AR-1138

MERRIMACK RIVER MONITORING PROGRAM

SUMMARY REPORT

Prepared for

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1.0 OBJECTIVE

The objective of this report is to provide an overview of the physical, chemical and biological data collected throughout a twelve-year (1967 to 1978) monitoring period at Public Service Company of New Hampshire's Merrimack Generating Station in Bow, New Hampshire. This document is a summarization and interpretation of data relevant both to the operation of Merrimack Station and to existing Merrimack River environmental conditions.

2.0 INTRODUCTION

The Merrimack River Monitoring Program, developed to partially fulfill the requirements of Merrimack Station NPDES permit NH 0001465 issued to Public Service Company of New Hampshire (PSCoNH), was designed to detect both spatial and temporal changes in Merrimack River biotic communities and to determine whether the operation of Merrimack Station causes any significant impacts on these communities. These studies included water quality and temperature monitoring as well as plankton, entrainment, periphyton, aquatic macrophyte, aquatic insect, benthic macroinvertebrate and fishery evaluations.

2.1 Merrimack Station

Merrimack Station, located at river kilometer 135 midway between the Hooksett and Garvins Falls Dams (Figure 2-1), is a coal-fired steam-electric generating station producing a total of 470 MWe (443 MWe net normal). Unit I (120 MWe) began operating in December 1960 and Unit II (350 MWe) was brought on line in May 1968. The station requires 12.6 m^3/s (cms) of river water for once-through condenser cooling with a designed total temperature increase (ΔT) of 12.8°C. Cooling water is drawn through two intake structures on the west bank that are equipped with 9.5 mm mesh traveling screens. Water velocities in the Unit I and II intake structures average 45.7 cm/sec.

Prior to 1972, cooling water from the station flowed through a 518 m discharge canal, and reentered the Merrimack River at Station Zero (Figure 2-2, inset). The average summer ΔT between the discharge canal mouth and ambient river water during the 1968 to 1971 period was 10.2°C. On June 30, 1972 a supplemental cooling system was put into operation. This consisted of an 1189 m discharge canal equipped with 54 power spray modules (PSM), each module composed of four spray units (216 total). The mean summer ambient to discharge ΔT following this change in canal configuration was 6.0°C.

The thermal plume assumes the form of a warm-water surface lens upon entering the Merrimack River. This surface lens is generally confined to the west bank during high-flow periods, but crosses to the east bank during low-flow periods. The ΔT decreases rapidly through mixing such that the area of greatest thermal influence is generally restricted to the region between the discharge and the confluence of the Suncook River. Mixing occurs progressively southward to Hooksett Dam; waters exiting the pond through the dam are normally fully mixed with a ΔT of 0.4 to 2.3°C from ambient.

2.2 Study Area

This monitoring program emphasized that section of the Merrimack River referred to as Hooksett Pond, a 9.3 km pool bounded on the southern, downstream end by Hooksett Dam at river kilometer 130.4 and on the northern, upstream end by Garvins Falls Dam at river kilometer 139.7 (Figures 2-1 and 2-2). Both dams are low-head (4.6 and 10.1 m, respectively), run-of-river type peaking hydropower units; neither has significant storage capacity. Garvins Falls is currently operated by PSCoNH for peaking power; flow varies according to power demand with a minimum required discharge of approximately 14.2 cms. Hooksett Dam is operated by PSCoNH to maintain suitable head for the cooling system at Merrimack Station, to generate hydroelectric power, and to regulate flow for Amoskeag Dam, located 12.6 km downstream.

Hooksett Pond is fairly shallow; most regions are less than 3 m deep. However, depths exceed 6 m along the west bank at the Soucook River confluence, at the Narrows, and just above Hooksett Dam (Figure 2-2). The reach from Garvins Falls downstream to the Soucook River changes quickly from a rapidly flowing tailrace and spillway area to a broad, shallow reach typified by a sand bottom with several extensive shoals and sandbars. A short distance below the Soucook River confluence the river becomes somewhat constricted (the Narrows). River current in this reach is greater with the substrate changing from sand to cobble. In this region, several submerged macrophyte beds are noticeable late in the growing season.

Below Merrimack Station, the river is fairly uniform southward to the confluence of the Suncook River. This reach is characterized by sediments ranging from sand to cobble with macrophyte beds along the banks. The Merrimack becomes progressively wider and deeper from the Suncook River southward, with more varied substrate.

Sampling stations have been established and marked at transects north and south of the discharge canal mouth. These are numbered N-1 to N-10, and S-1 to S-24, respectively (Figure 2-2). Stations N-1 through N-6 are 152 m (500 ft) apart, N-6 to N-10 are 305 m (1000 ft) apart, and stations south of the discharge canal (S-1 to S-24) are located at 152 m intervals. The north stations, particularly N-10, have been used to characterize ambient river conditions as contrasted with the mixing zone (Station 0-W to S-4) and far-field station (S-17).

2.3 General Overview

The Merrimack River Monitoring Program has studied the following aspects of Hooksett Pond:

TABLE 2-1. PARAMETERS STUDIED DURING THE MERRIMACK RIVER MONITORING PROGRAM, 1967 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

PHYSICAL	CHEMICAL	BIOLOGICAL
River Discharge	Dissolved Oxygen	Net phytoplankton
Depth of Visibility	pH	Periphyton
Turbidity	Nitrate nitrogen	Zooplankton
Temperature	Nitrite nitrogen	Plankton entrainment
	Total phosphate phosphorus	Aquatic macrophytes
	Orthophosphate phosphorus	Aquatic insects
	Silica	Benthic macroinvertebrates
	Chlorophyll *a*	Finfish community

Throughout the twelve years that Hooksett Pond has been studied, sampling and analytical methods were changed as the program evolved and as new techniques gained credibility in the scientific community. Study methods have been detailed in each annual report, and are summarized in Appendix A. The following reports contain the results of each sampling season, and will not be further cited throughout this report: Normandeau, 1969; NAI, 1969, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978a, 1978b, 1979a. The work of Wightman (1971) on Hooksett Pond finfish communities from 1967 to 1969 has also been utilized.

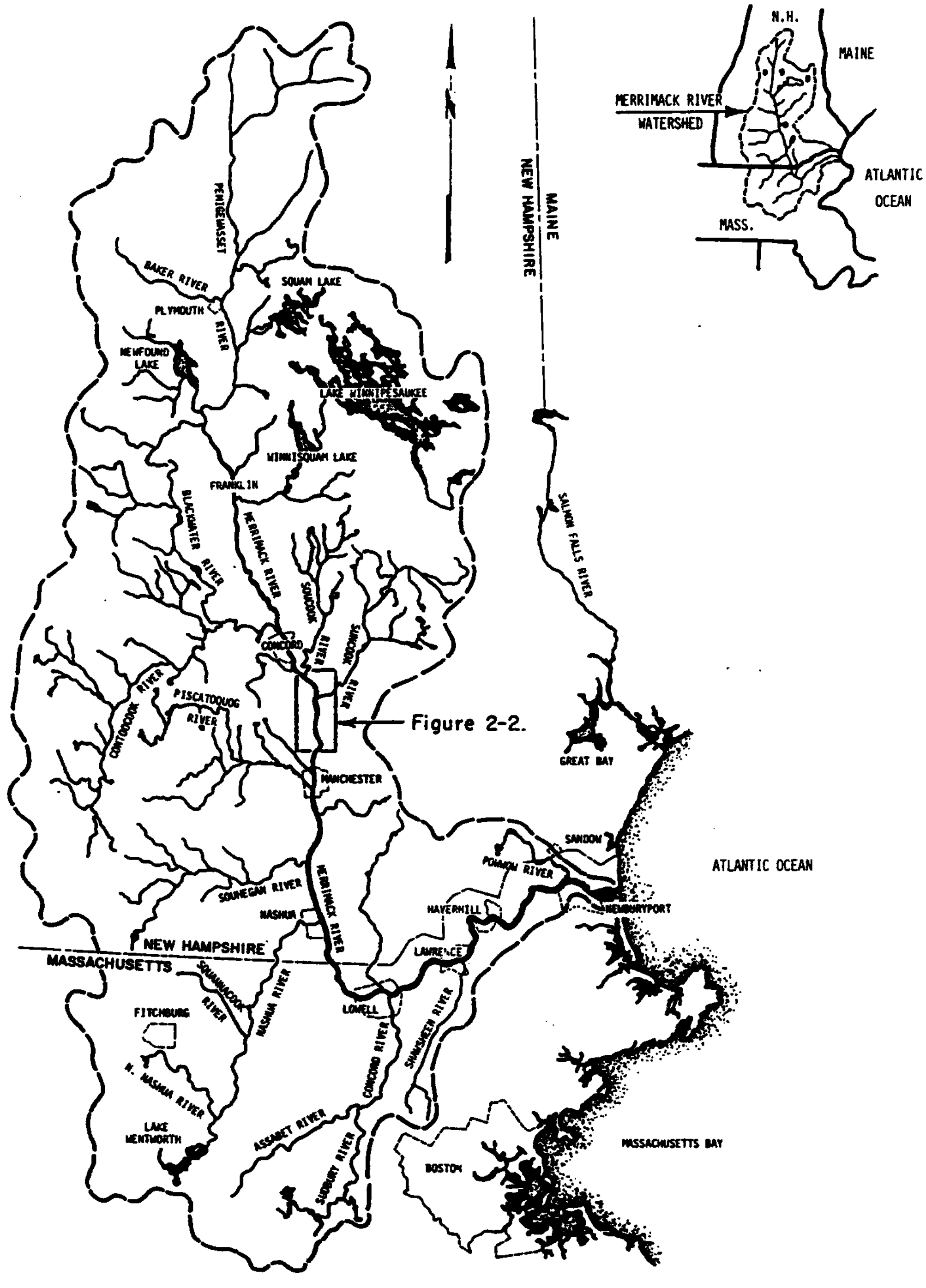


Figure 2-1. Merrimack River watershed. Merrimack River Summary Report, 1979.

3.0 PHYSICAL PARAMETERS

3.1 River Discharge

Variations of river discharge, the volume of water passing a given location within a specified time period, are regulated by climatic conditions within the catchment basin, vegetative cover, land use, basin morphometry and geology, and hydraulic geometry of the river channel. Seasonal flow patterns are distinctive within each geographic region of the earth. Most New England rivers exhibit seasonally highest flows during the early spring as the result of snowmelt (Whitton, 1975). Merrimack River discharge at Garvins Falls normally attains a maximum of 453 to 680 cms during March and April (Figure 3-1). Discharge is usually lowest (7 to 10 cms) during the summer, although storm-related runoff caused unseasonably high discharges during July 1973 and 1975, August 1976 and October 1977. River discharge was consistently low throughout the summer and autumn of 1970, 1971 and 1978, making these the three driest years during the monitoring program.

Merrimack Generating Station Units I and II utilize 3.79 and 8.83 cms, respectively for once-through cooling water. Thus, during maximum power generation, the station withdraws 12.62 cms (199,000 GPM) from the Merrimack River. Because the river discharge in Hooksett Pond is sometimes less than the required 12.62 cms, the generating station may utilize more than 100% of the river volume during coincident periods of low flow and maximum power generation (Figure 3-2). During these periods, water from the discharge canal may recirculate and flow upstream towards the circulating water intakes. This situation occurs infrequently but was evident from the thermal profiles measured on September 2, 1977 (Appendix Figure B-5).

3.2 Turbidity

Most streams and rivers are fairly clear at times of low water, and become more turbid during spates. Dorris *et al.* (1963; cited in Hynes, 1970) found a close relationship between river discharge and turbidity in the Mississippi River. This same relationship was observed on the Merrimack River with maximum turbidities coinciding with the spring discharge maximum and during spates (Figure 3-1). For example, river turbidity increased from 1.3 to 13.5 Formazine turbidity units (FTU) following heavy precipitation during the first week of October 1977. Turbidity was generally, similar throughout Hooksett Pond (Table 3-1), but during high flow periods the water within the mixing zone was often less turbid than the water upstream or at the far-field locations. This may have been due to a clarification of the water drawn through the Merrimack Station by settling of the particulate matter within the discharge canal.

The New Hampshire Water Supply and Pollution Control Commission (NHWSPCC, 1978) has established 25 standard turbidity units as the maximum that is acceptable for warm-water fisheries in Class B waters; ten turbidity units is the standard for cold-water habitats (NHWSPCC, 1978; Lund, 1971). These standard turbidity units are equivalent to Formazine turbidity units. Although turbidities on the Merrimack River have been as high as 16.0 units during maximum flow periods, Hooksett Pond turbidities were typically within the range of 0.5 to 4.0 which is well within the established cold- and warm-water standards.

3.3 Temperature

Hooksett Pond is a warm-water reach of the Merrimack River, with ambient temperatures reaching 25.5 to 31.0°C during July and August (Appendix Tables B-1 and B-2). During the winter, ambient river temperatures typically fall to 0°C.

Since Merrimack Station has a cooling water circulating capacity of 12.6 cms with a maximum design ΔT of 12.8°C, there is an addition of heat to the river water downstream of the discharge canal. Thermal surveys conducted from 1967 to 1969 to identify any thermal effects caused by Merrimack Unit II start-up in 1968 indicated that although generating capacity was increased almost three-fold, thermal effects were not substantially greater during 1968 or 1969 compared to 1967. The average ΔT between ambient and discharged waters from June through September 1968-1971 was 10.2°C (Table 3-2).

Maximum water temperatures and ΔT's at the discharge canal mouth were reduced following a change in the discharge canal configuration during 1971 and activation of 54 power spray module units in June 1972. The maximum discharge temperature observed from 1972 to 1978 was 36.4°C, although temperatures greater than 35.0°C at the canal mouth were rare. The temperature difference between ambient and discharge waters ranged from -2.2 to 10.3°C during the months of June through September, 1972 to 1978, with a mean ΔT of approximately 6.0°C (Figure 3-3; Appendix Tables B-1 and B-2). This is an approximate decrease in discharge temperature of 4.2°C compared to the period prior to PSM installation.

The configuration of the thermal plume is dependent on the volume of cooling water utilized and river discharge. The thermal plume extends as a lens of warm water one to two meters deep southward from the discharge canal mouth; bottom waters are affected only at the discharge canal mouth. This stratification provides an ambient zone of passage throughout the mixing zone. Under certain conditions of low flows and high utilization for cooling purposes, recirculation may be evident as far upstream as N-5, but is usually only visible upstream to Station N-1 (Appendix Figures B-5 and B-9). The plume typically flows across the river under low flow conditions, reaching the east bank at Stations S-1 to S-3, and disperses throughout the river width as it approaches Station S-4. Mixing with the ambient water is dependent on river ischarge and meteorological conditions. Generally, mixing increases as river discharge increases. Thus, under low flow conditions (<30 cms), stratification is often evident as far downstream as Station S-24 which is immediately upstream of Hooksett Dam (Appendix Figures B-3 and B-7). Under higher flow conditions, the plume mixes completely with the ambient water farther upstream (Appendix Figures B-13 to B-17). Water leaving the pond over Hooksett Dam is usually fully mixed, with a ΔT of 0.4 to 2.3°C from ambient (Figure 3-3). Part of this ΔT is attributable to insolation warming the river downstream of the discharge, although this contribution of solar radiation has not been quantified.

During 1975 an oil containment boom was used to test the potential for confining the thermal plume along the west bank. Thermal surveys after installation of the boom, indicated that water which would normally be found only on the surface was more thoroughly mixed with ambient water. This had the effect of increasing thermal mixing at depth and decreasing the zone of passage. It was concluded that the boom was not a successful method of containing the plume to the west bank.

Permit guidelines since 1975 have stated that Merrimack Station "...shall not at any time cause, directly or indirectly, the maximum temperature rise in the Merrimack River to exceed 5°F [2.8°C], or 1°F [0.6°C] when the ambient temperature of the river is 68°F [20.0°C] or higher, unless it can be demonstrated to the satisfaction of the New Hampshire Water Supply and Pollution Control Commission and the Environmental Protection Agency that greater rises at various times will not be harmful to fish, other aquatic life, or other uses. Cognizance will be given to reasonable time and distance to allow for mixing of the heated effluent and receiving waters." According to these criteria and based on weekly thermal monitoring at the mixing zone station (S-4), Merrimack Station exceeded operating guidelines intermittently during approximately 16 weeks per year from 1972 to 1978 (Table 3-3; Appendix Table B-1). These dates of non-attainment generally occurred during periods of low flow when ambient river temperature was greater than 20°C.

However, the chemical and biological portions of the monitoring program have consistently demonstrated that these temperature increases have not been "harmful to fish, other aquatic life, or other uses," even though the NPDES Permit thermal guidelines were exceeded during certain weeks. As will be indicated in later sections of this report, the dispersal of the thermal plume along the surface as well as the thermal tolerance of the aquatic communities are largely responsible for the absence of adverse temperature influences on the Hooksett Pond biota.

3.4 Conclusions

The addition of heat is the primary physical influence of Merrimack Station on Hooksett Pond. Modifications of the cooling water system during 1972 effectively decreased the mean temperature of the discharged cooling water by 4°C. Present levels of thermal addition to Hooksett Pond sometimes exceed the conditional guidelines established in 1975 for operation of Merrimack Station, but the chemical and biological portions of this monitoring program have consistently demonstrated that existing levels of thermal loading have not been harmful to fish or other aquatic life forms. Stratification of the thermal plume provides an ambient zone of passage throughout the mixing zone.

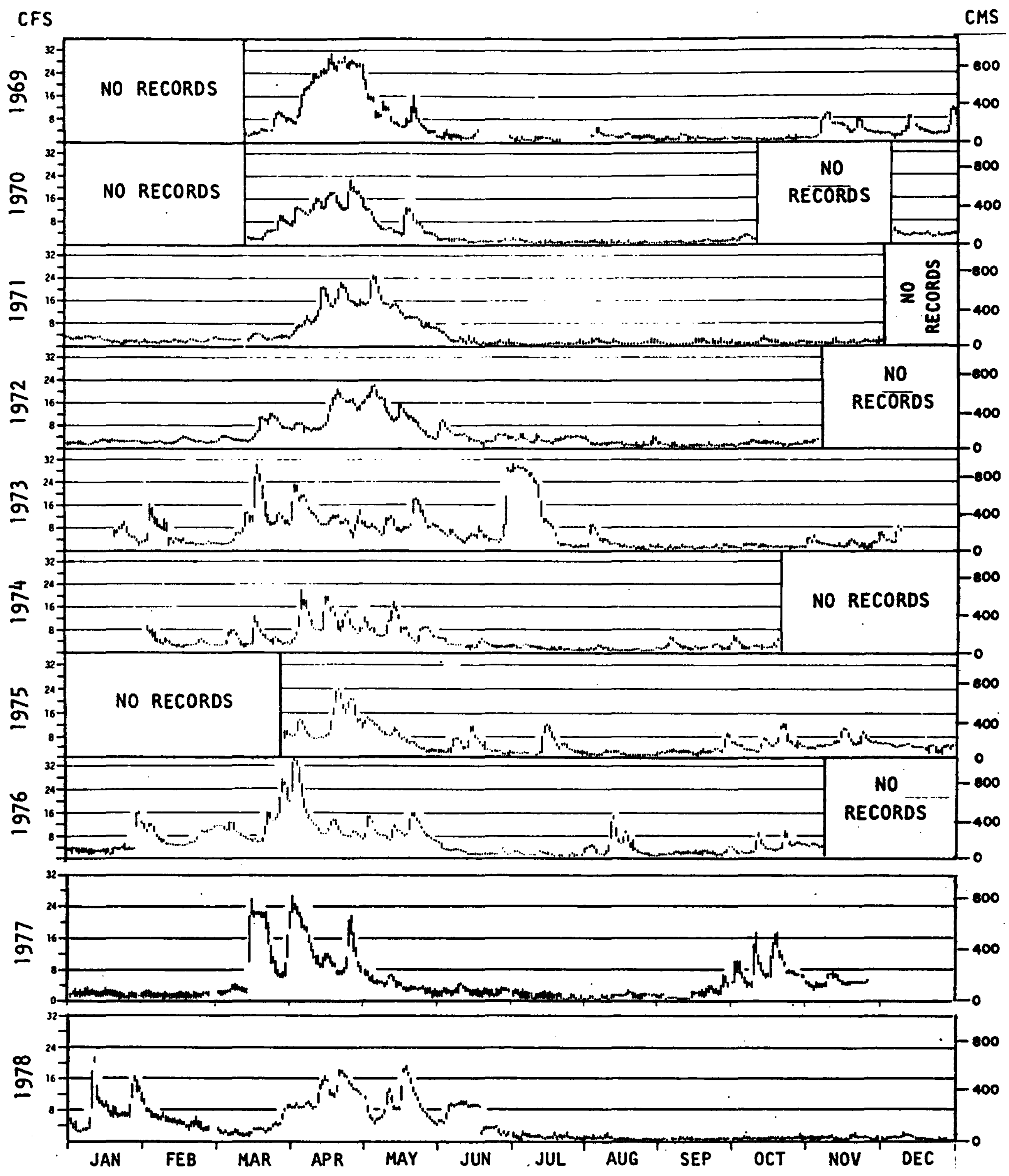


Figure 3-1. Range of daily Garvin's Falls discharge, 1969-1978. Discharge expressed as thousands of cubic feet per second (cfs) and cubic meters per second (cms). Merrimack River Summary Report, 1979.

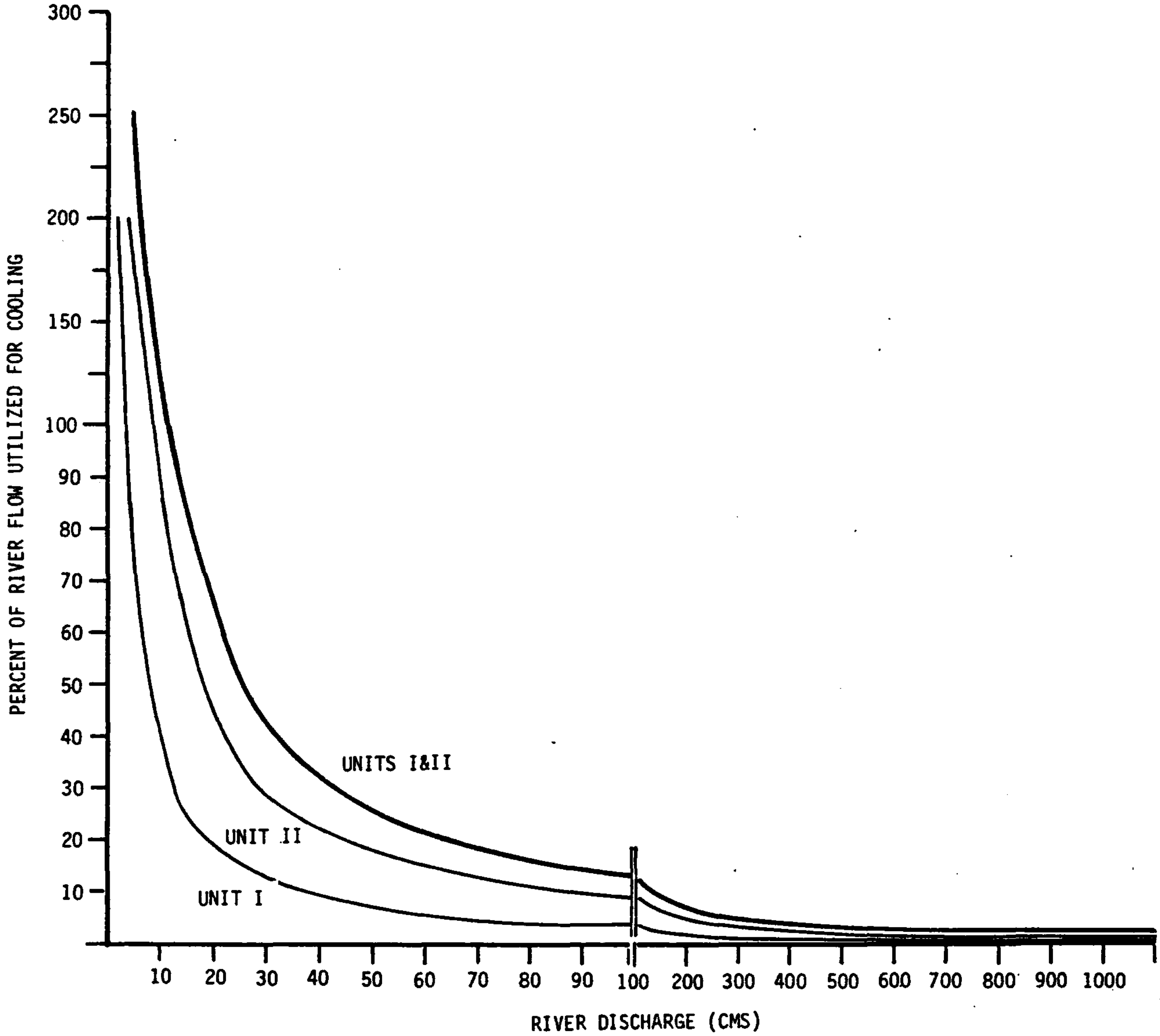


Figure 3-2. Percent of river discharge utilized for cooling water by Merrimack Generating Station. Merrimack River Summary Report, 1979.

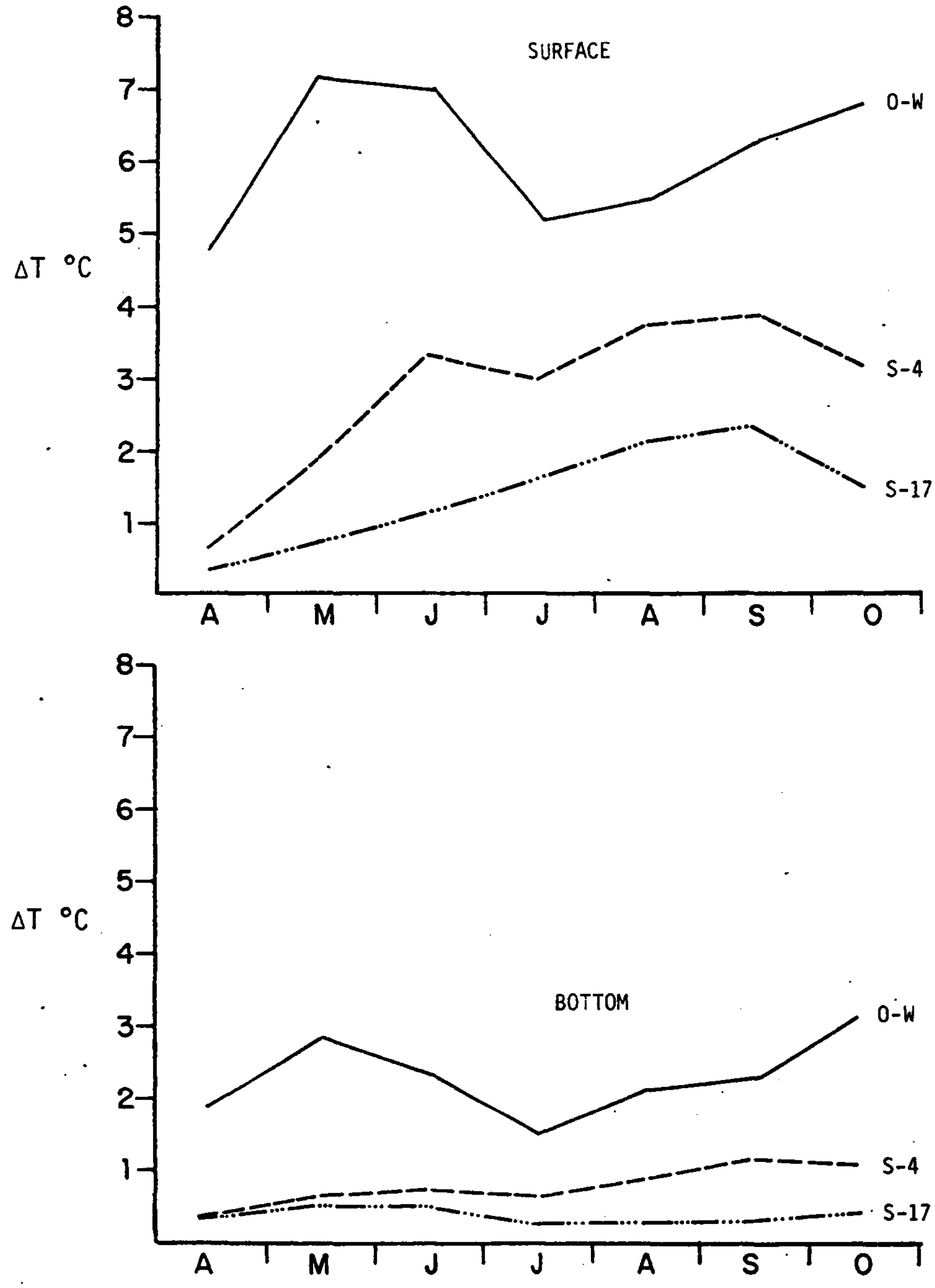


Figure 3-3. Mean monthly ΔT between N-10 and three monitoring stations, averaged over the years 1972 through 1978. Merrimack River Summary Report, 1979.

TABLE 3-1. MONTHLY MEANS AND RANGES OF TURBIDITY MEASUREMENTS (FTU) AT FOUR STATIONS, 1976-1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

		STATION							
		N-10		O-W		S-4		S-17	
MONTH	YEAR	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
April	1976	2.9	1.7-3.9	3.1	1.7-4.7	2.5	1.9-3.6	2.6	1.7-4.1
	1977	2.4	0.7-3.0	2.7	0.8-3.3	2.8	1.5-3.3	2.6	0.9-3.3
	1978	2.2	1.2-3.1	2.8	1.8-3.5	2.7	1.9-3.7	2.3	1.1-3.7
May	1976	2.4	0.9-3.6	2.3	0.9-3.3	2.3	1.0-3.3	2.7	1.1-4.3
	1977	0.8	0.5-0.9	1.0	0.8-1.3	0.9	0.6-1.3	0.8	0.4-1.2
	1978	2.2	1.2-3.8	2.3	1.6-3.4	1.9	1.3-2.7	2.0	1.4-3.0
June	1976	0.7	0.5-1.0	0.8	0.2-1.5	0.6	0.2-1.0	0.7	0.2-1.0
	1977	0.8	0.6-1.0	0.9	0.8-0.9	0.7	0.6-0.8	0.8	0.7-0.8
	1978	2.1	1.3-3.0	2.3	1.5-3.0	1.9	1.1-2.9	2.0	1.1-3.0
July	1976	0.9	0.6-1.3	0.8	0.6-1.3	1.5	0.4-4.0	1.5	0.5-4.1
	1977	0.4	0.3-0.7	0.5	0.5-0.5	0.4	0.3-0.6	0.4	0.3-0.5
	1978	0.8	0.6-1.1	1.1	0.8-1.2	0.9	0.5-1.4	0.8	0.5-1.0
August	1976	1.0	0.5-1.9	0.7	0.4-1.0	0.7	0.5-1.2	0.6	0.4-1.0
	1977	0.5	0.3-0.8	0.7	0.5-0.9	0.8	0.3-1.9	0.5	0.4-0.8
	1978	1.1	0.7-1.4	1.4	0.9-2.0	1.0	0.6-1.2	1.0	0.7-1.2
September	1976	1.1	0.5-2.5	1.1	0.5-2.5	0.8	0.4-1.5	0.8	0.5-1.5
	1977	0.8	0.5-1.3	1.0	0.3-1.6	0.8	0.3-1.8	1.0	0.7-1.3
	1978	1.0	0.7-1.2	1.1	0.8-1.3	0.8	0.6-1.0	0.8	0.6-0.9
October	1976	2.7	1.7-3.5	2.0	1.5-3.0	2.5	1.4-2.8	2.4	1.4-3.3
	1977	6.5	1.8-13.5	3.3	1.3-6.3	4.9	1.8-9.0	6.6	2.5-16.0
	1978	0.8	0.3-1.5	0.8	0.5-1.1	0.8	0.5-1.3	0.8	0.5-1.1

TABLE 3-2. MEAN MONTHLY AMBIENT-TO-DISCHARGE* ΔT FROM 1968 THROUGH 1971. MERRIMACK RIVER SUMMARY REPORT, 1979.

MONTH	1968	1969	1970	1971
April	NA	NA	20.4	9.4
May	NA	NA	13.2	11.5
June	9.9	NA	11.8	13.1
July	10.5	9.3	6.3	11.7
August	8.1	10.9	9.6	11.8
September	12.4	2.4	12.8	10.1
October	NA	0.8	12.5	8.1

*1969 Data adapted from continuous temperature monitoring at the discharge canal mouth, July 31 to October 8, 1969.

1970 ΔT measured between the river intake (N-5) and the discharge weir.

1968 and 1971 ΔT measured between ambient (N-10) and the discharge canal mouth.

NA - Data not available

TABLE 3-3. DATES ON WHICH THERMAL GUIDELINES WERE EXCEEDED ON THE SURFACE AT STATION S-4 DURING WEEKLY TEMPERATURE MONITORING, 1972 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

	1972	1973	1974	1975	1976	1977	1978
April	None	None	None	None	None	None	None
May	11, 22, 30	None	None	19	24	31	8, 15, 30
June	13, 19, 29	12, 18, 24	10, 17, 24	9, 16, 30	1, 14, 22, 28	6, 20, 27	19, 26
July	5, 10, 17, 24, 31	16, 24, 30	8, 15, 22, 29	8, 14, 21, 28	6, 12, 20, 26	5, 11, 25	17
August	7, 31	6, 13, 20, 28	5, 12, 19, 26	4, 11, 25	9, 17, 23, 31	1, 8, 15, 22	7, 14, 28
September	5, 14, 19, 27	4, 10, 18, 25	3, 9, 16	2, 10, 15, 22	20	6, 12, 19, 26	5
October	None	1, 10, 16	15, 21	20	4, 11, 18	None	9, 16, 23, 30

4.0 WATER QUALITY

New Hampshire water quality standards classify the Merrimack River from Concord, NH, to the Massachusetts border as "less than C"; high total coliform bacteria and low dissolved oxygen concentrations are quoted as responsible for non-attainment of the legislated Class B standards. At present, the 3.5 million gallons per day (MGD) untreated discharge from the city of Concord is the cause of the high bacteria concentrations and low dissolved oxygen content reported in river segment No. 24, Concord to Manchester (NHWSPCC, 1973; 1978). In addition, all surface waters of the Merrimack River basin are classified as effluent limited (EL), requiring secondary treatment of all wastewater discharges.

4.1 Nutrients

Nitrogen and phosphorus are two important elements in aquatic systems because of their role as plant nutrients. Potassium is also required for plant growth, but is not usually a limiting factor in natural waters (Hynes, 1970).

Inorganic nitrogen commonly exists as ammonium, nitrite, or nitrate. Nitrate is the form most readily available for utilization by aquatic plants, and the most abundant form in flowing, well-oxygenated waters. In natural waters, phosphorus is present primarily in two forms, inorganic soluble phosphorus (orthophosphate) and bound phosphate in soluble or particulate form. Orthophosphate generally comprises about 10% of the total, with 20% in dissolved form and 70% in organic particulate matter (Hutchinson, 1957; Wetzel, 1975). Dissolved organic phosphorus and orthophosphate are particularly important forms for plant utilization. Because bound phosphate is continuously released by bacterial action, fertility of rivers and streams is often measured in terms of total phosphate (Hynes, 1970).

The main sources of nitrate and phosphate in rivers are precipitation and surface runoff. During recent years phosphorus inputs have increased due to accelerated municipal, industrial and agricultural use and inefficient recovery. However, this input of nitrogen and phosphorus is offset by aquatic plant uptake which normally keeps the nutrient concentrations in the water column quite low. This nutrient cycling through the plant communities is fairly rapid, giving rise to seasonal variations in nutrient concentrations throughout the water column. As a result, nitrate nitrogen concentrations in north temperate rivers are usually highest during the spring when surface runoff is high and biological activity is low. These concentrations typically decrease through the summer as river flows decrease and biological activity increases. Nitrite is an intermediate product in the conversion of ammonia to nitrate, and unless there is an excess contribution of nitrogen into the system (e.g. municipal sewage), nitrite is generally not abundant in the water column. Total phosphorus is usually most abundant during periods of maximum surface runoff which increases the input from terrestrial sources. Orthophosphate concentrations are typically highest during the winter, and lowest during the summer when biological utilization is maximum. These four nutrients, nitrate and nitrite nitrogen, and total and orthophosphate phosphorus were monitored throughout Hooksett Pond weekly from April through October, 1967 to 1978.

Silica is another nutrient that is important to the primary productivity of aquatic habitats because of its utilization by diatoms which are dominant members of river phytoplankton communities. Inputs of silica from rainwater and surface runoff tend to be low (Edwards, 1973, 1974; Parker *et al.*, 1977a) and most silica utilized by the diatoms is recycled within the aquatic system. Silica concentrations tend to be lowest during the spring and fall diatom blooms when the silica is incorporated into diatom frustules (Parker *et al.*, 1977b). Silica concentrations in Hooksett Pond were monitored weekly from April through October during 1977 and 1978.

Nutrient concentrations in Hooksett Pond varied seasonally in the pattern typical of north temperate rivers. Nitrate concentrations tended to be elevated during the spring or early summer as the result of high river discharge and surface runoff (Table 4-1). Nitrite concentrations were uniformly low throughout the April to October sampling periods (Table 4-2). Total phosphate and orthophosphate concentrations were maximum during September or October (Tables 4-3 and 4-4), presumably due to the decay and input of terrestrial (leaf litter) and aquatic vegetation in conjunction with decreasing biological utilization. During the two year period that silica was monitored, concentrations were highest during October (Table 4-5), and would have been expected to reach a yearly maximum during the winter when biological uptake is minimal.

Nutrient concentrations from 1967 through 1970 contrast sharply with those observed from 1971 through 1978 (Figure 4-1). Nitrite, nitrate, orthophosphate, and total phosphate concentrations decreased by an order of magnitude from 1970 to 1971. Municipal and industrial pollution abatement activity in the upper Merrimack River basin prior to 1971 was most likely responsible for this decrease in Hooksett Pond nutrient concentrations. Nutrient concentrations were uniform from 1972 through 1978, although seasonal mean nitrate concentrations were unexplainably elevated during 1974 and 1975, and phosphate concentrations were high during 1975 (Figure 4-1). These concentrations were unformly elevated at all stations throughout Hooksett Pond (Tables 4-1 and 4-3).

Statistical analysis of nutrient concentrations upstream and downstream of Merrimack Station from 1976 through 1978 has shown that concentrations of nitrite, total phosphate, orthophosphate, and silica have not differed significantly throughout Hooksett Pond. During 1976 and 1978 this analysis did show nitrate concentrations to be higher downstream of the station, but this difference was the result of low interaction between sampling stations and weeks, and was not sufficiently large to be biologically meaningful (Table 4-1).

4.2 Dissolved Oxygen

Dissolved oxygen is required by most aquatic organisms for respiration, and any decreases in concentration below certain critical levels may be harmful to the resident life forms. Although dissolved oxygen is normally near or above saturation in flowing water, variations do occur as the result of physical, chemical and biological interactions. There is a tendency for oxygen concentrations to decrease during the day and increase at night because the solubility of oxygen varies inversely with temperature. However, this response to temperature is typically offset by photosynthesis and respiration of aquatic organisms so that oxygen concentrations are usually highest in the afternoon and lowest just before dawn. Daily variations as high as 10 mg/l have been observed in unpolluted waters (Owens and Edwards, 1964).

Oxygen concentrations in Hooksett Pond have been highest (typically 11 to 14 mg/l) during the spring and fall, and lowest during the summer (6 to 8 mg/l). Daily variation has been 1.5 to 2.5 mg/l with highest concentrations occurring during the afternoon and the lowest just before dawn.

Dissolved oxygen concentrations were lower during 1968 than during the 1972 to 1978 survey period (Table 4-6). Concentrations as low as 5.2 and 4.8 mg/l were recorded at the ambient and discharge canal stations, respectively, during 1968. From 1972 through 1978, oxygen concentrations ranged from 6.6 to 13.9 mg/l upstream of Merrimack Station, and from 5.5 to 13.6 mg/l at the discharge canal mouth. The oxygen content of the discharged cooling water was typically a few tenths to 1.8 mg/l less than in ambient river water; this difference is attributable to decreasing oxygen solubility with increasing water temperatures (Table 4-6). During some sampling periods both dissolved oxygen concentration and percent saturation were higher at the discharge canal than at the control station, N-10, probably as the result of aeration within the discharge canal by the power spray modules. At times, particularly during the autumn, the discharge water has been moderately supersaturated with oxygen; such temporary, moderate supersaturation is not harmful and has been observed in the discharge water at other generating stations (Adams, 1969; Jacobsen, 1976).

New Hampshire water quality standards for Class B waters require dissolved oxygen concentrations to be greater than 75% saturation and 6.0 mg/l for cold-water habitats unless naturally occurring (NHWSPCC, 1978). The US EPA (1976) and the National Technical Advisory Committee (NTAC, 1968) stipulate that a minimum dissolved oxygen concentration of 5.0 mg/l is necessary to maintain healthy fish populations. Hooksett Pond dissolved oxygen concentrations have consistently attained the federal standards since 1972, and only occasionally have decreased below the more stringent cold-water standards established by the State of New Hampshire. The lowest dissolved oxygen concentration observed within the Merrimack Station mixing zone (Station Zero to S-4) since 1972 was 4.3 mg/l. This concentration, recorded at Station S-4-E during the night of August 8, 1972, was temporary because the oxygen concentration at the same station four hours later was greater than 5.0 mg/l. In addition, this was the only oxygen concentration less than 5.0 mg/l observed in Hooksett Pond since 1971. Although the NHWSPCC (1978) has indicated that low dissolved oxygen concentrations are partially responsible for the non-attainment of the legal B classification for this river segment, dissolved oxygen concentrations measured in Hooksett Pond during this survey have rarely declined below Class B 6.0 mg/l and 75% saturation levels during the past seven years.

4.3 pH

The hydrogen ion concentration (pH) of Hooksett Pond ranged from 5.1 to 7.9 during the 1967 to 1978 monitoring period, although values between 6.0 and 7.0 have been typical. Lund (1971) recommended that waters in which aquatic life is to be maintained should have a pH between 6.0 and 9.0. The NHWSPCC (1978) has established "6.0 to 8.5 or as naturally occurs" as Class B water standards for pH. Hooksett Pond is normally within this range, although pH values less than 6.0 have been observed occasionally. There has been no indication that pH values have been influenced by the operation of Merrimack Station.

4.4 Conclusions

Hooksett Pond pH was normally within Class B water standards, and was uniform throughout the pond. Nutrient concentrations in Hooksett Pond declined sharply between 1970 and 1971, most likely as the result of pollution abatement activities in the upper Merrimack River basin. Present concentrations of nitrate and nitrite are within state and federal guidelines. Total phosphate phosphorus concentrations exceed New Hampshire Class B water quality standards, but are normally within levels recommended by federal guidelines for flowing waters. Hooksett Pond nutrient concentrations have not been altered by operation of Merrimack Generating Station.

Dissolved oxygen concentrations in Hooksett Pond have consistently attained federal standards (>5.0 mg/l) since 1972, and have rarely decreased below New Hampshire cold-water standards (6.0 mg/l; 75% saturation). Although the New Hampshire Water Supply and Pollution Control Commission has indicated that low oxygen concentrations have been partially responsible for non-attainment of Class B standards in this portion of the Merrimack River, this monitoring program has indicated only isolated incidents of substandard oxygen concentrations during the past seven years. Discharged cooling water from Merrimack Station has typically been 90 to 100% oxygen saturated, although absolute oxygen concentrations have been reduced as much as 1.8 mg/l compared to ambient because of decreased oxygen solubility at higher temperatures. These reduced oxygen concentrations have not been of sufficient magnitude to jeopardize the Hooksett Pond aquatic ecosystem.

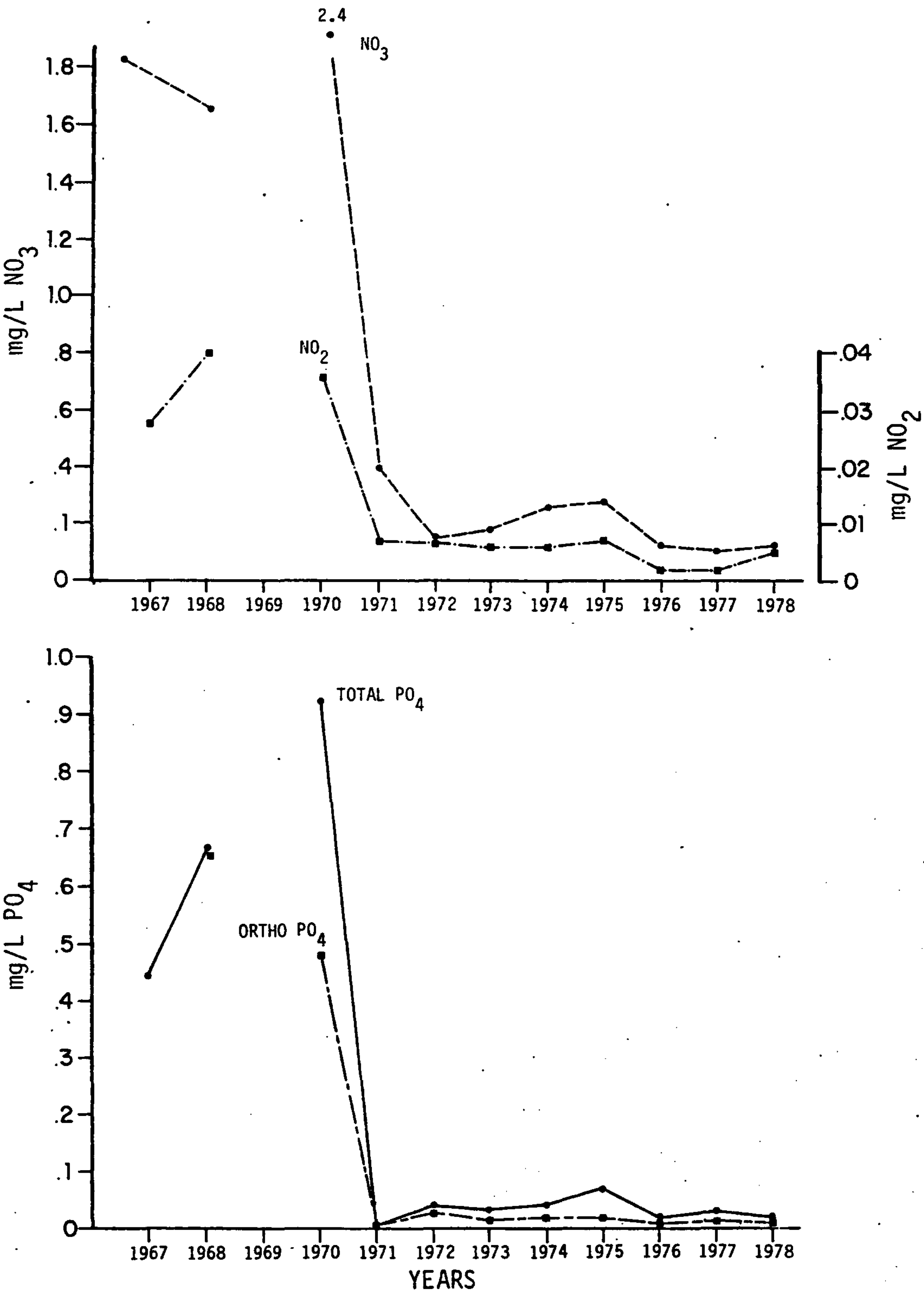


Figure 4-1. Seasonal mean nutrient concentrations at ambient Hooksett Pond locations. Merrimack River Summary Report, 1979.

