data gaps caused by digital system failure.

Data Summary

Table 2.1 summarizes condenser cooling water intake and discharge temperatures, their differences, and the maximum hourly rate of change during each day of 1979. Intake temperature ranged between 30.6°F on February 17 and 75.0°F in August. Discharge temperatures ranged between ambient at periods of shutdown and a maximum of 97.3°F on September 1. The specified maximum discharge temperature of 105°F was not exceeded at any time.

The specified maximum temperature increase (ΔT) of 28°F was not exceeded during routine operation. An apparent increase of up to 30.4°F on October 8 was caused by a drop in indicated intake temperature at low tide on the sensor for Unit 1. No appreciable drop was registered by the Unit 2 sensor or by either discharge temperature.

During nonroutine operation, when only three of the four condenser cooling water pumps were operating at one of the units, the ΔT exceeded 28°F only three times and did not exceed the specified maximum of 32°F at any time.

2.1.2 Rate of Change of Discharge Temperature

Monitoring

The rate of change of discharge temperature is determined from those temperature sensors at the quarry cut required by ETS Section 2.1.1.6. Sensor outputs are differentiated and recorded.

Data Summary

Maximum rates of change in discharge temperature (MRC) are recorded in

Table 2.1 for each day. The specified MRC of $6^{o}F/hr$ was not exceeded in 1979.

2.1.3 Heat Treatment of Circulating Water System

Monitoring

The influence of heat treatment on discharge water temperature is determined from water temperature measurements at the quarry cut as specified in ETS Section 2.1.1.6.

Data Summary

Heat treatments for mussel control in 1979 are summarized in Table 2.2 The maximum condenser water box temperature attained was $123^{o}F$ on September 22. Increased water box temperature and reduced coolant flow were offset, at least in part, by reduced power. The overall effect on quarry discharge temperature ranged from 0.9 to $4.6^{o}F$. Power reduction ranged from 2% to 33%.

The time required varied from 2.25 hours on July 14 to over eleven hours on September 22.

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 JAN 79/0015 - 31 JAN 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	7.9- 7.9	45.1	42.8	43.8	68.7	65.3	67.4	-1.4	25.2	20.5	23.6
2	8.0- 7.9	46.4	43.9	44.8	66.7	65.1	65.6	0.7	21.6	19.6	21.1
3	8.0- 7.9	45.7	42.6	43.7	66.7	64.4	65.3	-0.5	22.1	20.9	21.6
4	8.0- 7.9	42.4	40.8	41.5	64.2	62.8	63.5	-0.4	23.0	21.6	22.0
5	8.0- 7.9	41.5	40.6	40.9	63.3	62.6	63.0	0.4	22.3	21.6	22.0
6	8.0- 8.0	42.1	40.3	41.3	58.8	54.1	56.7	1.6	18.5	13.6	15.4
7	8.0- 7.9	42.4	40.8	41.6	61.7	59.0	60.5	0.5	19.8	17.5	18.9
8	8.0- 7.9	43.5	41.7	42.6	62.8	61.5	62.4	0.7	20.5	19.1	19.6
9	8.0- 7.9	41.5	40.1	41.1	61.9	61.3	61.5	-0.2	21.2	20.0	20.5
10	8.0- 8.0	41.0	39.4	40.3	61.3	60.8	61.0	-0.4	21.6	20.0	20.6
11	8.0- 8.6	41.2	40.3	40.7	61.0	60.6	60.8	-0.2	20.5	19.8	20.1
12	8.0- 8.0	41.5	39.7	40.4	60.6	59.7	60.2	0.4	20.3	16.9	19.8
13	8.0- 7.9	41.5	39.7	40.5	60.4	59.7	60.0	0.5	20.2	18.5	19.6
14	8.1- 8.0	41.0	40.3	40.7	59.7	41.0	46.8	-2.5	18.7	0.4	6.1
15	8.1- 8.1	40.6	38.8	39.7	41.0	38.8	39.7	-0.4	0.5	0.0	0.1
16	8.1- 8.1	39.4	38.1	39.1	39.0	38.3	38.6	-0.4	0.4	0.0	0.0
17	8.1- 8.6	39.4	38.5	39.0	50.2	38.5	43.0	2.0	11.7	0.0	4.0
18	8.0- 7.9	39.9	37.9	38.7	56.8	50.7	54.6	1.3	18.5	11.9	15.9
19	8.0- 7.9	42.1	37.2	38.0	57.7	52.7	56.2	1.4	19.8	12.1	18.2
20	8.0- 7.9	40.6	37.9	38.7	59.2	52.9	56.0	-1.8	20.2	14.2	17.3
21	8.0- 7.9	41.9	38.3	40.0	60.8	56.3	58.9	0.9	21.2	16.2	18.9
22	7.9- 7.9	40.6	38.1	39.4	61.3	59.2	60.6	-0.9	22.3	20.7	21.2
23	7.9- 7.9	40.8	37.9	39.1	61.0	56.1	56.7	1.3	21.2	17.1	19.6
24	7.9- 7.9	42.1	39.2	39.8	61.5	60.1	60.6	0.9	21.2	18.9	20.7
25	7.9- 7.8	41.0	39.7	40.1	63.7	60.1	61.9	-1.3	23.6	20.2	21.8
26	7.9- 7.6	41.5	39.7	40.2	61.3	58.8	60.0	-0.7	21.2	17.5	19.7
27	7.9- 7.9	41.0	39.9	40.3	61.5	58.6	60.4	0.4	21.2	18.7	20.1
28	7.9- 7.9	42.1	40.1	40.5	61.9	61.0	61.4	0.5	21.4	19.5	21.0
29	8.0- 7.9	41.9	39.9	40.2	61.7	61.6	61.3	0.4	21.4	19.4	21.1
30	8.0- 7.9	40.1	39.4	39.7	61.0	60.8	60.9	0.2	21.6	20.7	21.2
31	8.0- 7.9	40.6	39.2	39.8	61.0	60.6	60.8	0.2	21.4	20.3	21.1
MONTH	8.1- 7.6	46.4	37.2	40.5	68.7	38.3	58.3	-2.5	25.2	0.0	17.8