TABLE 4-1. MEAN MONTHLY NITRATE CONCENTRATION (mg/l) AT FOUR STATIONS, 1973 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

		STATION			
MONTH	YEAR	N-10	O-W*	S-4	S-17*
April	1973	0.133	0.113	0.066	0.072
	1974	0.325	0.329	0.323	0.332
	1975	0.558	0.620	0.572	0.625
	1976	0.128	0.140	0.129	0.130
	1977	0.167	0.220	0.165	0.220
	1978	0.112	0.112	0.112	0.112
May	1973	0.113	0.122	0.119	0.098
	1974	0.308	0.289	0.322	0.332
	1975	0.346	0.305	0.324	0.291
	1976	0.125	0.120	0.125	0.125
	1977	0.128	0.140	0.126	0.140
	1978	0.142	0.140	0.142	0.142
June	1973	0.114	0.143	0.132	0.125
	1974	0.403	0.401	0.384	0.384
	1975	0.239	0.359	0.246	0.362
	1976	0.142	0.120	0.142	0.120
	1977	0.140	0.110	0.142	0.130
	1978	0.102	0.108	0.110	0.108
July	1973	0.112	0.085	0.119	0.118
	1974	0.296	0.317	0.320	0.317
	1975	0.184	0.180	0.186	0.157
	1976	0.165	0.185	0.183	0.190
	1977	0.080	0.130	0.025	0.150
	1978	0.140	0.140	0.150	0.150
August	1973	0.007	0.008	0.007	0.008
	1974	0.139	0.173	0.214	0.232
	1975	0.180	0.172	0.181	0.217
	1976	0.103	0.148	0.106	0.143
	1977	0.040	0.051	0.065	0.039
	1978	0.120	0.120	0.130	0.140
September	1973	0.008	0.009	0.008	0.006
	1974	0.187	0.155	0.171	0.162
	1975	0.162	0.171	0.163	0.175
	1976	0.126	0.078	0.126	0.078
	1977	0.108	0.070	0.108	0.080
	1978	0.090	0.100	0.100	0.110
October	1973	0.006	0.007	0.006	0.006
	1974	0.233	0.247	0.230	0.246
	1975	0.284	0.318	0.295	0.312
	1976	0.003	0.007	0.003	0.007
	1977	0.086	0.110	0.086	0.100
	1978	0.100	0.120	0.120	0.120

* one observation per month, 1975-1977; weekly observations otherwise

** monthly means of weekly samples, 1975.

TABLE 4-2. MEAN MONTHLY NITRITE CONCENTRATION (mg/l) AT FOUR STATIONS, 1973 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

MONTH	YEAR	STATION N-10	O-W*	S-4	S-17*
April	1973	.005	.004	.004	.004
	1974	.002	.002	.002	.002
	1975	.002	.002	.002	<.001
	1976	.001	.002	.001	.002
	1977	.001	.001	.001	.001
	1978	.001	.002	.001	.002
May	1973	.005	.004	.004	.004
	1974	.002	.003	.003	.002
	1975	.009	.005	.006	.004
	1976	.002	.002	.001	.001
	1977	.001	<.001	.001	<.001
	1978	<.001	.001	<.001	<.001
June	1973	.007	.007	.007	.007
	1974	.004	.004	.004	.004
	1975	.008	.010	.008	.010
	1976	.001	.001	.001	.001
	1977	.005	.002	.004	.002
	1978	.002	.002	.002	.002
July	1973	.006	.007	.004	.007
	1974	.007	.007	.007	.007
	1975	.009	.011	.008	.009
	1976	.002	.001	.002	.002
	1977	.003	.001	.003	.001
	1978	.005	.005	.005	.005
August	1973	.007	.008	.007	.007
	1974	.010	.011	.012	.011
	1975	.007	.008	.009	.007
	1976	.001	.002	.002	.002
	1977	.002	.006	.002	.006
	1978	.009	.008	.010	.010
September	1973	.008	.009	.008	.006
	1974	.010	.010	.009	.010
	1975	.007	.009	.007	.008
	1976	.001	.002	.001	.001
	1977	.002	.002	.002	.002
	1978	.010	.011	.012	.012
October	1973	.006	.007	.006	.006
	1974	.006	.008	.007	.007
	1975	.006	.004	.005	.004
	1976	.003	.007	.003	.007
	1977	.001	.003	.001	.002
	1978	.006	.007	.006	.006

*one observation per month, 1975-1977; weekly observations otherwise

TABLE 4-3. MEAN MONTHLY TOTAL PHOSPHATE CONCENTRATION (mg/l) AT FOUR STATIONS, 1973 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

		STATION			
MONTH	YEAR	N-10	O-W*	S-4	S-17*
April	1973	.011	.008	.004	.005
	1974	---	---	---	---
	1975	.091	.088	.087	.100
	1976	.021	.177	.034	.015
	1977	.013	.016	.017	.015
	1978	<.005	.006	<.005	.007
May	1973	.014	.017	.016	.016
	1974	.032	.044	.037	.032
	1975	.087	.087	.084	.081
	1976	.023	.033	.034	.027
	1977	.014	.029	.017	.010
	1978	.015	.010	.011	.014
June	1973	.023	.022	.021	.023
	1974	.056	.033	.052	.032
	1975	.083	.085	.083	.090
	1976	.018	.010	.023	.010
	1977	.024	.013	.025	.013
	1978	.022	.022	.018	.020
July	1973	.032	.032	.033	.031
	1974	.037	.031	.039	.054
	1975	.036	.055	.038	.047
	1976	.021	.018	.023	.021
	1977	.023	.014	.021	.016
	1978	.012	.016	.015	.014
August	1973	.048	.040	.038	.039
	1974	.021	.020	.018	.018
	1975	.058	.061	.059	.033
	1976	.024	.024	.021	.025
	1977	.022	.028	.028	.024
	1978	.022	.019	.020	.026
September	1973	.046	.043	.043	.045
	1974	.046	.052	.050	.067
	1975	.058	.085	.062	.079
	1976	.024	.027	.021	.026
	1977	.019	.018	.019	.020
	1978	.029	.030	.029	.031
October	1973	.066	.060	.056	.056
	1974	.060	.058	.058	.053
	1975	.071	.073	.077	.223
	1976	.021	.018	.017	.025
	1977	.070	.051	.053	.125
	1978	.025	.028	.024	.027

--- difficulties in laboratory analyses; questionable data eliminated

* one observation per month, 1975-1977; weekly observations otherwise

TABLE 4-4. MEAN MONTHLY ORTHOPHOSPHATE CONCENTRATION (mg/l) AT FOUR STATIONS, 1973 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

		STATION			
MONTH	YEAR	N-10	O-W*	S-4	S-17*
April	1973	.004	.004	.004	.004
	1974	---	---	---	---
	1975	.004	.007	.003	.011
	1976	.003	.002	.003	.003
	1977	.008	.012	.008	.012
	1978	.004	.008	.004	.004
May	1973	.006	.007	.008	.010
	1974	.006	.009	.008	.006
	1975	.012	.000	.023	.000
	1976	.005	.006	.004	.006
	1977	.005	.006	.006	.005
	1978	.004	.004	.004	.004
June	1973	.012	.013	.012	.013
	1974	.014	.016	.028	.014
	1975	.036	.039	.020	.036
	1976	.006	.006	.007	.004
	1977	.010	.004	.010	.005
	1978	.005	.007	.006	.006
July	1973	.014	.015	.016	.017
	1974	.026	.022	.030	.042
	1975	.012	.016	.015	.015
	1976	.007	.006	.009	.005
	1977	.008	.004	.006	.004
	1978	.007	.006	.006	.007
August	1973	.016	.016	.015	.014
	1974	.015	.020	.018	.016
	1975	.023	.016	.030	.011
	1976	.007	.005	.007	.007
	1977	.009	.006	.009	.005
	1978	.009	.008	.007	.011
September	1973	.021	.013	.016	.016
	1974	.033	.035	.028	.043
	1975	.025	.028	.022	.021
	1976	.008	.006	.008	.006
	1977	.013	.010	.012	.012
	1978	.015	.014	.016	.016
October	1973	.042	.038	.039	.038
	1974	.038	.035	.036	.030
	1975	.016	.027	.025	.191
	1976	.010	.011	.009	.018
	1977	.037	.048	.040	.041
	1978	.009	.012	.009	.013

*one observation per month, 1975-1977; weekly observations otherwise
---difficulties in laboratory analyses; questionable data eliminated

TABLE 4-5. MEAN MONTHLY SILICA CONCENTRATION (mg/l) AT FOUR STATIONS, 1977 AND 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

MONTH	YEAR	STATION N-10	O-W*	S-4	S-17*
April	1977	NA	NA	NA	NA
	1978	5.35	5.45	5.35	5.35
May	1977	4.58	5.49	5.42	5.49
	1978	4.88	4.86	4.84	4.86
June	1977	5.35	2.30	5.38	0.90
	1978	5.50	5.58	5.55	5.53
July	1977	4.28	4.70	4.03	4.60
	1978	5.10	5.30	5.20	5.20
August	1977	3.55	4.40	3.61	4.40
	1978	4.00	4.00	4.00	4.00
September	1977	4.20	3.10	4.40	3.00
	1978	3.60	3.40	3.40	3.40
October	1977	5.38	5.60	5.36	6.00
	1978	6.80	6.80	6.80	6.70

*one observation per month during 1977; weekly observations during 1978

NA - not analyzed

TABLE 4-6. SEASONAL MEANS AND RANGES OF SURFACE DISSOLVED OXYGEN CONCENTRATIONS (mg/l) AND PERCENT SATURATION MONITORED WEEKLY FROM APRIL THROUGH OCTOBER, 1968 AND 1971-1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

		N-10-M		O-W†		S-4-M		S-17-M	
		MEAN	RANGE	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
1968*	DO	7.4	5.2- 10.6	6.6	4.8- 9.0	NA	NA	7.2	5.4- 10.6
	%Sat	83.4	58.0-103.0	89.7	67.0-118.0	NA	NA	79.3	57.0-108.0
1971	DO	10.0	6.4- 14.8	8.4	6.0- 12.0	9.2	5.3- 13.6	9.3	6.9- 12.8
	%Sat	94.6	67.4-123.6	101.7	74.7-120.9	99.0	59.5-115.8	97.9	71.5-129.3
1972	DO	9.9	8.0- 13.7	9.1	7.2- 13.0	9.4	7.3- 13.7	9.6	7.6- 13.3
	%Sat	97.4	83.8-112.6	100.2	87.5-124.0	97.8	88.2-111.2	97.3	84.1-110.3
1973	DO	9.2	6.8- 13.3	8.6	5.5- 11.5	9.0	6.2- 13.0	9.2	6.5- 12.3
	%Sat	92.2	77.9-104.7	94.4	72.4-105.3	93.7	75.6-106.3	94.1	72.0-114.1
1974	DO	9.5	6.7- 13.8	8.7	6.7- 13.6	9.3	7.1- 13.1	8.9	6.8- 13.6
	%Sat	92.4	77.4-105.9	95.6	80.7-116.0	95.6	85.2-112.2	94.5	78.8-114.5
1975	DO	9.8	7.3- 13.8	8.8	6.6- 12.4	9.6	7.1- 13.5	9.9	7.3- 14.1
	%Sat	96.1	85.1-112.0	91.3	76.2-119.1	93.9	88.3-116.2	100.1	89.0-118.7
1976	DO	10.1	7.3- 13.4	8.8	6.6- 12.8	9.8	7.0- 13.3	9.3	7.0- 14.1
	%Sat	94.1	81.3-107.1	92.6	82.1-105.1	95.9	87.4-108.5	91.4	81.7-108.2
1977	DO	9.6	6.7- 13.2	8.4	7.1- 13.2	9.3	7.0- 13.3	9.4	7.2- 13.2
	%Sat	95.5	81.5-102.6	97.8	91.1-105.6	97.3	85.0-106.4	93.3	86.2-108.3
1978	DO	9.3	6.6- 13.9	9.4	7.6- 13.5	9.6	6.7- 14.5	9.4	5.5- 14.5
	%Sat	95.1	74.8-118.8	103.3	78.5-138.2	98.3	80.3-125.2	94.7	62.8-130.1

*Average June through September

†1975 and 1976 data from midstream

5.0 PLANKTON

5.1 Phytoplankton

5.1.1 Indigenous Periphyton Communities

Periphyton communities usually comprise major biological assemblages in temperate rivers and streams and are frequently responsible for a large portion of the primary productivity that occurs in these flowing water habitats. Three major taxonomic groups usually dominate these periphytic communities: (1) diatoms (Bacillariophyceae), (2) green and yellow-green algae (Chlorophyta and Xanthophyceae), and (3) blue-green algae (Cyanophyta). Species from each of these phytoplankton divisions are usually present although relative group abundances vary with light intensity, current velocity, temperature and water quality (Whitton, 1975).

Periphyton are excellent test organisms for monitoring both short and long-term changes in a river's water quality because they are sessile. Shifts in species or division dominance, as well as changes in standing crop and productivity, reflect adjustments in the community structure to new environmental conditions (Collins and Weber, 1978).

Diatoms and green algae dominated the Hooksett Pond periphyton communities throughout the monitoring program. Sporadic colonizations by both blue-green and golden-brown algae were also observed each year.

Hooksett Pond periphyton assemblages have exhibited a seasonal succession pattern typical of most temperate rivers (Appendix Figure C-1) (Whitton, 1975; Hynes, 1970). Diatoms dominated both the spring and fall communities, while green algae, with the exception of several cool-water species, have been restricted to the summer months. Both blue-green and golden-brown algae have exhibited sporadic vernal and autumnal occurrences. Diatoms require cool water temperatures and moderate to high current velocities which are found in the spring and fall, while most green algae respond favorably only to warm summer water temperatures, low flow conditions, and high light intensities. Blue-green algae assemblages usually reflect increased water temperatures, reduced water currents or introduction via terrestrial runoff (Hynes, 1970; Smith, 1950).

Periphyton densities in Hooksett Pond were not significantly affected by the operation of Merrimack Station from 1971 through 1978. (Table 5-1). Diatom abundance was significantly reduced within the mixing zone (Stations 0-W and S-4) from 1973 to 1975, but not at the far-field station (S-17), indicating downstream recovery. Diatom abundance did not differ significantly among river stations throughout the remaining study years. Similarly, green algae densities did not vary significantly among river stations during any sampling season. However, green algae often accounted for a higher portion of the discharge canal community than the river communities. Blue-green algae typically contributed a higher percentage of the periphyton community within the discharge canal and in the mixing zone than at ambient or far-field locations. This is most likely the result of their affinity for higher temperatures than diatoms or green algae.

The absence of long-term changes in the Hooksett Pond periphyton community is most likely the result of minimal water temperature increases from ambient to far-field stations (Figure 3-3). As the water temperature exceeds the optimal range for a given organism, that species cannot successfully compete with other periphyton species, and is reduced in abundance. When water temperatures again become optimal for that organism, it competes successfully and becomes re-established (Patrick, 1971; Cairns, 1956). In Hooksett Pond, increased diatom density and increased green algae abundance within the discharge canal were temporary responses to elevated temperatures. Other periphyton studies have indicated similar patterns of temporary species reductions and downstream recovery at the far-field stations where water temperatures were similar to ambient (Trembly, 1960, 1965; Patrick, 1954).

affected at the discharge canal during 1976 and 1978; however, mixing zone concentrations indicated full recovery and were comparable to those found in the ambient waters.

Eudorina, *Pediastrum*, *Spirogyra*, and *Desmidium* constituted the major green algae genera found within Hooksett Pond. These genera were commonly observed through the summer and early fall; maximum green algae densities usually corresponded to peak chlorophyll *a* concentrations (Appendix Table C-2). Colonial forms, *Eudorina* and *Pediastrum* were present from early summer through early fall, while the dominant filamentous forms, *Spirogyra* and *Desmidium* were observed sporadically throughout the summer (Figure 5-2).

No consistent among-station changes in green algae abundances were observed throughout the monitoring study (Table 5-1). In 1978, green algae abundance was reduced at the discharge canal compared to the remaining river stations. This was most likely related to high *Oscillatoria* concentrations within the canal successfully out-competing the green algae species. Similarly, *Eudorina* and *Desmidium* abundances did not vary appreciably among stations, although both *Pediastrum* and *Spirogyra* formed a slightly higher percentage of the discharge canal community. Changes in the abundance of green algae among stations were not significant in 1974, 1975 and 1976, although significant reductions were observed at the far-field station during 1977 and 1978. However, these reductions were not evident for any of the major green algae genera (Figure 5-2).

Oscillatoria and *Dinobryon* were the most common blue-green and golden-brown algal genera observed in Hooksett Pond. *Oscillatoria* is a ubiquitous bluegreen alga associated with high temperatures and is usually introduced into an aquatic system through terrestrial runoff. *Dinobryon*, like most freshwater golden-brown algae, is restricted to cool seasons, and was a sporadic member of the Hooksett Pond community (Figure 5-3).

Blue-green algae abundance and contribution to the total phytoplankton community were significantly higher at the thermally-influenced stations during most of the study years (1973, 1974, 1975 and 1976). These years corresponded, for the most part, to periods of high discharge canal and mixing zone water temperatures. No blue-green algal changes were observed in either 1977 or 1978. Similarly, *Oscillatoria* concentrations were highest at the discharge canal and at the immediate downstream stations during 1975 and 1976, but not 1977 or 1978 (Figure 5-3).

Golden-brown algae apparently were not collected prior to 1975. Cell densities were reduced at the discharge canal compared to the ambient and far-field stations in 1976 and 1977, respectively. These reductions are most likely indicative of increased water temperatures in the canal. However, *Dinobryon*, the predominant golden-brown alga, did not exhibit similar changes (Figure 5-3). No significant among-station changes were evident during 1975 or 1978.

Overall Hooksett Pond net phytoplankton densities have fluctuated throughout the study years from 1,800 to 50,000 cells/liter (Table 5-2). These yearly density fluctuations were found both upstream and downstream from the generating station. Highest values were observed in 1971, 1975 and 1976 with lowest abundances in 1977 and 1978. However, chlorophyll *a* concentrations did not confirm this decrease in standing crop during 1977 and 1978. These yearly fluctuations most likely reflect overall changing river conditions, such as flooding, drought and reduction of available nutrients through elimination of point and non-point pollution sources. There is no evidence that these fluctuations in abundance are in response to any Merrimack Generating Station activity because they occurred both upstream and downstream of the station.

Relative changes in phytoplankton standing crop were also assessed by measuring changes in chlorophyll *a* concentrations. Chlorophyll *a* concentrations correlated well with seasonal succession patterns found in the net phytoplankton communities throughout the study. Peak concentrations consistently corresponded to summer green algae pulses, whereas seasonal low concentrations corresponded to spring and fall diatom abundance (Appendix Table C-2).

Throughout the study period, chlorophyll *a* concentrations were significantly reduced at the discharge canal compared to ambient and far-field concentrations. Similar chlorophyll *a* concentrations at both ambient and far-field stations suggest that the phytoplankton standing crop recovered downstream of the discharge canal mouth. Decreased phytoplankton standing crop at the discharge canal, as estimated by chlorophyll *a* concentrations, confirms the observation that periphyton and phytoplankton densities are often lower within the mixing zone than in ambient regions. However, recovery of these primary producers downstream of the mixing zone has been indicated by periphyton, net phytoplankton, and chlorophyll *a* studies. Therefore, any effects of Merrimack Station on the primary producers of Hooksett Pond appear to be temporary and limited to near-field regions.

5.1.3 Phytoplankton Entrainment

Entrainment studies were developed to assess the potential impacts of entrainment through the cooling system of the Merrimack Generating Station on the plankton communities. Potential impacts considered were cellular damage and destruction from mechanical forces, pressure changes, and elevated condenser temperatures as well as long-term effects including adverse changes in composition of the river's phytoplankton community.

Qualitative net studies were instituted during 1975 and 1976 to assess the mortality of entrained phytoplankton communities between the river and the discharge canal. Diatoms and green algae exhibited significantly higher mortalities within the discharge canal than at the intake structures during both years. In addition, these mortalities were higher at the discharge weir than at the discharge canal mouth, indicating recovery within the canal. In 1975, diatom mortality was correlated with the combined effects of ambient water temperature and plant-induced temperature changes. A similar mortality/temperature interdependence was not observed in 1976, suggesting that either mechanical or chemical stresses were significant mortality factors.

Green algae mortality was not significantly related to water temperatures in 1975. However, in 1976, green algae mortality correlated with plant-induced ΔT's, with indications of a possible synergistic relationship between ambient temperature and ΔT.

Quantitative whole water/net studies were instituted in 1977 to more accurately assess mortality at the Merrimack Station circulators and condensers. These changes in the sampling design were initiated (1) to assess specific station-induced mortality as it relates to each phytoplankton division and dominant genera and (2) to sample only entrained waters.

Diatom mortality was significantly higher at the condensers than at the circulators or the intake structures in 1977. The magnitude of condenser mortality varied seasonally, with highest mortalities occurring during the late spring and mid-summer. Diatom mortalities at the condensers were associated with high condenser temperatures, although this was not proven statistically. There was no evidence of any circulator-induced diatom mortality. However, studies of individual genera during 1978 suggested a possible correlation between physical form and circulator-induced mortality. These data implied that genera with minimal surface areas, such as *Asterionella* and *Melosira* are less susceptible to mechanical damage than a genus with greater surface area, such as *Tabellaria*.

Green algae mortality was minimal during 1977. Low condenser mortalities occurred during periods of peak ambient and condenser temperatures, suggesting minimal thermal damage to this division. Similarly, there was no evidence of any circulator-induced mortality. Green algae mortality, when present in 1978, was not correlated with either thermal or mechanical effects. Genera enclosed in gelatinous sheaths, such as *Sphaeocystis*, appeared to be less susceptible to either mechanical or thermal damage than those such as *Eudorina* which have protruding flagella.

Studies comparing phytoplankton survival with ambient temperatures and entrainment ΔT's (Gurtz & Weiss, 1974; Morgan & Stross, 1969) have reported various temperatures at which phytoplankton stimulation and inhibition occur, indicating the site-specific nature of most entrainment studies. In general, thermal discharges can alter the successional patterns within the receiving water body, especially if the thermal limits of the resident species are exceeded. A general literature summary of entrainment studies (Patrick, 1969) concluded that phytoplankton mortality is most severe if (1) the experienced ΔT is large, (2) the exposure to these high temperatures is continued for several hours, and (3) the increased water temperature approaches the upper thermal tolerance limits for either major phytoplankton species or divisions. Storr (1974) concluded that mechanical stress can also contribute to entrainment mortality.

A more-complete assessment of entrainment impacts on the phytoplankton community can be obtained by comparing seasonal mortality with the percent of river water entrained during that season. Seasonal river discharge and a summary of generating units operation were computed for 1975 through 1978 (Table 5-3). Peak flow conditions were found in the spring, with an average seasonal discharge of 294 cms. Diatoms, the dominant phytoplankton division in vernal waters, experienced varying degrees of mortality due to both mechanical and thermal effects. However, even under peak generating conditions, minimal impact to the river community is expected during the spring because only 4 to 13% of the river water is actually entrained through the Merrimack Station (Figure 3-2). This premise is further supported by the absence of long-term diatom reductions observed within the mixing zone and far-field communities.

River discharge was minimal during the summer, averaging 21.5 to 168.1 cms. Green algae exhibited low entrainment mortalities throughout the summer, even when ambient and condenser temperatures were highest. These results suggest minimal entrainment impact to the summer green algae community, even though 31% of the available river volume may be utilized for cooling purposes. The minimal entrainment impacts suggested are confirmed by the rarity of long-term community reductions at the downstream monitoring stations.

Autumnal flow values were erratic ranging from 20.8 to 146.8 cms, depending primarily on the amount of rainfall. Diatoms were the primary phytoplanktonic organisms found during autumn. When river discharge remains low and both units are operating, moderate to heavy impact could be expected since up to 63% of the available river volume may be entrained. Thus, some short-term diatom mortality is expected under these conditions. However, monitoring of the river diatom communities has indicated few far-field reductions in diatom abundance.

Morgan and Stross (1969) found that phytoplankton populations become re-established and continue normal rates of primary production within several hours after passage through the generating station cooling system. Other studies have determined that most freshwater phytoplankton species can, under favorable flow and nutrient conditions, undergo one to three cell divisions per day, thereby quickly negating any reduction in cell numbers (Talling, 1962). This high reproductive rate imparts a certain resilience to phytoplankton populations, enabling them to recover quickly from short-term impacts. This resilience may be largely responsible for the recovery of phytoplankton densities downstream of the Hooksett Pond mixing zone.

5.1.4 Conclusions

Studies of periphyton, net phytoplankton, and standing crop of primary producers as estimated by chlorophyll *a* concentrations have indicated short-term reductions in abundance of primary producers in the near-field regions. However, reductions in the far-field regions are rare in occurrence, and temporary. Maximum impact appears to coincide with low flows and maximum thermal output during the autumn when diatoms dominate the plankton communities. Overall, there have been no long-term reductions in autotrophic production within Hooksett Pond that can be attributed to the operation of Merrimack Generating Station.

5.2 Zooplankton

5.2.1 Net Zooplankton Communities

Zooplankton communities are usually considered to be transient members of a river system, although these primary consumers can comprise an integral part of the total river biota (Whitton, 1975). The most frequently encountered zooplanktonic organisms are rotifers; micro-crustacean cladocerans and copepods are also common, but are usually of lower abundance. Development of these organisms is most pronounced within the slower portions of the river; conversely, both zooplankton diversity and abundance are characteristically reduced within the swiftly-flowing river sections.

Many environmental factors can affect zooplankton productivity in a river. Season, light intensity, water temperature, and nutrient concentrations influence zooplankton by regulating the growth of the phytoplankton community which is their primary food source. Fluctuations in zooplankton abundance can be directly related to variations in phytoplankton density, with peak zooplankton concentrations usually lagging maximum phytoplankton abundance (Whitton, 1975; Reid, 1961). Similarly, changes in aquatic macrophyte composition and abundance within a river may also alter zooplantkon abundance. Chandler (1937; cited in Whitton, 1975) and Hynes (1970) have reported that most of a riverine zooplankton community, especially organisms possessing long spines, can be filtered from the water column by only 20 linear meters of aquatic vegetation. Rotifer densities seem to be inversely related to rainfall; during periods of heavy precipitation, most of these organisms are swept from the river system. The populations become re-established rapidly after the water level subsides and a stable primary producing community again becomes established (Whitton, 1975).

Total zooplankton abundance decreased from 1972 through 1978 (Table 5-4), but this change was not related to the operation of Merrimack Generating Station since the densities declined upstream and downstream of the station.

Observed changes within the Hooksett Pond zooplankton community were minimal from 1972 through 1974. Rotifers, cilliophorans, and copepods dominated the zooplankton community, with greatest densities occurring during the late summer and early autumn (Table 5-4). The lack of consistent changes in either density or community structure, from the ambient to far-field stations, indicates no permanent changes in the zooplankton community downstream of the Merrimack Station. Among-station differences in the zooplankton community structure were more evident in 1975 and 1976. In 1975, densities were greater at the discharge canal than in ambient regions. Conversely, zooplankton densities were greater at the ambient station than at the far-field station in 1976. No among-station differences were noted in 1977 or 1978. Copepod nauplii and rotifers, primarily *Lecane, Trichocera, Polyartha,* and *Kellicottia* were the dominant zooplankton observed throughout these latter study years. Again, the lack of consistent among-station changes in either zooplankton density or community structure throughout Hooksett Pond, suggests no long-term zooplankton changes attributable to operation of Merrimack Station.

5.2.2 Zooplankton Entrainment

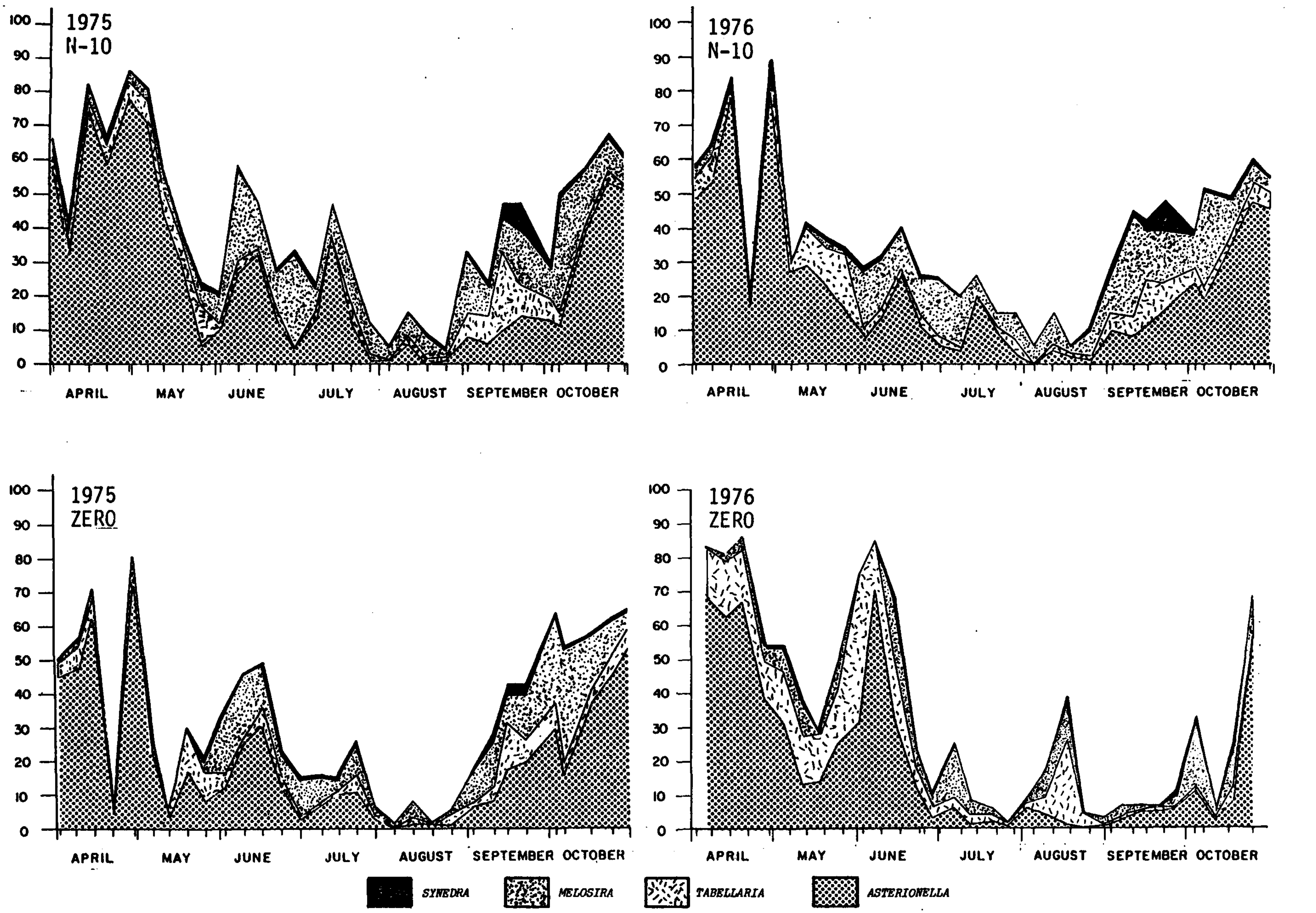
Zooplankton entrainment studies were instituted in 1975 to assess the potential impacts of entrainment through the cooling system of the Merrimack Generating Station. No significant among-station changes were evident in 1975; however, in 1976, mortalities were significantly higher at the discharge weir and canal than in the river. These effects did not correlate with either high ambient or condenser temperatures. Entrainment studies during 1977 and 1978 were redesigned (1) to assess specific station-induced mortality as it relates to both major zooplankton groups and dominant genera, and (2) to sample only entrained water. *Lecane, Trichocera, Polyartha, Kellicottia* and copepod nauplii were the predominant zooplankton observed. However, overall low zooplankton densities within the entrained water (1 organism/liter) precluded any statistical analyses or mortality estimates.

Studies comparing zooplankton survival with both ambient temperatures and condenser temperatures have established varying lethal temperatures (30-35°C) for 100% zooplankton entrainment mortality, indicating the site-specific nature of most entrainment studies (Massengill, 1976b; Davis and Jensen, 1975; and Storr, 1975). Zooplankton entrained in the Merrimack Station cooling system would typically be exposed to temperatures above 35°C during the summer. However, the absence of long-term reductions of zooplankton abundance within the mixing zone and downstream reaches suggests no permanent changes in the Hooksett Pond zooplankton community due to Merrimack Station operation.

5.2.3 Conclusions

The lack of among-station differences in the net zooplankton communities, coupled with apparent minimal entrainment mortality, in terms of the numbers of organisms entrained, suggests no reduction or adverse change in the Hooksett Pond zooplankton community due to the operation of the Merrimack Generating Station.

Figure 5-1. Percent composition of the diatoms, *Asterionella* sp., *Tabellaria* sp., *Melosira* sp. and *Synedra* sp. in net phytoplankton samples at four surface monitoring stations, 1975 through 1978. Merrimack River Summary Report, 1979.



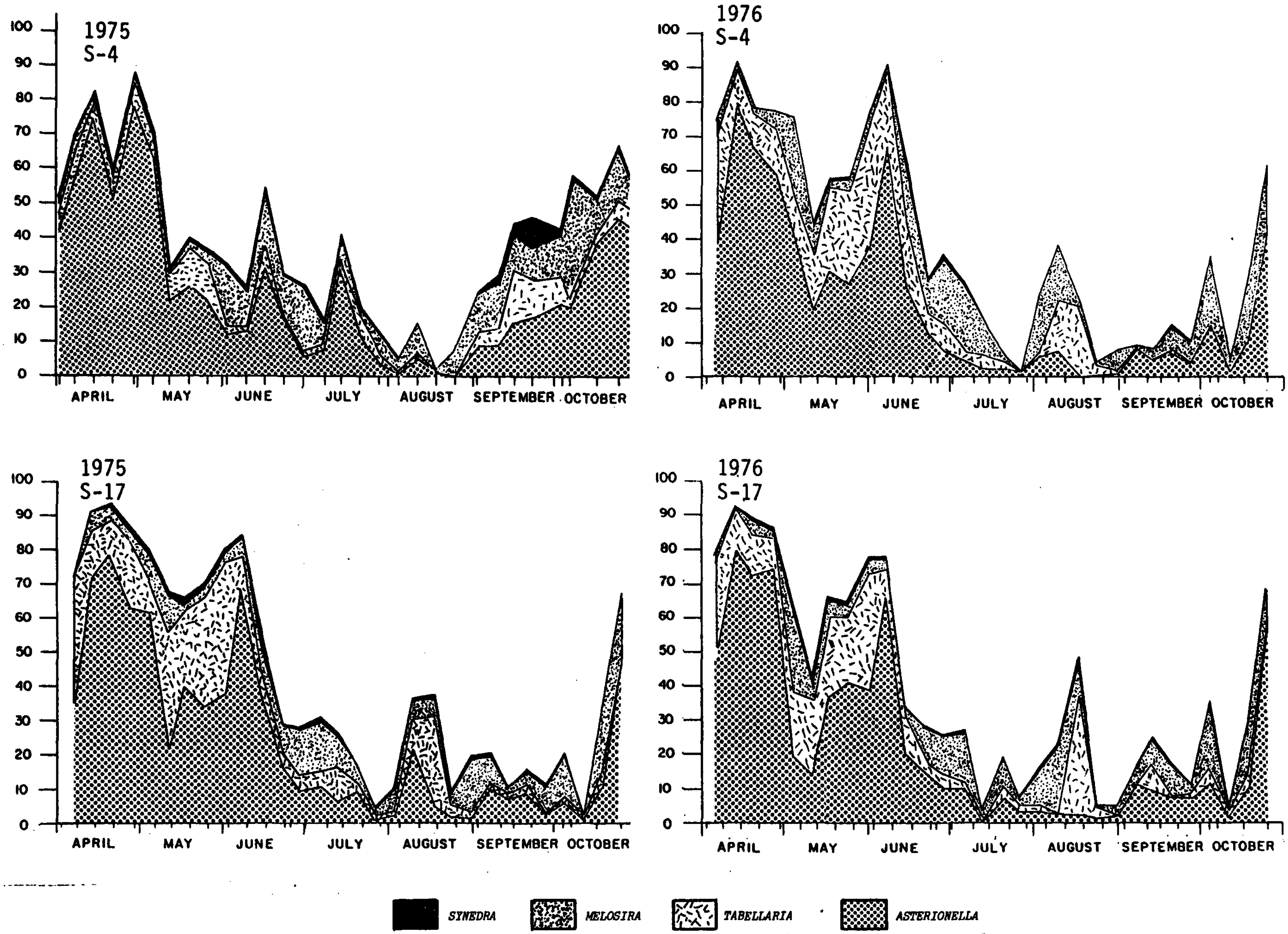
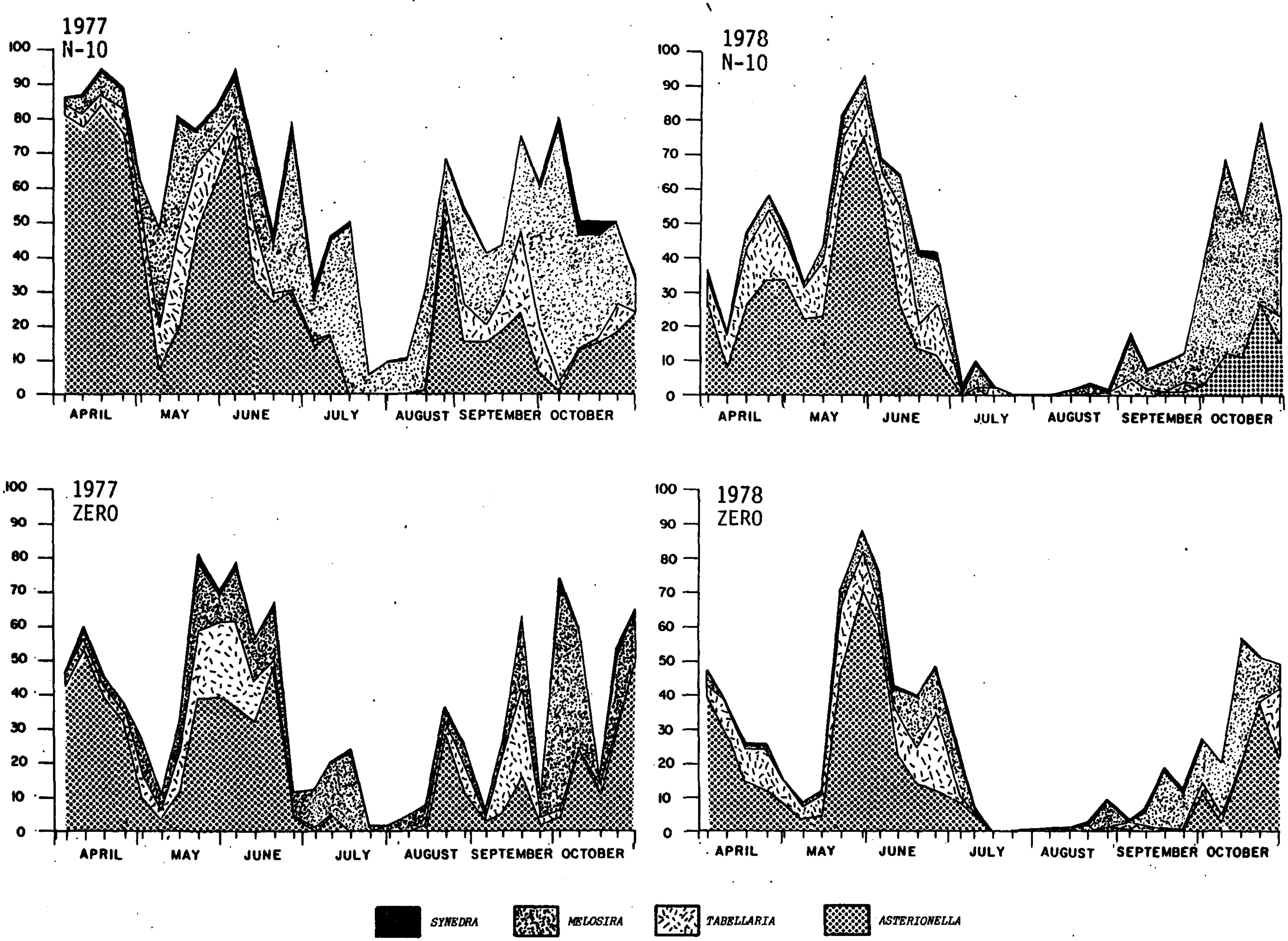


Figure 5-1. (Continued)

Figure 5-1. (Continued)



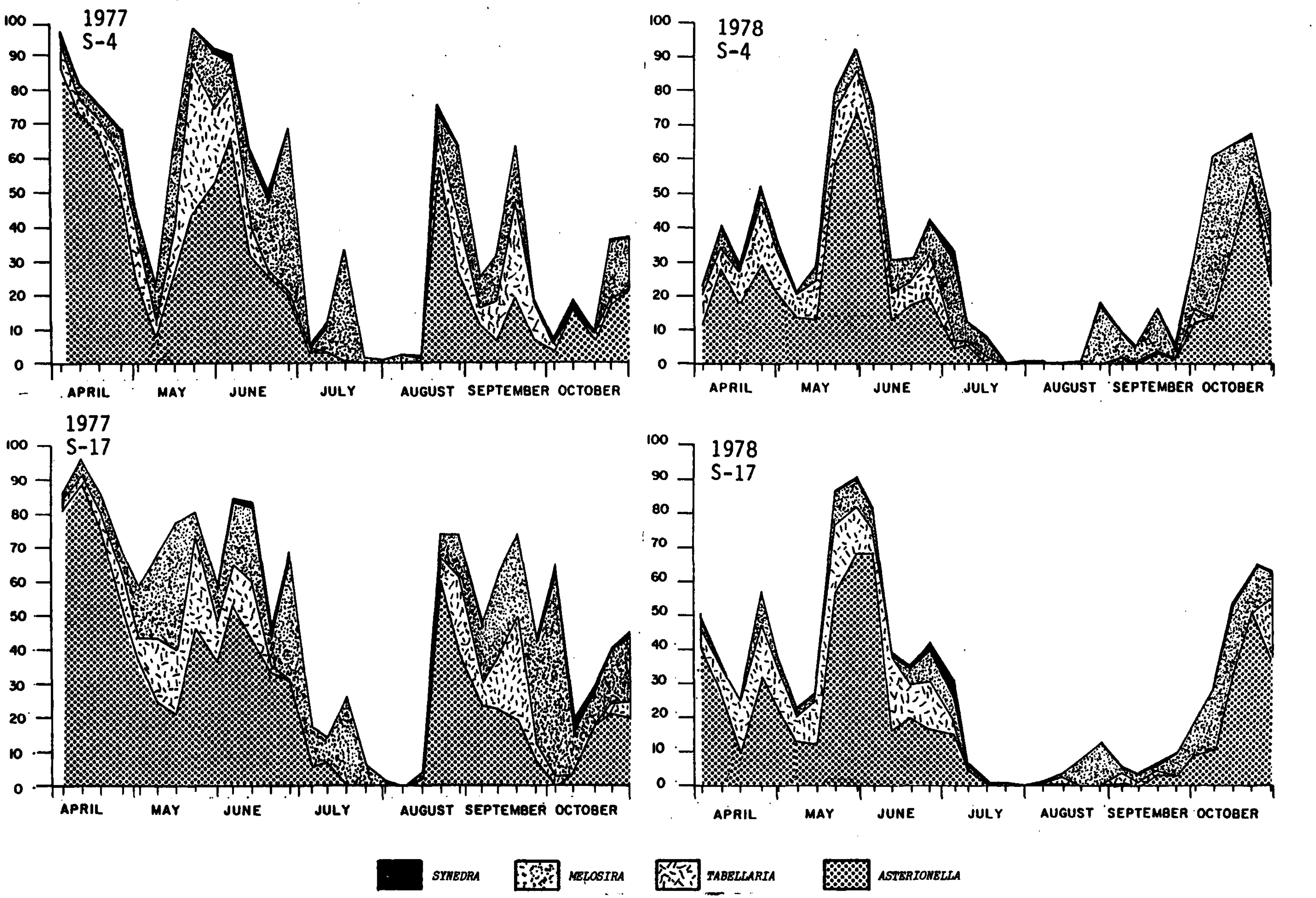
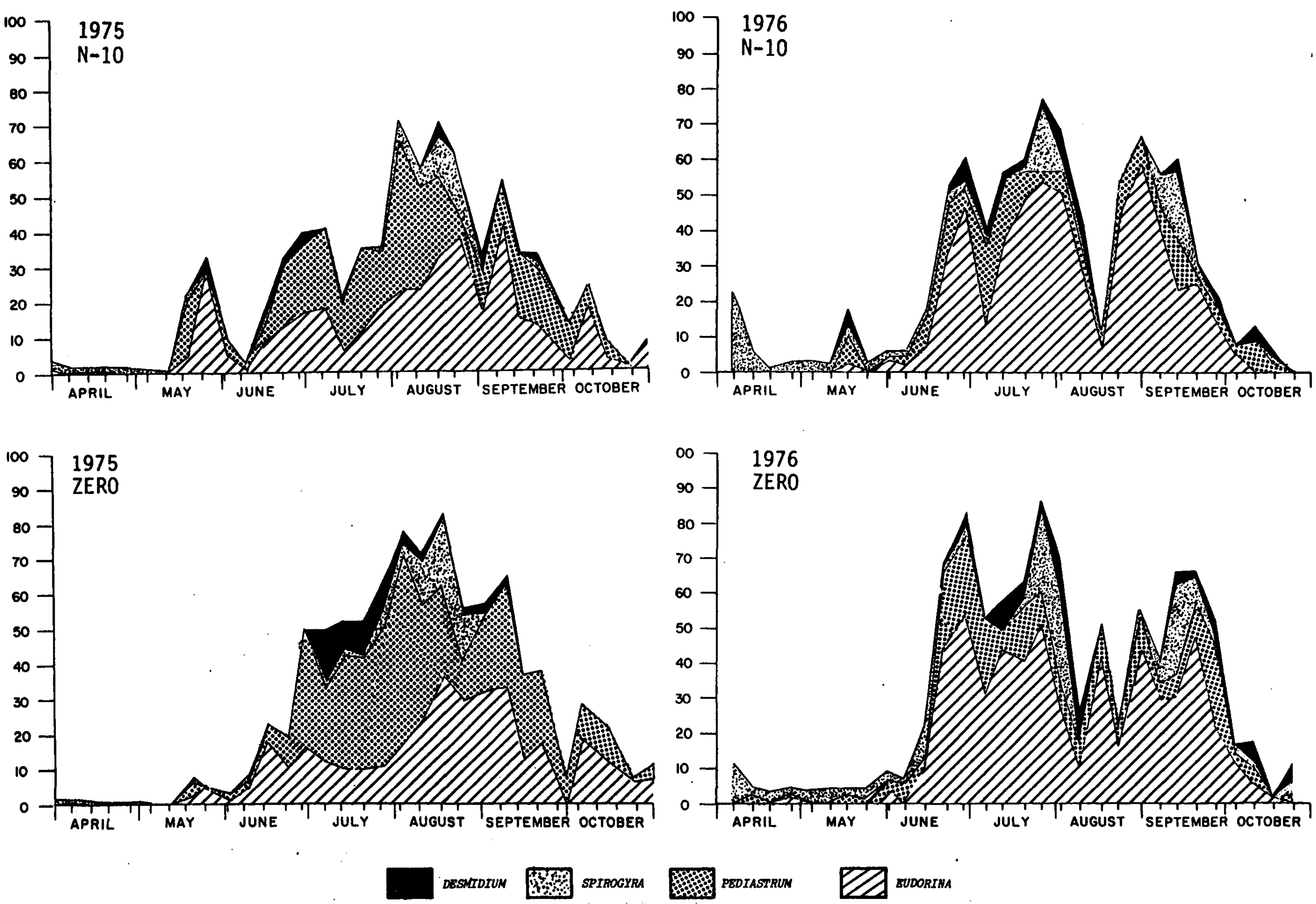


Figure 5-1. (Continued)

Figure 5-2. Percent composition of the green algae, *Eudorina* sp., *Pediastrum* sp., *Spirogyra* sp. and *Desmidium* sp. in net phytoplankton samples at four surface monitoring stations, 1975 through 1978. Merrimack River Summary Report, 1979.



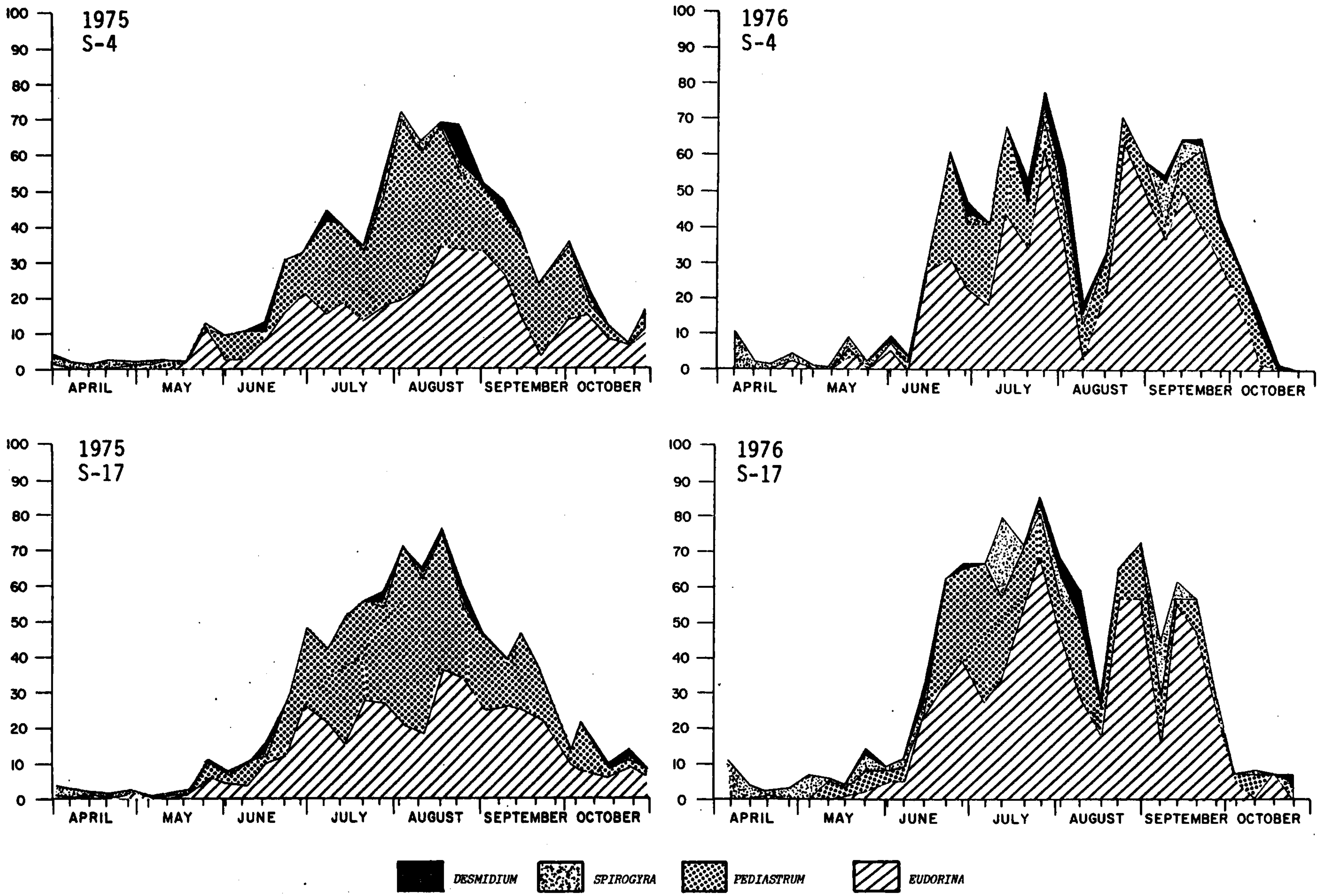
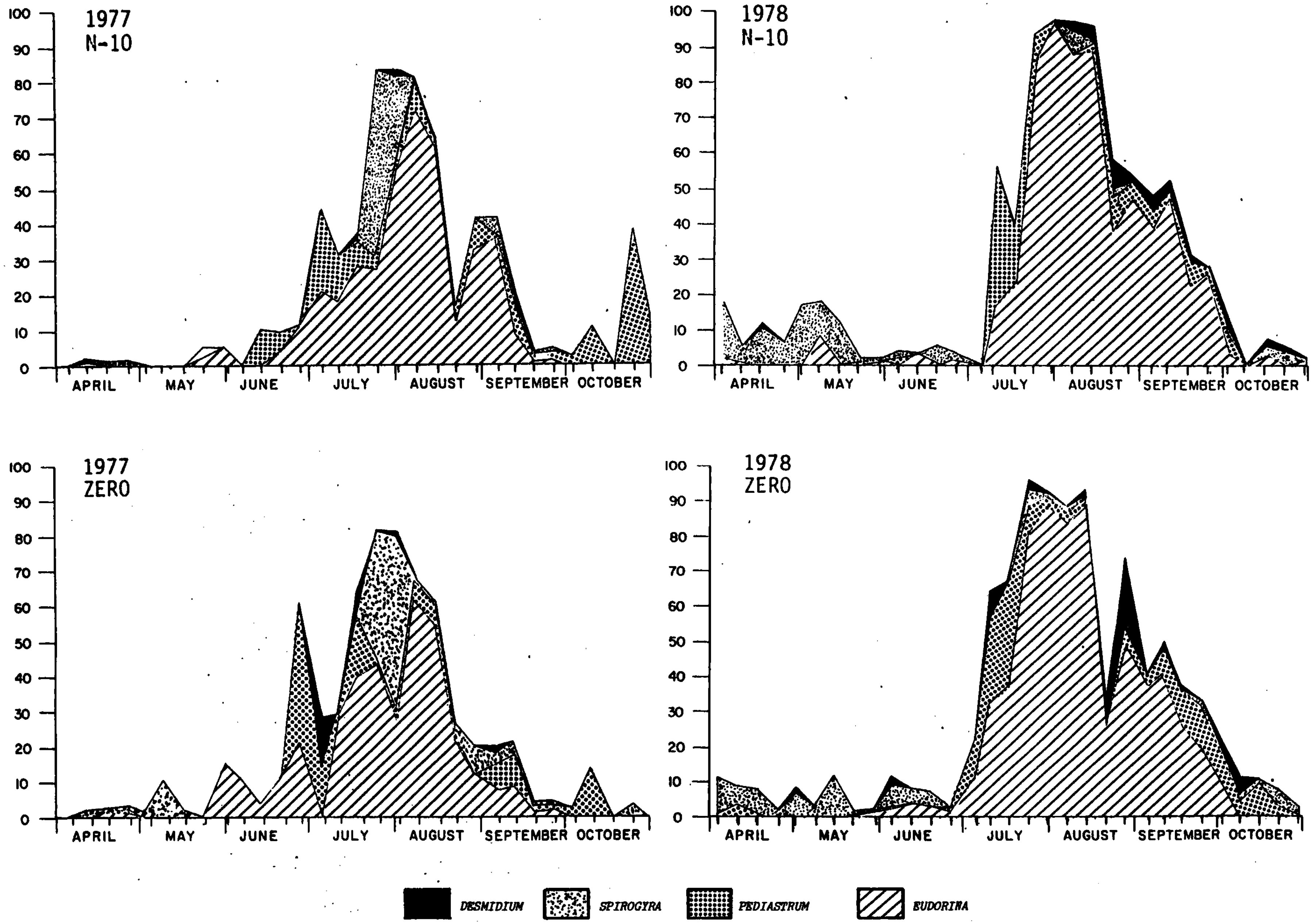


Figure 5-2. (Continued)

Figure 5-2. (Continued)



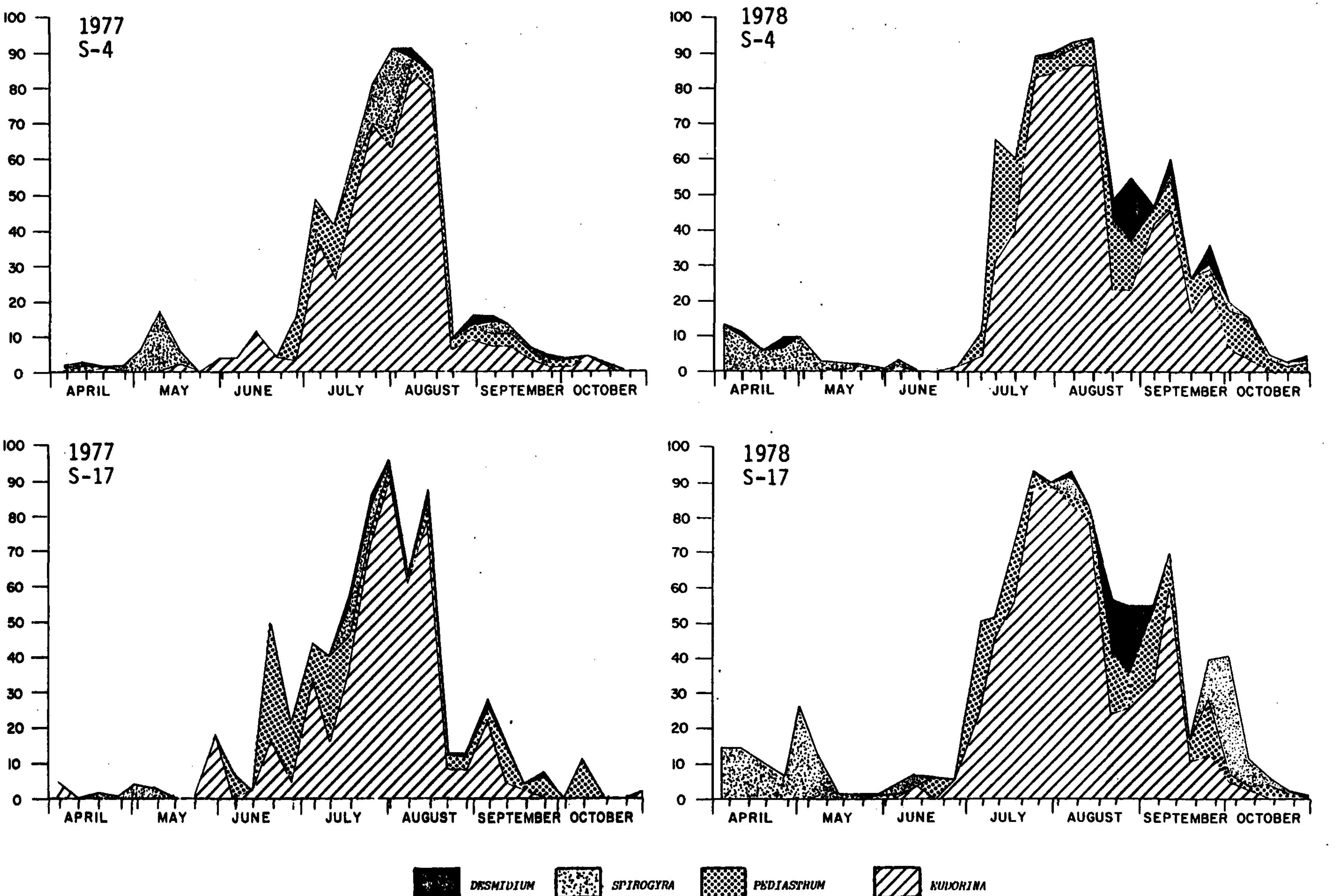
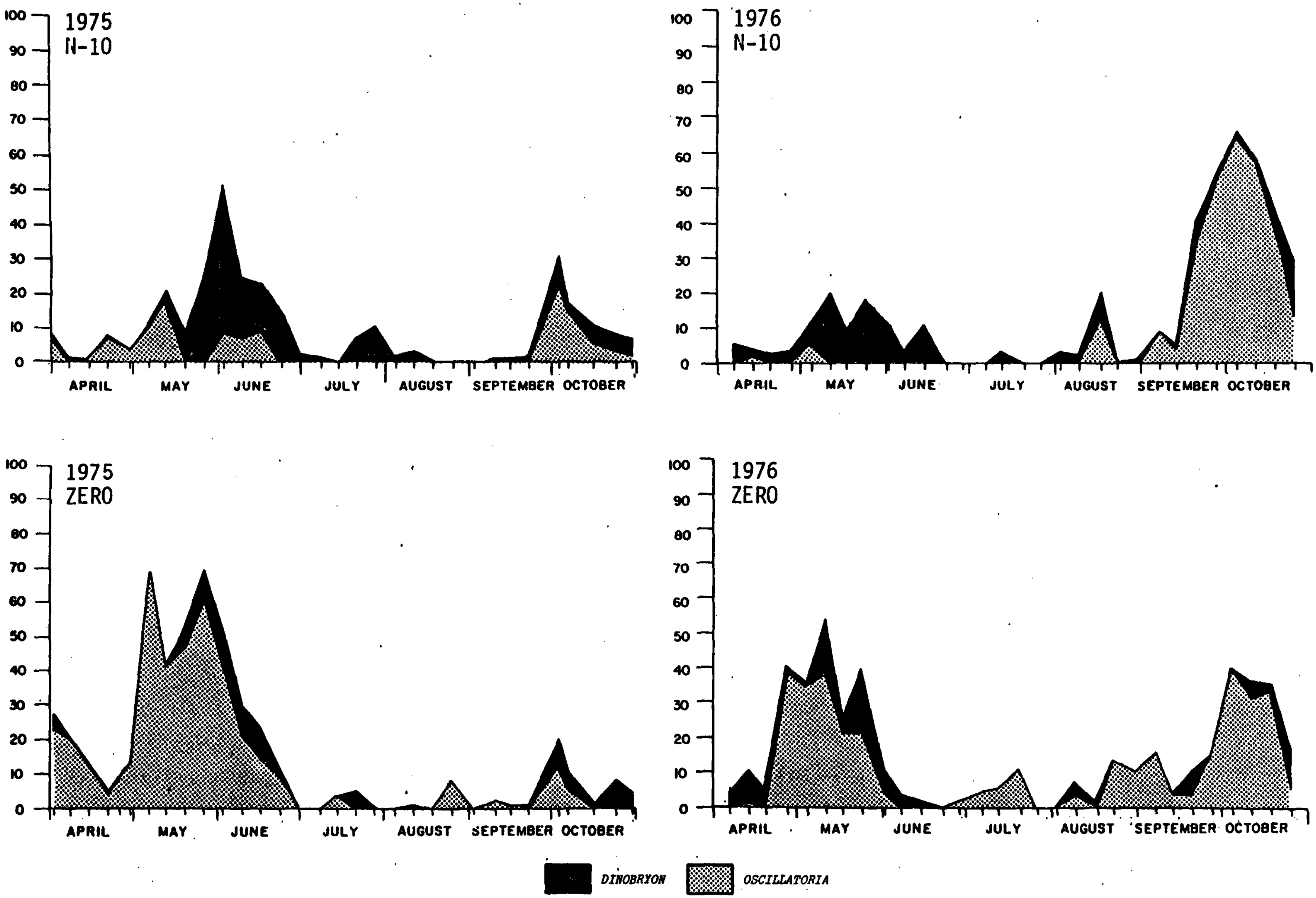


Figure 5-2. (Continued)

Figure 5-3. Percent composition of the blue-green algae, *Oscillatoria* sp. and the golden-brown alga *Dinobryon* sp. in net phytoplankton samples at four surface monitoring stations, 1975 through 1978. Merrimack River Summary Report, 1979.



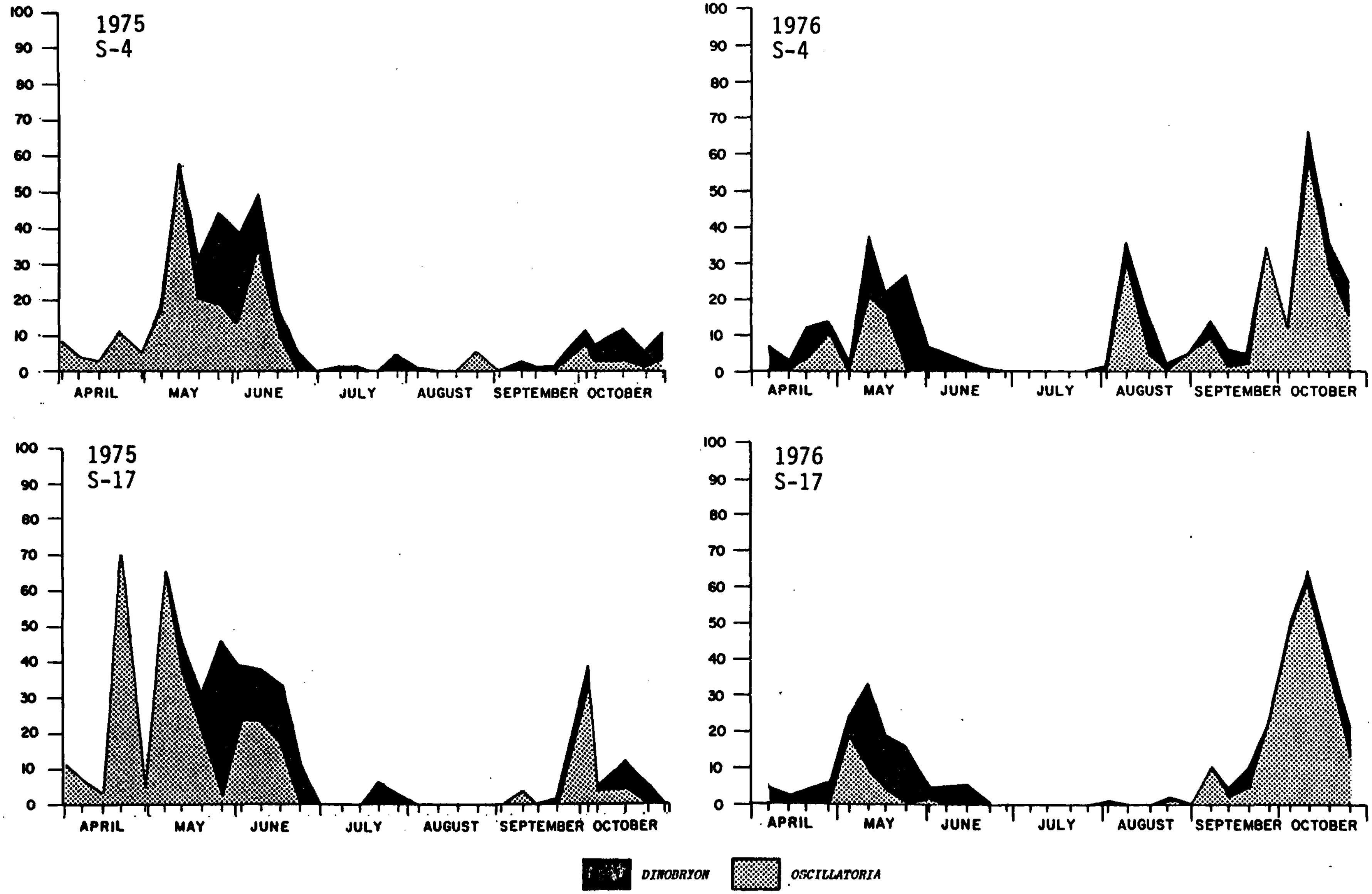
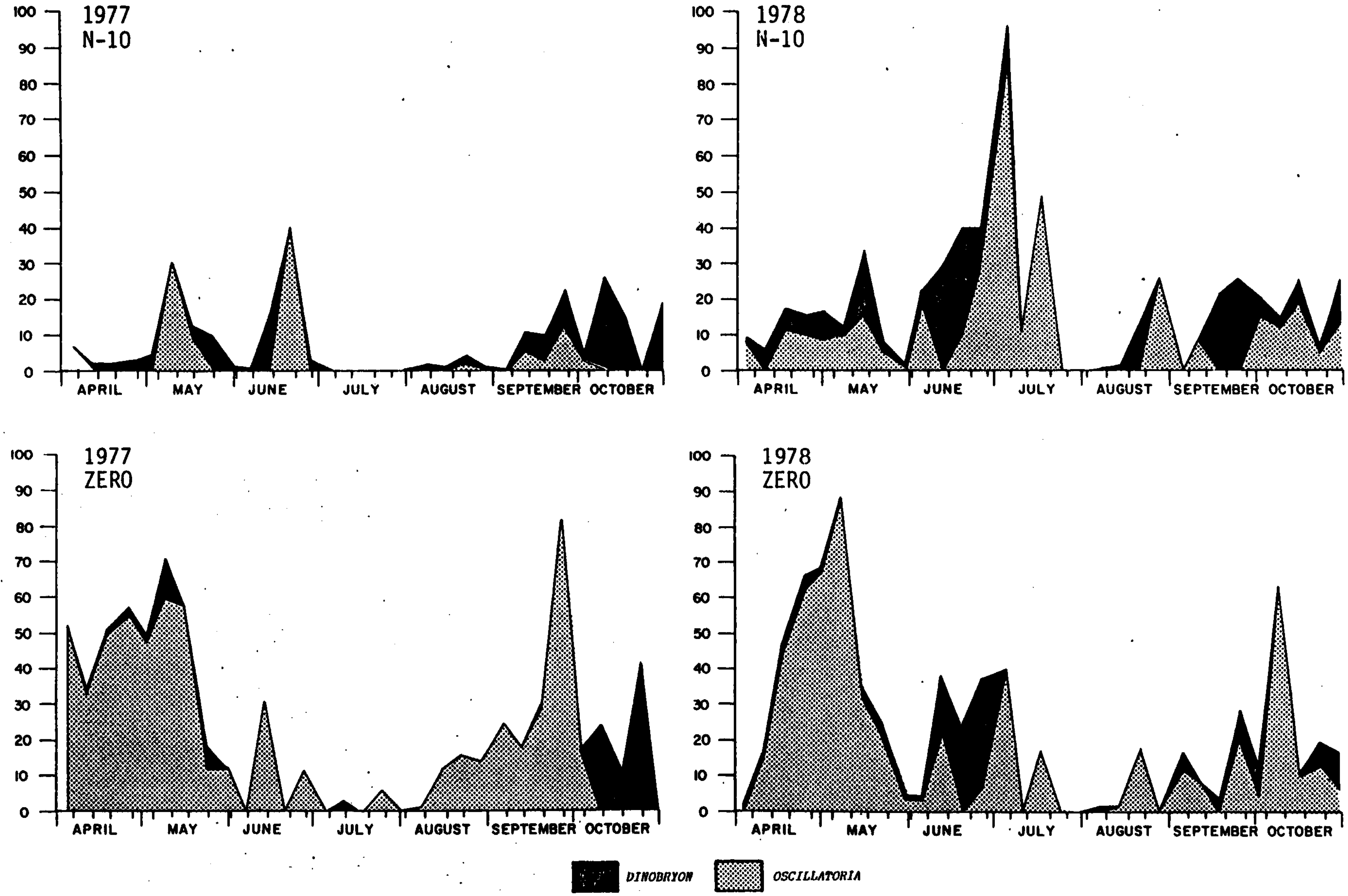


Figure 5-3. (Continued)

Figure 5-3. (Continued)



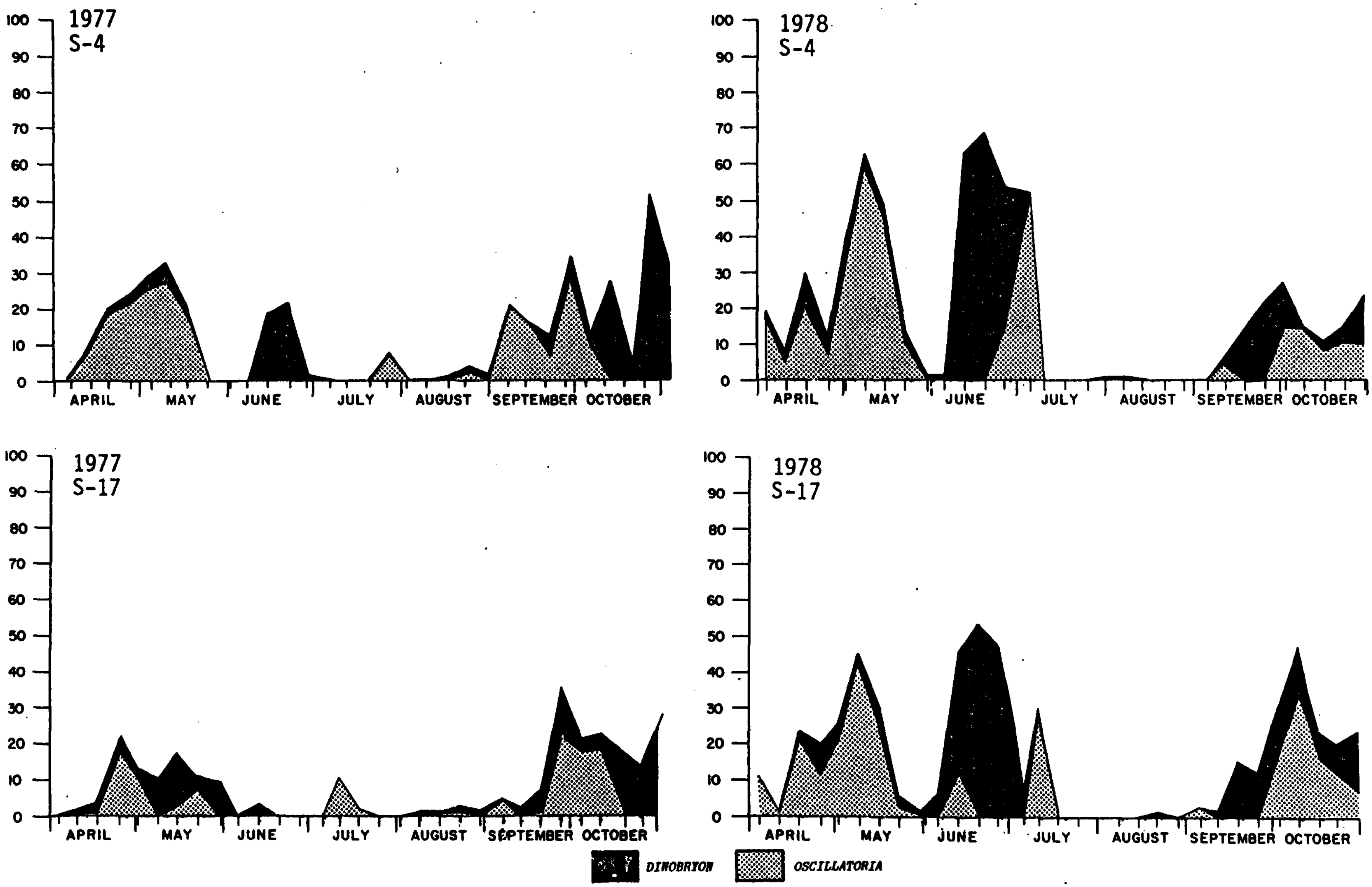


Figure 5-3. (Continued)

TABLE 5-1. AMONG-STATION CHANGES IN PLANKTONIC AND PERIPHYTIC PHYTO AND ZOOPLANKTON ABUNDANCES, 1968-1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

	PHYTOPLANKTON	METHOD	PERIPHYTON	METHOD
Diatoms				
1968	NT	--	NT	--
1970	NT	--	NT	--
1971	NT	--	NT	--
1972	NT	--	NT	--
1973	N-10>S-4>S-17>O-W	1	N-10>S-4>S-17>O-W	1
1974	N-10, S-4>O-W	2	N-10>O-W	2
1975	N-10>O-W	2	S-17>O-W	2
1976	N-10,S-4>O-W,S-17	1	NS	1
1977	N-10,S-4>O-W N-10>S-17	1	NS	1
1978	N-10>S-4>O-W>S-17	1	N-10,O-W,S-4, S-17>D.Weir	2
Green Algae				
1968	NT	--	NT	--
1970	NT	--	NT	--
1971	NT	--	NT	--
1972	NT	--	NT	--
1973	N-10>S-4>S-17>O-W	1	N-10>S-4>S-17>O-W	1
1974	NS	2	NS	2
1975	NS	2	NS	2
1976	NS	1	NS	2
1977	O-W>S-17	1	NS	1
1978	N-10>S-4>O-W>S-17	1	NS	2
Blue-green Algae				
1968	NT	--	NT	--
1970	NT	--	NT	--
1971	NT	--	NT	--
1972	NT	--	NT	--
1973	O-W>N-10>S-4>S-17	1	O-W>N-10>S-4>S-17	1
1974	O-W>N-10, S-17	2	NS	2
1975	NS	2	NS	2
1976	O-W>S-17	1	NS	2
1977	NS	1	NS	1
1978	NS	1	NS	2

continued

TABLE 5-1. (Continued)

	PHYTOPLANKTON	METHOD	PERIPHYTON	METHOD
Golden-brown Algae				
1968	NT	--	NT	--
1970	NT	--	NT	--
1971	NT	--	NT	--
1972	NT	--	NT	--
1973	NT	--	NT	--
1974	NT	--	NS	2
1975	NT	--	NS	2
1976	N-10>O-W	1	NS	2
1977	NS	1	NS	1
1978	NS	1	NS	2
Zooplankton				
1968	NT	--		--
1970	NT	--		--
1971	NT	--		--
1972	NT	--		--
1973	NS	1	NS	1
1974	NS	2	NS	2
1975	O-W>N-10	2	NS	2
1976	N-10>S-17	1	NS	2
1977	NS	1	NS	1
1978	NS	1	NS	2

Methods:

1 = Friedman non-parametric two-way ANOVA
2 = Parametric two-way ANOVA with Tukey's methods for multiple comparisons

NT = Not tested
NS = Not significant

TABLE 5-2. AVERAGE SEASONAL NET PHYTOPLANKTON ABUNDANCE AT STATION N-10, 1971 THROUGH 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

ABUNDANCE (Cells/liter)

	1971	1972	1973	1974	1975	1976	1977	1978
Spring	4.8×10^{4}	1.2×10^{3}	3.1×10^{3}	5.2×10^{4}	5.2×10^{4}	9.2×10^{3}	1.7×10^{3}	1.0×10^{3}
Summer	2.9×10^{4}	5.3×10^{3}	0.6×10^{3}	2.8×10^{3}	1.1×10^{4}	1.2×10^{4}	1.6×10^{3}	1.0×10^{3}
Fall	2.7×10^{4}	1.4×10^{3}	2.8×10^{3}	1.2×10^{3}	2.8×10^{4}	2.1×10^{4}	2.9×10^{3}	1.2×10^{3}

TABLE 5-3. RIVER UTILIZATION BY SEASON AND MERRIMACK STATION GENERATING UNIT STATUS, 1975 THROUGH 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

MEAN RIVER DISCHARGE (cms)

	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
1978	351.9	269.9	168.1	30.4	21.5	18.6	23.1
1977	377.7	103.0	62.6	31.4	31.9	63.2	230.4
1976	465.9	268.3	69.6	45.8	112.7	47.6	96.9
1975	323.7	192.2	97.6	91.3	32.1	69.2	125.0
MEAN	294.0		66.2			84.2	

MONTHS WHEN MERRIMACK UNITS I AND II WERE IN OPERATION

	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
1978	I, II	I, II	I, II	I	I	I	I, II
1977	I, II	I, II	I	I, II	II	II	II
1976	I	I, II	I	I		I, II	II
1975	I	I, II	I, II	I, II	I, II	I, II	I, II

PERCENT OF RIVER VOLUME UTILIZED FOR COOLING WATER

UNITS OPERATING	APRIL MAY	JUNE JULY AUGUST	SEPTEMBER OCTOBER
I	1%	6%	8%
II	3-5%	7-28%	7-38%
I&II	4-13%	16-31%	13-63%

TABLE 5-4. AVERAGE SEASONAL NET ZOOPLANKTON ABUNDANCE AT AMBIENT STATIONS. MERRIMACK RIVER SUMMARY REPORT, 1979.

	ABUNDANCE (Organisms/Liter)						
	1972	1973	1974	1975	1976	1977	1978
Spring (April, May)	168.9	22.5	28.0	3.8	7.3	1.5	0.7
Summer (June, July, August)	604.1	13.3	31.6	5.1	8.5	1.0	0.5
Fall (September, October)	53.7	80.0	60.0	9.4	6.3	0.9	1.3

6.0 AQUATIC MACROPHYTES

6.1 Importance to Aquatic Organisms

Aquatic vascular plants, or macrophytes, provide habitats which supply food and shelter to numerous organisms such as bryozoans, snails and insects (Cole, 1975). Similarly, pondweeds (*Potamogeton* spp.) have been shown to be highly important to immature insects both as a food source and as cover (Berg, 1950; McGaha, 1952). Certain midge larvae (*Cricotopus*) construct galleries in the floating leaves of *Potamogeton natans* for use as shelter (Ruttner, 1961). Other macrophyte species such as *Scirpus* spp. and *Eleocharis* spp. also serve as foods for a large array of aquatic insects (Welch, 1952).

While fish occasionally utilize aquatic plants as food, water fowl, particularly ducks and geese, feed extensively on them (Martin *et al.*, 1961). Patches of aquatic macrophytes, particularly *Potamogeton* and *Nymphaea*, are the preferred nesting areas for certain sunfishes (Reid, 1961), and the juveniles of many fish species utilize the cover afforded by vegetation as nursery areas. Centrarchids as well as other fish feed on the aquatic insects living on the plants. All of the above-mentioned plant species have been observed in Hooksett Pond as members of various macrophyte communities and, provide essential food and habitat for the resident aquatic organisms.

6.2 Distribution and Abundance

Aquatic vascular plant surveys were conducted from 1970 to 1974; a total of 14 species were observed during these surveys. The species most frequently encountered were *Elodea canadensis, Potamogeton* spp., *Pontedaria cordata* and *Sagittaria* spp. These species were most abundant along the east bank at Stations N-10 through N-4 and from S-6 through S-20; these areas have slow current, shallow banks and a substrate consisting of medium-fine sand with accumulations of organic matter. *Valisneria americana* and *Scirpus* sp. were observed in scattered beds.

Populations of *Potamogeton* sp., *Elodea canadensis* and *Sagittaria* sp. were observed during June at Station O-W, but were generally absent during August, possibly due to the increased temperatures. *Eleocharis, Sagittaria* and *Ludwigia* were observed in the discharge canal during June and August despite the high August water temperatures. *Nymphaea odorata, Potamogeton, Elodea canadensis* and *Sagittaria* were regularly observed at Stations S-21 through S-24 where water depth is shallow and the current is slow.

Aquatic plants were generally more abundant during August and September than in June, which is probably due to the stimulation of plant productivity by increased temperatures and rates of nutrient turnover throughout the summer. In addition, certain species may not have been observable during June because they did not attain mature form until late summer or early fall. Analysis of the data for the entire period indicated that overall abundances were sparse, and did not change appreciably from year to year; seasonal differences were of greater magnitude. Similarly, changes in community composition over the survey period were slight, involving only a few species. *Eleocharis* was abundant at Station O-W during 1970 and 1971, but was never observed after dredging at that station. *Nitella* was observed only during the 1970-1971 sampling seasons, and *Callitriche* occurred during various years. *Fontinalis* was observed only during the 1973 and 1974 August samplings. Such changes are a natural part of riverine plant community dynamics, and are probably not of sufficient magnitude to be indicative of influences external to this system.

6.3 Factors Influencing Distribution and Abundance

The abundance and distribution of aquatic macrophytes are generally influenced by habitat characteristics such as substrate, water chemistry, current velocity and water depth. Substrate type is important in regulating the composition of the macrophyte community; sand and silt are generally the least favorable type of bottom, supporting the smallest number of plant species and individuals (Odum, 1971). Butcher (in Hynes, 1966) found that *Potamogeton* and *Saggitaria* occur as members of a community found on partially-silted gravel and sand substrates. These plants were observed in the littoral regions of Hooksett Pond where the substrate is partially-silted sand.

Water chemistry is also an important factor governing the general distribution of aquatic vegetation. Moyle (1945) classified Minnesota aquatic flora into hard-water, soft-water, and alkali or sulfate water groups based on water chemistry. In riverine systems, differences in chemical characteristics are generally less distinct than in lake systems, although conditions in pools and flatwater sections may be similar to those found in lakes and ponds (Hutchinson, 1967).

Current velocity is also important in determining macrophyte abundance and distribution. Plant communities found in swift waters are generally distinct from slow-water communities (Hynes, 1966). In Hooksett Pond, distinct differences in species composition were observed in relation to current velocity; *Potamogeton, Elodea, Pontedaria* and *Sagittaria* were found in regions of still water, whereas *Eleocharis* and *Ludwigia* were present in flowing waters.

Water depth is a major factor governing the distribution of aquatic macrophytes because of its influence on light availability. Spence and Chrystal (1970) observed a correlation between depth distribution and the inherent photosynthetic ability of some species of *Potamogeton*. Results of this study indicated that deep water species carry on photosynthesis at light intensities too dim for the shallow water forms. In Hooksett Pond, aquatic macrophytes were most diverse in shallow, slowly-flowing, open areas such as the east littoral zone from Station N-10 to N-4, and S-6 to S-20 where sediment accumulation was high. However, the current has created steep banks along the east bank from Station N-3 to S-2 and the west bank from S-4 to S-21. Coarse substrate, high current velocity, deep water and insufficient light penetration have created poor habitat for aquatic vascular plants at these locations.

Accordingly, plant species diversity and abundance in these areas were very low compared to the areas having favorable habitat conditions.

Plant species diversity was also low at Station O-W and within the discharge canal. Decreased diversity at these locations may be partially due to thermal effects, but dredging of the canal mouth has certainly contributed to this decrease.

6.4 Conclusions

Field surveys from 1970 to 1974 did not reveal any significant trends in macrophyte abundance and distribution; the variability evident between years is most likely attributable to long-term riverine cycles. Comparisons of similar habitats above and below the discharge canal revealed differences of lower magnitude than those occurring between years within a given station. These observations suggest that heated effluent from the Merrimack Station has generally had no adverse effect on the distribution and abundance of aquatic macrophytes in the Merrimack River.

7.0 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates inhabit the substrate of a river, lake or stream, and provide an important food source for higher animals, particularly fish. Macroinvertebrate communities serve as useful indicators of perturbations caused by human activities due to their limited mobility. They are unable to avoid adverse environmental conditions and are often eliminated from areas where stresses exceed their tolerance levels. Community characteristics such as composition, species richness, density and diversity are often used to monitor the effects of any particular stress within the environment. When stressed, the intolerant taxa typically diminish and the tolerant taxa increase in numbers. The overall response is toward a community comprised of high numbers of a few tolerant taxa (low diversity; high redundancy). Wilhm (1972) suggested that the following ranges of diversity values can be associated with a corresponding magnitude of water pollution: heavy pollution = 0 to 1; intermediate pollution = 1 to 3; and clean water = 3+.

The benthic macroinvertebrate communities observed in Hooksett Pond are represented by both lentic and lotic taxa. The lentic taxa prefer areas of low water velocity, fine sediments and accumulated organic debris (Pennak, 1953). Annelida, Diptera and Mollusca were the predominant organisms observed in lentic habitats during Ponar grab surveys from 1972 to 1978 (Figure 7-1, Appendix Table D-1). Lotic taxa such as Ephemeroptera and Trichoptera prefer moderate current velocities and were rarely observed during these surveys.

Several sampling methods were used to characterize the abundance and distribution of benthic macroinvertebrates throughout Hooksett Pond. Ponar sampling was conducted from 1972 to 1978 within the lentic and lotic zones. Qualitative kick samples and quantitative artificial multiplate samples were used throughout 1977 and 1978 to supplement the data gathered through Ponar surveys. Multiplate samplers were used primarily to segregate the interacting factors of water temperature, substrate size and organic content on benthic macroinvertebrate distribution by eliminating the effects of substrate composition. This provided a more-accurate assessment of thermal influences on the lotic and drifting benthic fauna. Lotic taxa were well represented in the multiplate samples, with Ephemeroptera, Trichoptera and Diptera dominant (Figure 7-2).

7.1 Ponar Sampling

7.1.1 Comparisons within Transects

The results of benthic macroinvertebrate community sampling from 1972 to 1978 revealed differences between littoral and mid-channel community composition, species richness and density. Littoral samples were comprised primarily of Chironomidae and Oligochaeta, whereas, *Palpomyia, Ephoron, Hydracarina* and Sphaeridae were the predominant taxa in mid-channel. *Ephoron* was the only taxon exhibiting a temporal change during the survey years. This taxon was observed in highest number during August (1972 - 1978), but was absent in October due to emergence of the adults and onset of the estivating (resting) egg stage.

Numerical cluster analysis was conducted on the eight sampling stations from 1976 to 1978 based on the abundance of each taxon using the Bray-Curtis coefficient (Clifford and Stephanson, 1975). The results of this analysis demonstrated consistent clustering into two primary groups, one including all littoral stations and the other all mid-channel stations. These results reinforce the observations that the benthic macroinvertebrate communities at mid-channel are distinct from those in littoral habitats. In addition, a significantly (α=.05) greater number of taxa and higher density of benthic macroinvertebrates were observed at littoral stations compared to mid-channel during 1977 and 1978.

Although there were slight variations in diversity and redundancy between littoral and mid-channel stations, there were no dramatic community composition or abundance variations among the littoral stations or the mid-channel stations (Figures 7-3 and 7-4). The community differences consistently observed between littoral and mid-channel stations were primarily due to differences in substrate and current than to thermal stress. As revealed by sediment sampling conducted concurrently with the Ponar grab surveys (Figure 7-4; Appendix Table D-2), the mid-channel stations contain coarser sediments and less organic debris than the littoral stations. This is attributable to faster flows at mid-channel which prevent accumulations of organic debris and cause the sand to shift, in turn reducing microhabitat diversity.

7.1.2 Comparisons among Transects

In general, diversity was slightly higher at the control and experimental transects (N-10 and Zero) than at the recovery and far-field transects (S-4 and S-17). Redundancy values indicated similar trends in faunal repetition. Annelida, Diptera and Mollusca were dominant at all transects from 1972 through 1978 (Figure 7-1; Appendix Table D-1). A slight reduction in Diptera (primarily Chironomidae) was observed between 1975 and 1978, whereas Mollusca (Sphaeridae), Ephemeroptera, Trichoptera, Coleoptera and Odonata increased from 1976 to 1978. These taxa were also observed in qualitative insect surveys conducted from 1972 to 1974. Such minor shifts in community composition were observed at all transects.

The mean annual density of benthic macroinvertebrates was higher at Transect N-10 than at Zero from 1972 to 1976 (Figure 7-3; Appendix Table D-1). The densities observed at the recovery (S-4) and far-field (S-17) transects either equalled or exceeded those of the control transect (N-10). The low benthic densities observed at Transect Zero during these years were attributed to discharge scour resulting in coarse substrate at the discharge canal mouth (Station O-W). The substrate conditions at this station were more similar to those found at mid-channel than at littoral habitats, and would be expected to yield macroinvertebrate densities similar to those found at the mid-channel stations. Therefore, during 1977 and 1978, samples collected from Station O-W were taken within the thermal plume, but in depositional areas having substrate conditions similar to those found at the other littoral stations. Subsequently, samples taken from these locations exhibited higher densities than those of the control transect.

During each survey year a few taxa were observed exclusively at either the control (N-10) or experimental (Zero) transect. However, taxa found only at N-10 or Zero in a particular year were observed at both transects during other years. These taxa were consistently present in low numbers and their absence from certain stations during certain years is probably attributable more to natural variations in numbers, distribution, and occurrence of suitable habitat than to operation of the Merrimack Station.