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 FEB 79/0015 - 28 FEB 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	8.0- 7.9	39.9	38.1	39.0	61.0	59.5	60.3	-0.5	22.0	20.7	21.3
2	8.0- 7.9	38.5	35.6	37.	59.5	57.7	58.7	0.7	22.5	20.0	21.4
3	8.0- 7.9	41.2	36.3	37.6	61.7	[illegible]	59.3	1.8	23.8	17.8	21.7
4	8.0- 8.0	39.4	36.7	37.8	59.5	[illegible]	59.6	0.5	22.5	19.6	21.2
5	8.0- 7.9	40.3	34.3	36.4	59.0	56.3	57.9	-0.5	22.5	20.3	21.5
6	8.0- 8.0	36.3	33.1	34.5	57.4	55.0	55.6	0.7	23.0	20.2	21.3
7	8.0- 8.0	38.3	35.4	36.6	58.6	57.2	57.9	0.5	22.1	19.0	21.3
8	8.0- 8.0	37.2	35.6	36.6	58.3	57.7	58.0	0.2	22.0	20.7	21.3
9	8.0- 8.0	37.2	35.4	36.3	58.1	57.2	57.7	0.5	22.3	20.2	21.4
10	8.1- 8.0	36.3	33.4	34.7	59.5	55.0	57.0	-1.6	25.0	20.5	22.3
11	8.0- 8.0	35.4	32.0	33.4	55.9	54.1	55.0	0.5	22.5	20.0	21.5
12	8.0- 8.0	35.8	33.4	34.5	56.5	55.0	55.8	0.4	22.0	20.5	21.3
13	8.0- 8.0	35.4	33.6	34.4	56.3	55.0	55.7	-0.5	21.8	20.5	21.3
14	8.1- 8.0	34.5	31.5	32.6	55.0	53.6	54.1	-0.5	22.7	20.0	21.5
15	8.0- 8.0	34.5	32.2	33.4	55.4	54.3	54.8	0.4	22.3	20.2	21.4
16	8.1- 8.0	34.9	33.1	33.8	55.4	50.9	54.5	-1.8	21.6	16.6	20.7
17	8.1- 8.0	34.3	30.6	32.1	52.5	50.5	51.4	0.5	20.3	17.3	19.3
18	8.1- 8.0	33.2	31.1	31.9	52.5	50.7	51.5	0.5	20.2	18.5	19.6
19	8.0- 8.0	33.4	32.0	32.7	53.6	52.7	53.2	0.4	23.9	20.0	20.4
20	8.0- 8.0	34.5	31.5	33.0	55.2	53.6	54.4	0.5	22.1	20.0	21.4
21	8.0- 8.0	35.2	32.9	33.8	55.4	54.3	55.0	-0.7	21.8	20.2	21.2
22	8.1- 8.0	35.6	33.8	34.5	54.1	46.2	50.0	1.6	19.4	12.2	15.4
23	8.0- 8.0	35.8	34.5	35.0	54.7	54.1	54.4	0.2	19.6	18.5	19.5
24	8.1- 8.0	36.3	34.5	35.1	54.5	49.8	52.2	-1.3	19.8	14.4	17.1
25	8.0- 8.0	36.3	34.3	34.9	55.6	53.4	54.3	0.9	20.7	17.8	19.3
26	8.1- 8.0	35.8	34.5	35.0	55.4	49.3	52.5	-2.9	20.5	14.0	17.5
27	8.1- 8.0	36.3	34.5	35.2	54.5	50.6	52.6	-1.4	19.8	14.8	17.4
28	8.0- 7.9	37.0	34.0	35.3	57.4	54.7	56.2	0.5	22.1	19.4	20.9
MONTH	8.1- 7.9	41.2	30.6	34.9	61.7	46.2	55.3	-2.9	25.0	12.2	20.4

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD - 1 MAR 79/0015 - 31 MAR 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	8.0- 8.0	37.6	34.9	36.0	57.4	56.5	57.0	0.7	21.6	19.3	21.0
2	8.0- 8.0	37.0	34.9	36.0	57.2	56.3	56.8	0.7	21.6	19.3	20.8
3	8.6- 8.6	37.4	35.4	36.3	59.0	56.1	57.3	0.9	22.0	20.0	21.0
4	8.0- 8.0	37.6	35.4	36.7	57.2	55.7	56.7	-0.7	21.4	16.4	19.5
5	8.0- 8.0	39.4	35.8	37.2	57.9	56.3	57.2	1.3	21.1	18.4	20.0
6	8.0- 8.0	39.7	36.1	38.1	59.5	56.6	58.4	1.6	21.6	16.2	20.3
7	8.0- 8.0	40.1	36.5	37.9	59.5	57.2	58.1	0.9	22.1	17.8	20.2
8	8.0- 8.0	39.7	36.5	38.4	59.0	57.2	58.3	0.7	20.9	18.5	19.9
9	8.6- 8.6	40.1	36.7	38.1	58.8	57.4	58.2	0.9	21.2	17.8	20.1
10	8.1- 8.0	39.9	37.2	38.1	58.3	46.4	51.6	-2.5	20.7	8.8	12.9
11	8.1- 8.0	44.6	36.3	38.1	53.2	44.6	48.5	2.3	13.	6.5	10.3
12	8.1- 8.1	37.0	35.4	36.2	49.6	47.8	48.5	-1.3	13.1	11.3	12.3
13	8.1- 8.1	38.3	35.6	36.8	50.0	47.8	49.1	-1.3	14.0	11.2	12.3
14	8.1- 8.0	38.3	36.7	37.7	50.9	48.9	50.0	-0.9	13.0	11.7	12.3
15	8.1- 8.6	37.9	36.3	36.9	51.4	48.4	49.6	-1.8	14.2	10.8	12.7
16	8.1- 8.1	36.7	35.6	36.2	49.8	47.3	48.0	-1.3	13.5	11.2	12.4
17	8.1- 8.1	37.9	36.3	37.1	50.9	46.2	49.3	-1.8	13.7	8.8	12.7
18	8.3- 8.1	39.4	36.5	37.2	47.1	37.6	41.6	1.6	9.7	0.4	4.4
19	8.1- 8.1	38.8	37.0	37.8	53.4	47.3	50.2	1.8	14.8	9.5	12.4
20	8.1- 8.1	39.7	37.9	38.4	53.6	51.6	52.6	0.9	15.3	13.1	14.2
21	8.1- 8.6	39.9	37.9	38.8	53.4	51.6	52.6	1.1	14.9	13.1	13.8
22	8.1- 8.1	41.5	38.8	40.6	55.9	52.3	54.1	1.8	15.1	12.6	14.6
23	8.1- 8.0	42.8	39.4	40.4	56.1	53.2	54.4	-1.1	14.9	11.9	14.0
24	8.3- 8.1	44.2	39.0	40.5	54.7	46.9	51.7	2.7	15.3	4.0	11.2
25	8.1- 8.0	41.7	39.4	40.7	56.3	54.1	55.2	1.1	16.0	13.5	14.6
26	8.1- 8.0	42.4	39.7	41.1	57.9	53.8	55.3	1.3	16.7	12.8	14.3
27	8.1- 8.6	41.6	39.7	40.4	57.9	53.2	55.1	2.5	17.8	12.4	14.7
28	8.1- 8.0	41.0	39.7	40.3	57.2	53.2	55.0	2.9	17.3	12.6	14.7
29	8.1- 8.0	41.7	39.2	40.2	56.8	52.0	53.5	-3.2	17.1	10.6	13.3
30	8.1- 8.6	48.9	39.7	40.7	53.4	47.8	51.8	-2.3	13.7	3.6	11.1
31	8.0- 8.0	42.8	40.1	41.1	55.0	52.7	53.9	0.7	13.7	11.5	12.8
MONTH	8.3- 8.0	48.9	34.9	38.4	59.5	37.6	53.2	-3.2	22.1	0.4	14.6

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 APR 79/0015 - 30 APR 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	8.1- 8.6	41.9	40.6	41.0	54.5	52.7	53.8	0.9	13.3	11.2	12.7
2	8.0- 8.0	41.5	40.8	41.2	54.1	53.4	53.7	-0.5	12.8	12.1	12.4
3	8.0- 8.0	42.8	40.3	41.3	54.5	52.9	53.7	0.7	13.3	11.0	12.4
4	8.0- 7.9	42.4	40.3	41.1	54.5	52.7	53.6	0.5	13.3	11.2	12.4
5	8.0- 7.9	42.8	41.0	41.7	55.6	53.4	54.2	0.7	13.6	11.5	12.5
6	8.0- 7.9	45.3	41.0	41.6	56.5	52.7	54.4	-1.6	14.5	10.1	12.8
7	8.0- 7.9	42.1	40.6	41.3	56.3	54.1	55.2	-0.9	14.8	12.1	13.9
8	8.0- 7.9	41.7	39.9	40.7	55.5	54.3	54.8	-0.5	15.1	13.3	14.1
9	8.0- 7.9	42.1	40.6	41.1	56.1	54.5	55.1	-0.7	15.1	12.8	13.9
10	8.1- 8.0	41.5	40.3	41.0	55.9	54.3	54.9	0.7	14.8	13.3	13.9
11	8.1- 8.0	42.8	40.6	41.7	56.8	54.3	55.5	0.7	14.4	13.0	13.9
12	8.1- 7.9	43.3	41.7	42.3	57.2	55.4	56.4	-0.9	15.1	13.0	14.2
13	8.0- 7.9	43.0	41.5	42.3	58.3	54.7	56.2	-3.1	16.4	12.4	13.9
14	8.1- 7.9	43.0	41.5	42.3	57.7	49.3	54.4	-2.5	15.1	7.2	12.2
15	8.0- 8.0	42.6	41.5	41.9	56.1	54.7	55.4	0.7	14.0	12.6	13.5
16	8.0- 8.0	42.8	41.7	42.1	56.1	54.5	55.4	-0.9	14.2	12.6	13.3
17	8.0- 8.0	43.5	41.7	42.5	56.3	55.2	55.7	0.4	14.0	12.1	13.2
18	8.0- 8.0	43.0	42.1	42.5	56.1	54.7	55.4	-0.5	13.5	12.4	12.9
19	8.0- 8.0	43.7	42.4	42.8	56.1	54.7	55.4	0.5	13.5	12.1	12.6
20	8.0- 8.0	44.8	42.6	43.4	56.8	55.0	55.9	0.7	13.5	11.5	12.5
21	8.1- 8.0	45.3	42.8	44.1	57.7	55.6	56.4	0.9	13.3	11.2	12.3
22	8.0- 7.9	46.2	43.7	44.8	57.9	56.5	57.2	0.7	13.5	10.6	12.4
23	8.0- 7.9	46.6	43.5	45.1	59.0	56.5	57.7	0.9	13.7	11.6	12.6
24	8.0- 7.9	46.9	43.9	45.2	58.6	57.0	57.6	0.7	13.3	11.3	12.4
25	8.3- 7.8	46.4	44.4	45.3	64.0	57.4	59.7	2.0	18.5	12.1	14.3
26	8.3- 7.8	46.2	44.6	45.2	58.8	57.7	58.2	-0.7	13.5	12.1	13.0
27	7.9- 7.8	47.1	44.4	45.7	61.9	57.7	58.6	-2.3	15.5	11.2	12.9
28	8.0- 7.9	48.7	45.1	46.4	55.6	45.7	47.6	-3.1	9.2	0.6	1.6
29	8.0- 7.9	48.4	45.5	47.0	46.6	45.7	46.2	0.4	0.7	0.0	0.1
30	8.0- 7.9	49.8	46.0	47.6	47.1	45.7	46.4	0.7	0.0	0.0	0.0
MONTH	8.1- 7.8	49.8	39.9	43.1	64.0	45.7	54.8	-3.1	18.5	0.0	11.8

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD - 1 MAY 79/0015 - 31 MAY 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	8.0- 7.9	49.8	46.2	46.1	47.6	46.2	46.8	-0.7	1.1	0.0	0.1
2	8.0- 7.9	48.7	46.4	47.5	46.9	45.7	46.2	-0.4	0.0	0.0	0.0
3	8.0- 8.0	49.6	46.6	48.3	47.8	46.2	46.8	0.5	0.0	0.0	0.0
4	8.0- 8.0	51.1	47.1	49.3	48.2	47.1	47.7	0.5	0.4	0.0	0.0
5	8.0- 7.9	48.9	47.1	47.9	47.8	46.2	46.7	-0.5	0.7	0.0	0.0
6	8.0- 7.9	49.6	46.9	48.3	47.8	46.2	46.8	0.4	0.0	0.0	0.0
7	8.0- 8.0	52.0	47.5	49.9	49.3	47.1	48.1	0.5	0.0	0.0	0.0
8	8.0- 7.9	52.7	47.8	49.8	49.6	47.8	48.4	-0.7	0.5	0.0	0.1
9	8.1- 8.0	52.7	47.3	50.0	49.6	47.5	48.5	-0.7	0.7	0.0	0.1
10	8.0- 8.0	53.4	49.6	51.4	50.2	48.4	49.4	0.7	0.0	0.0	0.0
11	8.1- 8.0	50.9	49.1	50.3	49.6	48.7	49.2	-0.4	0.0	0.0	0.0
12	8.0- 7.9	50.7	49.8	50.3	49.3	48.7	49.1	0.2	0.0	0.0	0.0
13	8.0- 7.9	50.7	48.9	49.8	49.1	48.0	48.7	-0.4	0.0	0.0	0.0
14	8.0- 7.8	50.0	49.1	49.5	48.4	47.6	48.1	-0.4	0.0	0.0	0.0
15	8.0- 7.8	50.7	49.1	49.6	48.7	47.8	48.2	-0.5	0.0	0.0	0.0
16	8.0- 7.8	52.0	49.3	50.3	49.6	48.0	48.6	-0.4	0.0	0.0	0.0
17	8.0- 7.9	50.9	49.6	50.2	49.3	48.4	49.0	0.5	0.0	0.0	0.0
18	8.0- 7.6	51.6	50.0	50.7	50.0	48.7	49.3	0.5	0.0	0.0	0.0
19	7.9- 7.6	51.6	50.2	51.0	49.8	49.1	49.6	0.4	0.0	0.0	0.0
20	7.9- 7.6	52.3	50.2	51.1	50.2	48.9	49.5	-0.5	0.0	0.0	0.0
21	8.0- 7.4	53.2	50.9	51.7	51.1	49.6	50.2	0.5	0.0	0.0	0.0
22	7.6- 7.4	54.1	51.1	52.3	53.6	50.7	52.0	-0.7	1.4	0.0	0.3
23	7.8- 7.4	52.9	51.4	52.1	63.7	52.3	57.5	1.3	11.0	0.0	5.4
24	7.6- 7.3	54.3	52.6	52.9	66.2	64.2	65.3	0.5	13.1	11.7	12.4
25	7.6- 7.3	54.3	52.0	53.0	66.2	62.6	64.5	-1.4	13.1	9.4	11.5
26	7.8- 7.3	57.0	52.3	54.3	67.6	62.2	63.8	0.9	11.5	7.2	9.6
27	7.9- 7.3	58.1	54.7	56.2	74.5	68.0	72.5	0.9	18.2	11.9	16.2
28	7.6- 7.3	57.2	54.7	56.1	74.8	73.4	74.1	-0.5	19.1	17.1	18.1
29	7.5- 7.3	58.6	53.6	56.6	75.2	72.7	74.1	-0.7	19.1	16.0	17.4
30	7.6- 7.3	59.9	55.4	57.4	75.7	73.6	74.7	-0.5	18.7	15.3	17.3
31	7.8- 7.3	59.9	55.9	57.6	77.5	74.5	75.9	0.9	19.8	17.1	18.1
MONTH	8.1- 7.3	59.9	46.2	51.4	77.5	45.7	54.4	-1.4	19.8	0.0	4.0