At normal flow, the thermal plume from Merrimack Station flows along the surface, contacting only a small portion of the river bottom. From 1972 to 1978 the area subjected to the greatest thermal stress in Hooksett Pond was Station O-W where the mean maximum surface and bottom ΔT's were 7.0° and 3.1°C, respectively (Appendix Tables B-1 and B-2). Such thermal stratification substantially reduces potential impacts of thermal effluents on benthic macroinvertebrate communities (Benda and Proffitt, 1974; Koss *et al.*, 1976). There were generally no consistent differences observed in community composition, density, richness, or diversity among the transects which were attributed to Merrimack Station operation.

7.2 Artificial Multiplate Colonization

7.2.1 Comparisons within Transects

During 1977 and 1978, the predominant taxa colonizing artificial multiplates at all stations included Ephemeroptera (*Stenonema)*, Trichoptera *(Cheumatopsyche)*, Diptera *(Cricotopus)*, *Cladotanytarsus* and Simuliidae. Community composition of the littoral and mid-channel stations was similar, although observed densities were higher at all mid-channel stations. This was primarily a result of increased abundances of *Cladotanytarsus*, *Cricotopus*, *Cheumatopsyche* and Simuliidae. These taxa prefer faster-flowing water which provides more-favorable conditions for filtering plankton from the water (Merritt and Cummins, 1978).

7.2.2 Comparisons among Transects

Comparisons among transects showed that mean annual densities were higher at the experimental transect than at the control, recovery, or far-field transects during 1977 and 1978 (Appendix Table D-1). Abundances of the dominant taxa were all higher at the experimental transect during 1978, and overall density was significantly higher (α=.05) at O-W than at N-10-W during 1977.

Species richness was higher at the experimental and control transects (range 33-38) than at the recovery and far-field transects (range 26-36) during 1977 and 1978 (Appendix Table D-3). There were no significant (α=.05) differences in number of taxa between the control and experimental transects. Diversity of benthic macroinvertebrate communities colonizing multiplates was similar among transects. Species redundancy values varied only slightly among transects, reflecting low faunal repetition.

The water penny, *Psephenus*, was observed in high numbers during August 1977 at all littoral stations except O-W. Because of its high numbers at all other littoral stations, this absence of *Psephenus* at O-W may have been related to thermal conditions. Trembley (1961) also reported the absence of *Psephenus* from thermally-influenced regions of the Delaware River. However, because this organism did not colonize the multiplates during any other 1977 or 1978 sampling period, this single observation does not provide conclusive evidence of thermal exclusion at the discharge canal mouth.

The eight sampling stations were subjected to numerical cluster analysis during 1977 based on the abundance of each taxon using the Bray-Curtis coefficient. The results of this analysis did not demonstrate any tendency toward clustering into groups; the samples from all stations clustered at a fairly high level indicating that the benthic communities were similar at all stations. This similarity is attributable primarily to the elimination of variations in substrate and organic matter between stations by using artificial multiplates which reduce the selectivity of sampling on the basis of adaptations to mull (littoral) or sand (mid-channel).

7.3 Conclusions

Benthic macroinvertebrate distribution throughout Hooksett Pond is influenced primarily by water velocity and substrate composition. The communities observed at mid-channel are, therefore, distinct from the littoral communities; the littoral communities have higher densities and number of taxa because of the finer substrate and increased amount of organic matter. Benthic macroinvertebrate communities upstream and downstream of the Merrimack Generating Station were similar. This similarity may be attributed to: 1) the thermal tolerance of the benthic macroinvertebrate communities, and 2) the surface-configuration of the discharge plume which tends to ameliorate any potential effects. Therefore, the operation of Merrimack Generating Station has not adversely affected the downstream benthic macroinvertebrate communities in comparison with those from ambient regions.

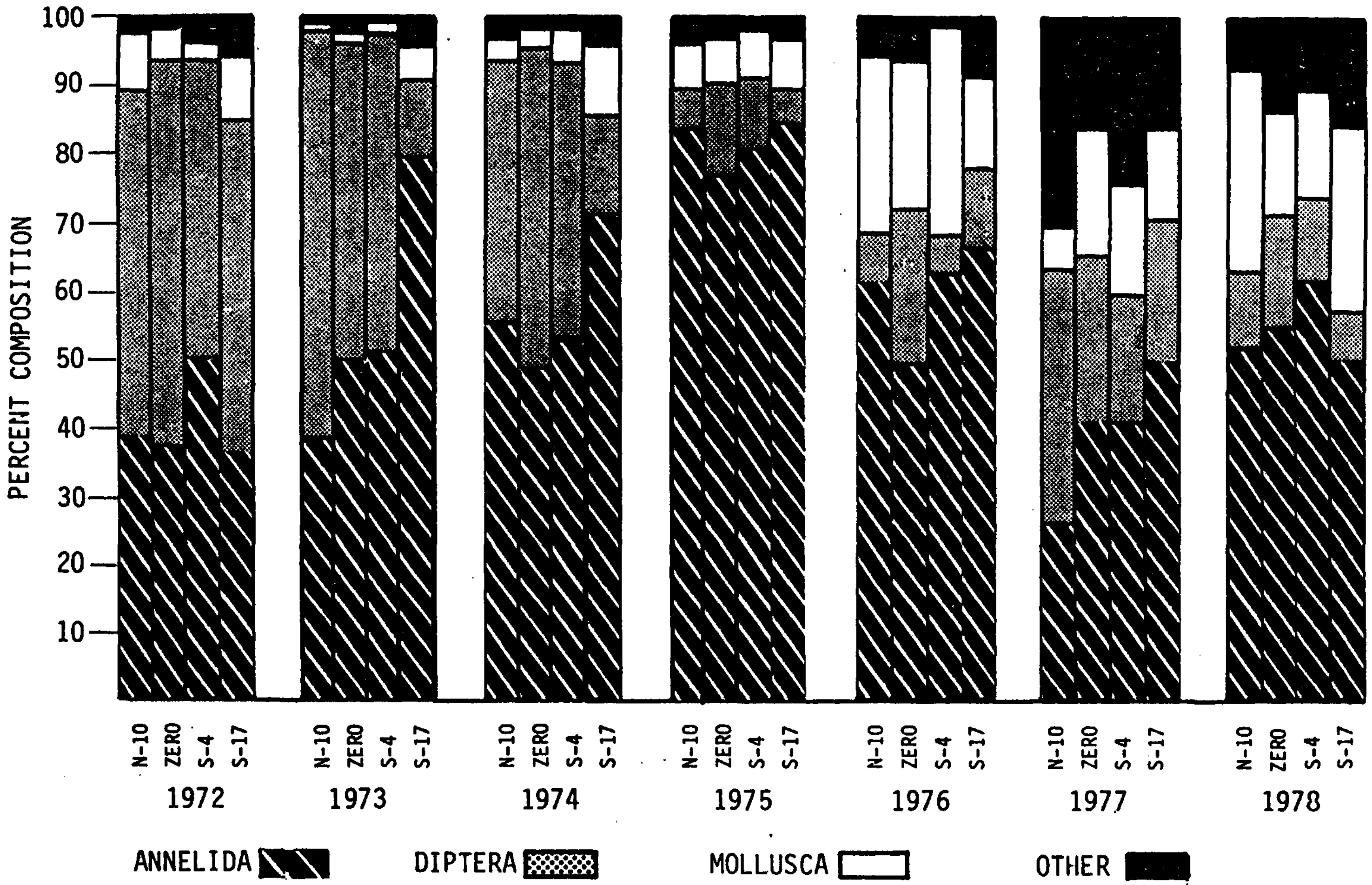


Figure 7-1. Cumulative percent composition of the Hooksett Pond Benthic Macroinvertebrate Community as determined by Ponar sampling from 1972 through 1978. Merrimack River Summary Report, 1979.

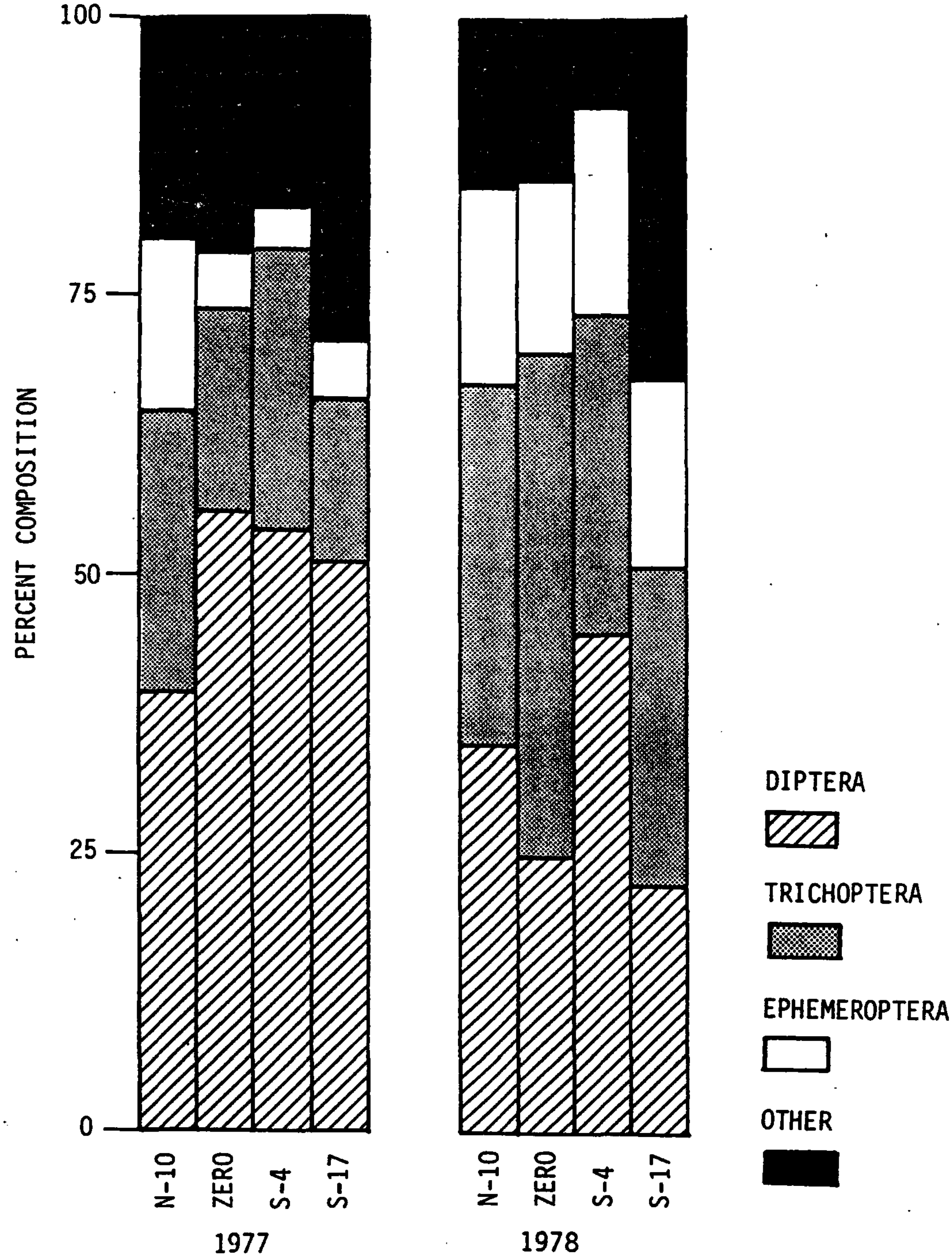


Figure 7-2. Cumulative percent composition of the Hooksett Pond Benthic Macroinvertebrate Community as determined by artificial multiplate colonization during 1977 and 1978. Merrimack River Summary Report, 1979.

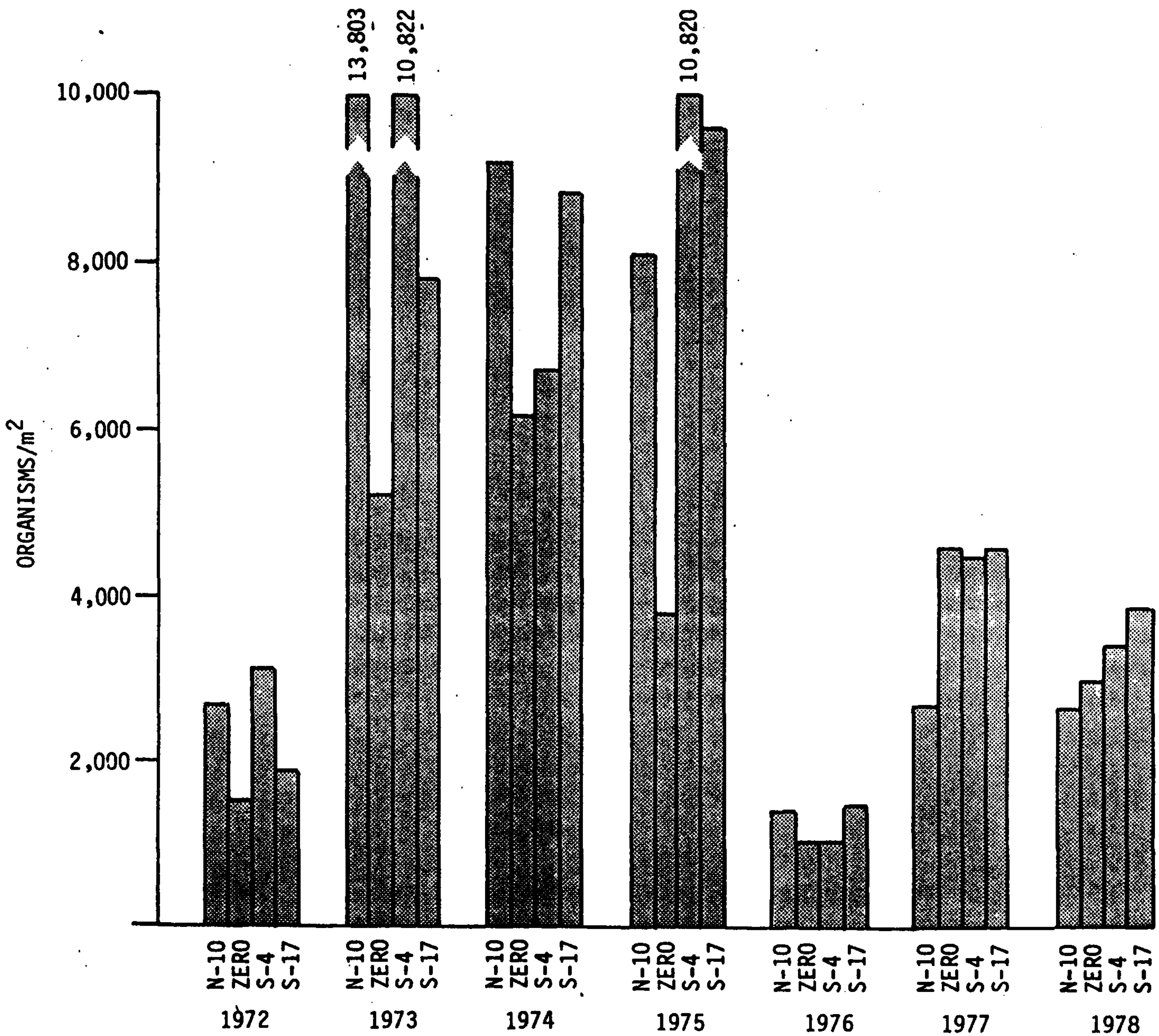


Figure 7-3. Mean annual density (number/m^2) of benthic macroinvertebrates collected at four Hooksett Pond stations by Ponar sampling, 1972 through 1978. Merrimack River Summary Report, 1979.

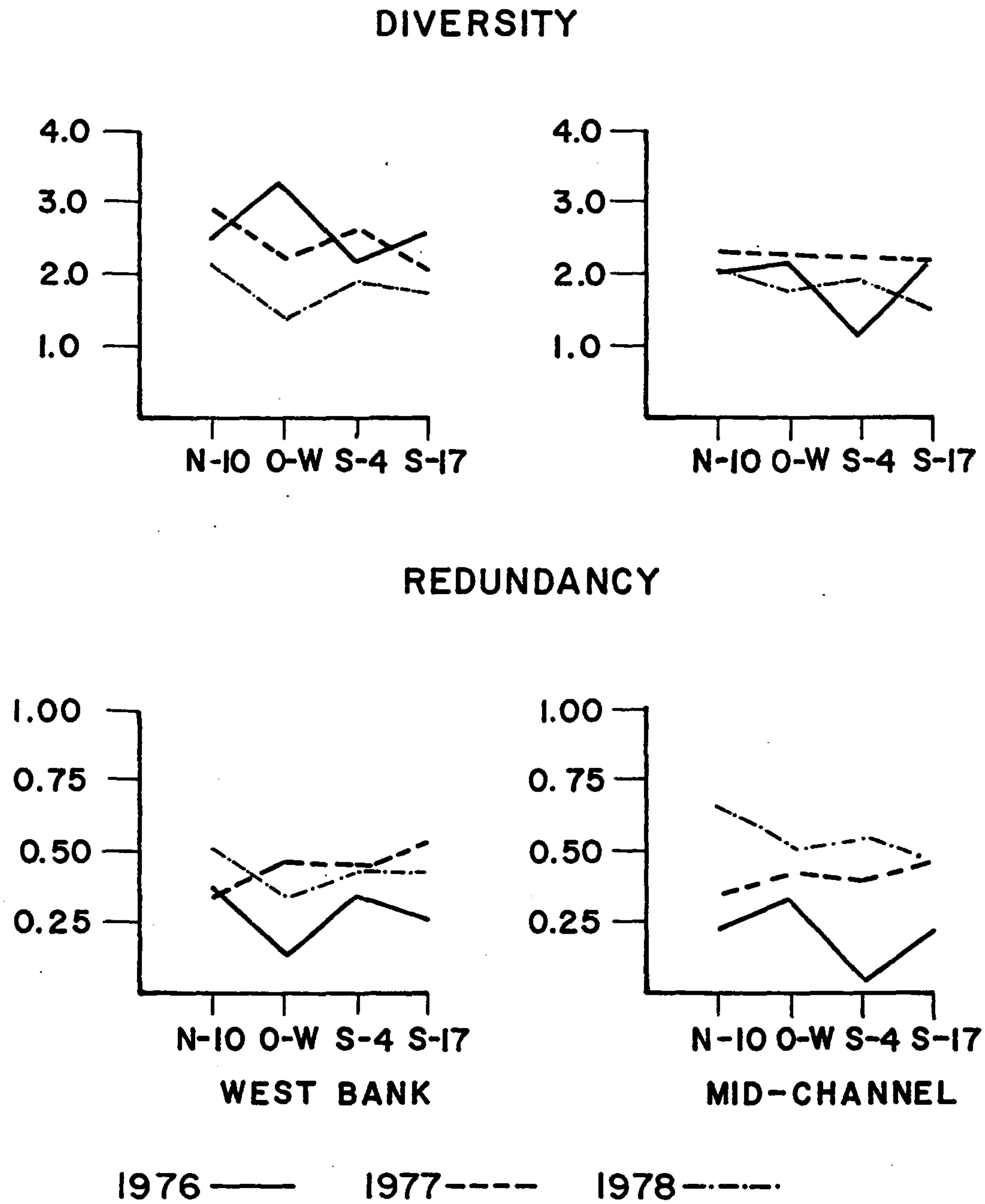


Figure 7-4. Diversity and redundancy of the Benthic Macroinvertebrate Communities at four Hooksett Pond stations as determined by Ponar sampling from 1976 to 1978. Merrimack River Summary Report, 1979.

8.0 FINFISH

8.1 Hooksett Pond Finfish Community

Hooksett Pond supports a diverse, warm-water finfish community that is dominated by sunfish and bass (Centrarchids), minnows (Cyprinids), white suckers (Catostomids), and bullhead (Ictalurids); (Table 8-1; Appendix Tables E-1 and E-2). Nineteen species are resident in Hooksett Pond, spending their entire life cycle within this portion of the river. Other species, including trout and smelt, are not adapted for living in this river section and have occurred only as strays from the upper portions of the watershed. Atlantic salmon and American shad have been introduced into the watershed as part of a migratory fish restoration program. The presence of these migratory species in Hooksett Pond is the result of introductions of salmon eggs and fry into the cold-water streams of the upper watershed, the introduction of fertilized American shad eggs into Garvins Falls Pool in 1971, Hooksett Pond in 1975 and 1976, and the introduction of shad eggs and spawning adults into Hooksett Pond during 1978. Four dams downstream of Hooksett Pond prevent these migratory species from ascending the river at this time. There are no rare or endangered fish species in Hooksett Pond (U.S.D.I., 1976).

8.2 Potential Impacts Due to Plant Operation

The operation of Merrimack Station may influence the resident finfish populations in several ways. First, eggs and larvae may be entrained in the cooling water system and subjected to thermal stress and mechanical damage. Second, juveniles and adults may be entrapped or impinged on the traveling screens that prevent debris from entering the cooling water system. Third, various aspects of fish life cycles may be altered by the thermal additions from the cooling water discharge. These effects may be direct or indirect. Direct effects would include thermal shock, alteration of reproductive cycles, exclusion by lethal temperatures from otherwise optimal habitat, alteration of growth rates, or reduction of physiological resistance to disease. Indirect influences may include alteration of water quality parameters, particularly dissolved oxygen, or the life cycles of the organisms that fish utilize as food. The impacts of entrainment, entrapment, and thermal additions on the Hooksett Pond fish community are discussed in the following sections.

8.2.1 Ichthyoplankton Pump Entrainment

The susceptibility of drifting fish larvae (ichthyoplankton) to entrainment through the Merrimack Station cooling water system was studied from 1975 to 1977 using an epibenthic larvae trawl in front of the intake structures, at the discharge weir, in the discharge canal, and at the canal mouth. Sunfish (*Lepomis* spp.) were the most frequently collected larvae, but even these were not found in appreciable numbers in front of the intake structures (Appendix Table E-3). Larval sunfish were collected primarily during June, July, and early August, with a typical total length of 5 to 10 mm (range = 4.8 to 17.9 mm). Reduced larval abundance after mid-August was probably the result of larval growth increasing the ability of these individuals to avoid the trawl. Collections from 1975 to 1977 indicated that sunfish larvae drift from the upstream littoral zone past the station cooling water intakes. Sunfish larvae collected in larval tows in front of the intakes during 1975 were dead, but all larvae were collected alive during 1976 and 1977. Qualitative sampling with a dipnet in the littoral zone immediately upstream of the intakes during 1977 collected minnow, white sucker, and golden shiner larvae, but none of these species were collected in the trawl samples.

The method for sampling ichthyoplankton entrainment was modified in 1978. Water entering the intake of Unit I was sampled on a diel basis using an ichthyoplankton pump system from May 23 through July 27, 1978. White sucker, golden shiner, minnow (*Notropis* spp.), and sunfish larvae were most commonly collected (Appendix Table E-4).

Most larvae were collected during the night. White sucker and minnow larvae were found only in the samples collected between 2000 and 0400 hours. Golden shiner larvae also predominated during the period from 2000 hours to 0400 hours, although some were collected in the early morning and during the afternoon. Minnow, golden shiner, and white sucker larvae were abundant in the littoral zone just upstream of the power plant intake structure during 1977, but were not captured during daytime sampling at the intakes. This suggests that these species are more susceptible to entrainment during periods of darkness. Other studies have also reported an increase in the number of larvae subject to entrainment during periods of darkness (Knutson, 1974; Marcy, 1976a; Teleki, 1976).

Sunfish larvae were collected during both light and dark periods, with the majority captured between 1200 and 1600 hours. This periodic occurrence is likely the principal reason that sunfish larvae were the dominant organisms collected during the previous years of ichthyoplankton sampling in front of the intakes during the day. It is probable that the smaller centrarchid larvae (4-8 mm) that were drifting past the intakes had left the nest prematurely. These individuals may be considered lost from the population because their probability of survival is minimal outside the nest at this life stage. Therefore, entrainment of these drifting larvae should not influence the resident population more than natural mortality factors. Overall, the number of larvae collected during the 1978 entrainment sampling was considered to be minimal.

Ichthyoplankton sampling has provided qualitative evidence that Merrimack Station does not deleteriously influence Hooksett Pond fish populations through pump entrainment, although there is no quantitative estimate of horizontal larval distribution or the percent of larvae available within the river that are actually entrained. First, most resident fish species in Hooksett Pond do not have pelagic eggs or larvae. Centrarchids and bullheads are nest-builders and guard their eggs and larvae. Those larvae leaving the nest prematurely are generally considered to be lost from the population because their chances for survival are low. Other fish species such as white suckers, common shiners, golden shiners and white perch have adhesive, demersal eggs and the larvae typically develop in or near the substrate. This reduces the potential for pelagic drift and decreases the probability of entrainment. White sucker, golden shiner, minnow and sunfish larvae were collected in small quantities during 1978 entrainment sampling (Appendix Table E-4), indicating that the pump entrainment impact upon these species is minimal.

Second, any adverse effects of Merrimack Unit II entrainment upon the indigenous fish community in Hooksett Pond probably would have occurred within the first few years of station operation. At that time, the station may have induced additional mortality upon the parent stock populations and therefore reduced reproductive potential and subsequent standing crops. Fish populations, however, may intrinsically compensate for losses by a decrease in death rate or increase in birth rate as the population density declines. Many fish populations have been exploited by man through commercial and sport fishing and power plants without becoming extinct due to this utilization. An extensive review of the literature by McFadden (1977) illustrates the resilience of fish populations even when exploitation rates approach 50% for some age classes annually. Mortality of larval fish due to entrainment at Merrimack Station may therefore have minimal adverse effects upon the Hooksett Pond fish populations because of this compensation.

Fisheries surveys in Hooksett Pond have indicated that the resident fish populations are healthy and reproduce successfully. Since Merrimack Unit II has been in operation for 10 years, these populations have sustained themselves either because of negligible entrainment impact or through compensation, apparently offsetting any losses due to pump entrainment. As a result, larval entrainment is probably not a limiting factor affecting population structures in Hooksett Pond at this time.

8.2.2 Entrapment

The fish entrapment monitoring program for Merrimack Station Units I and II was conducted originally from January 1976 through December 1977 for the purpose of documenting "the types, numbers and frequency of occurrence of fishes entrapped upon the intake screens."

Results of entrapment monitoring during 1976 indicated that the total number of fish impinged throughout the year was 1449, representing 17 species. Bullhead, yellow perch, minnows and sunfish comprised most of the individuals impinged (Appendix Table E-5). Gamefish species such as largemouth and smallmouth bass accounted for only 4% of the catch by number. Projections utilizing 1976 and 1977 data estimated a total annual impingement during 1977 of 2504 fish, of which 74% or 1853 individuals would be minnows.

Based on the 1976 and 1977 entrapment monitoring, the NHWSPCC and USEPA granted a waiver for future entrapment monitoring at Merrimack Station with two stipulations. First, impingement monitoring would resume during May and June 1978, if downstream movement of Atlantic salmon smolts was observed in Hooksett Pond. Second, entrapment monitoring would be conducted from August through October 1978 to determine the entrapment susceptibility of American shad juveniles introduced by PSCoNH during 1978. Entrapment monitoring was, subsequently conducted at Unit I during these stipulated periods, and provided further indication of low impingement rates for resident fish species. Brown bullhead, fallfish, golden shiner, and yellow perch were the species most commonly impinged; only one smallmouth bass, three largemouth bass, and one American shad were collected during the 13 sampling periods (Appendix Table E-6). Greatest entrapment rates appeared to coincide with increased river flow, suspended debris and turbidity, as has been observed during other PSCoNH entrapment studies. Because no salmon smolts and only one American shad were collected during 1978, this entrapment program gave preliminary evidence that American shad juveniles and Atlantic salmon smolts would not be impinged in substantial numbers while migrating downstream through Hooksett Pond.

8.2.3 Potential Thermal Effects on Representative Finfish Species

Seven of the nineteen resident species in Hooksett Pond were chosen for discussion as representatives of the finfish community on the basis of abundance, sport potential, and value as forage for other species:

TABLE 8-2. REPRESENTATIVE FINFISH SPECIES AND THEIR IMPORTANCE. MERRIMACK RIVER SUMMARY REPORT, 1979.

SPECIES	IMPORTANCE
Smallmouth bass	Gamefish, abundant
Largemouth bass	Gamefish
Pumpkinseed	Community dominant
Yellow perch	Gamefish, abundant, juveniles provide forage
White sucker	Abundant
Brown bullhead	Abundant
Golden shiners	Forage

Anadromous fish species were excluded from consideration because they are not naturally present or self-sustaining in the Merrimack River at this time. The relationship between Merrimack Station and American shad viability in Hooksett Pond has been discussed in NAI (1979b).

Each representative species will be discussed in the following sections with regard to growth, condition, distribution and temperature criteria as observed in Hooksett Pond and established in the literature.

8.2.3.1 Smallmouth Bass

Smallmouth bass inhabit moderately shallow, rocky and sandy areas of rivers. Spawning occurs from May through June in New England at temperatures of 12.8 to 20°C, although most egg deposition occurs between 16.1 and 18.3°C (Scott and Crossman, 1973). Male smallmouth bass guard the eggs and fry while they are in the nest, and may continue to guard them up to 28 days after the fry leave the nest (Carlander, 1977). Sudden increases in river flow or turbidity usually do not damage nests with eggs or fry, but advanced fry that have just left the nest may be displaced downstream by slight flow increases (Carlander, 1977). The protective behavior of the adults helps to prevent the downstream displacement of the fry, thus minimizing the probability that the larvae would be entrained. For this reason it is understood why smallmouth bass larvae have been absent in ichthyoplankton entrainment samples at Merrimack Station (Appendix Tables E-3 and E-4).

Egg survival in the laboratory was shown to be highest at an incubation temperature of 23°C; survival decreased at higher or lower incubation temperatures (Wallace, 1973). Eggs near the hatching stage and newly-hatched fry appear to be resistant to mild (<7°C) thermal shock (Tester, 1930; Webster, 1945).

The smallmouth bass has a summer thermal preference between 25 and 35°C, although differences exist among seasons and between adults and juveniles (Figure 8-1; Coutant, 1977). Juvenile smallmouth bass tend to choose temperatures between 28 and 31°C during the summer and grow best at 26 to 29°C (Horning and Pearson, 1973). The NTAC (1968) has recommended 28.9°C as the maximum temperature compatible with adequate growth of juvenile smallmouth bass. General field observations indicate that young bass remain in warmer waters than older individuals (Ferguson, 1958), but this is not indicated by the thermal preferences illustrated in Figure 8-1.

Wrenn (1976a), Hokansen (1969), Stauffer *et al.* (1976) and Trembley (1960) have indicated that thermal effluents do not create a barrier to smallmouth bass movements, and have observed smallmouth bass in waters warmer than 34°C. Trembley recorded body temperatures up to 33.3°C for smallmouth bass taken from the Delaware River below a thermal outfall; in the associated discharge lagoon, smallmouth bass body temperatures ranged up to 34.4°C. Although smallmouth bass do enter thermal plumes, Van Vliet (1957; cited in Brown, 1974) indicated that the smallmouth bass abundance within a Delaware River thermal discharge increased as decreasing river water temperatures approached 26.7°C. Similarly, Gammon (1971; cited in Brown, 1974) observed that smallmouth bass avoided a Wabash River heated effluent during summer, but returned to the heated regions when temperatures decreased to 27°C in the autumn.

Hooksett Pond smallmouth bass have been collected most frequently near the discharge canal and within the mixing zone, but have also been found at far-field and control regions during the summer. Modal seining temperatures from 1974 to 1978 were 30-34°C (Figure 8-2), indicating a distribution pattern favoring the warmest portions of Hooksett Pond. Because temperatures in this range occur primarily in the discharge canal area, this distribution pattern may also be influenced by preference of other habitat parameters. This distribution does, however, indicate that the thermal discharge from Merrimack Station does not normally restrict smallmouth bass movement throughout Hooksett Pond.

Smallmouth bass were used in thermal toxicity studies from 1975 through 1977 to determine if the Merrimack Station thermal discharge was acutely toxic to centrarchids. Bass were held for a three-day acclimation period and a subsequent ten-day test period in live cars at the discharge canal mouth (experimental station) and upstream of the generating station intakes (control station). Mortality between these stations was compared over the ten-day test period. Only one of eight test series resulted in significantly (α=.05) higher mortality at the discharge canal mouth than at the ambient river location (Table 8-3;

Appendix Tables E-7 to E-9). During the third series in September 1975 (Appendix Table E-7) an accidental chemical discharge from Merrimack Station caused a fish kill in the discharge canal and induced complete mortality among the experimental fish. Only two such station-related fish kills were observed during the 12-year monitoring program (April 1971; September 1975). In both instances, effects were limited to the discharge canal; there was no evidence that these effects extended into the river. The construction of a wastewater (chemical) treatment facility at Merrimack Station during 1977 will help to further preclude any such inadvertent chemical discharges.

Growth rates of smallmouth bass during the pre-operational period (1967 and 1968) were similar to present growth rates, as indicated by back-calculated lengths at annulus formation (Appendix Table E-10). Growth rates to the first annulus from 1972 through 1974 appeared to be unusually rapid, and the length-at-capture data for age 0 and 1 fish indicate that these growth rates were artificially inflated, likely through mis-reading of the scales and omitting the first annular ring. Thus, these data have been disregarded, although they were presented in annual reports. The 1975 to 1978 growth rates, however, were similar to pre-operational growth rates.

Length-weight relationships for smallmouth bass in Hooksett Pond indicate that bass from all portions of this river section are healthy and have a condition factor near 3.0 (Appendix Table E-13). The value of this index should be near 3.0 since the weight of an object will vary as the cube of its length if shape and specific gravity remain the same (Carlander, 1977). Thus, the thermal discharge does not tend to accelerate growth in length at the expense of weight and cause emaciation within the smallmouth bass population.

8.2.3.2 Largemouth Bass

Largemouth bass generally inhabit the warm, upper levels of lakes or slow river sections with mud substrates and extensive vegetation (Scott and Crossman, 1973). They spawn from late spring through mid-summer at water temperatures of 15.6 to 26.4°C, although optimum spawning temperature is 20.5 to 22.0°C (Carlson and Hale, 1972). Eggs are deposited in a nest constructed by the male, and hatch in 47 (26.1°C) to 96 hr (15.6°C; Carr, 1942; Kramer and Smith, 1960). Males guard the nest after spawning, but may desert the nest if temperatures fluctuate extensively (Kelley, 1968). This nesting behavior and guarding of the eggs and fry helps to decrease the entrainment potential for the eggs and larvae, particularly compared to broadcast-spawning species or species with pelagic larvae. Largemouth bass can spawn successfully in heated waters, and although juveniles often appear in heated regions before unaffected areas, it does not appear that thermal effluents significantly alter the annual reproductive cycle (Clugston, 1973; Bennet and Gibbons, 1975). Growth studies have shown that largemouth bass fry held at temperatures between 17.5 and 30°C grew best at 27.5°C (Strawn, 1961), and juveniles reared between 24 and 35.5°C grew most rapidly between 26 and 28°C (Coutant and Cox, 1974).

The preferred temperature range for largemouth bass is 25 to 32°C (Figure 8-3). Neill (1971), Neill and Magnuson (1974), Busacker (1971), Marcy (1976) and Gibbons *et al.* (1972) report largemouth bass concentrations in thermal discharges, particularly during winter. These aggregations appear to be transitory; no distinct plume population is established (Clugston, 1973). Largemouth bass distributions around thermal outfalls may also be controlled by forage fish movements rather than by temperature preference (Hatch, 1973). The ability of this species to move through thermal gradients has been supported by work demonstrating that largemouth bass can occupy widely-ranging thermal habitats through physiological tolerance rather than through direct adaptation (Denyes and Joseph, 1956).

Hooksett Pond largemouth bass have been captured in water as warm as 25.5°C (Figures 8-3 and 8-4). Juveniles were collected primarily at near-field regions during June and July, and from areas farther from the discharge canal during August (Figure 8-4). During 1977 and 1978, adult and juvenile largemouth bass were collected most frequently within the mixing zone. Modal seining temperatures suggest a distribution pattern favoring the warmest regions of Hooksett Pond. This distribution may be influenced by other factors such as habitat type, cover and distribution of forage species. However, largemouth bass were commonly encountered near the discharge canal mouth, and the maximum water temperature discharged into the Merrimack River rarely exceeded the maximum temperatures tolerated by this species. This indicates that existing thermal discharges from Merrimack Station would not restrict the distribution of largemouth bass in Hooksett Pond.

8.2.3.3 Pumpkinseed

The pumpkinseed is a warm-water species usually found in weedy bays of large lakes and in slow-moving rivers and streams. They nest from May through August at temperatures of 20 to 28°C and spawn at temperatures around 28°C (Breder, 1936; Scott and Crossman, 1973). Males prepare a nest on clay, sand or gravel substrate, usually near submerged vegetation, and guard the nest, eggs and newly-hatched fry.

Young (18 mm) pumpkinseed can survive exposure to water temperatures up to 38°C (Bailey, 1955), but the final thermal preferendum for juveniles is approximately 31.5°C (Anderson, 1951; Figure 8-5). Neill and Magnuson (1974) observed that small pumpkinseed were more abundant in a thermal outfall than in similar reference areas from August through October. This affinity of juveniles for warmer water is supported by the work of O'Hara (1966, 1968), indicating that small pumpkinseed are better adapted to warmer water than larger individuals because of a lesser temperature effect on respiratory metabolism.

Neill and Magnuson (1974) captured adult pumpkinseed in Lake Monona, Wisconsin, at temperatures of 27.5 to 32.5°C; median body temperatures for these fish were 30.5°C during the day and 28°C at night (Figure 8-5). Catch per unit effort of large pumpkinseed in that study was not significantly different between the thermal outfall and reference areas. Trembley (1960) reported pumpkinseed body temperatures up to 31.7°C below a thermal effluent in the Delaware River, and up to 35.6°C for pumpkinseed captured within the discharge canal. Pumpkinseed were unusually abundant in the discharge canal, although temperatures greater than 32.2°C were generally avoided.

Hooksett Pond pumpkinseed have been found in waters up to 35°C, the warmest available in the river exclusive of the inner discharge canal. Modal seining temperatures from 1974 to 1978 were 30-35.5°C (Figure 8-6); however, as with other centrarchid species, this pattern may have been influenced by habitat as well as thermal preference. Highest pumpkinseed catches have been recorded near the discharge and mixing zones, and, although no quantified data have been recorded, pumpkinseed spawning and live fry have been observed within the discharge canal.

Pumpkinseed were used in thermal toxicity studies from 1975 through 1977 to determine if the Merrimack Station thermal discharge was acutely toxic to centrarchids. Only one of eight test series resulted in significantly (α=.05) higher mortality at the discharge canal mouth than at the ambient river location (Table 8-3). During the third series in 1975 (Appendix Table E-7) an apparent chemical discharge from Merrimack Station caused a fish kill in the discharge canal and induced complete mortality among the experimental fish (see discussion on page 87, paragraph 1). Mortality was not significantly different between the control and experimental stations during the remaining seven test series (Table 8-3; Appendix Tables E-7 to E-9).

Back-calculated lengths at annulus formation were calculated for pumpkinseed collected from 1975 through 1978 and compared to pre-operational growth rates (Appendix Table E-11). These comparisons indicated that growth rates during the first two years were similar during pre-operational and operational periods. However, growth after the third summer appears to be slower during the 1975 to 1978 period. This discrepancy may be partially due to differences in interpretation of the ages and growth patterns by Wightman (1971) and NAI in the present study. Wightman's pre-operational data indicate that Hooksett Pond pumpkinseed attained 180 mm total length by age 4+, whereas the operational data suggest that 5 to 6 years are required to attain this length. This may reflect a reduction in growth rate among the older fish, but more likely this is a difference in aging of the fish. Growth rates during the pre-operational period appear to be unusually high, while the growth from 1975 to 1978 compares favorably with pumpkinseed growth rates in Massachusetts and New York (Carlander, 1977). Growth rates for Hooksett Pond pumpkinseed occasionally appeared to be higher downstream of the discharge canal (1977 and 1978) but this was not observed consistently and may be attributed to natural variations in growth rates and variability of sampling between years rather than to effects of the thermal discharge.

Length-weight relationships for pumpkinseed captured from 1972 through 1978 show that pumpkinseed throughout Hooksett Pond have a condition factor near 3.0, indicating a healthy increase in weight as a function of length (Appendix Table E-14).

8.2.3.4 Yellow Perch

Yellow perch prefer cooler water temperatures than the centrarchids, and frequently inhabit lakes and rivers with clear water, moderate amounts of vegetation and substrates of mud, sand or gravel (Scott and Crossman, 1973). Hooksett Pond affords all these habitat characteristics.

Spawning occurs between 2° and 14°C (Muncy, 1962; Brazo, 1973), but is optimal at 7.8 to 12.2°C (U. S. Fish and Wildlife Service, 1970). The National Technical Advisory Committee (1968) recommends 20°C as the maximum temperature compatible with successful egg development. Eggs are spawned in a ribbon-like egg mass over submerged vegetation. Upon hatching, the larvae are positively phototactic and pelagic; generally they can not sustain themselves against wind-generated currents. These larvae could be subject to entrainment during this pelagic phase, but have not been observed in Hooksett Pond entrainment samples. The larvae become substrate oriented when they attain 25 to 40 mm total length.

Larval yellow perch prefer temperatures of 20 to 24°C (Mount, 1969; Ross *et al.*, 1977). Juvenile temperature preferenda are typically 20 to 25°C (Ferguson, 1958), although Barans and Tubb (1973) reported thermal preferences during the autumn to be as high as 31°C (Figure 8-7).

The preferred temperature of adult yellow perch is 20 to 21°C. Adult yellow perch tend to avoid thermal outfalls during the summer (Neill, 1971; Neill and Magnuson, 1974), but may congregate in thermal effluents during the winter and spring (Marcy, 1976b; Marcy and Galvin, 1973).

Modal seining temperatures for Hooksett Pond yellow perch were 21-25°C from 1974-1977 and 27.7-29.9°C in 1978, although this species was captured from waters as warm as 34°C (Figures 8-7 and 8-8). The 1978 thermal mode reflects the warmer thermal preference of juveniles; most of the yellow perch contributing to this thermal mode were juveniles collected at Station O-W. This distribution pattern may be related to habitat as well as thermal preference. Adults appeared to prefer the cooler waters north and south of the discharge canal.

Yellow perch were used in thermal toxicity studies from 1975 through 1977 to determine if the Merrimack Station cooling-water discharge was acutely toxic to this species. Two of the eight series indicated significantly higher (α=.05) mortality at the discharge canal mouth than at the ambient river locations (Table 8-3). An apparent chemical discharge from Merrimack Station during the third 1975 test series induced total mortality among the experimental fish (Appendix Table E-7; see also discussion on page 87, paragraph 1). The other significant mortality difference occurred during the third 1976 series, when 63% of the discharge canal perch died, but none of the yellow perch at the control site died (Appendix Table E-8). It was inconclusive whether this mortality was the result of thermal stress because the maximum discharge temperature (24°C) during this test series was within the acceptable thermal range for yellow perch (Ferguson, 1958; Barans and Tubb, 1973). In addition, the relevance of this mortality may be questioned because the fish were artificially confined within a region that, under normal circumstances, the perch probably would have left when thermal conditions became deleterious. The absence of adult yellow perch in the vicinity of the discharge canal mouth during the summer attests to this ability.

Back-calculated lengths at annulus formation were calcuated for yellow perch collected from 1975 through 1978 and compared to pre-operational growth rates (Appendix Table E-12). Age 0+ yellow perch grew faster during post-operational years, but growth rates subsequently declined in the older fish. Yellow perch growth rates are extremely variable, depending on population size, habitat and productivity (Scott and Crossman, 1973). Increased growth rate among the younger age classes may reflect changes in population size or habitat (e.g., temperature), whether natural or artificially induced. Faster growth may induce the onset of maturity at an earlier age than before, and thus slow the growth during successive years. This cannot be verified by existing data, however, because the age at maturity was not examined. Growth rates also appeared to be faster downstream of Merrimack Station during the first summer, but this difference was minimal during successive years.

Length-weight relationships of yellow perch from 1972 to 1978 indicate no long-term decreases in condition or consistent variations in condition of perch captured upstream and downstream of Merrimack Station (Appendix Table E-15).

8.2.3.5 White Sucker

The white sucker is the least heat-tolerant species that resides in Hooksett Pond. Juvenile suckers have a thermal tolerance limit of 35 to 36°C in the laboratory, but have been killed at 31.4°C under natural conditions (Huntsman, 1942). Adult white suckers prefer temperatures less than 27°C, although they have been observed in regions as warm as 31°C (Figure 8-9).

The white sucker was the most deleteriously affected species by thermal additions to the Ohio River from an Ohio power station (Yoder and Gammon, 1976). Prior to plant operation, white suckers had been distributed throughout the river. Following plant start-up, white suckers were confined to the backwater zones at temperatures of 25 to 27°C throughout the summer. Trembley (1960) reported white suckers in the Delaware River congregating at the cooler end (23.9°C) of a heated lagoon; some suckers died when chased into higher temperatures. Body temperatures of dying white suckers ranged from 30 to 33.3°C.

White suckers in Hooksett Pond have been captured from waters as warm as 34°C although modal seining temperatures (Figure 8-10) from 1974 through 1978 ranged from 21 to 30°C. Seining and electrofishing surveys prior to 1978 collected adult suckers most frequently in the ambient regions of Hooksett Pond (i.e., upriver of the discharge). During 1978 white suckers were most abundant near the discharge canal in spring and fall, and within the mixing zone during the summer. Water temperatures throughout 1978 were generally cooler than during previous years.

Although the white sucker is perhaps the least thermally-tolerant resident fish species in Hooksett Pond, their continued abundance north and south of the generating station indicates successful growth and reproduction.

8.2.3.6 Brown Bullhead

Brown bullhead inhabit shallow regions of lakes and slow-flowing streams, preferring areas of muddy substrate with abundant vegetation. Spawning occurs at temperatures around 21°C from March through September (Carlander, 1969; Scott and Crossman, 1973). Shallow nests are cleared in the sandy or muddy substrate, and the eggs are fanned and guarded by both parents. After hatching and leaving the nest, the larvae are guarded for several weeks by one or both parents until the young reach ∿50 mm total length. This guarding is one possible reason why no brown bullhead larvae were collected in entrainment samples at Merrimack Station.

Laboratory and field observations have indicated an upper thermal tolerance of approximately 35°C for adult brown bullhead (Figure 8-11), although juveniles generally tolerate warmer waters (Baily, 1955; Marcy, 1976b). Trembley (1960) found that bullheads in a Delaware River discharge lagoon with temperatures ranging from 23.9 to 37.8°C usually avoided regions warmer than 32.2°C. When the lagoon temperatures ranged between 31.7 and 41.1°C, brown bullhead congregated in areas of 31.7 to 32.2°C. The bullheads were observed briefly entering 40°C water to take food, but quickly retreated into cooler water.