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 JUN 79/0015 - 30 JUN 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	7.6- 7.3	60.6	56.8	58.5	78.8	75.7	76.8	-0.7	19.3	17.1	18.4
2	7.6- 7.3	61.0	57.0	59.1	79.7	76.3	77.8	-1.8	22.6	17.6	18.7
3	7.6- 7.3	60.1	57.9	59.4	77.5	76.6	77.0	-0.5	18.5	16.9	17.6
4	7.6- 7.3	59.2	56.3	58.1	77.0	75.7	76.3	-0.7	19.4	16.9	18.2
5	7.5- 7.3	61.5	56.5	58.7	78.4	75.4	76.8	0.7	19.3	16.2	18.1
6	7.5- 7.3	61.0	57.7	59.3	76.4	76.6	77.4	-0.7	18.5	16.7	18.0
7	7.6- 7.3	60.8	57.4	59.2	78.8	77.6	77.7	0.9	20.6	17.3	18.5
8	7.6- 7.3	61.0	58.3	59.9	79.0	77.7	78.3	0.9	19.4	17.6	18.4
9	7.6- 7.4	60.8	58.6	59.7	78.8	77.7	78.3	0.9	19.3	17.8	18.5
10	7.9- 7.5	60.6	56.6	59.7	79.6	59.2	71.9	-2.5	19.1	0.0	12.2
11	7.9- 7.6	60.4	58.8	59.7	58.8	57.4	58.7	-0.5	0.0	0.0	0.0
12	7.9- 7.5	59.9	53.6	59.3	58.3	57.4	57.9	-0.5	0.0	0.0	0.0
13	7.9- 7.6	60.6	58.6	59.5	58.3	56.8	57.6	0.4	0.0	0.0	0.0
14	8.1- 7.8	61.7	59.0	60.2	59.5	57.4	58.4	0.5	0.0	0.0	0.0
15	8.1- 7.8	62.2	60.1	60.9	59.9	58.6	59.2	0.4	0.0	0.0	0.0
16	8.3- 7.8	63.3	59.6	61.5	60.6	58.8	59.6	0.5	0.0	0.0	0.0
17	8.1- 8.0	62.4	60.8	61.5	60.6	59.2	59.9	0.5	0.0	0.0	0.0
18	8.1- 8.0	62.8	61.0	61.8	60.8	59.7	60.2	0.5	0.0	0.0	0.0
19	8.1- 7.9	61.5	60.4	60.6	59.5	58.8	59.2	0.5	0.0	0.0	0.0
20	8.0- 7.8	62.8	60.4	61.5	78.1	59.5	65.4	2.3	16.4	0.0	4.5
21	7.9- 7.6	63.5	60.4	61.7	80.6	78.1	79.2	0.7	18.9	16.0	17.5
22	7.8- 7.5	63.1	60.6	61.8	80.6	79.5	80.1	-0.7	19.3	17.6	18.3
23	7.9- 7.5	64.0	60.8	62.6	82.6	80.2	81.3	0.5	19.8	17.8	18.6
24	7.9- 7.6	63.1	61.3	62.1	81.5	80.4	80.9	-0.4	19.3	18.4	18.8
25	7.8- 7.5	61.9	61.0	61.4	80.6	80.2	80.4	0.4	19.4	18.7	19.0
26	8.0- 7.6	64.2	60.4	62.5	82.4	78.1	80.9	-1.4	19.6	15.3	18.4
27	8.1- 7.9	65.5	61.5	63.0	77.9	75.2	76.6	-1.3	15.3	11.7	13.6
28	8.0- 7.8	65.1	61.9	63.2	82.2	75.2	78.6	1.8	19.8	12.4	15.4
29	7.9- 7.6	65.1	61.9	63.5	83.1	79.9	81.7	0.5	19.6	16.6	17.7
30	7.9- 7.6	65.1	62.6	63.9	84.4	82.4	83.3	0.7	20.5	15.2	19.4
MONTH	8.3- 7.3	65.5	56.3	60.8	84.4	56.8	72.2	-2.5	22.6	0.0	11.9

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 JUL 79/0015 - 31 JUL 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	7.9- 7.5	65.8	62.8	64.6	85.6	84.4	85.1	0.5	22.1	19.4	20.4
2	7.8- 7.5	67.1	63.7	65.6	86.6	77.7	82.3	-3.1	21.1	16.8	16.6
3	7.9- 7.6	66.7	63.7	65.1	82.6	77.9	79.2	1.1	18.4	11.7	14.1
4	7.9- 7.5	70.9	63.3	65.0	84.7	82.0	83.2	-1.3	20.7	13.0	18.2
5	7.8- 7.5	64.2	62.8	63.4	84.2	82.9	83.4	0.4	21.1	19.1	20.1
6	7.9- 7.8	64.6	62.6	63.2	84.9	83.8	84.3	-0.5	21.6	20.3	21.1
7	7.9- 7.6	65.5	62.8	64.0	86.7	84.4	85.3	-0.5	22.3	20.3	21.3
8	7.9- 7.6	65.8	63.3	64.5	87.1	85.3	86.6	-6.5	23.6	20.3	21.5
9	7.9- 7.6	66.4	63.1	64.6	86.9	85.3	86.2	0.7	22.7	19.8	21.6
10	7.9- 7.5	67.3	63.5	64.8	86.9	85.6	86.1	-0.7	22.5	19.3	21.4
11	7.8- 7.5	66.2	63.3	64.4	86.2	85.1	85.6	-0.5	22.5	19.8	21.2
12	7.9- 7.6	68.2	64.0	65.4	88.0	84.7	86.3	0.9	22.7	18.5	20.9
13	7.8- 7.6	68.5	63.5	65.5	88.5	85.8	86.8	[illegible]	25.0	18.5	21.2
14	7.9- 7.6	66.9	64.4	65.6	90.1	86.6	88.2	1.3	25.7	20.7	22.7
15	7.6- 7.6	66.7	64.6	65.7	90.1	86.5	87.6	-1.4	24.7	20.7	22.0
16	7.9- 7.6	67.1	64.9	66.0	88.0	86.5	87.2	0.7	22.3	20.0	21.2
17	7.9- 7.5	67.8	65.1	66.5	88.0	86.9	87.5	0.7	22.3	20.6	21.0
18	7.9- 7.6	77.7	65.3	66.9	87.6	86.5	87.2	-0.7	21.8	9.7	20.2
19	7.8- 7.5	69.6	65.3	67.2	88.5	86.7	87.7	0.7	22.3	18.2	20.4
20	7.9- 7.6	70.5	66.0	67.8	89.2	87.4	88.2	0.7	22.6	18.2	20.3
21	7.8- 7.4	69.6	66.2	67.9	89.4	87.6	88.4	-0.7	22.1	19.1	20.5
22	7.6- 7.4	70.0	66.4	68.0	89.8	87.6	88.7	-0.7	22.5	19.1	20.7
23	7.8- 7.5	71.2	66.7	68.5	90.3	88.0	89.0	-0.5	21.8	19.1	20.5
24	7.6- 7.5	70.3	66.9	68.3	90.1	88.3	89.2	0.5	22.3	19.3	20.9
25	7.6- 7.5	70.7	67.3	68.7	90.1	88.3	89.1	-0.5	21.6	19.1	20.4
26	7.8- 7.4	72.5	67.8	69.5	91.0	88.7	89.7	-0.7	22.1	18.6	20.2
27	7.9- 7.4	73.4	68.2	70.3	90.1	86.0	88.5	-1.3	20.9	14.4	18.2
28	7.8- 7.6	73.0	69.4	70.7	92.8	89.8	91.1	0.7	22.0	19.1	20.4
29	7.8- 7.6	73.6	69.6	71.2	93.2	91.0	[illegible]	0.7	21.6	18.5	20.6
30	7.8- 7.5	73.0	69.6	71.2	93.0	91.2	[illegible]	.7	22.1	19.1	20.7
31	7.9- 7.6	72.7	69.6	71.7	93.4	91.6	92.6	0.9	22.3	19.1	20.9
MONTH	7.9- 7.4	77.7	62.6	66.9	93.4	77.7	87.3	-3.1	25.7	9.7	20.4

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 AUG 79/0015 - 31 AUG 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	7.8- 7.5	97.5	70.5	74.1	93.2	89.8	91.7	0.9	21.4	0.0	17.9
2	7.8- 7.5	74.5	69.8	72.3	93.7	91.6	92.3	-0.7	22.1	17.5	20.0
3	7.6- 7.5	74.3	71.2	72.9	93.4	91.9	92.8	-1.3	21.4	18.9	19.9
4	7.6- 7.4	73.4	71.6	72.5	93.2	90.1	92.4	-1.4	21.6	17.1	19.8
5	7.6- 7.4	73.9	70.9	72.7	93.7	91.0	92.5	0.9	22.0	17.3	19.6
6	7.8- 7.4	72.7	70.7	71.5	93.2	91.6	92.4	-0.5	22.0	19.6	20.8
7	7.8- 7.6	72.7	70.0	71.1	93.0	91.0	92.1	0.7	22.3	19.8	21.0
8	7.9- 7.5	82.9	70.5	72.1	92.5	79.0	85.6	-2.3	21.1	7.4	13.5
9	8.0- 7.8	72.1	69.8	70.7	82.4	81.1	81.8	0.7	11.7	10.3	11.1
10	8.0- 7.8	71.8	67.6	70.5	82.4	81.1	81.6	-0.9	13.5	9.9	11.3
11	7.7- 7.7	75.0	73.0	73.2	86.6	82.6	83.9	-2.0	13.6	9.0	10.7
12	7.7- 7.7	72.0	72.0	72.0	82.0	81.0	81.2	1.1	10.1	9.0	9.2
13	7.8- 7.8	72.0	71.1	71.4	83.8	82.0	82.9	1.0	12.4	10.1	11.5
14	8.0- 7.9	71.1	71.1	71.1	85.1	80.2	82.3	4.1	12.4	9.9	11.5
15	8.0- 7.9	71.1	66.9	70.2	82.4	74.3	78.7	-4.7	11.3	3.2	8.8
16	8.0- 7.8	67.1	65.8	66.4	81.5	78.4	79.7	1.4	14.6	11.7	13.3
17	8.1- 8.0	68.9	67.3	68.2	82.9	81.1	82.1	-1.6	15.1	13.1	13.9
18	8.0- 8.0	68.0	67.1	67.3	82.0	80.8	81.4	-0.4	14.6	13.5	14.1
19	8.0- 8.0	68.5	66.9	67.5	82.0	78.4	80.6	-2.2	14.4	10.6	13.0
20	8.0- 8.0	68.7	67.1	67.8	83.5	80.8	82.0	-2.3	15.8	13.1	14.2
21	8.1- 8.0	69.4	67.6	68.3	84.0	81.3	82.6	-1.8	16.0	13.1	14.3
22	8.1- 8.0	69.4	67.1	68.[illegible]	84.7	81.3	82.7	2.3	16.4	13.3	14.5
23	8.1- 8.0	69.4	67.8	68.3	84.4	81.1	82.5	-2.2	16.6	13.1	14.2
24	8.1- 8.0	70.0	[illegible].8	68.9	84.0	82.2	83.0	0.5	15.3	13.1	14.2
25	8.1- 8.0	70.9	[illegible].5	69.3	84.7	82.6	83.6	-0.7	15.7	12.6	14.3
26	8.1- 8.0	70.9	68.5	69.4	84.4	82.0	83.3	-0.9	14.9	12.6	13.9
27	8.1- 8.0	71.2	68.7	69.7	88.9	79.5	82.1	1.4	19.1	9.9	12.4
28	7.9- 7.9	71.2	68.5	69.8	95.9	90.5	93.7	1.6	25.2	20.7	23.9
29	8.0- 7.9	79.5	68.7	70.8	95.7	93.7	94.6	0.5	25.9	14.2	23.7
30	8.0- 7.9	73.0	69.4	71.1	96.1	94.1	95.0	0.5	25.7	22.1	23.9
31	8.0- 7.9	72.5	69.1	71.0	95.9	94.1	94.9	-0.7	25.6	22.3	23.9
MONTH	8.1- 7.4	97.5	65.8	70.3	96.1	74.3	86.5	-4.7	25.9	0.0	16.3