Marcy (1976b) studied brown bullhead distributions before and during operation of the Connecticut Yankee Atomic Power Plant. After plant start-up, brown bullhead abundance was significantly reduced at both control and heated river stations; this decrease was attributed to the movement of bullheads into the discharge canal. Although this species was captured in the canal year-round, abundance was greatest during March and April. Most bullhead moved from the canal into the river during the spring, but returned to the canal as water temperatures decreased to 20°C in the autumn. Those bullhead remaining in the canal during the summer generally avoided waters warmer than 33.6°C.

Brown bullhead have been captured by fyke netting and electrofishing throughout Hooksett Pond. Prior to 1977 few were captured or observed near the discharge canal during the summer; however, during 1977 and 1978 brown bullhead were seined at the discharge canal mouth in waters up to 33°C (Figure 8-11). The ability of brown bullhead to sense temperature changes and move into more favorable thermal conditions, and the abundance of this species throughout the past 12 years indicate that present levels of thermal addition into Hooksett Pond have not adversely influenced the resident brown bullhead population.

8.2.3.7 Golden Shiners

Golden shiners commonly inhabit clear, weedy waters. They spawn from May through August at temperatures of 15.6 to 21°C. The adhesive eggs are scattered over filamentous algae or macrophytes and then abandoned; there is no parental care of the eggs or larvae. Both warm temperatures and long photoperiods are necessary for gonadal development, and neither factor alone will stimulate maturation (DeVlaming, 1975). This indicates that golden shiners inhabiting artifically heated regions would not be expected to mature and spawn earlier than populations inhabiting ambient conditions.

Field observations of golden shiner distribution within a thermal gradient at a Delaware River power plant showed that shiners swam throughout the gradient at temperatures of 25 to 32.2°C. When water temperatures ranged between 28.9 and 37.2°C, the shiners tended to crowd within the cooler regions (Trembley, 1961). When Trembley (1960) chased golden shiners from 25-26.1°C into 36°C regions, two died (body temperatures = 33.3 and 33.9°C) and the others returned successfully to cooler waters. However, Trembley also netted two live shiners that had body temperatures of 32.8 and 35°C. Golden shiners were found year-round in the Connecticut Yankee Atomic Plant discharge canal at temperatures between 6.7 and 40.0°C (Marcy, 1976b). They were most abundant within the canal during June, July and August.

Laboratory studies have indicated upper lethal temperatures of 30 to 35°C (Figure 8-12). Hart (1952) estimated the upper incipient lethal temperature for golden shiners to be 35°C, which agrees with field observations.

Relatively few golden shiners were collected during Merrimack River surveys prior to 1977. Therefore the effect of the discharge from Merrimack Station on this species is based on the 1977 and 1978 seining data. Golden shiners were collected throughout Hooksett Pond, but were most abundant at the discharge canal mouth both years. These shiners were collected in water temperatures up to 34°C (Figure 8-12), and had modal seining temperatures of 31.1-33.3°C (1977) and 23.3-25.5°C (1978). This lower modal seining temperature in 1978 was partially due to the lower seasonal temperatures observed throughout the summer of 1978. The abundance of golden shiners near the discharge canal mouth indicates that present levels of thermal additions do not limit the distribution of this species by exclusion throughout the summer. In turn, the abundance of golden shiners in the near-field regions may be an important factor influencing the distribution of the larger, piscivorous species in Hooksett Pond that feed on the golden shiners.

8.3 Conclusions

Hooksett Pond supports a diverse, warm-water finfish community. Fishery surveys from 1967 to 1978 have indicated the continued abundance of the dominant species: smallmouth bass, pumpkinseed, golden and common shiner, white sucker and brown bullhead. The resident populations appear to be healthy and to reproduce successfully. The operation of Merrimack Station appears to have had minimal impacts on these populations through entrapment, entrainment, and thermal additions. The continued success of these species throughout Hooksett Pond indicates that the populations have sustained themselves either because of negligible impact or through compensation, offsetting any losses due to the operation of Merrimack Station.

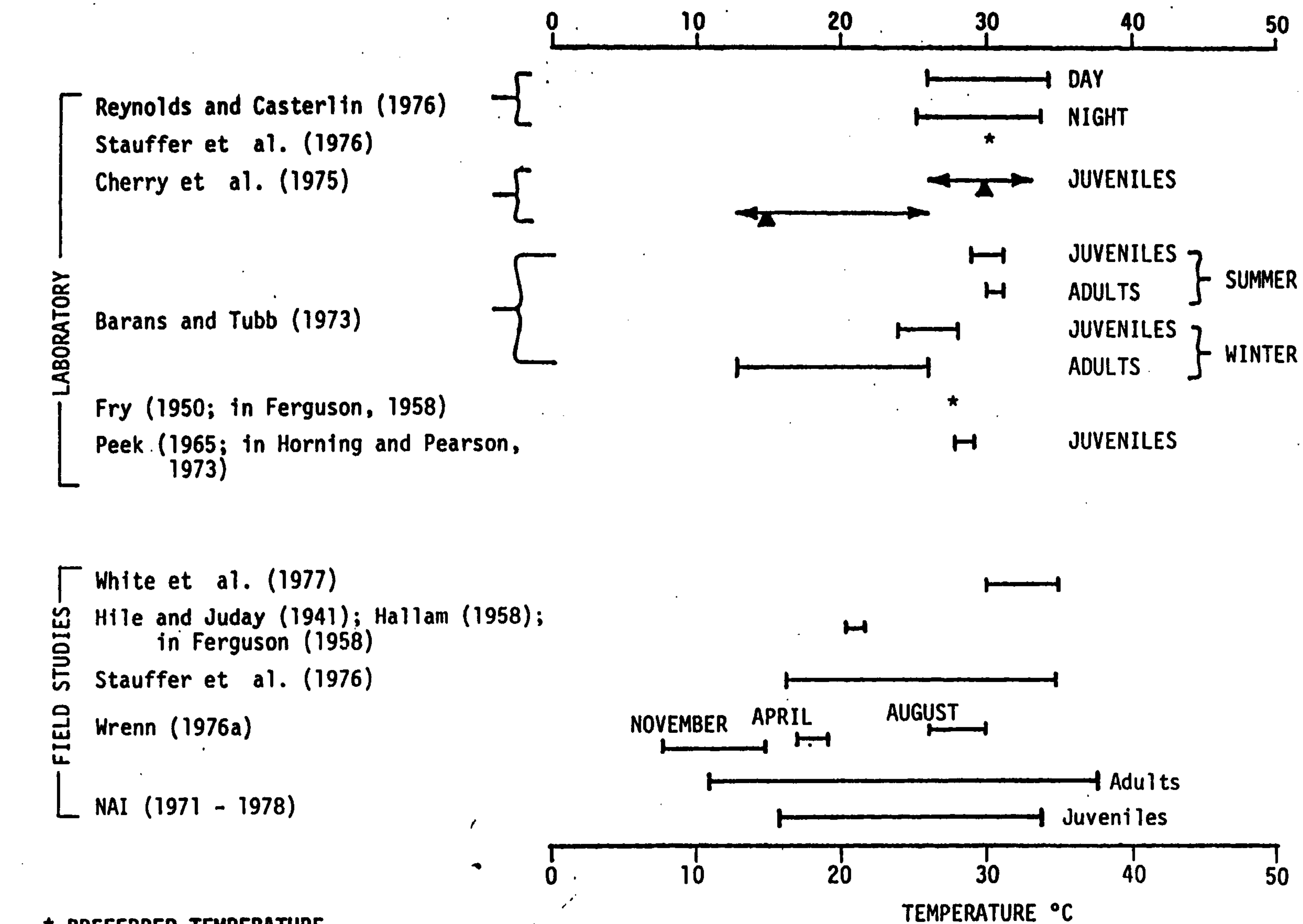


Figure 8-1. Thermal preference of smallmouth bass.
Merrimack River Summary Report, 1979.

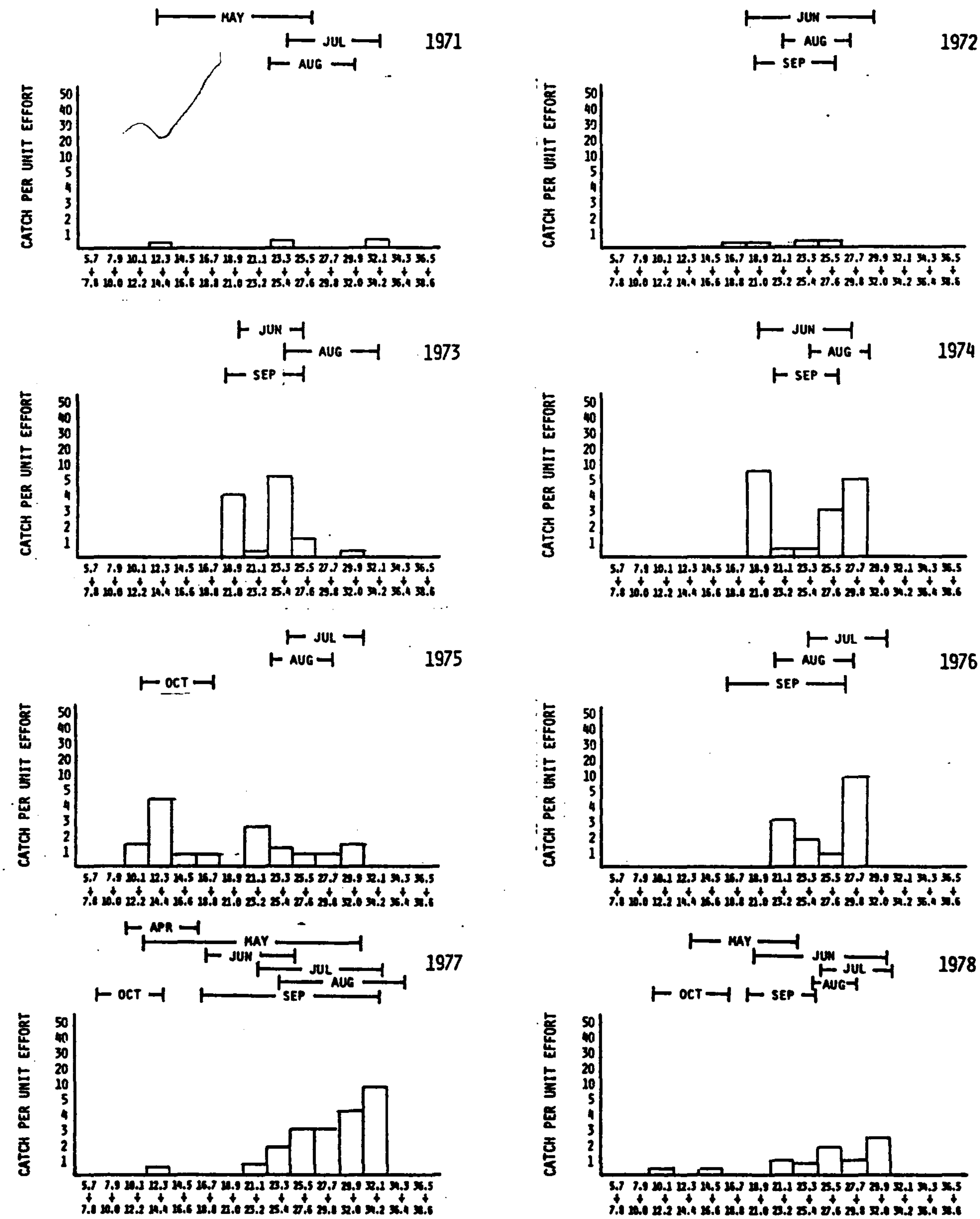


Figure 8-2. Catch per unit electrofishing effort (1971 to 1976) and seining effort (1977 and 1978) per 2.2°C (4°F) interval for smallmouth bass. Merrimack River Summary Report, 1979.

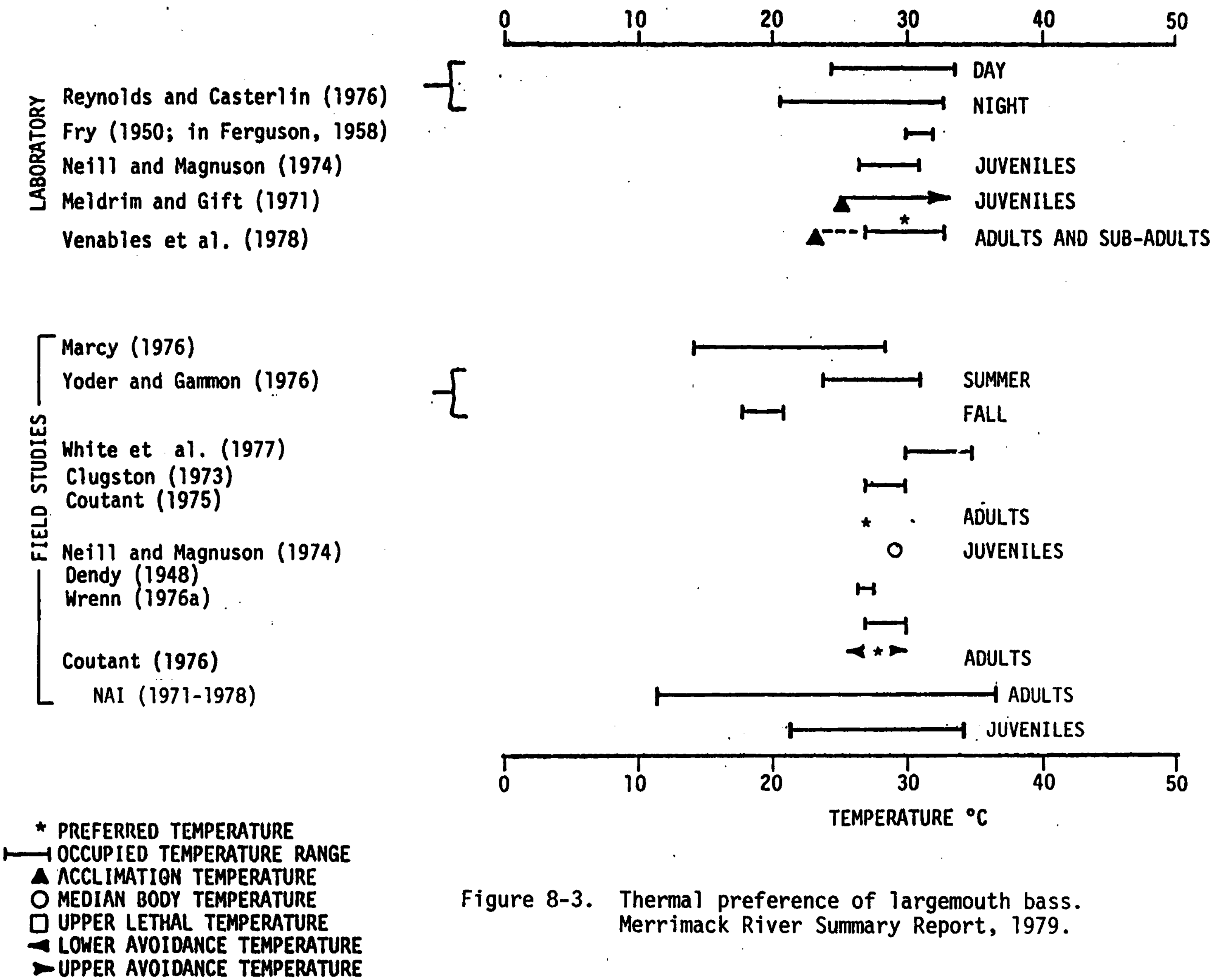


Figure 8-3. Thermal preference of largemouth bass. Merrimack River Summary Report, 1979.

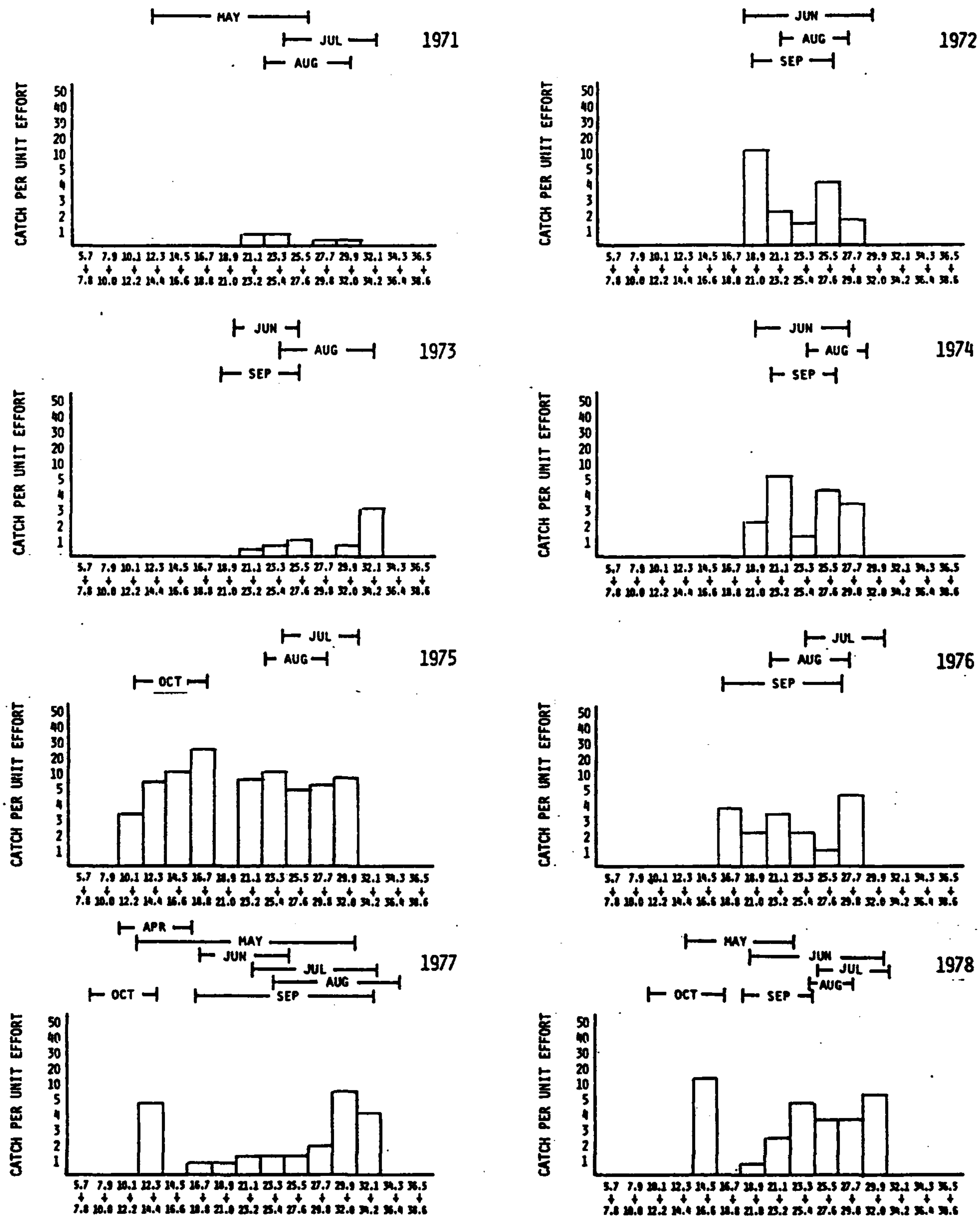
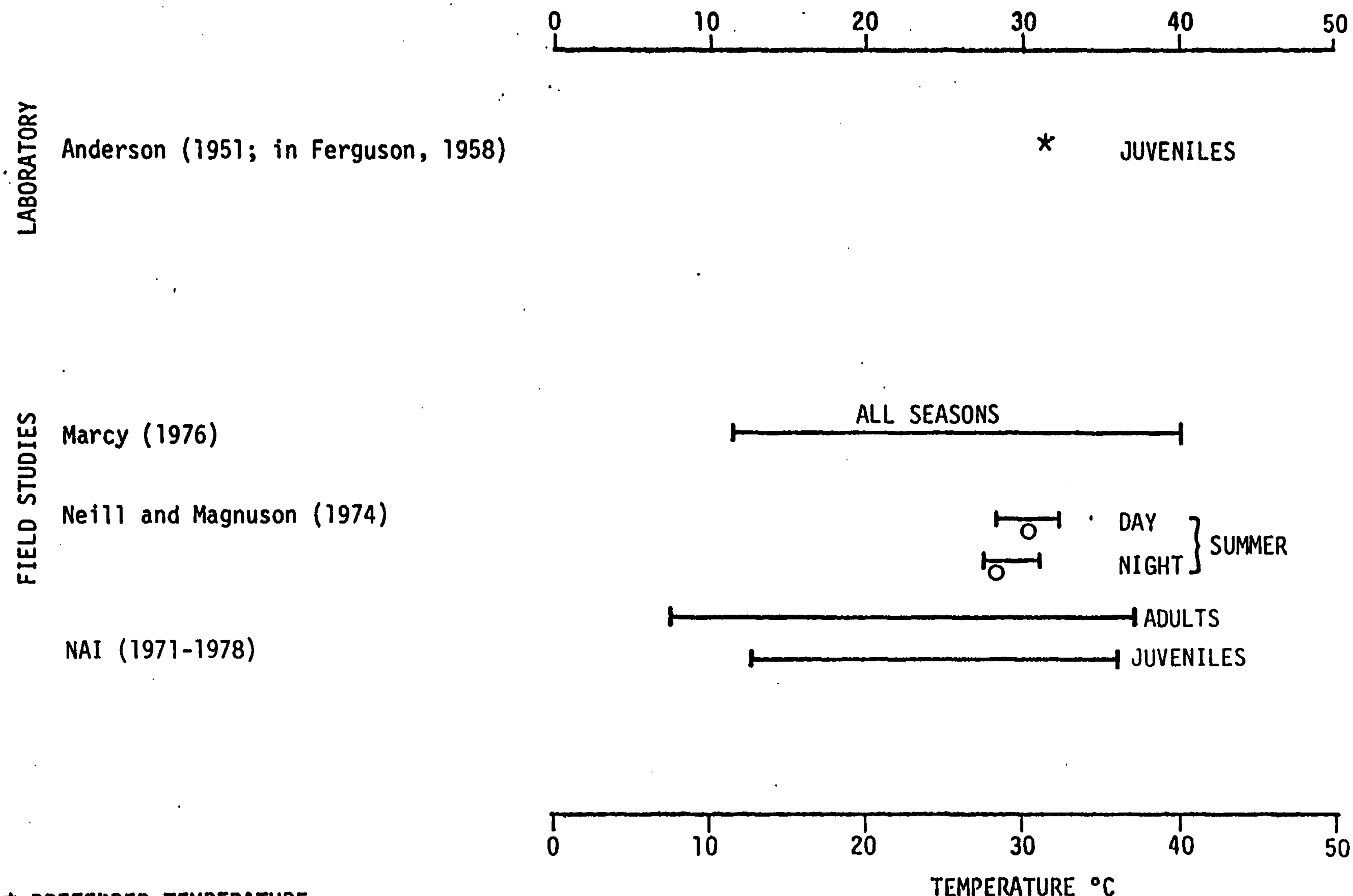


Figure 8-4. Catch per unit electrofishing effort (1971 to 1976) and seining effort (1977 and 1978) per 2.2°C (4°F) interval for largemouth bass. Merrimack River Summary Report, 1979.



* PREFERRED TEMPERATURE
OCCUPIED TEMPERATURE RANGE
ACCLIMATION TEMPERATURE
MEDIAN BODY TEMPERATURE
UPPER LETHAL TEMPERATURE
LOWER AVOIDANCE TEMPERATURE
UPPER AVOIDANCE TEMPERATURE

Figure 8-5. Thermal preference of pumpkinseed. Merrimack River Summary Report, 1979.

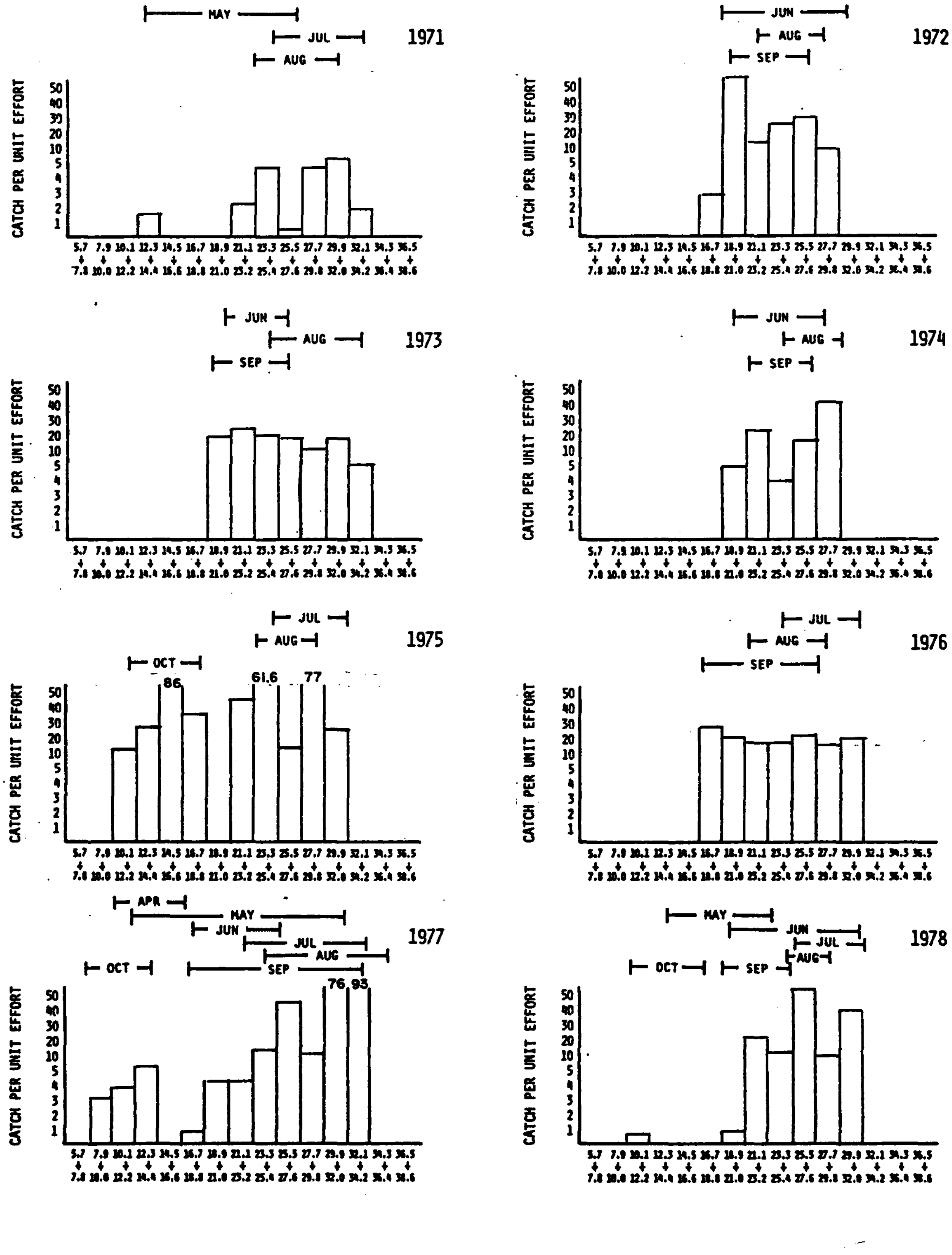


Figure 8-6. Catch per unit electrofishing effort (1971 to 1976) and seining effort (1977 and 1978) per 2.2°C (4°F) interval for pumpkinseed. Merrimack River Summary Report, 1979.

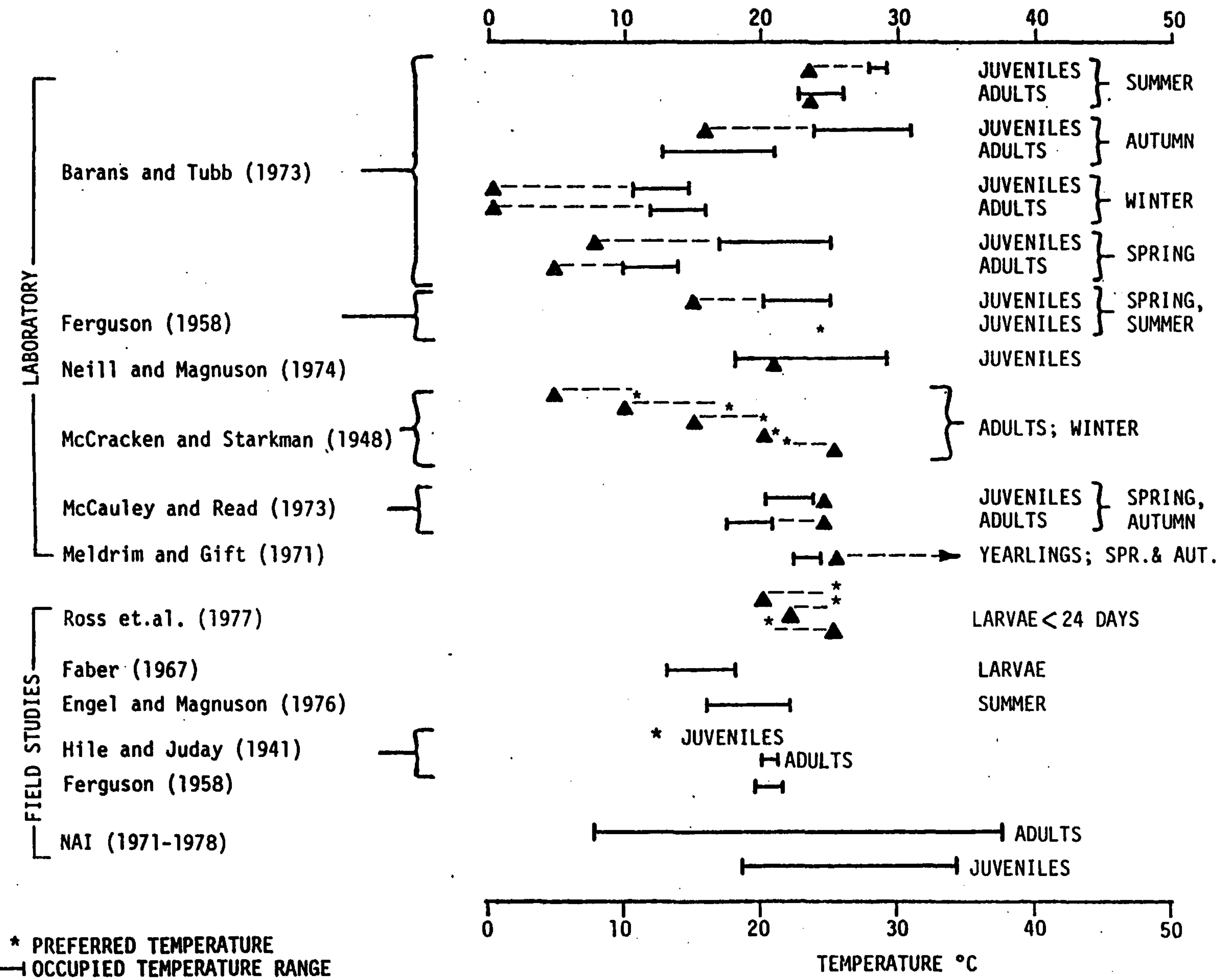


Figure 8-7. Thermal preference of yellow perch.
Merrimack River Summary Report, 1979.

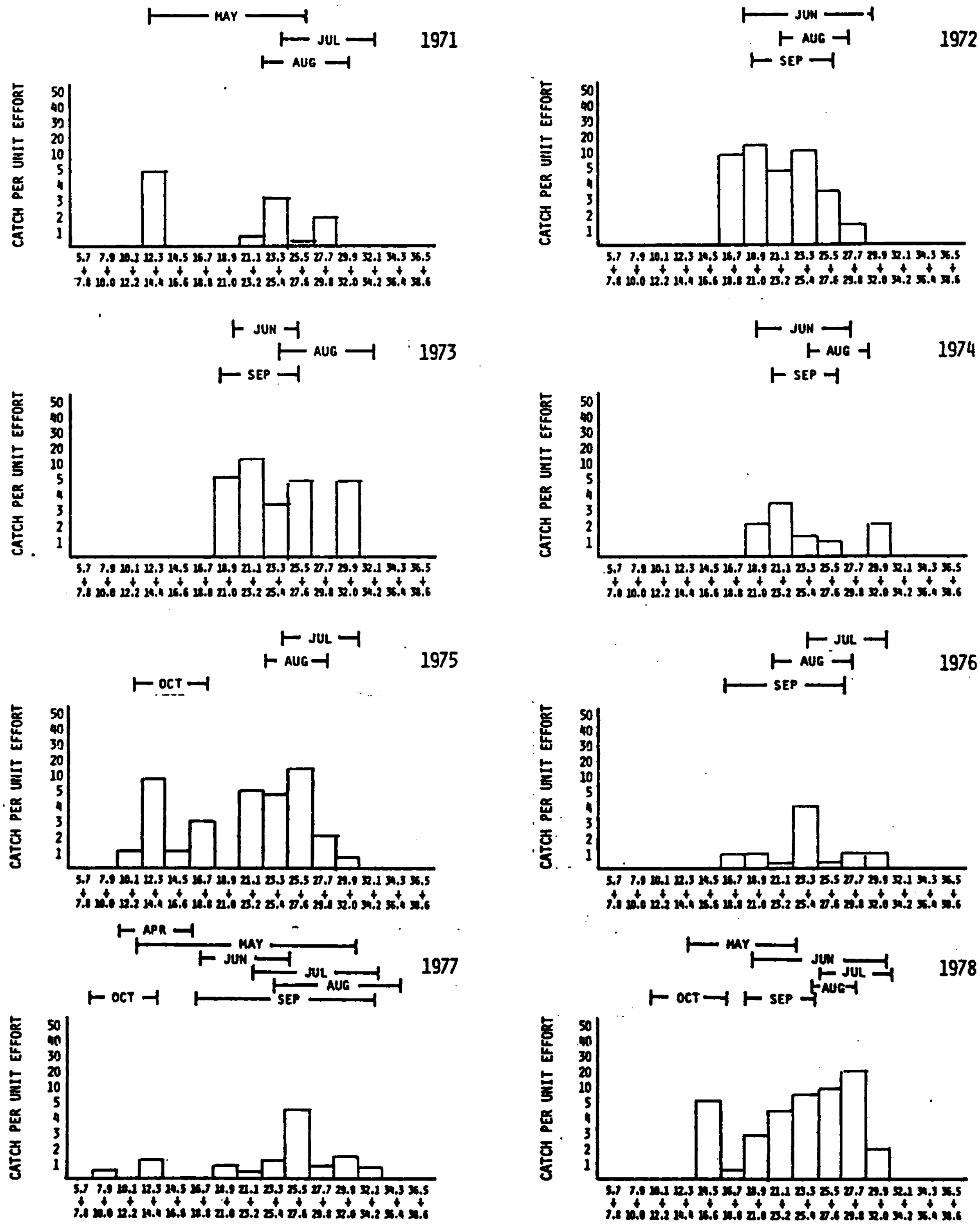


Figure 8-8. Catch per unit electrofishing effort (1971 to 1976) and seining effort (1977 and 1978) per 2.2°C (4°F) interval for yellow perch. Merrimack River Summary Report, 1979.

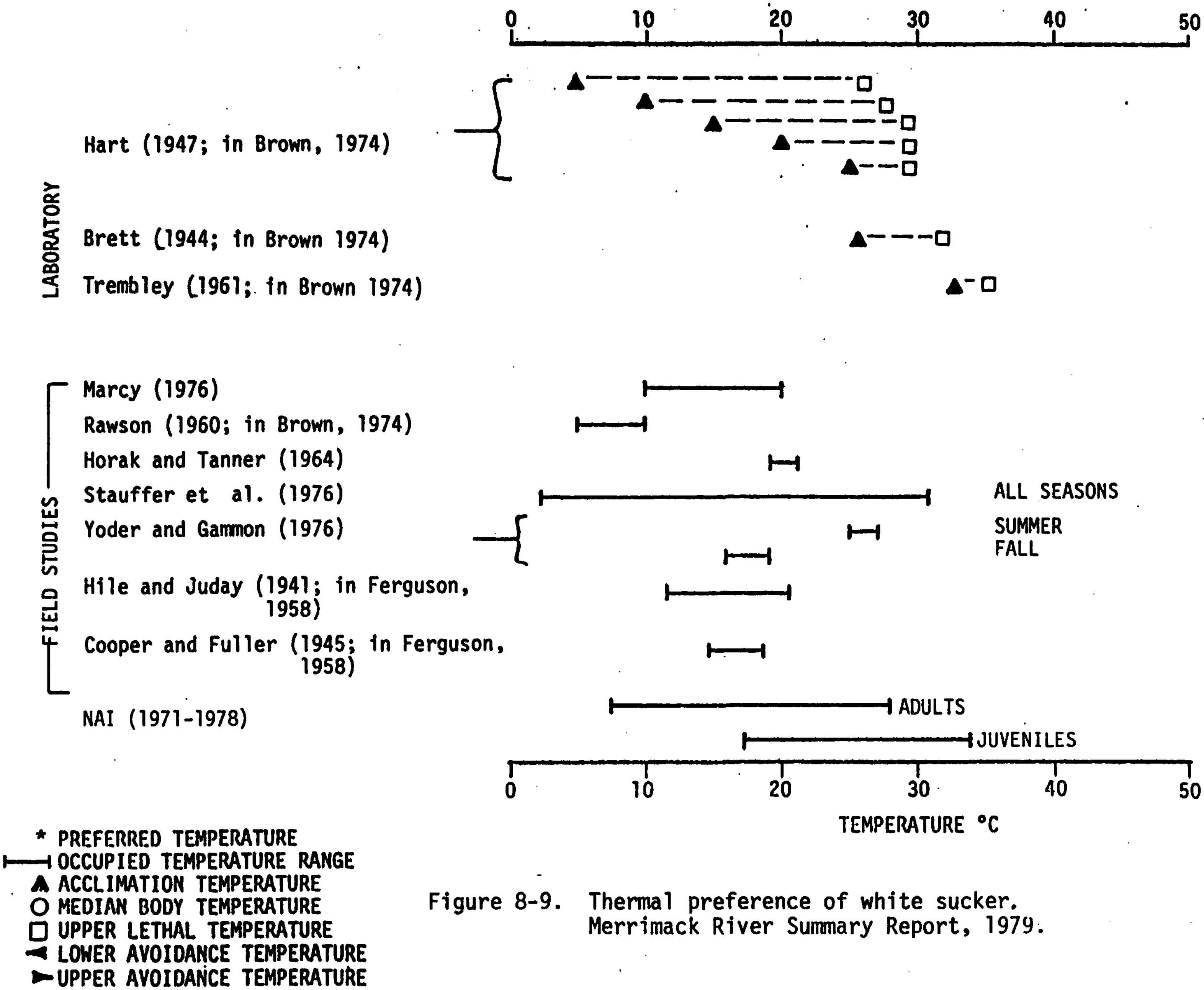


Figure 8-9. Thermal preference of white sucker. Merrimack River Summary Report, 1979.

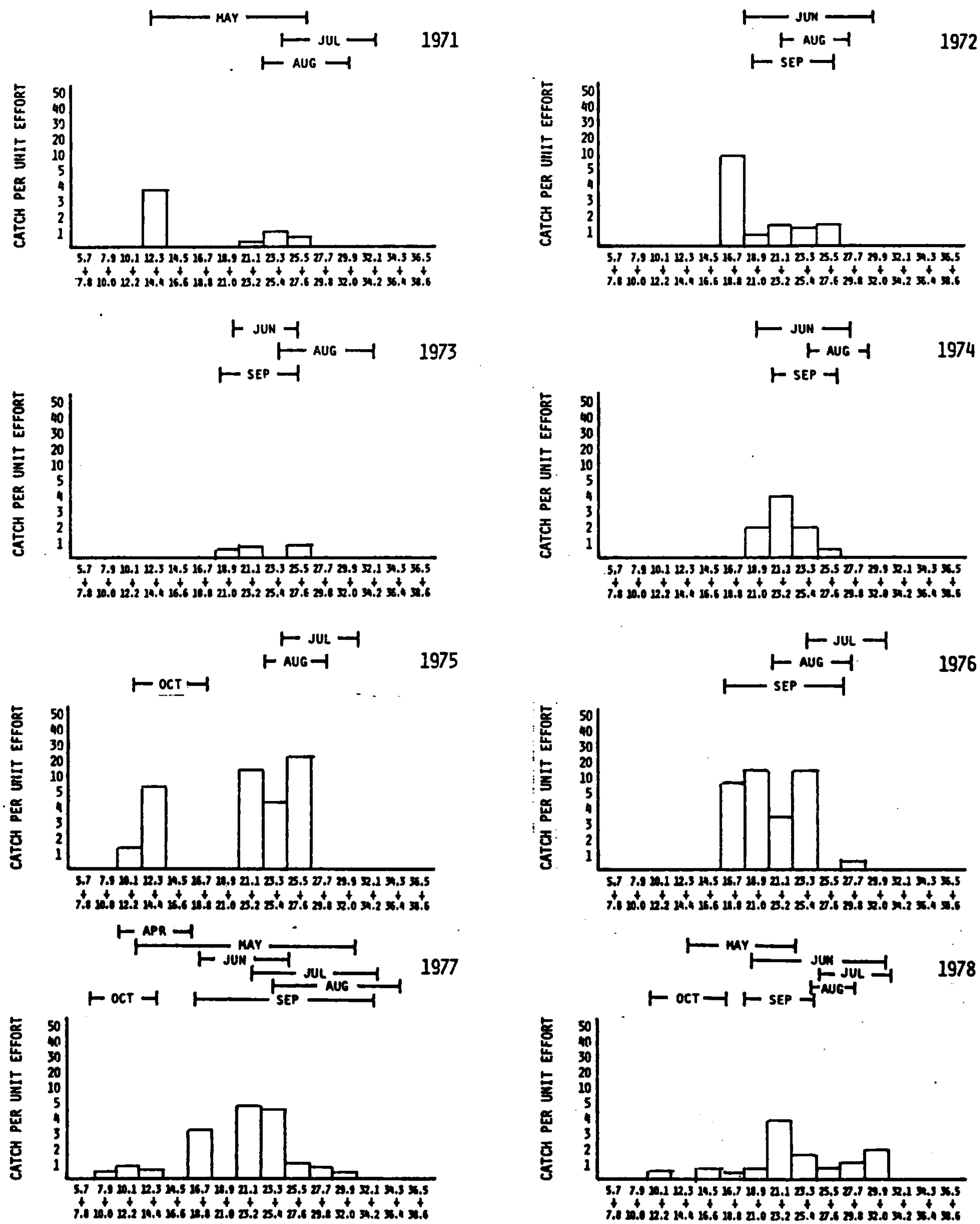


Figure 8-10. Catch per unit electrofishing effort (1971 to 1976) and seining effort (1977 and 1978) per 2.2°C (4°F) interval for white sucker. Merrimack River Summary Report, 1979.

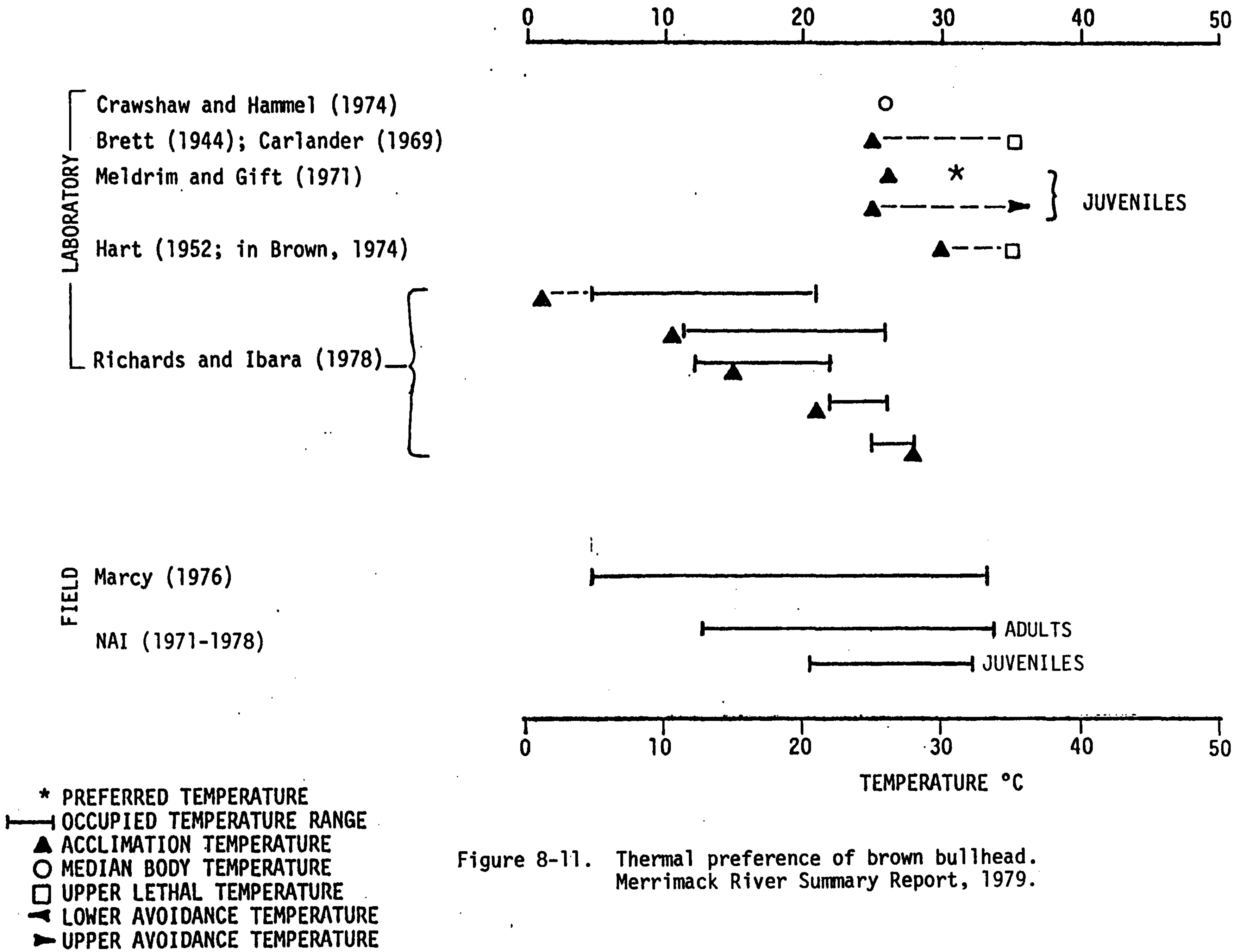


Figure 8-11. Thermal preference of brown bullhead. Merrimack River Summary Report, 1979.