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD - 1 SEP 79/0015 - 30 SEP 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	8.0- 7.9	73.9	69.6	71.5	97.3	94.3	95.9	-0.9	25.7	22.1	24.4
2	8.0- 7.9	72.1	69.6	70.8	96.4	94.6	95.4	0.7	25.6	23.6	24.5
3	8.0- 7.9	72.1	69.8	71.0	95.9	94.6	95.5	-0.5	25.9	23.4	24.5
4	8.0- 7.9	72.1	68.9	70.4	95.9	88.0	94.1	-2.0	25.7	17.1	23.8
5	8.1- 8.0	70.9	69.1	69.9	86.9	83.8	85.7	-1.1	17.1	14.2	15.9
6	8.1- 7.9	72.1	69.4	70.5	92.1	85.3	87.8	1.6	21.8	14.9	17.3
7	7.9- 7.9	71.4	65.5	70.5	95.7	92.8	94.1	-0.9	25.2	22.0	23.6
8	7.9- 7.9	70.0	68.9	69.5	95.5	94.3	95.0	0.5	26.1	24.3	25.4
9	7.9- 7.9	70.0	66.2	68.7	95.0	93.9	94.4	-0.4	27.9	24.1	25.1
10	7.9- 7.9	70.5	66.7	68.9	94.6	94.1	94.4	-0.4	27.9	23.8	25.4
11	7.9- 7.9	69.8	68.6	68.9	94.3	93.4	94.0	0.4	26.3	24.5	25.1
12	7.9- 7.9	70.9	68.5	69.2	94.6	93.2	94.0	0.4	25.2	23.4	24.7
13	7.9- 7.9	70.3	[illegible]	69.3	94.6	93.0	93.9	0.7	25.2	23.9	24.7
14	7.9- 7.6	71.6	69.1	70.4	95.9	94.1	94.6	-0.7	25.2	23.8	24.6
15	7.8- 7.6	70.5	69.4	69.8	95.5	93.7	94.6	-0.4	25.2	23.8	24.8
16	7.8- 7.6	70.3	68.2	69.2	94.6	93.2	93.9	-0.7	25.2	23.9	24.7
17	7.8- 7.8	70.5	68.2	69.2	95.0	93.6	94.6	-0.5	25.6	24.3	24.8
18	7.8- 7.8	70.3	68.9	69.5	95.0	93.9	94.5	0.4	25.6	24.5	25.0
19	7.8- 7.8	69.8	67.6	69.1	94.3	91.9	93.2	-0.7	24.7	23.6	24.1
20	7.9- 7.8	68.0	66.9	67.5	92.1	91.0	91.4	-0.7	24.3	23.2	23.9
21	7.8- 7.8	68.2	66.7	67.3	91.9	90.7	91.3	0.5	24.5	23.4	24.0
22	7.8- 7.6	68.2	66.7	67.4	93.7	91.0	92.7	1.1	26.5	23.8	25.3
23	7.8- 7.8	67.6	66.2	66.6	90.7	89.6	90.3	-1.4	24.1	22.5	23.7
24	7.8- 7.8	66.7	65.1	65.8	89.8	88.9	89.4	0.4	24.1	22.7	23.5
25	7.9- 7.8	66.0	64.9	65.4	90.1	86.2	88.8	0.7	24.7	20.2	23.3
26	7.9- 7.8	66.7	64.9	65.7	91.0	89.2	89.9	1.6	24.7	23.2	24.1
27	7.9- 7.8	66.7	65.3	65.9	90.7	89.4	90.0	0.5	24.7	23.4	24.1
28	7.9- 7.8	67.1	65.3	66.0	91.0	89.4	90.2	0.7	24.7	23.4	24.1
29	7.9- 7.8	67.6	65.8	66.4	91.0	90.3	90.6	[illegible]	24.8	23.0	24.2
30	7.8- 7.8	67.8	65.8	66.3	91.2	90.1	90.5	0.5	24.7	22.9	24.1
MONTH	8.1- 7.6	73.9	64.9	68.6	97.3	83.8	[illegible]	-2.0	27.9	14.2	23.9

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 OCT 79/0615 - 31 OCT 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	7.8- 7.8	66.4	65.3	65.7	90.1	89.4	89.7	0.4	24.8	23.7	23.9
2	7.8- 7.8	66.9	65.1	65.9	91.0	89.4	90.1	-0.4	24.8	23.6	24.2
3	7.8- 7.8	112.6	65.3	69.2	90.5	88.6	89.6	-1.1	24.5	0.0	21.6
4	7.8- 7.8	67.1	65.5	66.2	91.2	90.1	90.6	0.5	24.8	23.9	24.4
5	7.8- 7.8	67.1	65.5	66.2	90.7	90.1	90.4	0.4	24.6	23.6	24.3
6	7.8- 7.6	67.3	64.6	65.6	91.6	90.1	90.5	0.7	25.9	23.6	24.9
7	7.8- 7.8	66.9	64.4	65.1	91.2	89.6	90.4	-0.7	26.1	23.8	25.4
8	7.6- 7.8	64.4	59.0	62.9	89.4	88.7	89.0	0.5	30.4	24.7	26.1
9	7.8- 7.6	67.8	62.4	63.5	89.4	88.0	88.8	-0.5	26.5	21.1	25.3
10	7.8- 7.8	71.4	59.9	62.4	88.7	85.1	86.8	0.7	25.6	17.3	24.5
11	7.8- 7.8	62.6	58.8	60.9	86.9	84.2	85.8	0.9	26.5	23.2	24.9
12	7.8- 7.8	62.6	59.7	61.0	87.1	85.3	86.3	0.5	26.1	23.0	25.2
13	7.8- 7.8	61.7	59.2	60.3	88.3	84.9	86.8	-1.4	28.4	24.7	26.5
14	7.9- 7.8	60.4	57.7	59.0	85.3	83.1	84.1	-0.7	26.1	24.5	25.2
15	7.9- 7.8	59.7	57.7	58.7	84.2	82.4	83.5	-1.4	25.6	24.3	24.8
16	7.9- 7.6	60.6	57.4	58.7	84.4	81.9	82.9	0.4	24.7	23.6	24.2
17	7.9- 7.8	61.0	59.2	60.0	84.7	83.5	84.1	0.5	24.7	23.0	24.1
18	7.9- 7.8	60.6	59.7	60.1	85.3	83.8	84.3	0.7	25.2	23.6	24.2
19	7.9- 7.8	61.5	59.5	60.0	84.4	83.5	83.9	0.7	24.3	22.7	23.9
20	7.9- 7.8	60.8	59.5	60.2	84.7	83.5	84.2	0.5	24.7	23.0	23.9
21	7.8- 7.8	61.3	59.5	60.4	84.7	84.6	84.4	-0.4	24.8	23.6	24.0
22	7.8- 7.8	61.5	59.5	60.5	85.6	84.6	84.7	-0.5	25.0	23.0	24.1
23	7.8- 7.8	61.3	59.7	60.5	85.3	84.2	84.6	-0.5	25.2	23.0	24.1
24	7.8- 7.8	61.0	59.7	60.5	84.9	84.2	84.5	-0.4	24.7	23.2	23.9
25	7.9- 7.8	59.9	58.8	59.3	84.0	83.3	83.6	-0.4	24.7	23.8	24.3
26	7.9- 7.8	59.7	58.1	58.6	83.1	82.6	82.9	-0.4	24.7	23.4	24.2
27	7.9- 7.8	58.6	56.3	57.4	82.6	80.8	81.6	-0.5	25.0	23.6	24.2
28	7.9- 7.3	58.6	56.1	57.4	82.4	80.6	81.5	-0.5	25.0	23.2	24.1
29	7.9- 7.8	58.3	56.3	57.2	85.1	81.3	83.5	1.1	28.1	23.6	26.3
30	7.9- 7.8	58.8	55.6	57.0	85.6	81.5	84.2	-1.8	26.3	25.2	27.2
31	7.9- 7.9	62.8	55.4	57.0	81.1	73.6	75.4	-2.5	25.0	17.3	22.4
MONTH	7.9- 7.6	112.6	55.4	61.3	91.6	73.6	85.7	-2.5	30.4	0.0	24.5

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
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MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 NOV 79/0015 - 30 NOV 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	8.0- 8.0	57.4	55.9	56.7	70.0	66.2	68.0	1.4	13.7	10.1	11.3
2	8.0- 7.9	58.1	55.9	57.1	72.5	68.0	71.2	1.4	14.9	12.1	14.2
3	8.0- 7.9	59.0	56.8	57.5	73.0	70.9	71.5	-1.1	15.1	13.7	14.4
4	8.0- 7.9	56.8	55.9	56.4	70.9	70.0	70.4	-0.7	14.6	13.5	14.1
5	8.0- 7.9	56.5	55.6	56.1	72.7	69.4	71.1	-1.6	16.6	13.3	15.0
6	8.0- 7.9	56.8	55.4	56.0	72.3	70.3	71.5	1.1	16.2	14.4	15.6
7	8.0- 7.9	56.8	55.4	56.2	73.0	70.7	71.8	1.3	16.6	14.9	15.7
8	8.0- 7.9	56.3	55.0	55.6	72.3	70.0	71.1	-0.7	16.4	14.6	15.4
9	8.0- 7.9	56.5	55.2	55.8	71.2	69.8	70.6	-0.7	15.3	14.2	14.8
10	8.0- 7.9	57.4	55.9	56.5	72.3	69.1	71.1	-2.2	15.3	12.6	14.7
11	8.1- 8.0	57.0	55.6	56.1	66.7	60.4	61.8	-2.5	9.7	4.3	5.7
12	8.0- 8.0	56.3	54.7	55.5	70.7	65.1	68.3	-3.1	15.5	9.2	12.8
13	8.0- 7.9	56.3	54.5	55.6	71.2	69.1	70.2	1.4	16.0	14.4	15.2
14	8.0- 8.0	55.4	53.6	54.4	70.5	68.5	69.4	1.1	15.7	14.0	14.9
15	8.1- 8.0	54.5	52.7	53.6	70.3	63.5	68.8	-3.6	16.4	10.8	15.2
16	8.1- 8.0	54.1	51.1	52.4	65.8	60.4	62.9	2.3	14.8	7.2	10.4
17	8.1- 8.0	53.8	50.5	51.8	66.7	64.6	65.7	0.9	15.1	12.1	13.8
18	8.0- 8.0	54.3	51.1	52.7	67.8	65.3	66.7	0.7	14.9	12.6	13.9
19	8.0- 8.0	53.8	52.7	53.2	67.8	66.9	67.4	0.5	14.6	13.7	14.1
20	8.0- 8.0	53.8	52.7	53.3	68.2	66.7	67.5	-0.7	14.6	13.7	14.2
21	8.0- 7.9	54.3	52.7	53.4	68.2	66.9	67.6	0.9	14.6	13.7	14.2
22	8.0- 8.0	54.5	53.2	53.7	68.5	66.9	67.6	-1.3	14.8	12.4	14.1
23	8.0- 8.0	55.2	53.4	54.0	68.5	67.1	68.0	-0.5	14.8	13.3	14.0
24	8.0- 8.0	55.0	53.6	54.3	69.6	67.6	68.4	1.1	14.9	12.4	14.1
25	8.0- 8.0	55.2	54.1	54.5	69.4	66.6	68.2	-1.3	14.4	11.5	13.7
26	8.0- 8.0	55.6	54.3	54.9	69.4	66.4	68.4	0.9	14.4	11.6	13.5
27	8.0- 7.9	55.2	54.1	54.6	71.6	65.5	69.1	-1.6	17.1	11.3	14.5
28	8.0- 8.0	55.0	53.6	54.4	69.1	66.6	66.8	-2.2	14.4	11.5	12.4
29	8.0- 8.0	54.3	52.0	53.4	66.4	64.6	65.5	-0.5	12.6	11.5	12.1
30	8.1- 8.0	53.2	50.5	51.8	64.9	62.6	63.8	-0.9	13.3	11.6	12.0
MONTH	8.1- 7.9	59.0	50.5	54.7	73.0	60.4	68.4	-3.6	17.1	4.3	13.7

PH RANGE = HIGHEST AND LOWEST PH AT QUARRY CUT (PH UNITS)
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MRC = MAXIMUM RATE OF CHANGE OF QUARRY CUT TEMPERATURE (DEGREES / HR.)
**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

TABLE 2.1 (CONT.)

MILLSTONE POINT

MONTHLY WATER QUALITY DATA SUMMARY

DATA PERIOD = 1 DEC 79/0015 - 31 DEC 79/2315

PARAMETER

DAY	QUARRY CUT PH RANGE	INTAKE TEMPERATURE MAX.	MIN.	AVE.	QUARRY CUT TEMPERATURE MAX.	MIN.	AVE.	MRC	TEMPERATURE RISE MAX.	MIN.	AVE.
1	8.1- 8.0	52.5	50.2	51.3	64.2	62.4	63.7	0.7	12.6	11.0	12.0
2	8.1- 8.0	52.0	49.1	50.8	63.5	61.9	62.9	-0.7	12.8	11.5	12.2
3	8.1- 8.0	50.9	47.5	49.4	61.7	58.8	60.5	1.3	13.0	9.4	11.0
4	8.0- 8.0	50.5	48.7	49.5	60.8	59.0	59.9	0.7	11.9	9.0	10.4
5	8.0- 7.9	50.9	48.0	49.3	66.7	58.6	61.4	1.1	16.2	9.4	12.0
6	8.0- 7.9	109.9	48.9	55.2	70.3	62.8	66.4	2.2	19.8	0.0	14.4
7	7.9- 7.9	59.5	49.6	50.8	71.6	67.8	69.4	-0.9	21.1	11.0	18.6
8	7.9- 7.9	50.7	47.3	49.0	71.6	69.1	70.5	-0.5	22.5	20.3	21.5
9	7.9- 7.9	56.0	47.1	48.2	70.5	68.7	69.7	0.5	22.7	20.0	21.5
10	7.9- 7.9	50.2	46.6	48.4	70.7	68.2	69.5	-0.7	22.3	19.6	21.1
11	7.9- 7.9	50.9	47.8	49.2	71.2	69.6	70.4	0.5	22.5	19.8	21.2
12	7.9- 7.9	51.6	48.2	49.4	71.2	66.2	69.7	-1.3	22.3	16.9	20.2
13	7.9- 7.9	51.1	49.3	49.9	66.9	66.2	66.5	-0.5	17.1	15.7	16.6
14	7.9- 7.9	49.8	47.3	48.8	69.8	64.4	66.6	1.3	22.0	16.2	17.9
15	7.9- 7.9	50.0	47.3	49.0	70.5	69.4	69.9	-0.4	22.3	19.6	20.8
16	7.9- 7.9	50.5	47.1	48.9	70.7	68.9	69.9	0.5	22.0	20.0	20.9
17	7.9- 7.9	49.6	45.7	47.9	70.5	66.7	69.1	-0.7	22.1	20.5	21.3
18	7.9- 7.9	47.8	43.7	45.4	66.9	64.9	66.1	0.9	21.6	18.7	20.6
19	8.0- 7.9	46.6	43.9	45.4	66.9	57.7	64.2	-2.5	22.0	11.9	18.8
20	8.0- 7.9	46.0	44.6	45.1	62.2	57.2	60.1	0.5	16.9	12.6	15.1
21	8.0- 7.9	46.2	44.2	44.9	63.1	61.3	62.1	1.3	18.0	16.6	17.2
22	8.0- 7.9	47.3	43.5	45.3	66.2	62.8	64.3	-0.9	20.9	17.5	18.9
23	7.9- 7.9	47.3	44.6	46.2	68.5	65.8	67.1	0.7	22.0	19.6	20.9
24	7.9- 7.9	48.0	46.6	46.8	68.9	67.8	68.3	-0.5	22.3	20.5	21.5
25	7.9- 7.9	46.4	46.9	47.4	68.9	68.5	68.8	0.4	21.8	20.2	21.3
26	7.9- 7.9	47.8	46.6	47.2	68.9	68.2	68.6	-0.4	21.6	20.9	21.4
27	7.9- 7.9	47.1	45.1	46.2	68.2	67.1	67.8	-0.4	22.1	21.1	21.6
28	8.0- 7.9	46.2	43.3	44.7	67.1	65.5	66.5	-0.5	22.5	20.9	21.7
29	8.0- 7.9	46.6	43.9	45.0	67.6	65.8	66.5	-0.5	22.5	20.7	21.6
30	8.0- 7.9	46.6	44.2	45.1	67.3	66.2	66.6	-0.5	22.3	20.3	21.5
31	8.0- 7.9	46.2	44.2	45.0	67.1	66.0	66.5	-0.5	22.1	20.9	21.5
MONTH	8.1- 7.9	109.9	43.3	47.9	71.8	57.2	66.4	-2.5	22.7	0.0	18.6