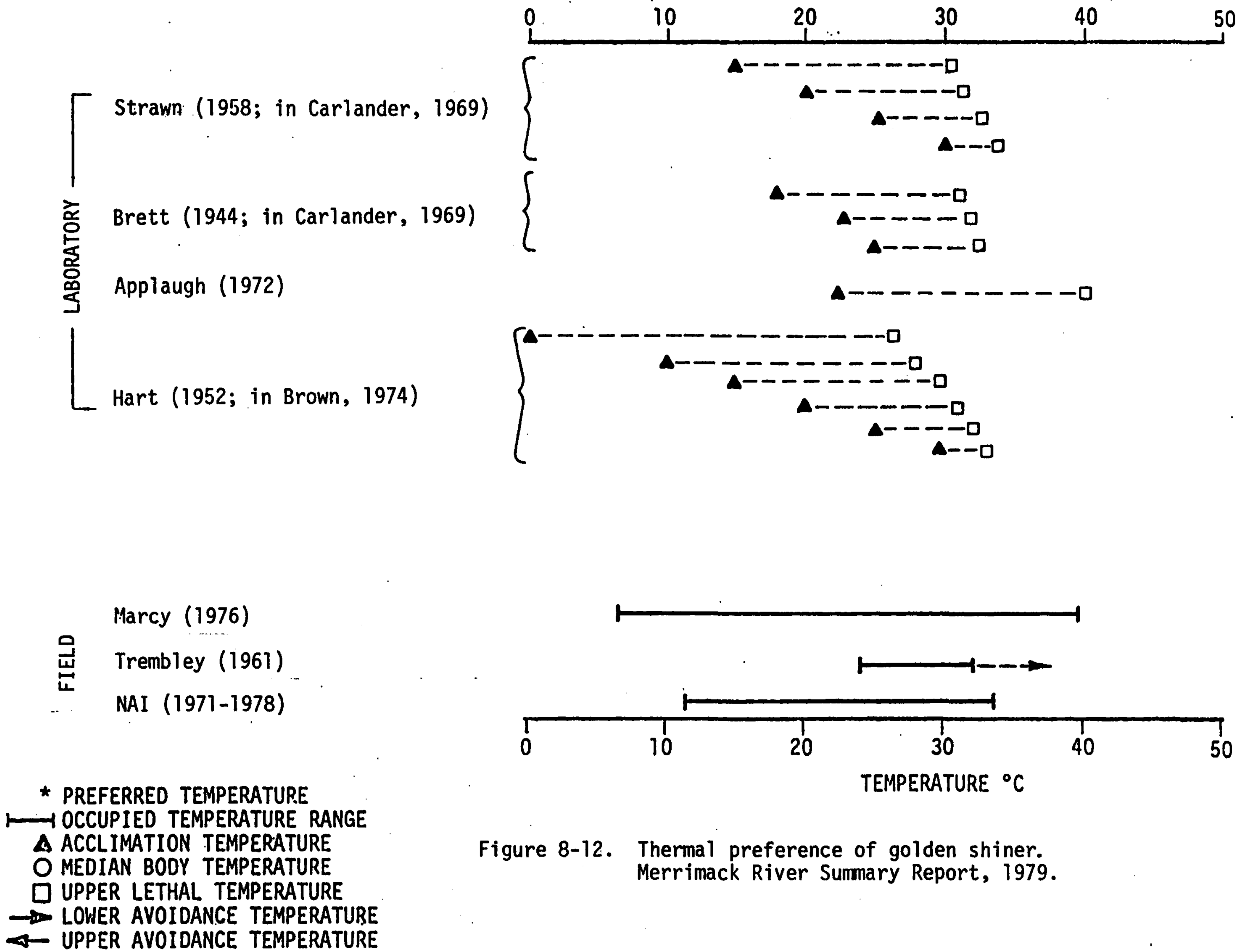


Figure 8-12. Thermal preference of golden shiner.
Merrimack River Summary Report, 1979.

TABLE 8-1. HOOKSETT POND FINFISH SPECIES LIST. MERRIMACK RIVER SUMMARY REPORT, 1979.

SCIENTIFIC NAME	COMMON NAME
Anguillidae	
Anguilla rostrata	American eel
Clupeidae	
Alosa sapidissima	American shad
Salmonidae	
Salmo gairdneri	Rainbow trout
Salmo salar	Atlantic salmon
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
Osmeridae	
Osmerus mordax	Rainbow smelt
Esocidae	
Esox niger	Chain pickerel
Cyprinidae	
Notemigonus crysoleucas	Golden shiner
Notropis cornutus	Common shiner
Notropis hudsonius	Spottail shiner
Notropis spp. (Larvae)	
Semotilus corporalis	Fallfish
Semotilus spp. (Larvae)	
Catostomidae	
Catostomus commersoni	White sucker
Ictaluridae	
Ictalurus natalis	Yellow bullhead
Ictalurus nebulosus	Brown bullhead
Noturus gyrinus	Tadpole madtom
Noturus insignus	Margined madtom
Percichthyidae	
Morone americana	White perch
Centrarchidae	
Lepomis auritus	Redbreast sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieui	Smallmouth bass
Micropterus salmoides	Largemouth bass
Percidae	
Etheostoma nigrum	Johnny darter
Perca flavescens	Yellow perch
Stizostedion vitreum	Walleye

TABLE 8-3. 1975-1977 FISH TOXICITY SUMMARY. MERRIMACK RIVER SUMMARY REPORT, 1979.

Results of Fisher Exact Probabilty Test to test acceptance (α=.05) of null hypothesis that mortality at Intake is equal to mortality at Discharge Canal

1975	Series 1*	Series 2	Series 3**
Smallmouth bass	Not tested	Accept H_o	Reject H_o
Yellow perch	Not tested	Accept H_o	Reject H_o
Pumpkinseed	Not tested	Accept H_o	Reject H_o

1976	Series 1	Series 2	Series 3
Smallmouth bass	Accept H_o	Accept H_o	Accept H_o
Yellow perch	Accept H_o	Accept H_o	Reject H_o
Pumpkinseed	Accept H_o	Accept H_o	Accept H_o

1977	Series 1	Series 2
Smallmouth bass	Accept H_o	Accept H_o
Yellow perch	Accept H_o	Accept H_o
Pumpkinseed	Accept H_o	Accept H_o

* In Series 1 all fish died during acclimation period at both locations.

** Fish-kill in discharge canal during Series 3, as a result of a chemical agent.

9.0 SUMMARY AND CONCLUSIONS

The addition of heat is the primary physical influence of Merrimack Station on Hooksett Pond. Modifications of the cooling water system during 1972 effectively decreased the mean temperature of the discharged cooling water by 4°C. Present levels of thermal addition to Hooksett Pond sometimes exceed the conditional guidelines established in 1975 for operation of Merrimack Station, but the chemical and biological portions of this monitoring program have consistently demonstrated that existing levels of thermal loading have not been harmful to fish or other aquatic life forms.

Hooksett Pond nutrient concentrations have not been altered by operation of Merrimack Generating Station. Nutrient concentrations declined sharply between 1970 and 1971, most likely as the result of pollution abatement activities in the upper Merrimack River basin. Present concentrations of nitrate and nitrite are within state and federal guidelines. Total phosphate phosphorus concentrations exceed New Hampshire Class B water quality standards, but are normally within levels recommended by federal guidelines for flowing waters.

Dissolved oxygen concentrations in Hooksett Pond have consistently attained federal standards (>5.0 mg/l) since 1972, and have rarely decreased below New Hampshire cold-water standards (6.0 mg/l; 75% saturation). Although the New Hampshire Water Supply and Pollution Control Commission has indicated that low oxygen concentrations have been partially responsible for nonattainment of Class B standards in this portion of the Merrimack River, this monitoring program has indicated only isolated incidents of substandard oxygen concentrations during the past seven years. Discharged cooling water from Merrimack Station has typically been 90 to 100% oxygen saturated, although absolute oxygen concentrations have been reduced as much as 1.8 mg/l compared to ambient because of decreased oxygen solubility at higher temperatures. These reduced oxygen concentrations have not been of sufficient magnitude to jeopardize the Hooksett Pond aquatic ecosystem.

Studies of periphyton, net phytoplankton, and standing crop of primary producers as estimated by chlorophyll *a* concentrations have indicated short-term reductions in abundance of primary producers in the near-field regions. However, reductions in the far-field regions are rare in occurrence, and temporary. Maximum impact appears to coincide with low flows and maximum thermal output during the autumn when diatoms dominate the plankton communities. Overall, there have been no long-term reductions in autotrophic production within Hooksett Pond that can be attributed to the operation of Merrimack Generating Station. In addition, the lack of among-station differences in the net zooplankton communities, coupled with apparent minimal entrainment mortality in terms of the numbers of organisms entrained, suggests no reduction or adverse change in the Hooksett Pond zooplankton community due to the operation of the Merrimack Generting Station.

Field surveys from 1970 to 1974 did not reveal any significant trends in aquatic macrophyte abundance and distribution; the variability evident between years is most likely attributable to long-term riverine cycles. Comparisons of similar habitats above and below the discharge canal revealed differences of lower magnitude than those occurring between years within a given station. These observations suggest that heated effluent from the Merrimack Station has generally had no adverse effect on the distribution and abundance of aquatic macrophytes in the Merrimack River.

Benthic macroinvertebrate distribution throughout Hooksett Pond was influenced primarily by water velocity and substrate composition. The communities observed at mid-channel are, therefore, distinct from the littoral communities; the littoral communities have higher densities and number of taxa because of the finer substrate and increased amount of organic matter. Benthic macroinvertebrate communities upstream and downstream of the Merrimack Generating Station were similar. This similarity may be attributed to: 1) the thermal tolerance of the benthic macroinvertebrate communities, and 2) the surface-configuration of the discharge plume which tends to ameliorate any potential effects.

Therefore, the operation of Merrimack Generating Station has not adversely affected the downstream benthic macroinvertebrate communities in comparison with those from ambient regions.

Hooksett Pond supports a diverse, warm-water finfish community. Fishery surveys from 1967 to 1978 have indicated the continued abundance of the dominant species: smallmouth bass, pumpkinseed, golden and common shiner, white sucker and brown bullhead. The resident populations appear to be healthy and to reproduce successfully. The operation of Merrimack Station appears to have had minimal impacts on these populations through entrapment, entrainment, and thermal additions. The continued success of these species throughout Hooksett Pond indicates that the populations have sustained themselves either because of negligible impact or through compensation, offsetting any losses due to the operation of Merrimack Station.

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11.0 APPENDICES

APPENDIX A

This appendix presents the methods used for all aspects of the Merrimack River Monitoring Program. More detailed procedures can be found in Annual reports (Normandeau 1969; NAI, 1969; 1971; 1972; 1973; 1974; 1975; 1976; 1977; 1978a, b; 1979a).

A. PHYSICAL STUDIES

1. River Discharge

Continuous discharge measurements were obtained from the Garvins Falls Gauging Station, maintained by PSCoNH. These data were reported as 6-hr means expressed in cubic feet per second (cfs) and, during 1976, 1977 and 1978, subsequently converted to cubic meters per second (cms).

2. Depth of Visibility

Secchi disc visibility was measured weekly at Stations N-10-M, Zero, S-4-M and S-17-M from April through October 1971-1978. Measurements at Station Zero were generally taken at 0-W, but during 1975 and 1976 they were taken mid-river. Depth at which the disc dissappeared from view was recorded to the nearest 1/2 ft and, from 1976 to 1978, subsequently expressed as meters. In 1970 Secchi disc visibility was measured at N-6, S-4, S-17 and the discharge canal.

3. Turbidity

Single surface water samples were taken weekly at N-10, Zero, S-4, and S-17 from 1976-1978. In the laboratory, turbidity was measured on the Formazine Turbidity Units (FTU) scale using a Hach Model 2100A Turbidimeter.

4. Temperature

Three types of temperature studies were conducted during the study period: a) continuous monitoring of surface temperatures; b) weekly temperature profiles; and c) monthly cross-sectional temperature profiles during late summer and early fall. Supplementary temperature data were also collected in conjunction with biological studies.

a. Continuous Temperature Monitoring

Rustrak temperature recorders were installed at N-5, 0-W and the tailrace of Hooksett Hydroelectric Station from 1968 to 1970; Geodyne model A-775 digitizer, digital temperature and dissolved oxygen recorders with thermistor sensors were installed at Stations N-10, Zero, and S-17. In 1971 only Rustrak strip recorders were used for continuous monitoring, and the Station O-W probe was moved downstream 400 feet due to power spray module construction. Yellow Springs (YSI) Instrument thermivolt thermometers connected to Westinghouse (Hagen) signal converter and Langamo digital pulse recorders recorded surface temperatures at N-10, O-W and S-4 from 1972 to 1978. Calibration was performed weekly. The system was linked by computer to the station control room in 1974 and a check of system operation was provided every 15 minutes.

b. Weekly Temperature Profiles

Temperature profiles during 1970 were measured at N-6-M, O-W, S-4-M and S-17-M; the control station was moved from N-6 to N-10 in 1971. Only surface and bottom temperatures were recorded in 1971; but mid-depth temperatures were also recorded in 1972. Starting in 1974 temperature profiles were also measured at Stations 0-M, 0-E, S-4-E and S-4-W. From 1975 to 1978 temperatures were recorded at the eight stations at one foot depth intervals. YSI Model 44 telethermometer was used from 1970 to 1977, but was replaced with a calibrated NAI digital thermistor during 1978.

c. Monthly Temperature Profiles

In 1967, 1968 and 1970 temperature profiles were taken with a YSI Model 44 telethermometer at one foot depth intervals and at five points across the river for each station. Profiles were taken at several stations north and south of the power plant and in Amoskeag Pond. The telethermometer was checked periodically against a precision grade mercury thermometer. A Martek Model 101 temperature, depth and conductivity meter was used for profiling from 1971 to 1974; a YSI thermistor unit was also used during 1974. Thermal profiling stations (N-10, N-5, N-1, Zero to S-10, S-14, S-18, S-22, S-24) were standardized in 1972, and the number of points across the river was increased to six in 1973. A YSI thermistor and a calibrated NAI field thermistor were used during 1975-1976 and 1977-1978, respectively. All electronic equipment was calibrated with a precision-grade mercury thermometer.

B. WATER QUALITY

1. Nutrients

Water samples were collected and analyzed twice a week during the summer and once a week until ice formation from June 1, 1967 to November 1968. Samples were collected at N-4, the discharge canal and S-17. Organic ammonia nitrogen, pH, nitrate, nitrite, orthophosphate, total phosphate, polyphosphate, chloride, hardness, calcium, biological oxygen demand, sulfate and turbidity were analyzed according to Standard Methods (APHA, 1965). Water quality samples were collected during the 1970 monitoring study period at N-6, N-4, the discharge canal, S-4 and S-17. Orthophosphate, polyphosphate and total phosphate concentrations were determined according to FWPCA Methods for Chemical Analyses of Water and Wastes (1969), and nitrates and nitrites determined according to Standard Methods (APHA, 1965). In 1971 nutrient stations were established at N-10, 0-W, S-4, S-17 and sampled weekly from April to October. Nitrate and nitrite determinations were made according to Strickland and Parsons (1968). Phosphate analysis procedures were the same as in 1970. Nutrients were analyzed in 1972 following the 13th Edition of Standard Methods (APHA, 1971). No further changes were made in procedures or sampling until 1975, when the frequency of sampling was decreased to once a month at Stations Zero and S-17; sampling at Station

Zero was also moved to mid-river during 1975 and 1976. Polyphosphate monitoring was discontinued in 1975. In 1976 analyses of nitrite, nitrate and orthophosphate was conducted in accordance with EPA (1974) techniques. Total phosphate samples collected April to September 15, 1976 were analysed using the Auto Analyzer II Automated Ascorbic Acid Reduction Method (Gales, 1975); in September the EPA (1974) procedure was adopted. Silica monitoring was begun in August of 1976. During 1977 and 1978 all nutrient analyses were conducted in accordance with EPA (1974) techniques.

2. pH

From 1968 to 1978 samples were taken during the sampling season at control (N-6-M, 1970; N-10, 1971-1978), discharge (O-W), and southern stations (S-4, S-17). The pH was measured in the lab using an Orion Research Model 401 specific ion meter until 1978. In 1978 pH was measured in the field with an Instrumentation Laboratory Inc. Portomatic pH meter 175.

3. Dissolved Oxygen

Dissolved oxygen (DO) was measured using the azide modification of the iodometric (Winkler) method (APHA 1971, 1965) from 1967 to 1977. DO measurements in 1978 were made with an Orbisphere Model 2709 meter at one foot intervals. Surface samples were collected weekly April through October (1970 through 1978) at N-10, O-W, S-4 and S-17. In 1967 and 1968 DO was measured several times a week June, July and early September at the following locations: north and south of the plant, the heated effluent, the Suncook River and the Amoskeag Pond. DO was also measured with a YSI Model 54 oxygen meter and Geodyne A775 Digitizer in 1967, 1968 and 1970. The YSI oxygen meter provided near bottom data and the Geodyne provided continuous DO data for June - November of 1968 at N-10, Zero and S-17.

A 24-hour survey of DO was initiated in 1971. DO was measured at N-10-M, O-W, S-4-M and S-17-M every four hours at one foot intervals. From 1972 through 1978 DO was measured at the following stations: N-10, Zero, S-4, S-17 and S-24 at east littoral, mid-channel and west littoral locations. Measurements were made using a YSI meter in 1971, 1975, and 1976; using a Martex Mark II unit from 1972 through 1974; and using an Orbisphere model 2709 meter in 1977 and 1978. Instrument calibration checks were made every four hours during the surveys.

C. PLANKTON

Plankton collections were made in 1967 and 1968 by towing a plankton net behind a boat for either 1000 or 500 feet; from 1970 to 1978 metered plankton nets (76µm, #20 mesh) were used. Samples were collected north of the power plant (usually N-10), the discharge canal, S-4 and S-17. From 1971 to 1978 subsurface samples were taken at N-10 and S-4., and also at S-17 in 1971. Samples were returned to the lab for identification, enumeration and preservation. In 1967 and 1968 four to five subsamples were examined within three hours of collection. Two drops were placed on a microscope slide and five scans made of each subsample. Results were reported as the number of scans in which a particular organism appeared compared to the total number of scans made. From 1970 to 1972, 25 fields of a Sedgwick-Rafter cell at 100X were scanned, counted and reported as the number of cells per 100 liters. Forty-five fields of a Sedwick Rafter cell were exmained at 100X for phytoplankton and nine vertical strips at 40 to 50X for zooplankton from 1973 to 1976. Abundances were expressed as cells/100 liter. In 1977 and 1978, two one-ml subsamples were examined for plankton. Counts were made on the whole ml for zooplankton and on three verticle passes for phytoplankton. Prior to 1975 cohesive phytoplankton cell groups were enumerated as single units; subsequently individual cells within the colony or group were counted to provide more consistant comparisons among years.

D. PERIPHYTON

In 1968 racks containing several microscope slides were suspended approximately 2 ft below the surface at N-10, the discharge weir, and S-17 on July 5, 1968 and removed July 24, 1968. In 1970 modified Catherwood diatometers were installed 3 ft below the surface at N-6, S-4 and S-17 in April, and at the discharge weir in March. Samples were collected monthly, immersed in water and returned to the laboratory for analyses. Twenty-five fields were examined at 400X, and the percentage of surface area occupied by each taxonomic group was estimated. Organisms were identified to the following taxa: protozoa, rotifers, gastrotrichs, annelids, nematodes, immature insects, blue green algae, green algae, diatoms, other yellow-green algae, dinoflagellates and fungi.

In 1971 periphyton accumulators were installed at N-10, Zero, S-4 and S-17 approximately 2 ft below the water surface. Slides were numbered 1-30; slide number one was removed weekly and replaced with a clean slide as a short term monitor; slides 2-30 were sampled in consecutive weeks as long-term accumulation indicators. Within 24 hours of collection, periphyton groups were counted. From 1972 to 1975 accumulators were also installed at Stations N-10 and S-4 at 6 ft depths. Slides were sampled weekly and monthly, biota identified to major groups, and percent composition determined from 1972 to 1975. Slides were collected monthly in 1976, every two weeks and monthly in 1977 and 1978.

Laboratory procedures have remained consistent since 1975. One side of each slide was scraped; the cells were suspended in 10 ml of water from which a one ml aliquot was drawn for examination; the cells or organisms within 25 fields per slide are examined at 250X, and populations estimated by extrapolating these counts to represent the total number of organisms per slide surface area.

E. CHLOROPHYLL *a*

Weekly water samples were taken at Stations N-10, Zero, S-4 and S-17 from 1971-1978 for chlorophyll *a* determintations. From 1971 through 1975 determinations were made using the trichromatic method (APHA, 1971) and from 1976 through 1978 using fluorometric method (Strickland and Parsons, 1968). Comparability tests of the two methods were performed at NAI analytical laboratory during 1976 and indicated the measurements were comparable (Wayne Johnston, NAI, personal communication).

F. AQUATIC MACROPHYTES

Qualitative surveys of aquatic macrophytes were conducted during early and late summer from 1970 to 1974 and late summer 1978 at the discharge canal and at Stations N-10 through S-24. Observations on the relative abundance and distribution of each species of emergent, submerged and floating-leaved vascular plant were made. Submerged species were collected by means of an anchor while the more readily accessible species were obtained without special collecting techniques. In cases where field identification was not possible type specimens were returned to the laboratory for conclusive identification. General habitat characteristics such as water depth, current and substrate type were noted at each survey station.

G. ENTRAINMENT

Entrainment samples were collected at four locations in 1975 and 1976: the intake structures, the discharge weir, immediately below the power spray modules, and the discharge canal mouth. Using a #20 (76μm) plankton net, duplicate plankton samples were collected weekly at the intake structures and canal mouth June 24 - October 14, and on October 28, 1975. At the discharge weir, samples were collected monthly until early August when weekly sampling was instituted. In 1976 samples were collected weekly at the intake, discharge weir, and canal mouth from June through September, and every other week during April, May and October. Samples were also taken monthly (May through October) immediately below the power spray modules during 1976. In both years all plankton samples were diluted to 0.95 total volume to which 28 ml of 5% Evans Blue solution was added.

Beginning in 1977, whole water samples were taken for plankton entrainment. Samples were collected at three locations in 1977: (1) the intake forebay of either Unit I or Unit II; (2) between the circulators and condensers of operating units; and (3) between the condensers and the discharge weir of opeating units. In 1978 samples were collected at five locations: (1) Station N-5, between the intake forebays at surface and near substrate; (2) between the circulators and condensers; (3) between the condensers and the discharge weir; (4) at the discharge weir; and (5) at the canal mouth. Five-gallon samples were collected prior to daily chlorination weekly from June through September and every other week during April, May and October. Concurrent with sampling, water temperature was measured ±0.1°C with a precision grade mercury thermometer from 1975 through 1977, or a calibrated NAI field thermister unit in 1978. Water for chlorophyll *a* determinations was also collected concurrently with plankton samples in 1975, 1976, 1977 and 1978.

During 1975 and 1976 phytoplankton and zooplankton samples were allowed to incubate in the Evans Blue solution for 3 and 2 hr respectively, washed and resuspended in filtered river water, and then analyzed. Phytoplankton samples were examined at 125X until 1000 cells were counted and identified to lowest practical taxon. Zooplankton were counted and identified for 0.5 hr per sample.

Two one liter and two 2-liter plankton samples were inoculated with Evans Blue solution in 1977 and 1978, respectively. In 1978 the remaining 4 gal were concentrated to one liter and stained with Evans Blue for zooplankton enumeration.

Plankton samples were allowed to incubate in the Evans Blue solution for 3 hr before being washed and rediluted to 10 ml with distilled water. Phytoplankton were enumerated by examining three verticle passes of a one ml sample in 1977 and by examining an entire milliliter sample in 1978, following the methods outlined in Biological Field and Laboratory Methods (Weber, 1973). Organisms were identified to the generic level.

The criteria for determining if a cell was live or dead was the same in all years. Cells exhibiting no blue color in the chloroplast were regarded as living, whereas those with blue coloration were considered dead (Gaff and Okong'O-Ogola, 1970; Crippen and Perrier, 1974). Identical counting procedures were used for the zooplankton samples. Zooplankters were regarded as living if they were (a) unstained, (b) exhibited blue color in the gut region only due to phytoplankton ingestion, or (c) were motile (Crippen and Perrier, 1974). Fully-stained organisms were classified as dead.

Chlorophyll *a* concentrations were determined by the fluorometric method (Strickland and Parsons, 1968) in 1976, 1977 and 1978, and by the trichromatic method (APHA, 1971) in 1975.

To measure ichthyoplankton entrainment, duplicate tows were taken along the bottom at each of the four entrainment stations in 1975 and 1976 using an NAI-modified 1/2 x 1 m Tucker Trawl (Tucker, 1951) with a 505μm nylon mesh. Only the canal mouth and N-5 were sampled in 1977 and April and May of 1978.

From May 23 through July 27, 1978 the water flowing into the Unit I intake was sampled on a diel basis to determine entrainment susceptibility of resident fish larvae. A recessed impeller trash pump rated at 41,000 gph maximum with 102 mm (4 in) suction and discharge pipes was used to sample intake water at three depths. Three intake pipes were manifolded into one 102 mm pipe before entering the pump. The water was pumped into a 1/2 m, 505μm mesh net suspended in a 208 liter (55 gal) drum. The pump rate was calibrated every 24 hrs by recording the time required to fill the 208 l drum, and converting this figure to liters per second. The pump was operated at a constant speed throughout the subsequent 24 hr sampling period; total run time was multiplied by the flow rate to estimate the total water volume sampled. Sample nets were changed every four hours. Samples were washed into a bottle and preserved in 10% buffered formalin in the laboratory. All larvae were hand sorted from debris and represerved in 5% buffered formalin prior to identification and enumeration.

H. BENTHOS

Duplicate ponar samples were taken at N-15, N-10, N-5, Zero, S-5, S-10 and S-15 at five points across the river during 1967 and 1968 to determine distribution of mussels and snails. After samples were sieved, mussels and snails were removed and returned to the lab for enumeration and identification. Ponar grabs were also collected (1967 to 1971) at two or three substations across the river at Stations N-8, S-8 and S-20 and returned to the lab for processing. Five 200 ml aliquots of each sample were sifted through a #24 mesh screen and examined.

Benthic sampling stations and procedures were consistant from 1972 to 1976. Two replicates were taken from mid-river, east and west littoral areas of Stations N-10, Zero, S-4 and S-17. Samples were sieved, stained with rose bengal (beginning in 1973), preserved with formalin and returned to the laboratory for processing. In the lab each sample was washed through a #30 sieve and transfered to a white sorting tray. Organisms were separated from debris by hand picking the entire sample, placed in 70% ethanol, and later enumerated and identified to the lowest possible taxon. Although procedures remained fairly constant from 1972 through 1976, several modifications were initiated in 1977. Triplicate ponar samples were taken in the west littoral and mid-river areas of N-10, Zero, S-4, and S-17. Duplicate artificial multiplate colonization samples were also collected from these stations during June, August and October of 1977 and 1978.

I. FISHERIES

The 1967, 1968 fisheries methods are reported in Wightman (1971). Coarse plankton nets, seines, dip nets and cameras were used in 1970 to observe and document the presence of larval and juvenile fish. Beginning in 1971 both larval and adult fish were studied; N-10, N-8, N-6, N-3, Zero, S-5, S-10 and S-18 were seined, dip netted, and electrofished for 150 foot lengths along both banks. Electrofishing was conducted from 1972 to 1976 by shocking 1000 ft sections of both banks using a boat mounted 220V, 3000W pulsating DC generator at: N-9 to N-10, N-6 to N-7, Zero to S-1, S-4 to S-5 and S-17 to S-18. In 1977 seining replaced electrofishing. Samples were collected from the east and west littoral regions of Stations N-10, Zero, S-4 and S-17 using a 100x8' bag seine (1" bar mesh wings, 1/4" bar mesh bag). Numbers, species and size were recorded.

Immature fish seining was conducted when flow permitted 1973 through 1976 at Stations N-10, Zero, S-2 and S-17 using a 15 foot 1/4" stretch mesh, minnow seine. N-7 was also seined in 1975 and 1976.

Fyke netting was conducted on the Merrimack River from 1972-1978. Fyke netting stations, N-10-E, N-10-W, S-3-E and S-2-W were sampled monthly from May through October. Nets were set twice a week for two day periods, and captured fish were identified, weighed, measured, and released; during 1972 and 1973 smallmouth bass, pumpkinseed and yellow perch were also sexed. Where possible scale samples from all smallmouth bass, pumpkinseed and yellow perch were taken for subsequent age determination. Age determinations were made initially to verify findings of length frequency analyses. However beginning in 1975 analyses of age and growth using the back-calculation method (Lagler, 1956) was used to define growth histories of the three major species. Data from 1972 through 1978 seasons were used in this method, and results were compared to those of Wightman (1971) for 1967 to 1969 populations to document whether any longterm growth rate changes had occurred.

Fish entrapment monitoring at Merrimack Station was conducted on a weekly basis from January 1976 through December 1977. The number of fish impinged during a continuous 48-hr period each week was used to estimate total annual impingement by calculating the number of fish impinged per sampling hour and multiplying this rate by the number of hours the circulators operated during the year. Sampling effort alternated between Units I and II when both units were operating.

Fish entrapment monitoring at Merrimack Station was further conducted on June 19 and 27, and from July 31 through October 23, 1978, to document any impingement of downstream-migrating Atlantic salmon smolts and juvenile American shad. Samples were not collected during the weeks of August 28, September 26 and October 16. Each week through mid-September all screen washings from one generating unit were collected for 48 continuous hours, but were collected for only 8 to 24 hrs per week from September 18 through October 23. During this time, the washings were periodically sorted, and all fish identified, measured (total length), and discarded. In previous years the sampling effort alternated between Units I and II on successive weeks. During 1978, however, entrapment monitoring was limited to Unit I because of the extended shut down period of Unit II. To project the number of fish impinged during each sampling week, the number of each species captured was divided by the number of sampling hours (catch/hour). This number was then multiplied by the total number of hours during that week in which the circulator pumps were operational.

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APPENDIX B

This appendix presents results from thermal plume surveys conducted in Hooksett Pond, Merrimack River, NH. Surveys presented were selected to show plume distribution during various river discharge conditions (Appendix Table B-3; page 148). In 1972, 1974 and 1975 temperatures were measured in °F for cross sectional profiles (Appendix Figures B-7, B-11 and B-15) and converted to °C for the longitudinal surface profiles (Appendix Figures B-8, B-12, B-16); after 1975 cross sectional profiles were measured in °C.

APPENDIX TABLE B-1. WEEKLY SURFACE TEMPERATURE PROFILES: AMBIENT TEMPERATURE (°C) AND OBSERVED ΔT FROM AMBIENT AT THREE MONITORING STATIONS, 1972-1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

1972

SAMPLE DATE	APRIL 4	APRIL 11	APRIL 18	APRIL 28	MAY 5	MAY 11	MAY 17	MAY 22	MAY 30	JUNE 6	JUNE 13	JUNE 19	JUNE 29	JULY 5	JULY 10	JULY 17	JULY 24	JULY 31	AUGUST 7	AUGUST 15	AUGUST 21	AUGUST 31	SEPTEMBER 5	SEPTEMBER 14	SEPTEMBER 19	SEPTEMBER 27	OCTOBER 2	OCTOBER 11	OCTOBER 19	OCTOBER 26
N-10	N/A	2.7	4.4	6.1	6.1	8.1	10.0	14.4	18.8	N/A	16.4	19.4	21.1	20.5	21.7	24.4	25.3	24.2	20.8	20.6	22.2	22.8	20.6	19.4	19.4	18.1	14.8	12.7	8.6	8.3
O-W	N/A	3.8	2.2	7.7	6.1	10.1	7.2	8.8	11.4	N/A	11.4	10.3	6.4	5.0	5.6	5.0	2.5	2.2	6.4	5.0	0.3	7.2	6.4	7.8	7.2	7.9	1.6	7.3	4.1	7.4
S-4	N/A	0.5	0.5	1.6	0.5	3.1	1.6	3.3	4.2	N/A	4.3	6.4	3.9	1.7	2.8	3.3	1.1	1.9	3.3	0.6	0.3	4.7	3.6	6.9	5.6	6.3	0.7	4.1	3.9	4.7
S-17	N/A	0.5	0.5	0.5	0.5	0.3	0.5	0.8	2.2	N/A	0.8	0.0	0.8	0.0	0.5	1.4	0.8	0.3	1.1	-1.7	2.2	2.2	3.1	3.9	2.8	5.4	1.3	1.2	1.9	2.8

1973

SAMPLE DATE	APRIL 10	APRIL 18	APRIL 25	APRIL 30	MAY 8	MAY 14	MAY 21	MAY 29	JUNE 5	JUNE 12	JUNE 18	JUNE 24	JULY 3	JULY 11	JULY 16	JULY 24	JULY 30	AUGUST 6	AUGUST 13	AUGUST 20	AUGUST 28	SEPTEMBER 4	SEPTEMBER 10	SEPTEMBER 18	SEPTEMBER 25	OCTOBER 1	OCTOBER 10	OCTOBER 16	OCTOBER 23	OCTOBER 31
N-10	4.8	8.3	11.9	9.1	12.1	12.2	11.4	12.7	16.7	21.7	18.0	20.0	19.0	22.1	21.4	23.2	24.7	24.8	24.9	24.5	24.4	26.3	19.1	16.7	14.4	15.1	13.0	12.5	9.8	9.7
O-W	8.2	3.3	7.5	0.9	3.2	2.3	1.3	1.8	2.7	8.1	5.1	6.8	1.6	0.3	5.2	6.7	7.6	5.9	7.4	7.6	7.6	7.1	7.4	4.7	7.8	8.2	9.5	7.9	0.3	4.3
S-4	0.8	0.3	1.9	0.7	0.2	0.1	0.7	0.5	0.1	4.8	3.3	3.3	-0.1	0.2	2.4	3.3	5.7	3.2	3.8	6.3	6.4	4.8	4.7	5.8	5.8	3.4	5.8	5.2	0.3	0.5
S-17	0.5	0.2	0.7	0.4	0.3	0.2	0.2	0.5	0.0	1.6	0.3	1.0	0.1	0.3	1.8	1.2	1.3	0.8	1.3	3.3	5.0	4.8	3.9	2.4	3.2	2.6	2.6	2.7	0.3	0.4

1974

SAMPLE DATE	APRIL 1	APRIL 10	APRIL 15	APRIL 23	APRIL 29	MAY 6	MAY 13	MAY 21	MAY 28	JUNE 3	JUNE 10	JUNE 17	JUNE 24	JULY 1	JULY 8	JULY 15	JULY 22	JULY 29	AUGUST 5	AUGUST 12	AUGUST 19	AUGUST 26	SEPTEMBER 3	SEPTEMBER 9	SEPTEMBER 16	SEPTEMBER 23	SEPTEMBER 30	OCTOBER 7	OCTOBER 15	OCTOBER 21	OCTOBER 28
N-10	3.1	2.8	5.3	9.5	10.5	9.5	10.0	14.8	11.1	14.6	21.7	20.1	22.1	20.7	24.4	25.7	23.9	22.8	25.6	23.2	23.6	23.9	21.7	19.2	20.1	18.4	16.1	13.8	10.8	6.3	6.7
O-W	14.9	2.0	1.1	3.9	0.7	1.2	5.0	3.9	5.7	6.0	8.9	9.5	8.1	4.6	8.1	8.5	8.1	7.7	3.3	7.4	2.9	6.7	7.2	6.8	6.6	7.0	7.4	4.0	10.9	9.3	7.6
S-4	1.9	0.2	0.0	0.5	0.1	0.0	1.1	1.1	1.1	2.4	3.9	4.1	4.3	0.6	5.8	5.4	6.1	6.0	2.4	4.9	2.1	4.5	4.9	4.2	2.9	0.8	0.8	2.6	5.6	3.1	1.7
S-17	1.6	0.0	0.3	0.2	0.1	0.2	0.5	0.5	-0.5	0.4	1.3	1.1	1.5	1.2	2.7	2.6	3.2	2.3	1.1	3.2	2.4	2.7	2.3	3.7	1.2	1.3	1.5	0.5	1.6	0.9	1.3

1975

SAMPLE DATE	APRIL 1	APRIL 7	APRIL 14	APRIL 21	APRIL 29	MAY 6	MAY 12	MAY 19	MAY 26	JUNE 2	JUNE 9	JUNE 16	JUNE 22	JUNE 30	JULY 8	JULY 14	JULY 21	JULY 28	AUGUST 4	AUGUST 11	AUGUST 14	AUGUST 25	SEPTEMBER 2	SEPTEMBER 10	SEPTEMBER 15	SEPTEMBER 22	SEPTEMBER 30	OCTOBER 6	OCTOBER 16	OCTOBER 20	OCTOBER 30
N-10	0.8	1.7	4.4	5.0	6.4	9.4	13.1	16.2	19.4	20.1	15.0	15.9	23.3	25.0	26.0	24.2	25.4	24.4	27.4	25.0	23.7	21.6	18.8	19.4	17.4	17.6	15.1	14.5	2.2	10.1	10.0
O-W	9.8	3.3	8.0	0.8	0.3	6.2	8.2	8.1	2.2	2.7	6.8	7.9	0.0	7.2	8.2	8.8	7.4	7.8	7.6	8.3	2.4	7.3	8.4	7.2	5.4	6.3	6.6	2.6	6.3	8.8	0.0
S-4	0.3	0.4	0.8	0.6	0.5	1.7	2.7	3.7	1.4	0.9	2.2	3.1	0.6	5.0	6.4	3.1	4.6	4.8	5.1	6.1	N/A	6.2	5.6	4.1	3.3	3.9	1.8	0.2	1.5	4.3	0.0
S-17	0.3	0.2	0.7	0.6	0.7	0.8	0.8	0.8	0.6	0.9	0.6	1.3	0.6	1.8	3.9	2.6	1.9	3.1	3.7	3.9	3.1	3.9	2.3	2.3	0.4	3.5	0.2	0.0	0.6	0.4	-0.1

Continued

APPENDIX TABLE B-1. (Continued)

		APRIL					MAY					JUNE				
	SAMPLE DATE	6	13	19	27		4	11	17	24		1	7	14	22	28
1976	N-10	6.4	4.4	10.8	8.1		10.0	13.3	15.6	11.2		17.4	17.2	20.8	25.2	24.7
	O-W	1.9	4.1	1.1	1.9		0.3	10.0	2.8	10.0		10.1	5.6	9.2	8.9	6.2
	S-4	0.0	0.3	0.6	0.3		0.3	0.8	1.0	2.9		4.3	1.1	6.4	6.8	4.0
	S-17	0.0	0.6	0.6	0.3		0.3	0.3	0.3	0.6		1.3	1.1	3.6	4.0	2.7
	SAMPLE DATE	4	11	18	26		2	9	16	23	31	6	13	20	27	
1977	N-10	3.6	3.0	7.2	2.2		10.1	12.9	13.5	21.5	20.0	19.6	17.2	20.7	22.9	
	O-W	1.2	0.0	13.3	8.8		12.0	11.3	12.5	4.0	8.9	8.7	4.4	11.2	7.1	
	S-4	0.4	0.0	1.7	1.9		2.1	1.9	2.3	1.4	6.0	5.6	0.8	0.9	1.8	
	S-17	0.3	0.0	0.8	1.3		1.7	0.4	1.9	0.5	3.9	3.7	0.6	0.9	1.3	
	SAMPLE DATE	3	10	17	25		1	8	15	22	30	5	12	19	26	
1978	N-10	1.2	4.3	3.8	6.5		7.0	11.3	11.0	13.5	20.7	19.1	19.1	19.3	22.5	
	O-W	0.3	4.7	15.8	5.1		11.4	12.0	11.1	9.8	11.8	9.0	11.1	10.7	3.9	
	S-4	0.1	-0.3	0.1	0.0		1.4	2.9	3.3	1.3	5.6	2.4	2.7	5.7	1.4	
	S-17	0.3	-0.3	0.1	0.0		0.4	0.4	0.5	0.5	1.7	-0.3	0.4	1.9	0.3	
All Years		$\bar{x}$	Range				$\bar{x}$	Range				$\bar{x}$	Range			
	N-10	5.5	0.8-11.9				12.9	6.1-21.5				19.9	14.6-25.2			
	O-W	4.7	0.0-15.8				7.2	0.3-13.4				7.0	0.0-11.4			
	S-4	0.6	-0.3- 1.9				1.9	0.0- 6.0				3.3	0.1- 6.8			
	S-17	0.4	-0.3- 1.6				0.7	-0.5- 3.9				1.2	-0.3- 4.0			

		JULY					AUGUST					SEPTEMBER				OCTOBER				
	SAMPLE DATE	6	12	20	26		2	9	17	23	31	7	14	20	27	4	11	18	25	
1976	N-10	24.8	24.4	23.9	22.8		19.7	19.1	20.5	24.2	19.9	18.0	N/A	18.7	16.2	13.0	12.7	8.2	6.4	
	O-W	6.7	8.7	6.8	5.4		0.5	6.8	4.6	7.8	6.5	6.9	N/A	6.8	0.0	10.3	7.2	9.9	0.6	
	S-4	5.6	6.3	4.5	3.8		0.6	5.6	1.5	5.3	4.3	2.2	N/A	5.2	0.3	8.0	3.4	2.9	0.0	
	S-17	4.3	3.6	3.5	2.5		0.0	2.9	0.5	1.6	1.4	1.2	N/A	4.2	0.1	5.0	1.1	1.9	0.1	
	SAMPLE DATE	5	11	18	25		1	8	15	22	29	6	12	19	26	3	10	17	24	31
1977	N-10	23.7	24.4	27.3	25.2		24.7	26.4	26.4	21.8	25.0	24.0	19.8	18.6	14.1	12.0	10.8	8.2	7.3	8.1
	O-W	4.6	3.4	5.5	3.5		9.9	7.0	7.6	8.6	0.1	8.7	9.0	9.8	10.3	8.8	7.2	8.5	8.1	3.7
	S-4	1.7	1.6	0.4	2.3		7.5	4.9	5.0	4.9	0.3	6.2	4.7	6.0	3.7	1.6	2.1	-0.1	2.0	0.6
	S-17	1.1	0.2	0.2	0.4		3.4	4.3	2.0	1.7	1.0	2.9	2.8	2.4	1.1	0.5	0.3	-0.2	0.5	0.0
	SAMPLE DATE	5	10	17	24	31	7	14	21	28		5	11	18	25	2	9	16	23	30
1978	N-10	20.1	26.5	22.3	26.6	23.9	24.5	24.2	25.2	17.9		21.7	17.7	18.1	18.5	14.1	11.6	10.4	10.9	8.9
	O-W	-0.1	2.7	3.0	0.7	0.1	3.9	4.0	0.9	2.1		2.1	3.7	3.2	-2.2	4.1	8.1	9.8	11.3	10.4
	S-4	0.0	-0.3	1.6	0.1	-0.4	1.4	2.1	0.6	2.0		1.1	2.1	2.4	-0.4	1.9	6.2	6.6	8.3	6.9
	S-17	-0.2	0.6	0.5	0.5	-0.4	0.2	2.3	0.5	1.7		0.9	1.1	1.0	0.1	1.5	3.4	3.6	4.4	2.9
All Years		$\bar{x}$	Range				$\bar{x}$	Range				$\bar{x}$	Range			x	Range			
	N-10	23.7	19.0-27.3				23.3	17.9-27.4				20.1	14.1-26.3			10.7	6.3-15.1			
	O-W	5.2	- 0.1- 8.8				5.5	0.1- 9.9				6.3	- 2.2-10.3			6.7	0.0-11.3			
	S-4	3.0	- 0.4- 6.4				3.7	0.3- 7.5				3.8	- 0.4- 6.9			3.2	- 0.1- 8.3			
	S-17	1.6	- 0.2- 4.3				2.1	-1.7- 5.4				2.3	0.1- 5.4			1.5	- 0.2- 5.0			

N/A - Data not available

APPENDIX TABLE B-2. WEEKLY BOTTOM TEMPERATURE PROFILES: AMBIENT TEMPERATURE (°C) AND OBSERVED ΔT FROM AMBIENT AT THREE MONITORING STATIONS, 1972-1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

1972

SAMPLE DATE	APRIL				MAY					JUNE				JULY					AUGUST				SEPTEMBER				OCTOBER			
	4	11	18	28	5	11	17	22	30	6	13	19	29	5	10	17	24	31	7	15	21	31	5	14	19	27	2	11	19	26
N-10	N/A	2.8	4.4	6.1	6.1	7.8	10.1	14.2	18.3	N/A	16.1	19.4	20.6	20.6	21.7	24.2	25.0	23.6	20.8	18.9	21.1	22.5	20.6	18.9	19.9	17.8	14.9	12.7	8.9	8.3
O-W	N/A	0.6	2.2	7.8	6.1	3.3	1.1	0.6	1.1	N/A	1.1	1.1	0.0	0.6	0.6	0.3	0.6	0.5	0.8	0.6	0.0	0.3	0.0	1.9	0.4	1.1	0.7	1.1	0.4	1.1
S-4	N/A	0.1	0.6	0.6	0.0	2.8	0.3	1.4	1.7	N/A	0.8	1.1	0.6	0.6	0.0	0.3	0.8	0.3	0.6	1.1	0.6	0.0	0.8	0.0	0.7	0.0	0.3	0.5	0.5	1.1
S-17	N/A	0.6	0.0	0.6	0.6	0.3	0.0	1.1	2.2	N/A	1.1	-2.2	1.1	0.6	0.3	0.3	0.8	0.3	0.8	1.1	0.3	0.8	2.2	0.6	0.8	1.1	1.1	1.1	1.7	2.8