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**** = MISSING DATA DUE TO MALFUNCTION OF MONITORING SYSTEM (AVAILABLE GRAB SAMPLE DATA HAVE BEEN INCLUDED)

POOR ORIGINAL

Table 2.2

Thermal Effects of Heat Treatment

Date	Duration of Heat Treatment (hours:min.)	Maximum Quarry Temp. (°F)	Net Rise Quarry Temp. (°F)	Reactor Power Level
February 3	3:45	62.6	4.6	98%
March 15	2:45	51.4	2.7	98%
April 6	7:00	53.0	3.0	97%
April 13	6:30	58.3	3.6	95%
June 2	3:10	79.9	3.2	84%
July 4	4:00	85.1	2.5	75%
July 14	3:00	86.9	0.9	85%
August 1	3:30	92.8	1.3	70%
September 22	11:42	93.7	3.2	83%
October 3	3:25	90.5	1.1	67%
October 13	2:15	87.8	1.3	82%
December 6	4:30	70.7	4.5	75%
December 6	3:45	69.4	3.2	77%

2.3 Chemical

2.3.1 Biocides

Monitoring

Plant releases of total residual chlorine were monitored as required by ETS Section 2.3.1.4 and 2.3.1.5. Weekly grab samples of water from the quarry cut were collected during periods of intermittent chlorination and daily grab samples during continuous chlorination. These samples were analyzed for total residual chlorine using an amperometric titrator.

Data Summary

All quarry cut samples analyzed have shown less than the detectable limit of 0.05 mg/l total residual chlorine.

2.3.2 pH

Monitoring

The pH is continuously monitored by two sensing units at the quarry cut. The sensor output data is handled similarly to that of the temperature sensor output. If the pH of the station discharge as measured at the quarry cut is outside the specified range of 6.8 and 8.5, an alarm is actuated.

Data Summary

The quarry cut pH measurements have been summarized and tabulated to give daily and monthly ranges as shown in Table 2.1.

There have been no instances where pH was less than 6.8 or more than 8.5. Sensor calibration was checked by analyzing weekly grab samples using standard methods. When both pH sensors were inoperative, daily grab samples were taken. These results have been incorporated in the tables.

ETS SECTION 3

ENVIRONMENTAL SURVEILLANCE

3.1 Nonradiological

3.1.1 Abiotic

3.1.1.1 Chemical Usage

An inventory of the major chemicals used at Units 1 and 2 in 1979 leads to the following quantities used and/or discharged.

A total of 234,000 lbs. of 96% sulfuric acid and 378,000 lbs. of 50% sodium hydroxide were used as regenerants for the ion exchange demineralizers which produce the high purity water needed for the station's steam generation system. The spent acid and caustic solutions were mixed and adjusted to neutral pH prior to being discharged. The spent, neutralized regenerant waste contained a total of 339,000 pounds of sodium sulfate and was discharged over a period of 1212 hours. The average concentration was 0.6 mg/l at the quarry cut during periods of discharge.

Boric acid is used in the primary coolant of Unit 2 for reactivity control. A boric acid evaporator system is used to recover boric acid from displaced coolant for reuse and to avoid discharging the material into the station effluent system. A second evaporator, previously used for processing low level radwaste, has ceased to be functional and will not be replaced. Henceforth, any boric acid in this system will be discharged to the cooling water stream. It has been determined that the quantities discharged are insignificant compared with the amounts naturally present in marine waters. Plant inventory records show that 72,000 lbs. of boric acid were issued for use in 1979. Waste monitor test tanks are discharged to the cooling water stream at concentrations no greater than 10,000 mg/l and with the further restriction that at least two circulating pumps are in service on Unit 2 at the time of discharge. Under these conditions, 14,400 pounds of boric acid were discharged in batch discharge periods totaling 576 hours. The average concentration in the discharge tanks prior to discharge was 1233 mg/l.

Liquid chlorine is used to chlorinate periodically the circulating and service water systems to control the growth of biological species on the intake structure and heat exchanger structures. A total of 165 tons of chlorine was used for this purpose. Of this, less than one ton of total residual chlorine was discharged from the quarry and at concentrations less than the detectable limit of 0.05 mg/l. Chlorine was discharged during periods totaling 4,928 hours.

3.1.1.2 Meteorological Monitoring

Meteorological data have been summarized and reported in a format consistent with the recommendations of Regulatory Guides 1.21 and 1.23. These data are found in the Semiannual Radioactive Effluents Release Reports for 1979.

3.1.2 Biota

Results of marine environmental surveillance at Millstone for 1979 are presented in the preceding sections 1-10 of this report.

3.1.2.2 Terrestrial

3.1.2.2.2 Transmission Rights-of-Way Management

Transmission rights-of-way associated with Millstone Units 1 and 2 received no herbicide treatment during 1979.

ETS SECTION 4

SPECIAL SURVEILLANCE, RESEARCH, OR STUDY ACTIVITIES

4.1 Mathematical Tidal Circulation Model

4.2 Mathematical Biological Model

The ETS require final reports upon completion of the mathematical modeling studies. A final report covering both ETS sections was submitted under separate cover in a letter dated November 24, 1976 to Mr. James P. O'Reilly.

4.7 Chlorination Study

This two year study was completed in 1977 and was submitted as Section 4.7 of the Annual Environmental Operating Report, Part A, dated March 31, 1978.