1973

SAMPLE DATE	APRIL				MAY				JUNE				JULY					AUGUST				SEPTEMBER				OCTOBER				
	10	18	25	30	8	14	21	29	5	12	18	24	3	11	16	24	30	6	13	20	28	4	10	18	25	1	10	16	23	31
N-10	4.9	8.3	11.9	12.1	11.4	12.7	11.4	12.7	16.7	21.4	17.9	20.0	18.9	22.1	21.3	22.9	24.6	24.6	25.0	24.4	23.9	26.0	19.2	16.6	14.4	14.8	13.1	12.5	9.9	9.6
O-W	5.7	0.6	0.4	0.2	0.2	0.3	0.2	0.3	0.2	0.8	0.9	0.8	0.1	0.1	0.3	2.7	2.3	0.5	2.8	6.1	1.7	1.7	0.8	7.6	0.6	1.9	5.2	1.9	0.1	0.2
S-4	0.4	0.1	0.7	0.2	0.1	0.3	0.1	0.3	0.0	0.4	0.1	0.2	0.0	0.1	0.3	0.4	0.1	0.1	0.3	0.1	0.0	0.0	0.3	0.4	0.2	0.3	0.6	0.4	0.3	0.2
S-17	0.7	0.0	0.7	0.2	0.1	0.3	0.1	0.3	0.0	1.4	0.4	0.1	0.2	0.2	0.5	1.1	1.1	0.8	1.3	0.1	0.4	0.6	1.2	1.2	1.0	1.6	2.3	1.0	0.3	0.4

1974

SAMPLE DATE	APRIL					MAY				JUNE				JULY					AUGUST				SEPTEMBER					OCTOBER			
	1	10	15	23	29	6	13	21	28	3	10	17	24	1	8	15	22	29	5	12	19	26	3	9	16	23	30	7	15	21	28
N-10	2.9	2.8	5.3	9.5	10.3	9.5	10.0	14.7	10.8	14.5	21.5	19.7	22.0	20.6	24.0	25.5	23.5	22.7	25.4	22.9	21.2	21.9	21.5	19.0	20.2	18.4	16.1	11.5	10.4	6.2	6.7
O-W	1.6	0.5	0.4	0.7	0.6	1.1	0.3	0.9	0.3	0.7	0.8	7.0	1.3	0.5	1.1	0.3	0.7	3.9	0.8	0.0	2.6	6.1	0.9	3.8	0.4	0.7	0.6	4.3	11.2	1.6	0.9
S-4	1.6	0.1	0.1	0.0	0.0	0.1	0.1	0.2	-0.2	0.2	0.5	0.5	0.5	0.2	0.4	0.1	3.1	0.1	0.0	0.1	0.8	0.2	0.5	0.2	0.5	0.7	0.8	-0.1	0.6	1.5	-0.1
S-17	1.6	0.1	0.2	0.1	0.0	0.2	0.3	0.5	-0.2	0.5	1.3	1.3	0.7	0.9	1.0	1.1	0.7	1.4	0.7	1.7	1.4	1.7	2.0	0.5	1.2	1.5	1.7	0.4	1.4	1.0	0.8

1975

SAMPLE DATE	APRIL					MAY				JUNE					JULY				AUGUST				SEPTEMBER					OCTOBER			
	1	7	14	21	29	6	12	19	26	2	9	16	23	30	8	14	21	28	4	11	19	25	2	10	15	22	30	6	16	20	30
N-10	0.8	1.7	4.4	5.0	6.2	9.3	N/A	16.2	19.2	20.0	15.0	15.9	22.8	25.0	25.4	24.0	25.2	24.3	27.3	24.4	23.3	20.7	18.8	19.0	17.1	17.6	15.0	14.4	12.2	10.2	10.1
O-N	5.1	2.9	1.7	0.4	0.5	0.4	N/A	0.7	1.9	2.4	0.9	1.2	0.3	4.0	8.7	1.6	1.0	1.4	0.4	4.4	2.9	8.6	2.3	7.9	6.7	5.0	0.3	0.1	1.5	3.1	-0.1
S-4	0.3	0.1	0.6	0.5	0.5	0.7	N/A	0.2	0.3	0.6	0.3	0.6	0.3	0.9	0.3	0.4	0.2	0.3	0.3	0.3	N/A	0.1	0.1	0.2	0.2	0.4	0.0	0.0	0.2	0.4	-0.1
S-17	0.3	0.2	0.6	0.5	0.8	0.7	N/A	0.7	0.6	1.1	0.6	1.0	0.3	1.8	0.9	0.9	0.7	0.2	0.6	0.6	3.5	1.1	0.8	2.2	0.2	0.8	0.0	0.0	0.6	0.8	-0.1

Continued

APPENDIX TABLE B-2. (Continued)

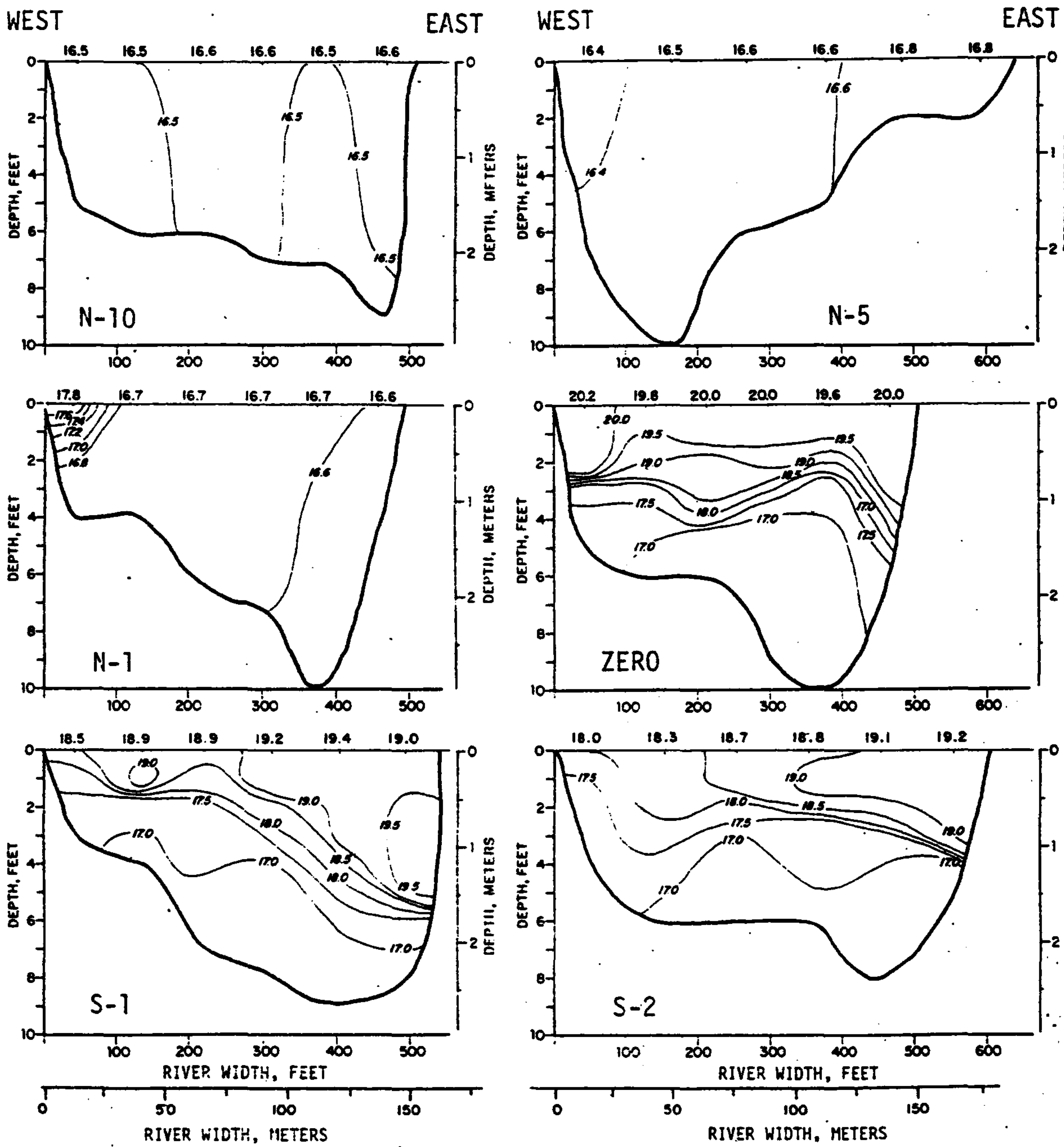
Year	Station	APRIL				MAY					JUNE				
1976	SAMPLE DATE	6	13	19	27	4	11	17	24		1	7	14	22	28
	N-10	6.1	4.4	10.8	8.1	10.0	13.1	15.4	11.1		17.3	18.3	20.6	24.8	24.7
	O-W	0.0	0.7	0.3	0.3	0.3	9.2	0.8	2.2		2.9	2.2	8.9	1.5	3.3
	S-4	0.3	0.3	0.3	0.3	0.3	0.6	0.7	0.2		0.4	0.6	1.1	0.7	0.6
	S-17	0.0	0.3	0.3	0.3	0.3	0.6	0.3	0.7		1.3	0.6	1.3	1.3	0.3
1977	SAMPLE DATE	4	11	18	26	2	9	16	23	31	6	13	20	27	
	N-10	3.6	3.0	7.2	7.2	10.1	12.9	13.2	21.0	19.9	19.4	17.1	20.5	22.5	
	O-W	0.4	-0.2	5.8	2.1	2.0	10.6	1.0	2.0	2.3	0.2	3.9	0.4	0.0	
	S-4	0.4	0.0	0.7	0.7	1.4	0.9	0.8	-0.1	0.0	0.0	0.1	0.1	-0.2	
	S-17	0.3	0.0	0.8	0.8	1.4	0.3	1.7	0.2	0.2	0.9	0.3	0.4	-0.3	
1978	SAMPLE DATE	3	10	17	25	1	8	15	22	30	5	12	19	26	
	N-10	1.1	3.1	3.7	6.4	7.0	11.2	11.0	13.4	20.5	19.0	18.8	19.2	22.2	
	O-W	0.5	5.9	4.9	3.2	4.0	3.3	9.7	7.6	11.0	8.4	4.0	10.5	0.5	
	S-4	0.1	0.7	0.1	0.1	0.2	0.6	0.1	0.1	0.5	0.1	1.1	1.0	0.2	
	S-17	0.2	0.4	0.2	0.1	0.3	0.4	0.5	0.5	1.6	0.3	0.5	1.8	0.5	
All Years		$\bar{x}$	Range			$\bar{x}$	Range				$\bar{x}$	Range			
	N-10	5.7	0.8-12.1			12.8	6.1-21.0				19.8	14.5-25.0			
	O-W	1.9	-0.2- 7.8			2.8	0.2-11.0				2.4	0.0-10.5			
	S-4	0.4	0.0- 1.6			0.5	-0.2- 2.8				0.5	0.2- 1.1			
	S-17	0.4	0.0- 1.6			0.6	-0.2- 1.7				0.7	-2.2- 1.8			

Year	Station	JULY				AUGUST					SEPTEMBER				OCTOBER				
1976	SAMPLE DATE	6	12	20	26	2	9	17	23	31	7	14	20	27	4	11	18	25	
	N-10	23.5	24.6	23.7	22.6	19.4	18.9	20.3	23.9	19.8	18.0	N/A	18.3	16.0	12.8	12.6	8.1	6.1	
	O-W	1.1	0.6	0.6	0.1	0.6	1.0	0.4	0.9	0.3	0.7	N/A	0.7	0.0	0.5	0.5	1.4	0.1	
	S-4	-0.1	0.5	-0.1	-0.1	0.6	0.4	0.9	0.1	0.3	0.3	N/A	0.1	0.0	0.3	0.3	1.7	0.1	
	S-17	0.3	1.1	0.7	0.6	0.6	0.4	0.6	0.6	0.4	1.1	N/A	0.9	0.0	2.2	1.2	2.0	0.0	
1977	SAMPLE DATE	5	11	18	25	1	8	15	22	29	6	12	19	26	3	10	12	24	31
	N-10	23.6	23.6	27.1	25.1	24.4	26.0	24.2	21.7	24.0	23.9	19.5	18.3	13.9	12.0	10.8	8.2	7.3	7.9
	O-W	3.3	2.7	0.9	3.6	10.1	0.2	6.7	2.4	0.8	5.5	4.7	0.6	3.0	5.3	0.3	4.4	3.0	2.2
	S-4	-0.1	0.1	0.2	0.6	0.1	-0.3	0.1	0.7	-0.5	-0.1	0.1	0.2	0.3	0.1	0.3	-0.1	0.3	0.2
	S-17	0.8	-0.4	0.2	0.5	0.8	0.7	1.5	1.6	-0.1	1.5	0.8	1.0	1.1	0.5	0.3	0.0	0.5	0.2
1978	SAMPLE DATE	5	10	17	24	7	14	21	28		5	11	18	25	2	9	16	23	30
	N-10	19.9	26.4	22.2	26.5	24.1	23.9	25.1	20.1		21.6	17.7	17.8	18.5	14.0	11.8	10.4	10.4	8.9
	O-W	0.0	2.4	0.2	0.8	1.2	0.9	0.9	1.0		2.4	3.8	3.7	-2.3	4.4	4.8	10.0	12.1	10.5
	S-4	0.0	-0.2	0.0	-0.1	0.1	0.6	-0.3	0.4		0.3	0.8	0.0	-0.3	1.7	0.2	0.3	0.0	0.2
	S-17	-0.2	-0.9	0.5	0.5	0.5	1.7	0.2	0.9		1.1	1.2	1.0	0.2	1.6	2.0	3.7	0.6	1.1
All Years		$\bar{x}$	Range			$\bar{x}$	Range				$\bar{x}$	Range			$\bar{x}$	Range			
	N-10	25.1	18.9-27.1			22.9	18.9-27.3				18.6	13.9-26.0			10.6	6.1-14.9			
	O-W	1.5	0.0- 8.7			2.2	0.0-10.1				2.3	-2.3- 7.9			3.1	- 0.1-12.1			
	S-4	0,3	- 0.2- 3.1			0.3	- 0.5- 1.1				0.3	- 0.3- 0.8			0.4	- 0.1- 1.7			
	S-17	0.6	- 0.9- 1.4			0.9	- 0.1- 3.5				1.2	0.0- 2.2			1.1	- 0.1- 3.7			

N/A = Data not available

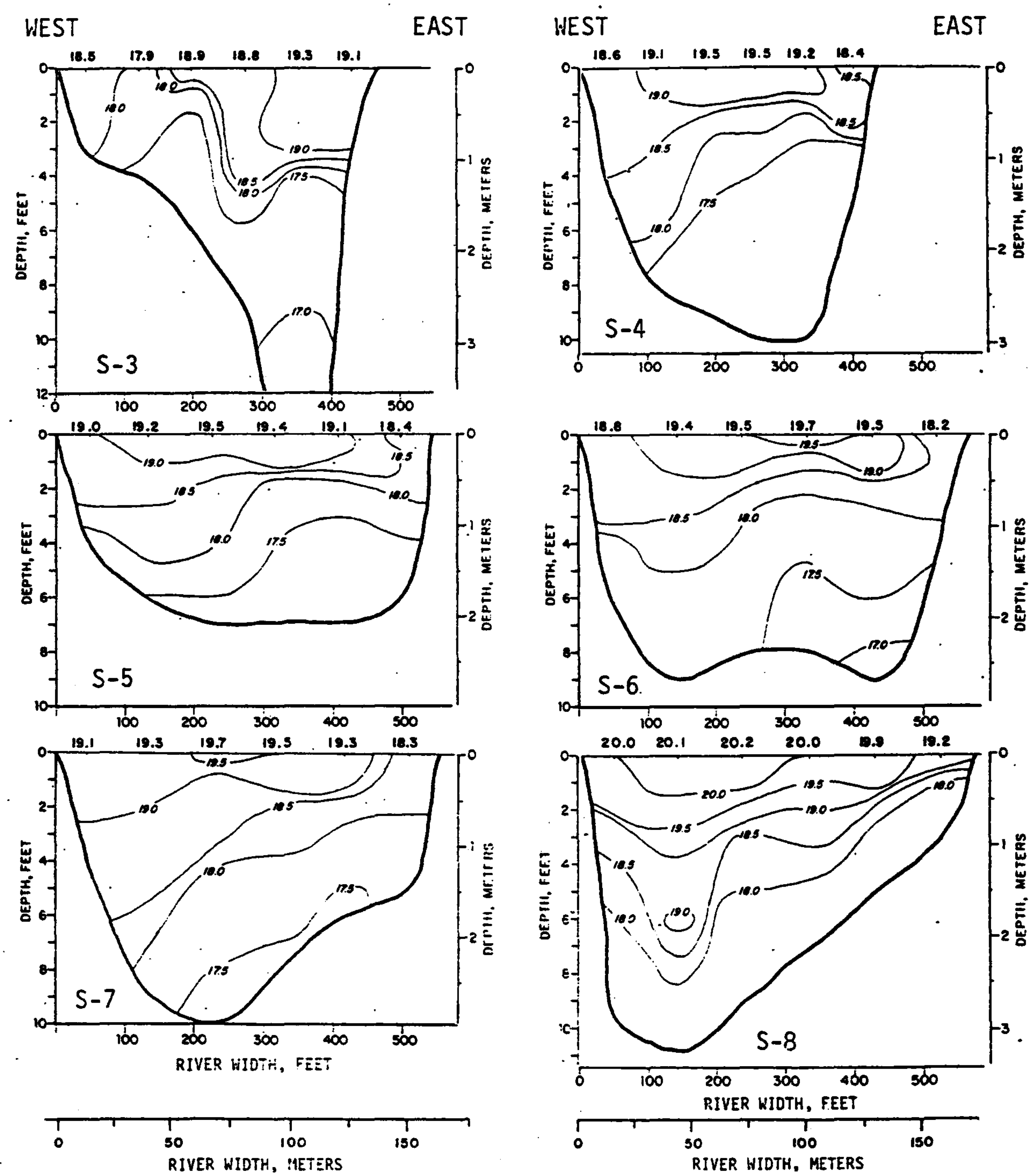
APPENDIX TABLE B-3. PHYSICAL PARAMETERS EXISTING DURING MEASUREMENT OF THERMAL PROFILES PRESENTED IN FIGURES B-1 THROUGH B-18. MERRIMACK RIVER SUMMARY REPORT, 1979.

FIGURE	DATE	FLOW (cms)	UNITS OPERATING	AMBIENT TEMPERATURE (°C)	PHYSICAL CONDITIONS REPRESENTED
B-1, B-2	9/19/78	15.1	I	16.5-16.6	lowest flow, 1967-1978
B-3, B-4	8/4/77	23.8	I, II	24.4-24.9	low flow; warm ambient temperature
B-5, B-6	9/2/77	33.1	II	24.9-25.1	low flow; warm ambient temperature
B-7, B-8	9/19/74	40.3	II	18.2-18.4	low to moderate flow
B-9, B-10	8/26/76	47.2	II	22.6-23.0	low to moderate flow; warm ambient temperature
B-11, B-12	6/26/75	53.9	I, II	24.6-25.1	low to moderate flow; warm ambient temperature
B-13, B-14	10/13/76	55.0	II	10.4-10.6	low to moderate flow; cool temperatures
B-15, B-16	7/7/72	88.5	II	20.6	moderate flow; moderate temperatures
B-17, B-18	9/28/77	165.7	II	13.2-13.6	high flow; cool temperatures



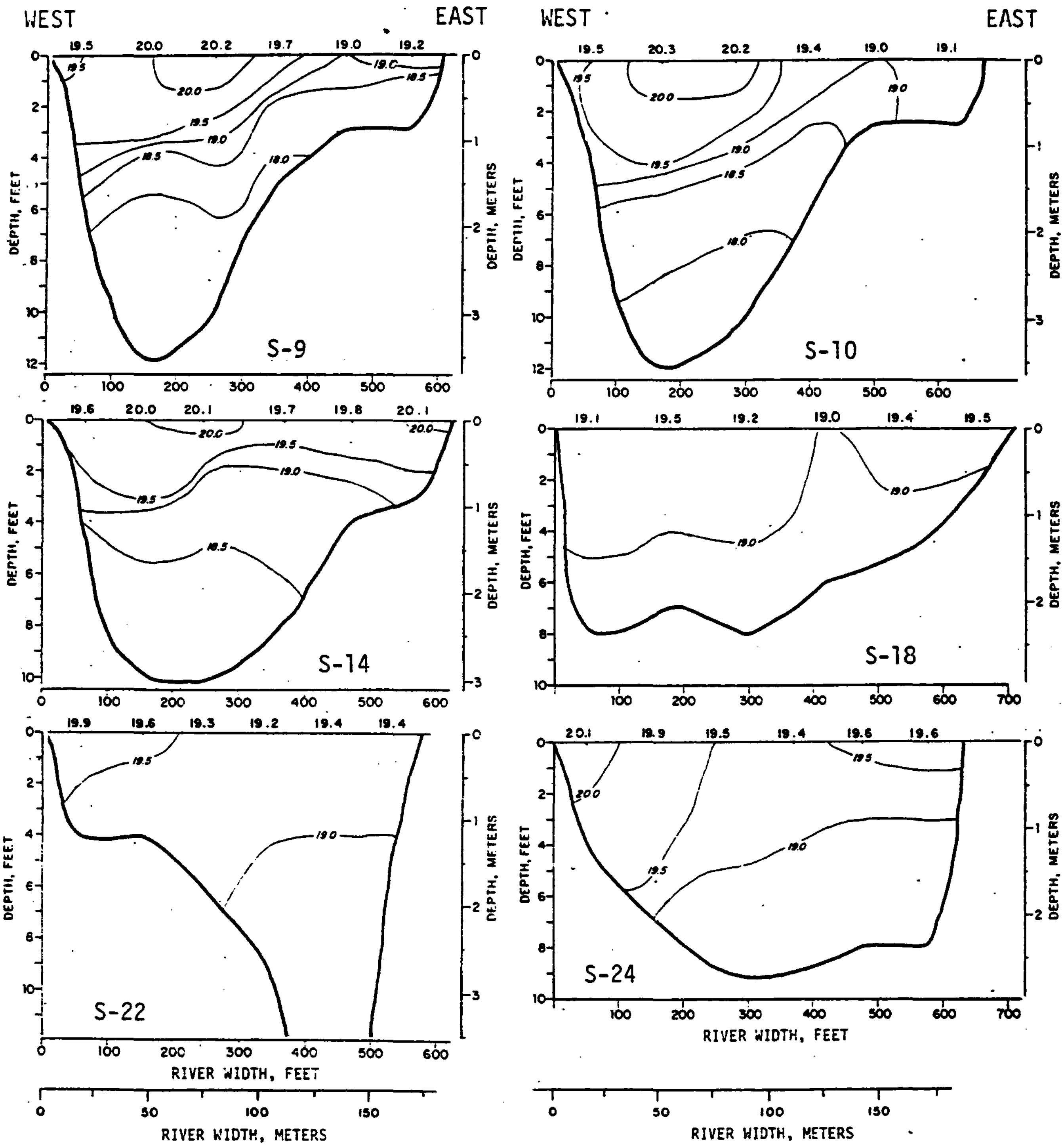
Appendix Figure B-1. Thermal profiles (°C), September 19, 1978.
Merrimack River Summary Report, 1979.

Continued

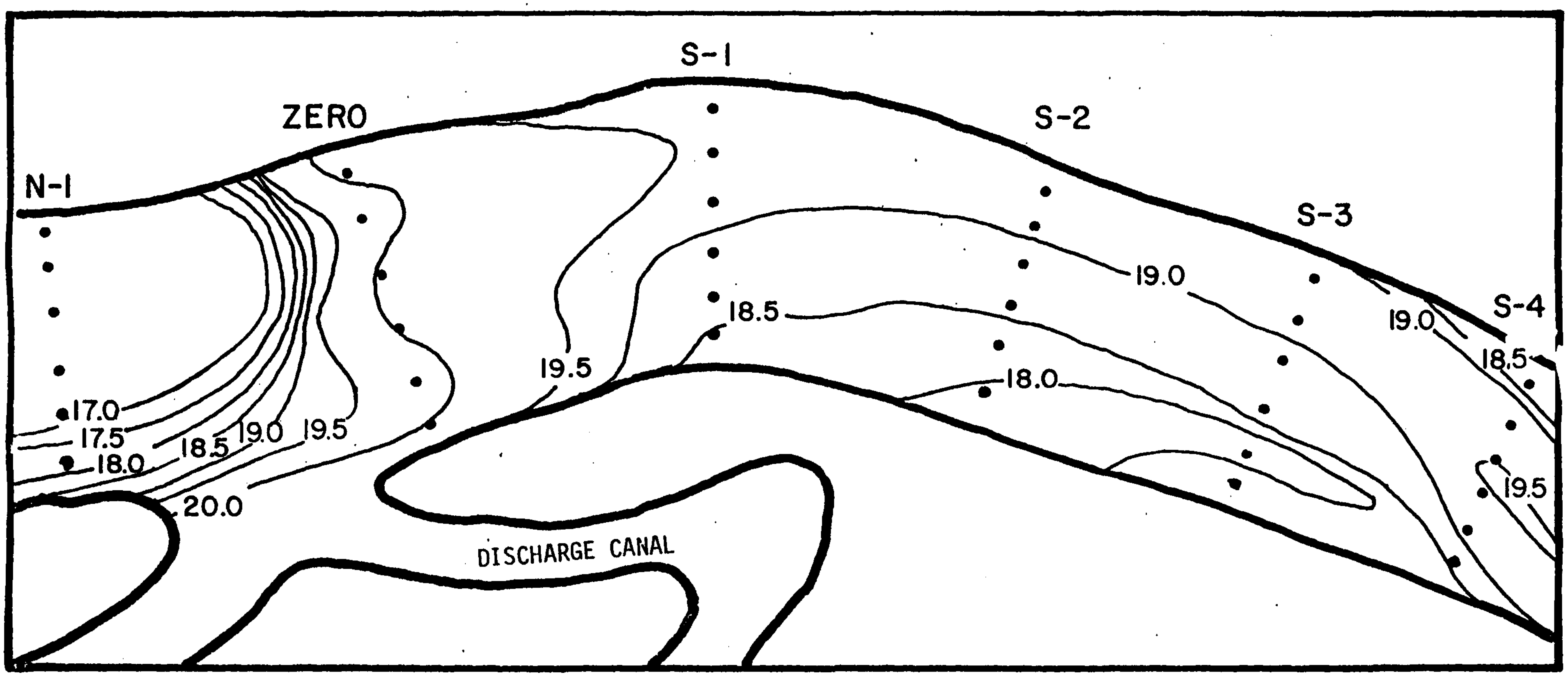


Appendix Figure B-1. (Continued)

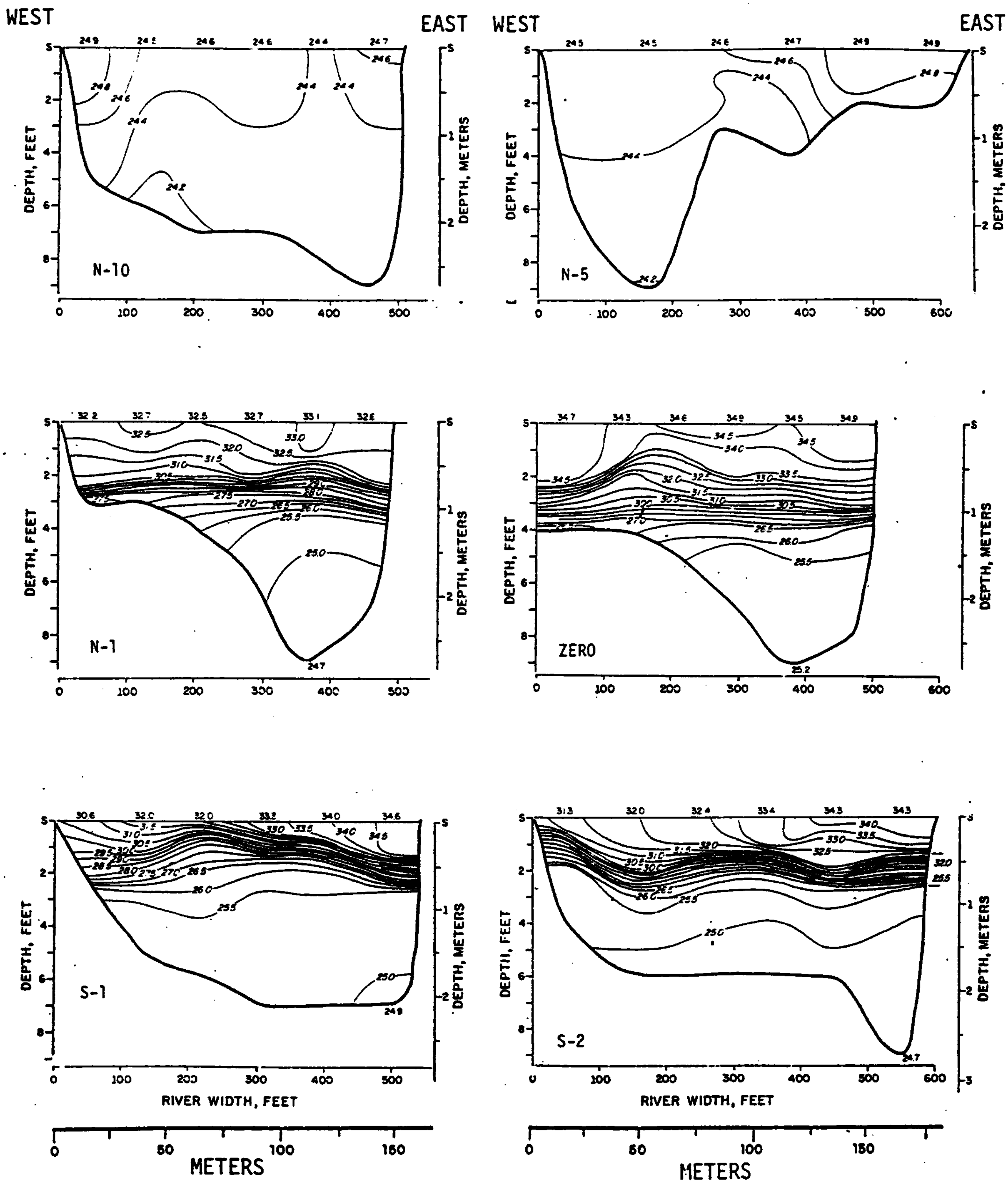
Continued



Appendix Figure B-1. (Continued)

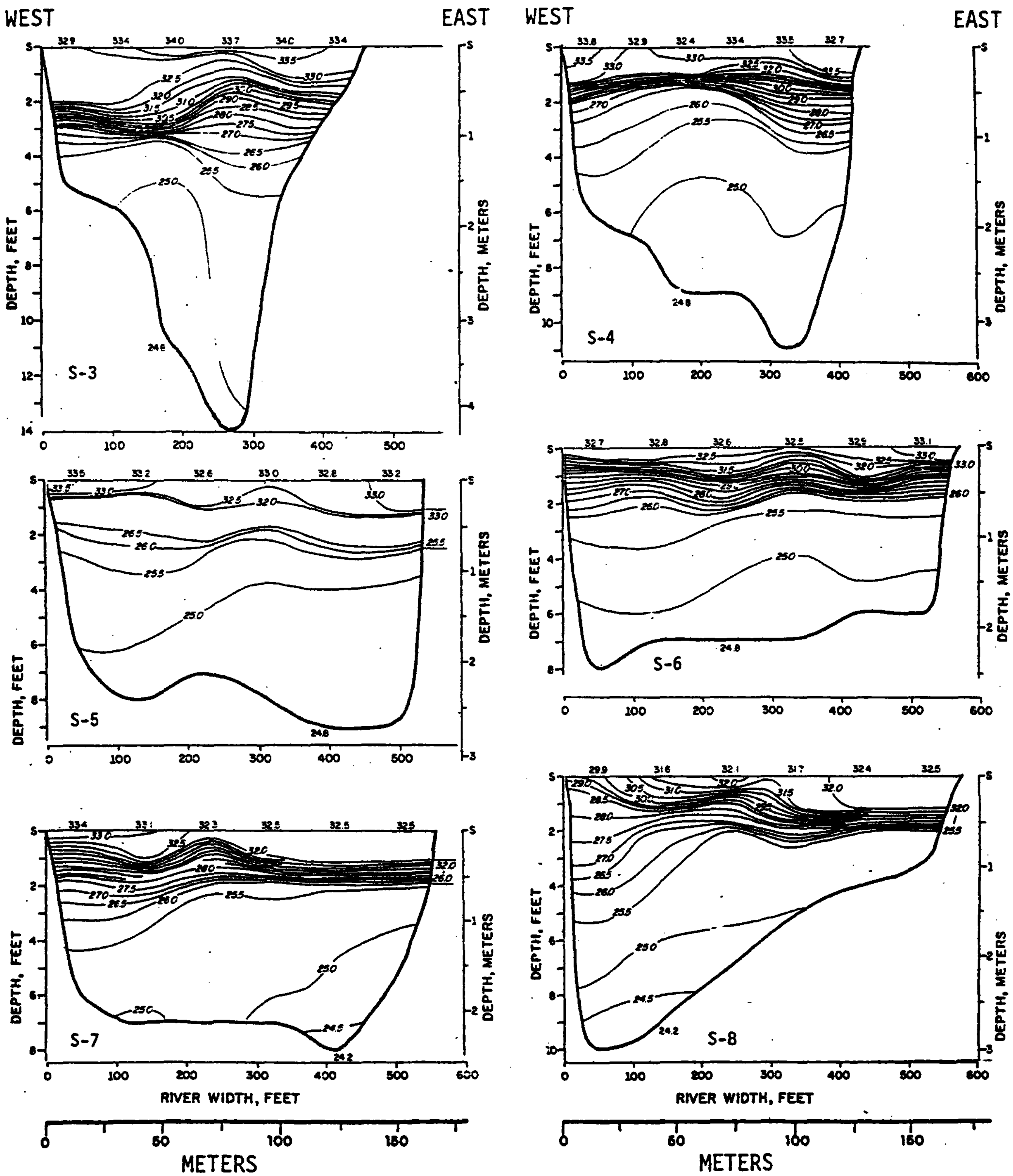


Appendix Figure B-2. Longitudinal surface thermal profile (°C) from September 19, 1978. Merrimack River Summary Report, 1979.



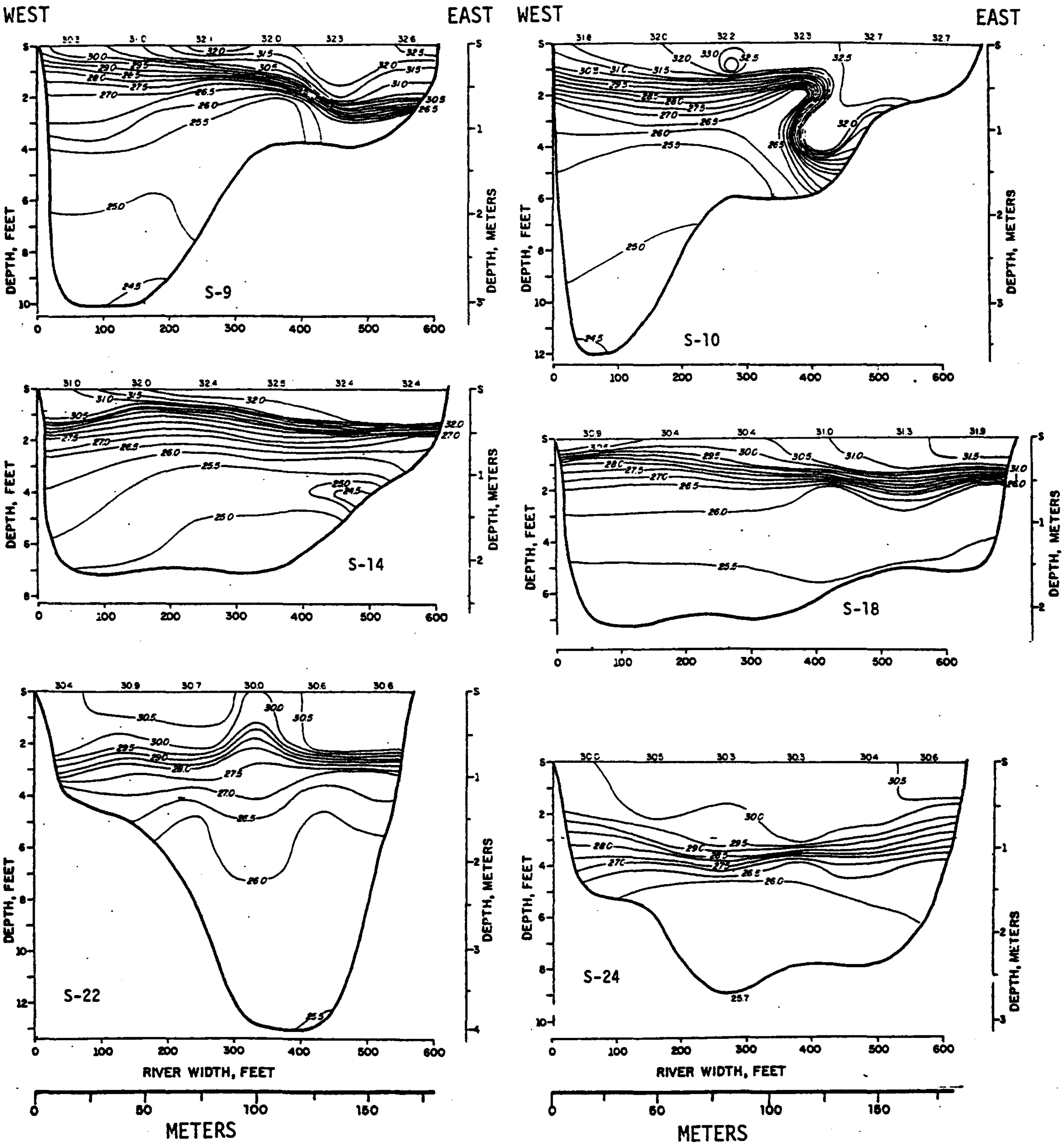
Appendix Figure B-3. Thermal profiles (°C), August 4, 1977.
Merrimack River Summary Report, 1979.

Continued

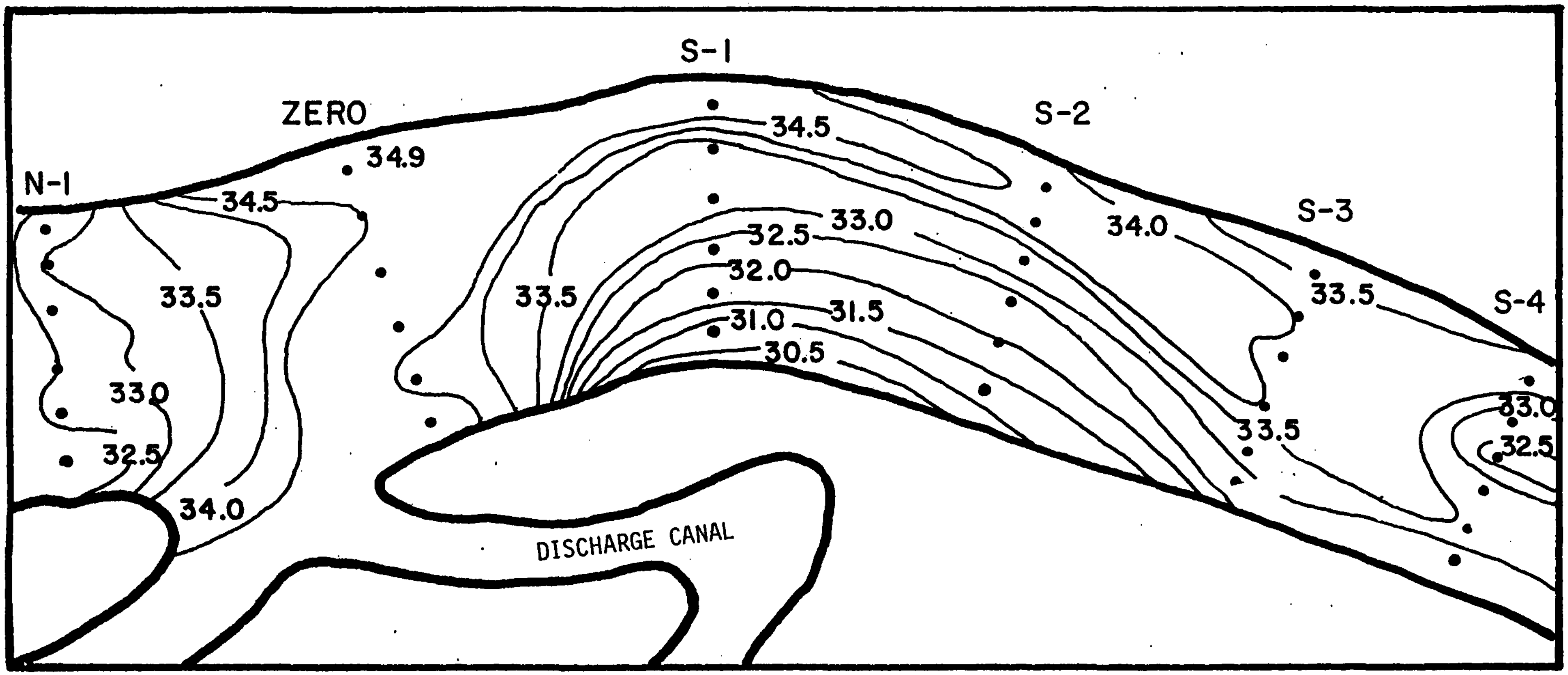


Appendix Figure B-3. (Continued)

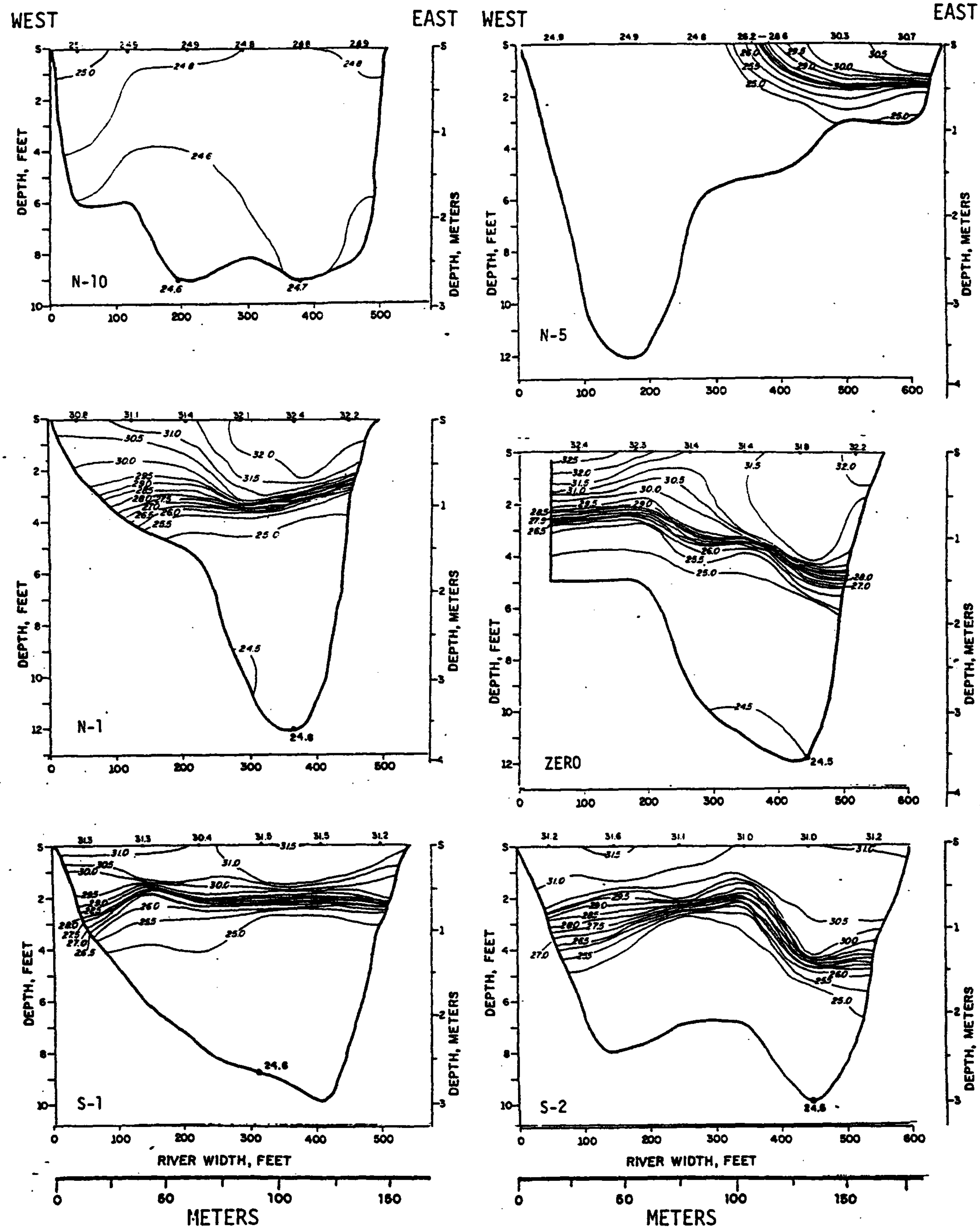
Continued



Appendix Figure B-3. (Continued)

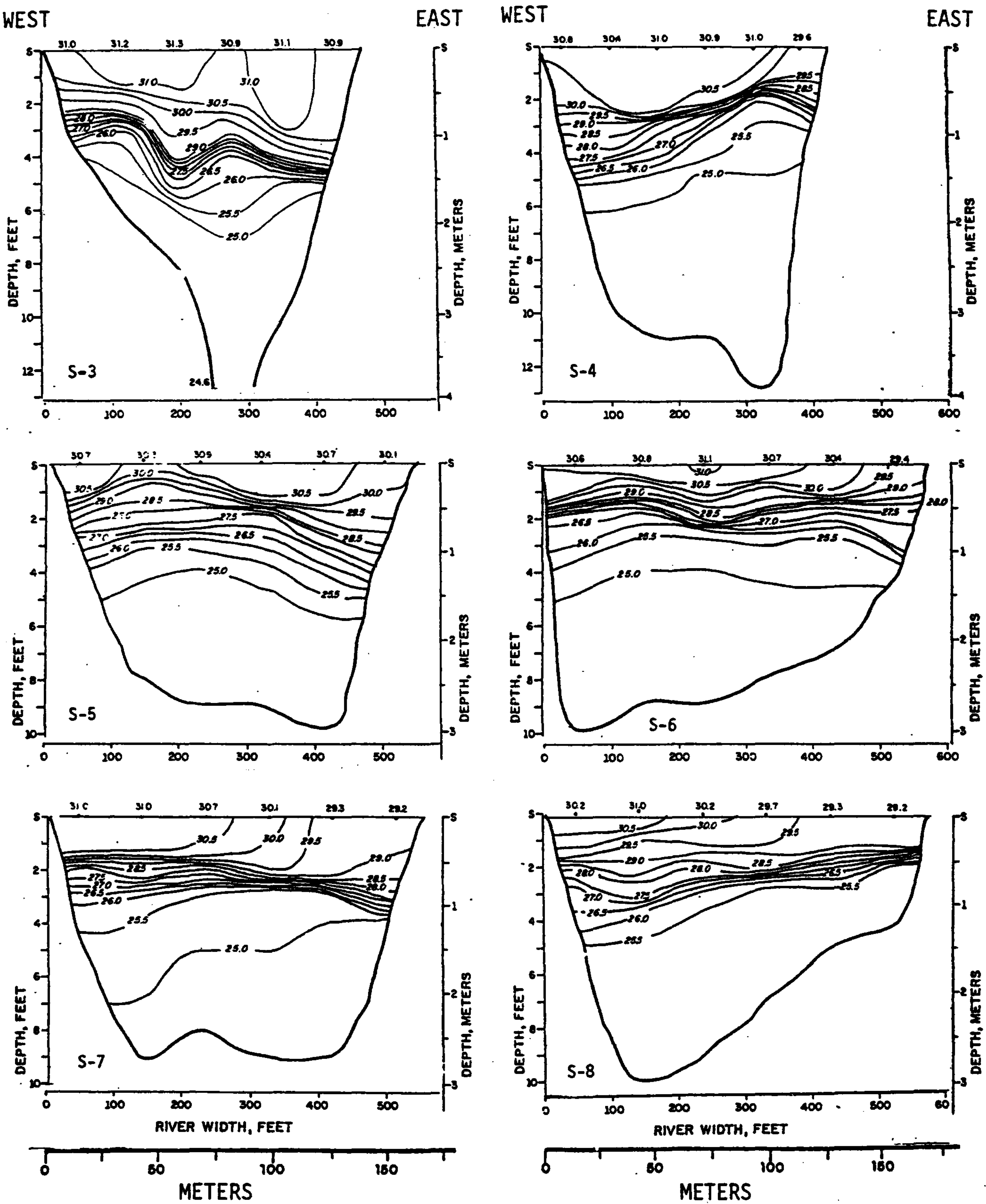


Appendix Figure B-4. Longitudinal surface thermal profile (°C) from August 4, 1977. Merrimack River Summary Report, 1979.



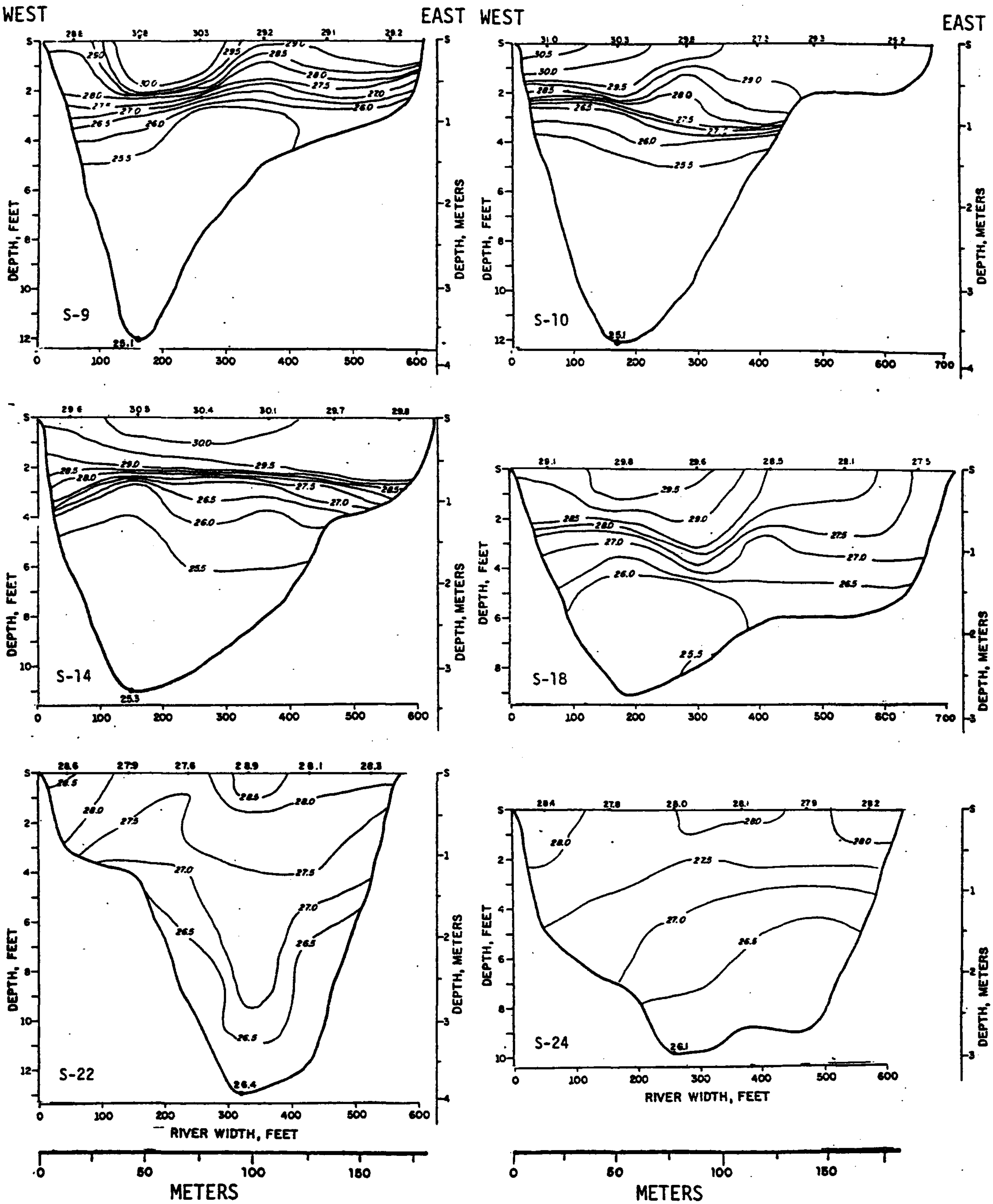
Appendix Figure B-5. Thermal profiles (°C), September 2, 1977.
Merrimack River Summary Report, 1979.

Continued

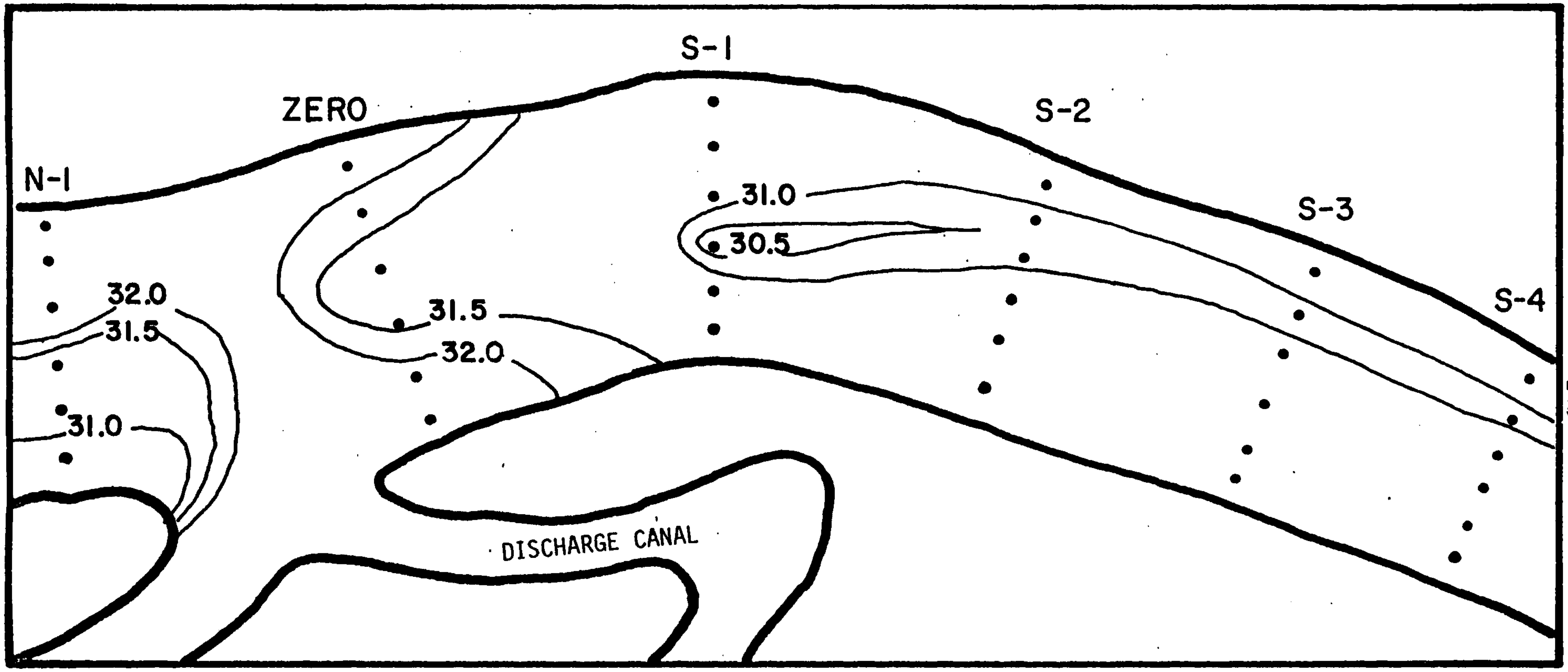


Appendix Figure B-5. (Continued)

Continued



Appendix Figure B-5. (Continued)



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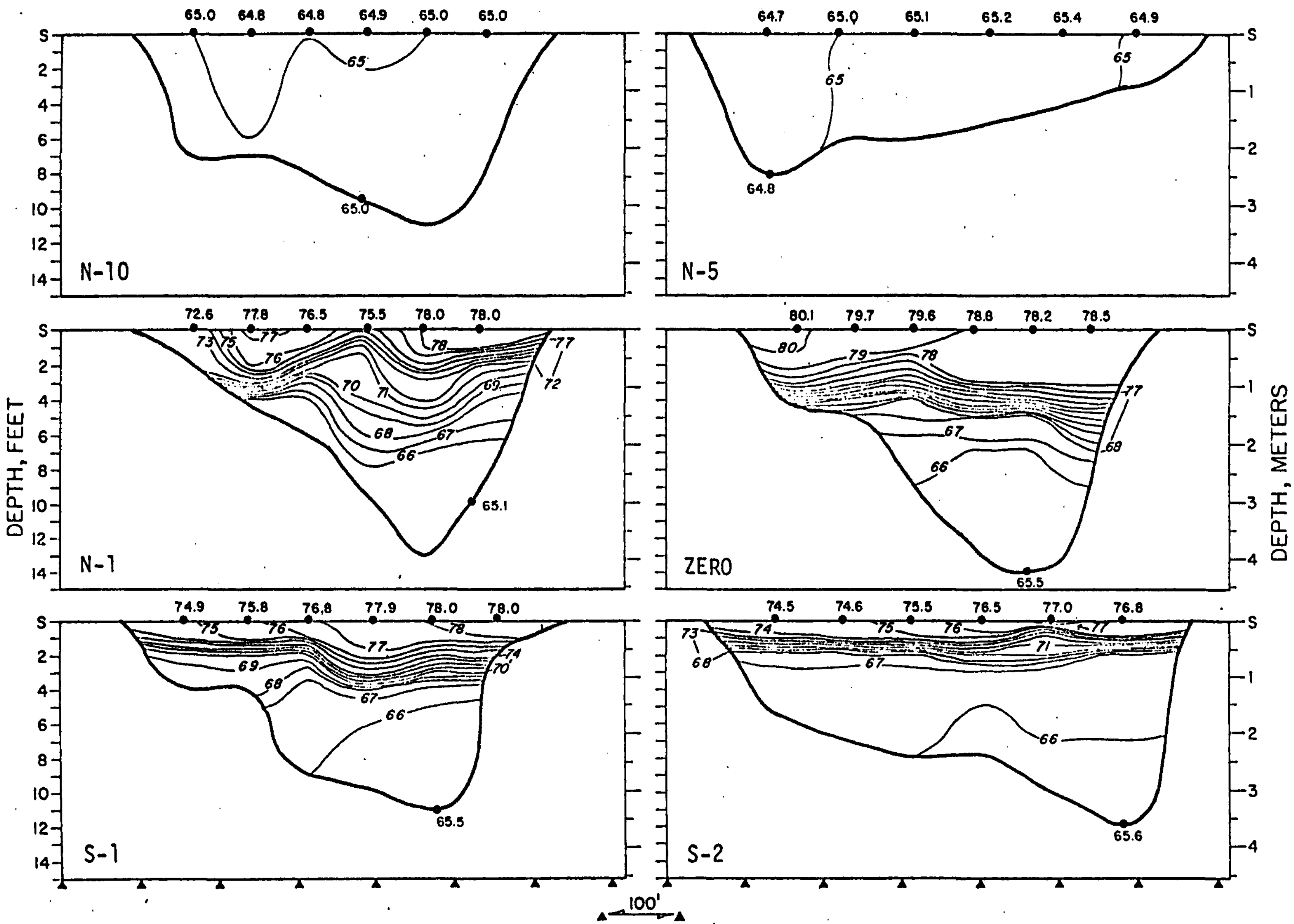
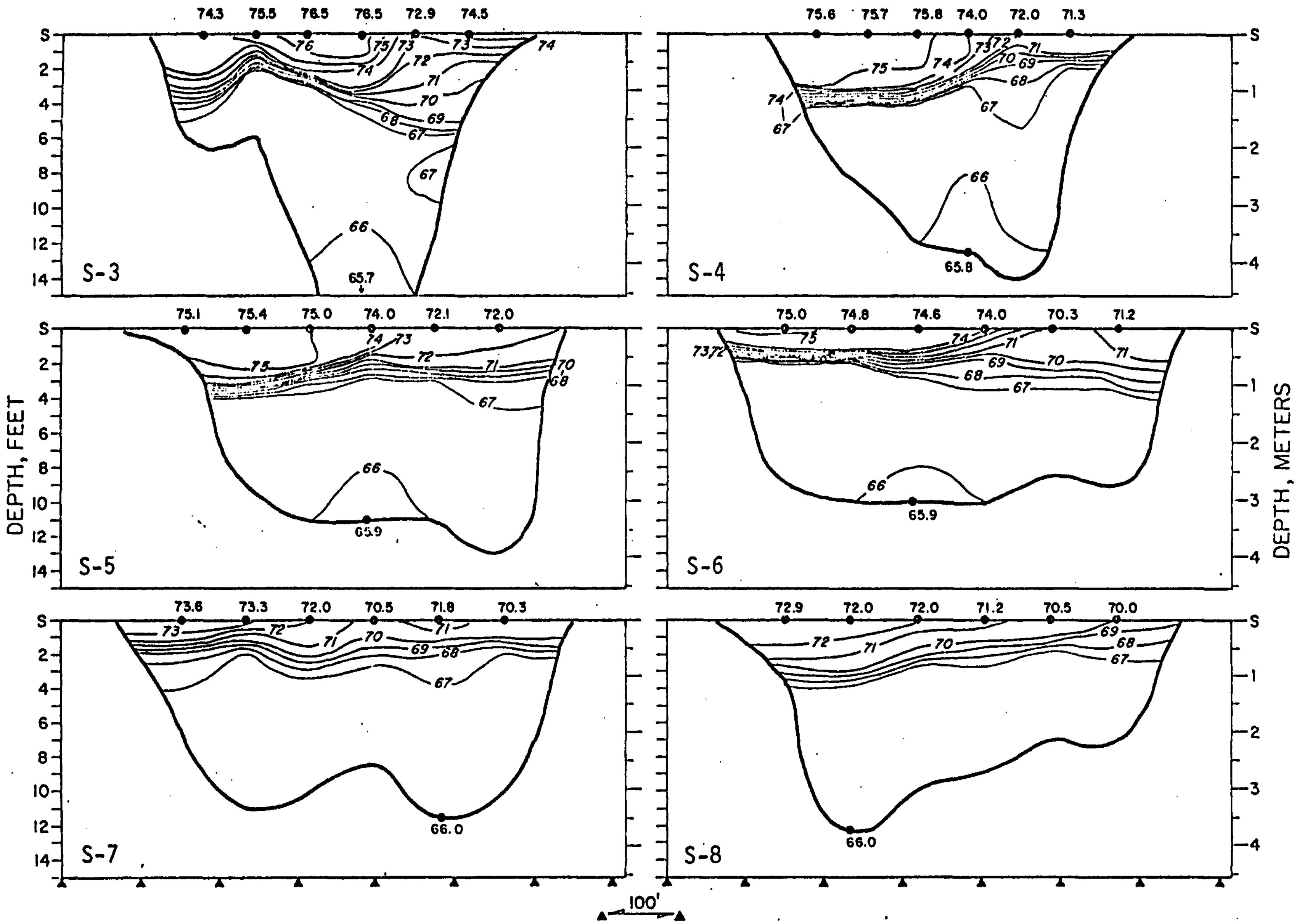
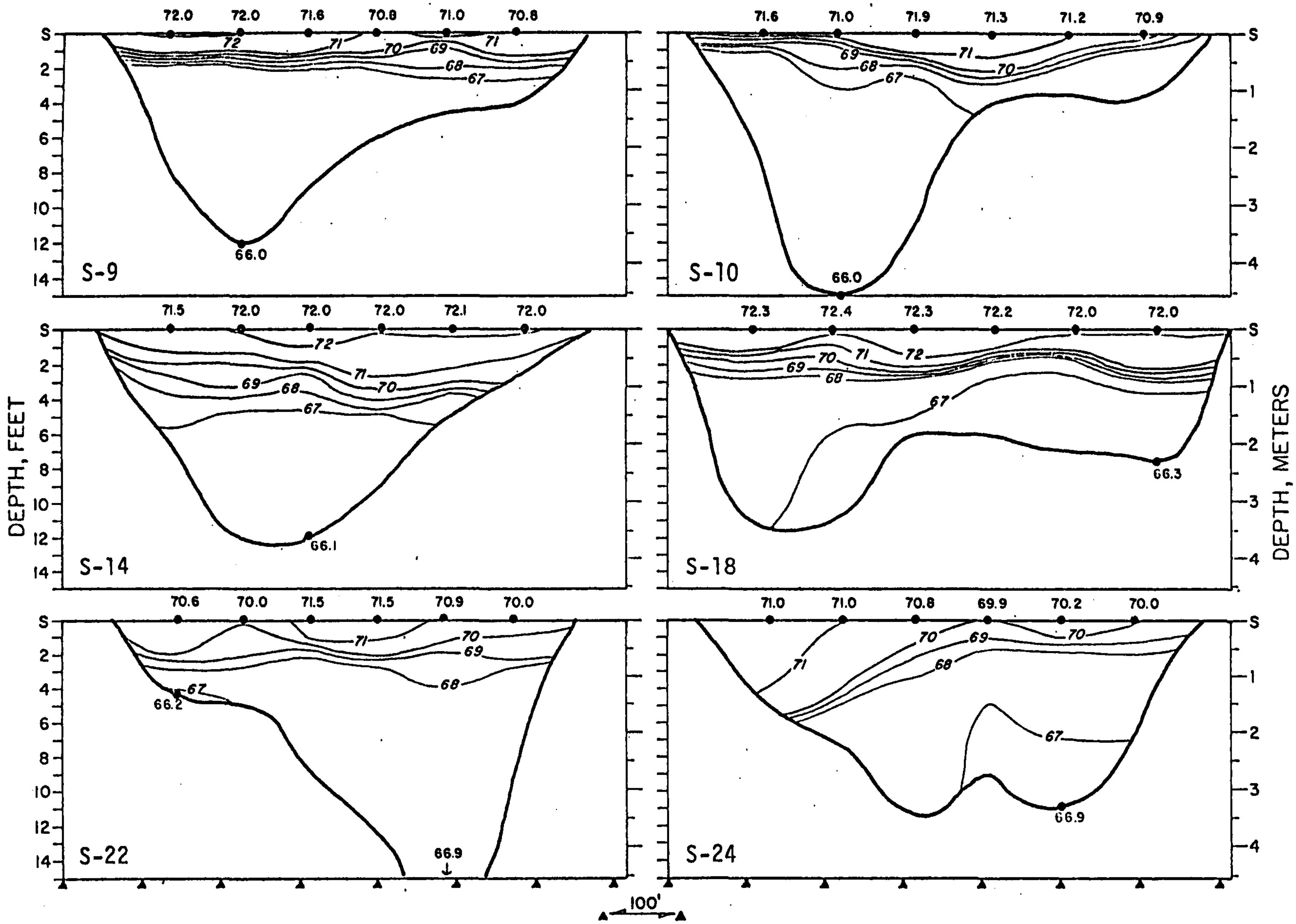
Appendix Figure B-6. Longitudinal surface thermal profile (°C) from September 2, 1977. Merrimack River Summary Report, 1979.



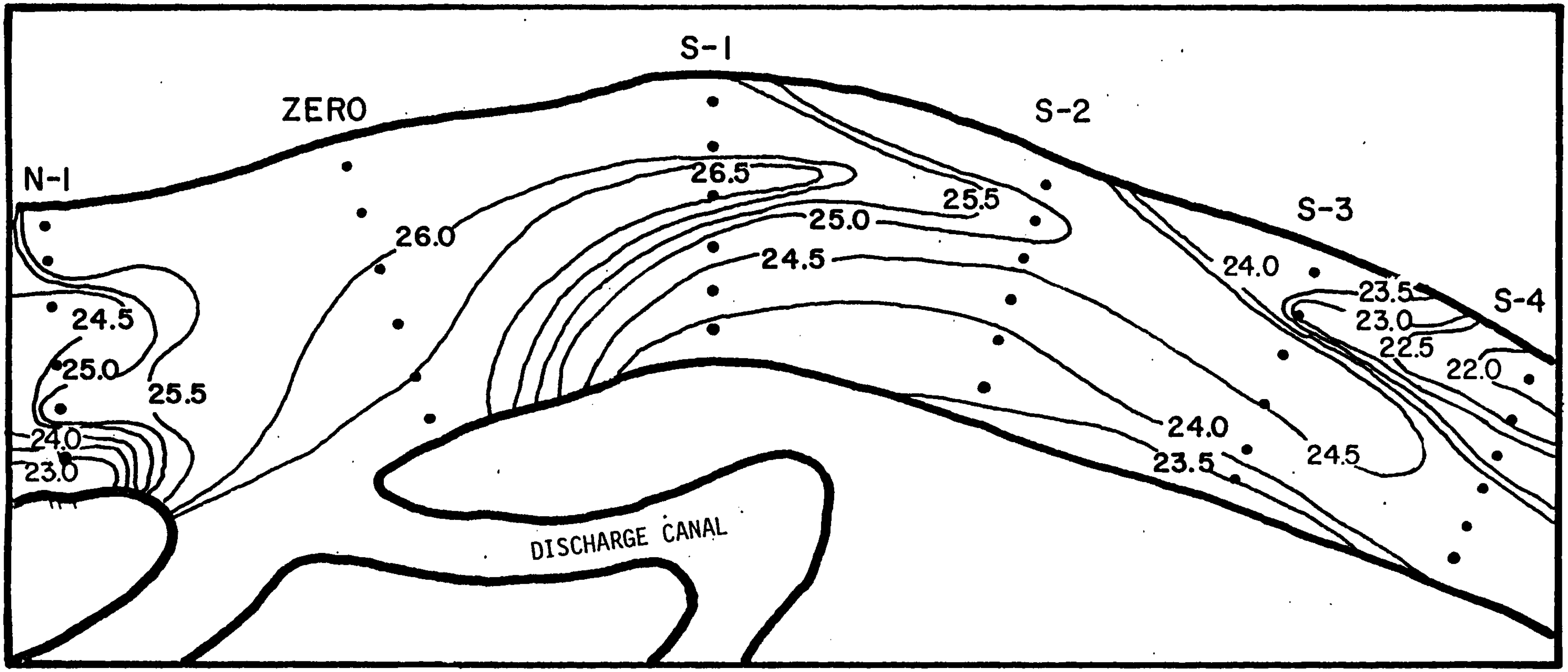
Appendix Figure B-7. Thermal profiles (°F), September 19, 1974.
Merrimack River Summary Report, 1979.



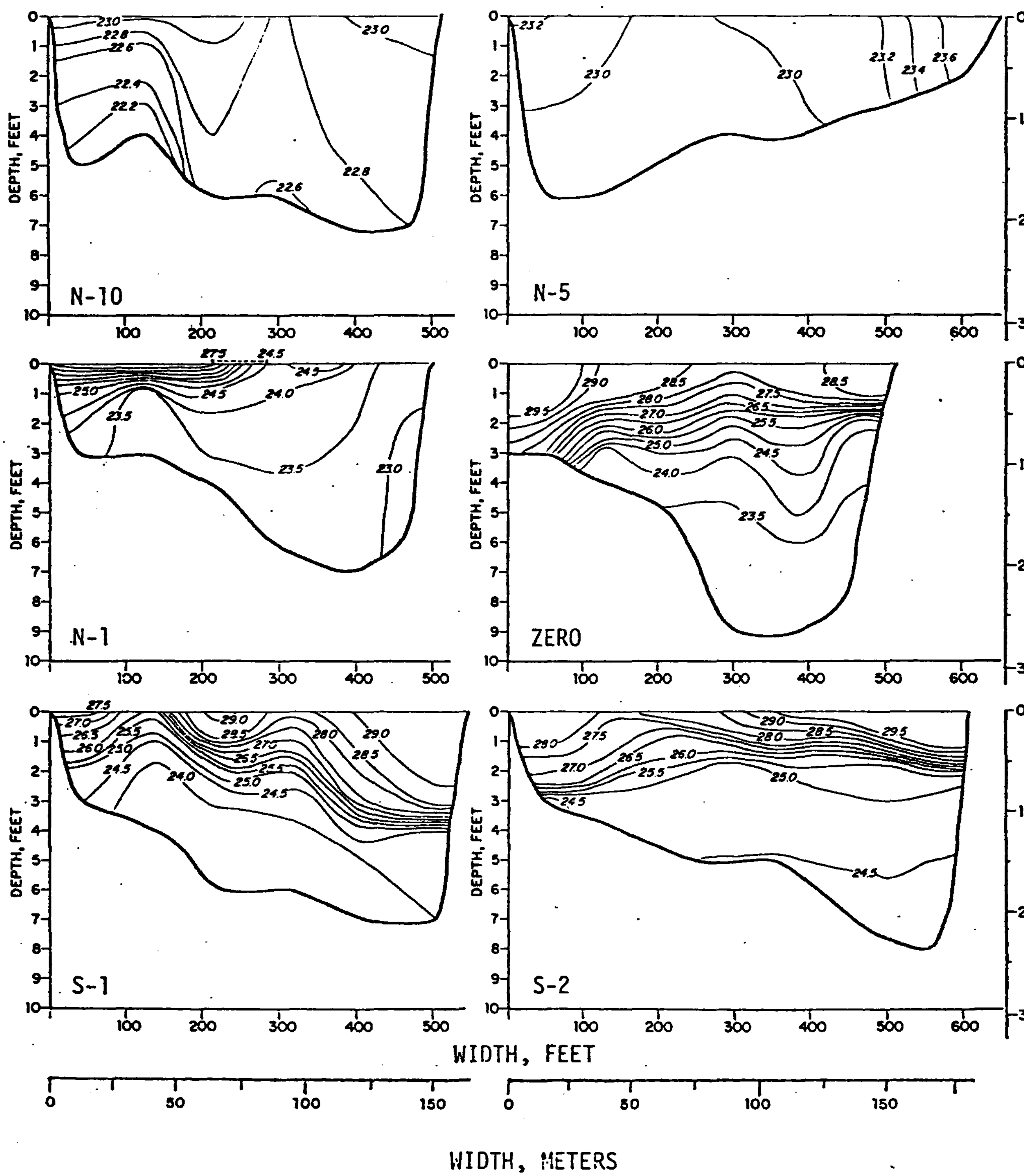
Appendix Figure B-7. (Continued)



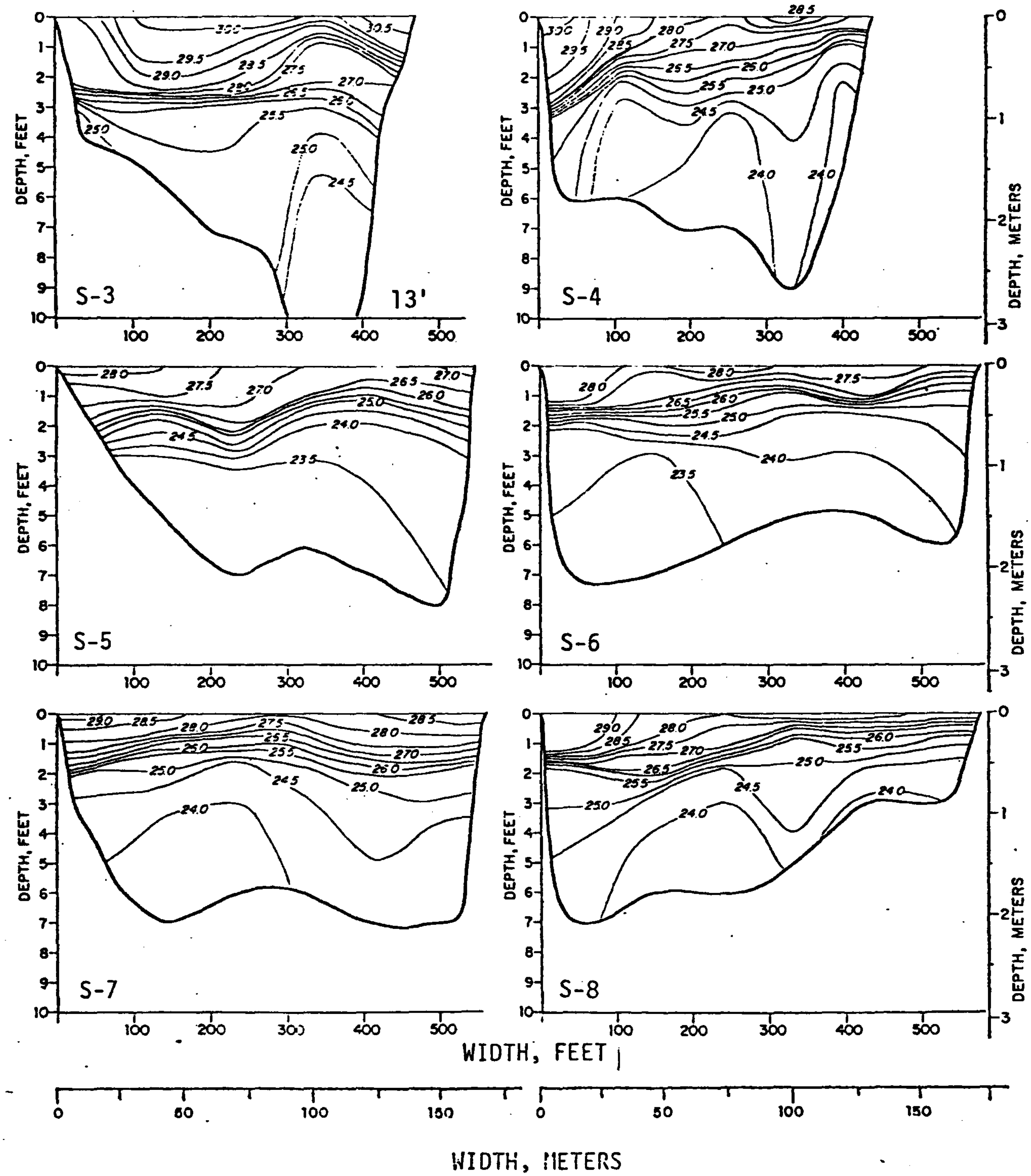
Appendix Figure B-7. (Continued)



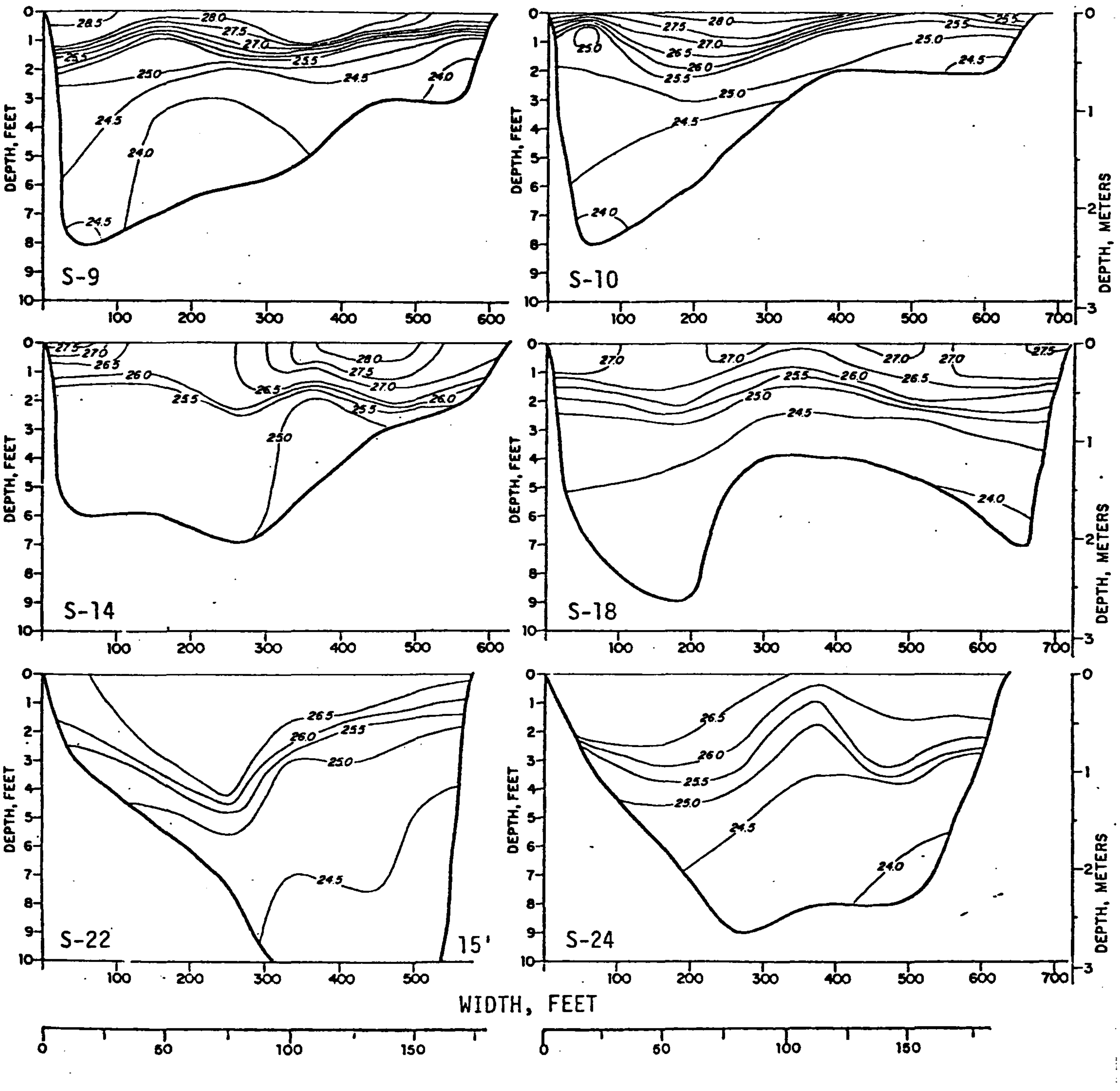
Appendix Figure B-8. Longitudinal surface thermal profile (°C) from September 19, 1974. Merrimack River Summary Report, 1979.



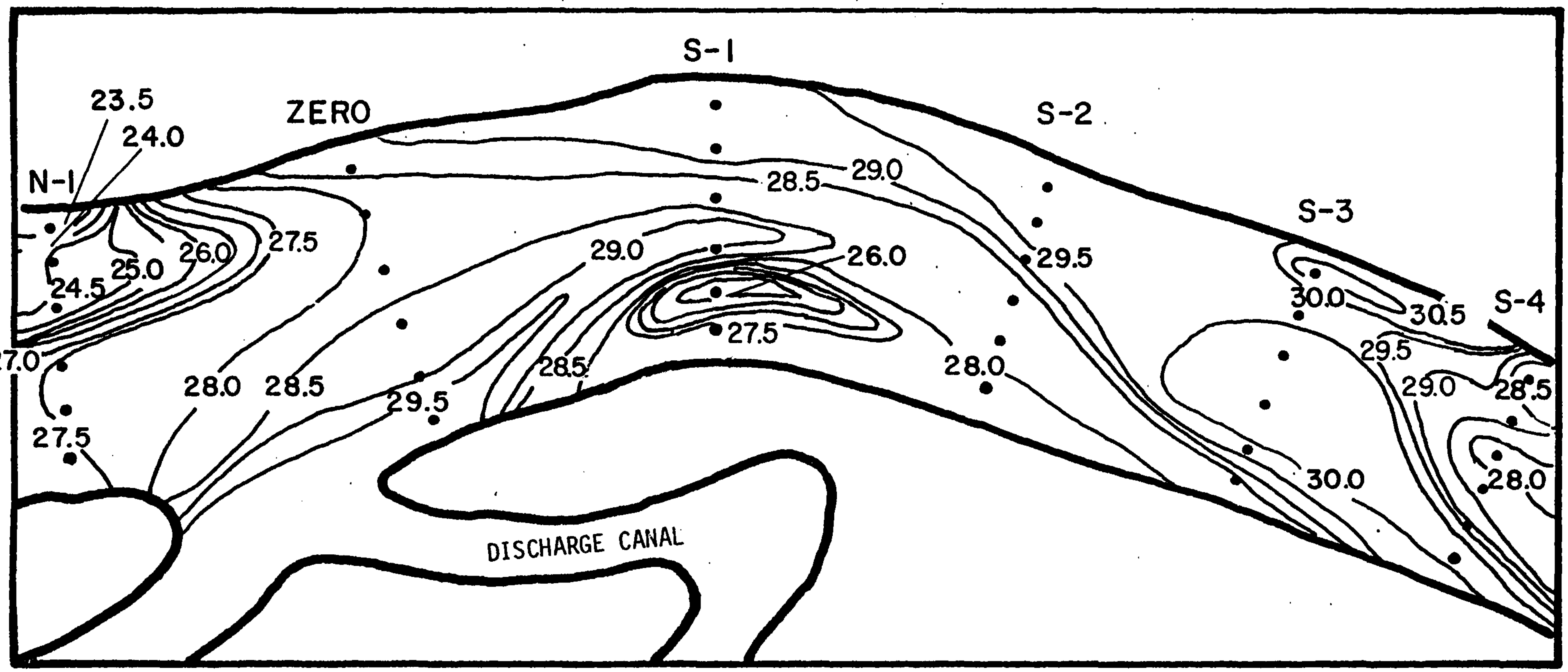
Appendix Figure B-9. Thermal profiles (°C), August 26, 1976.
Merrimack River Summary Report, 1979.



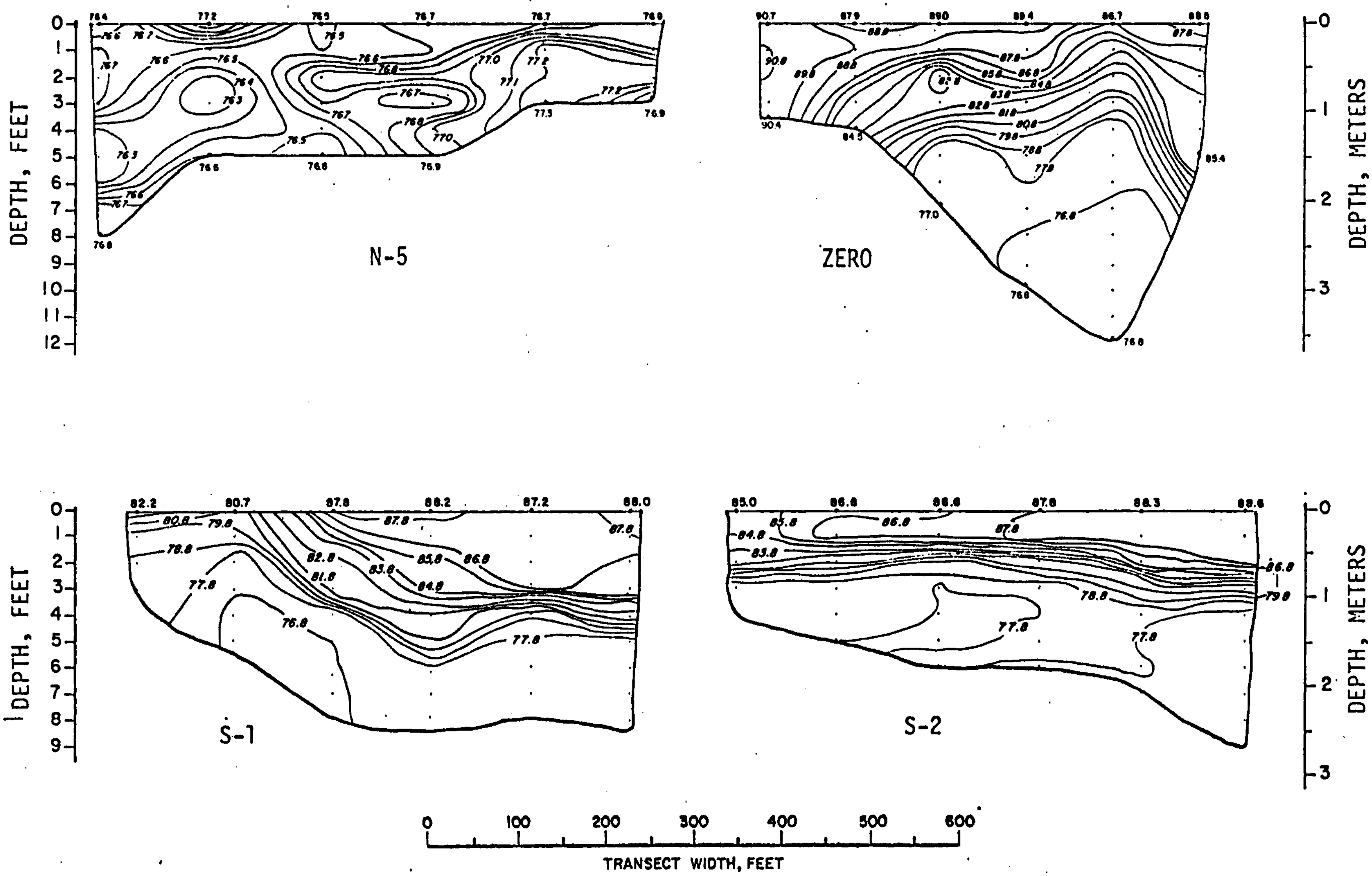
Appendix Figure B-9. (Continued)



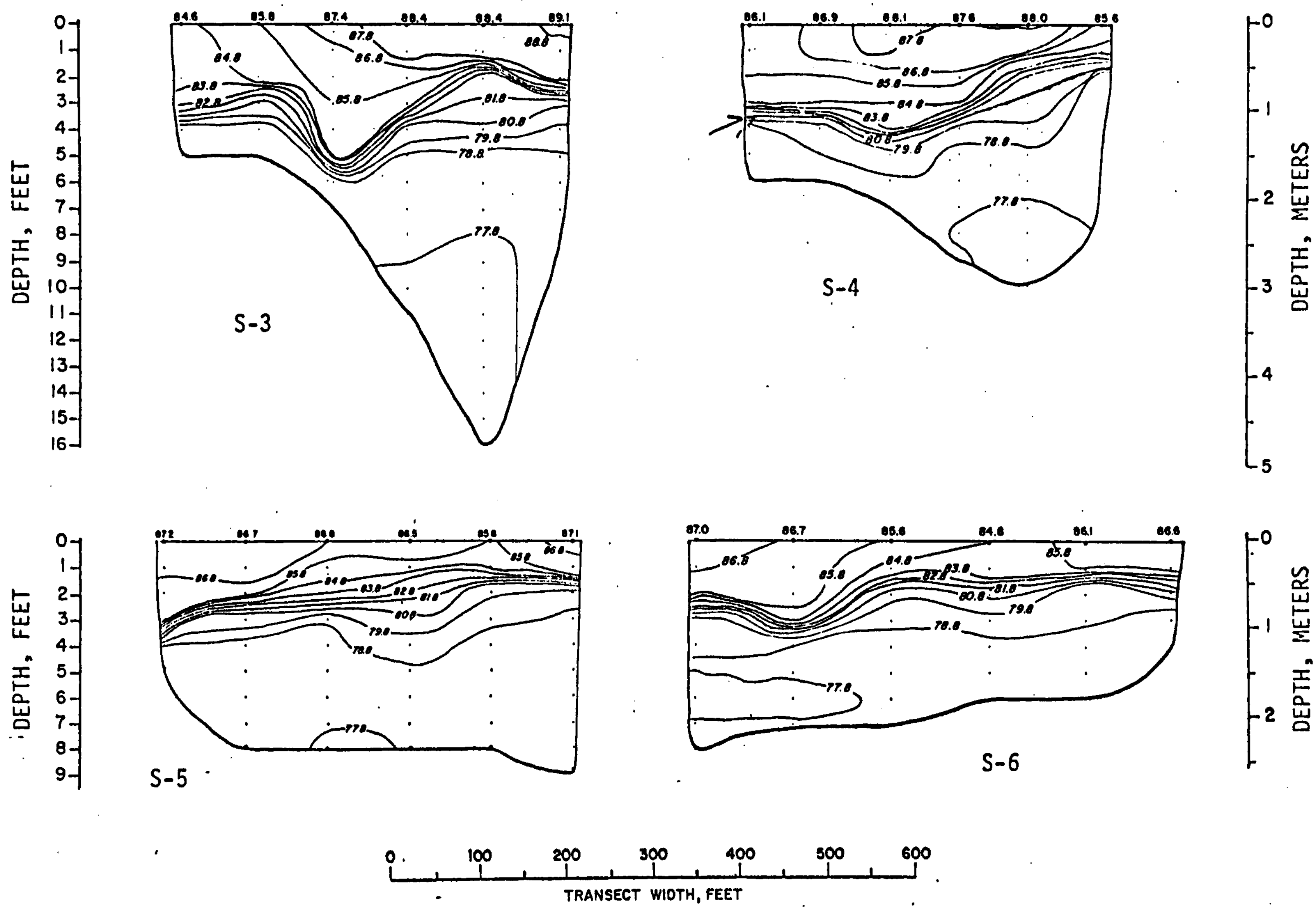
Appendix Figure B-9. (Continued)



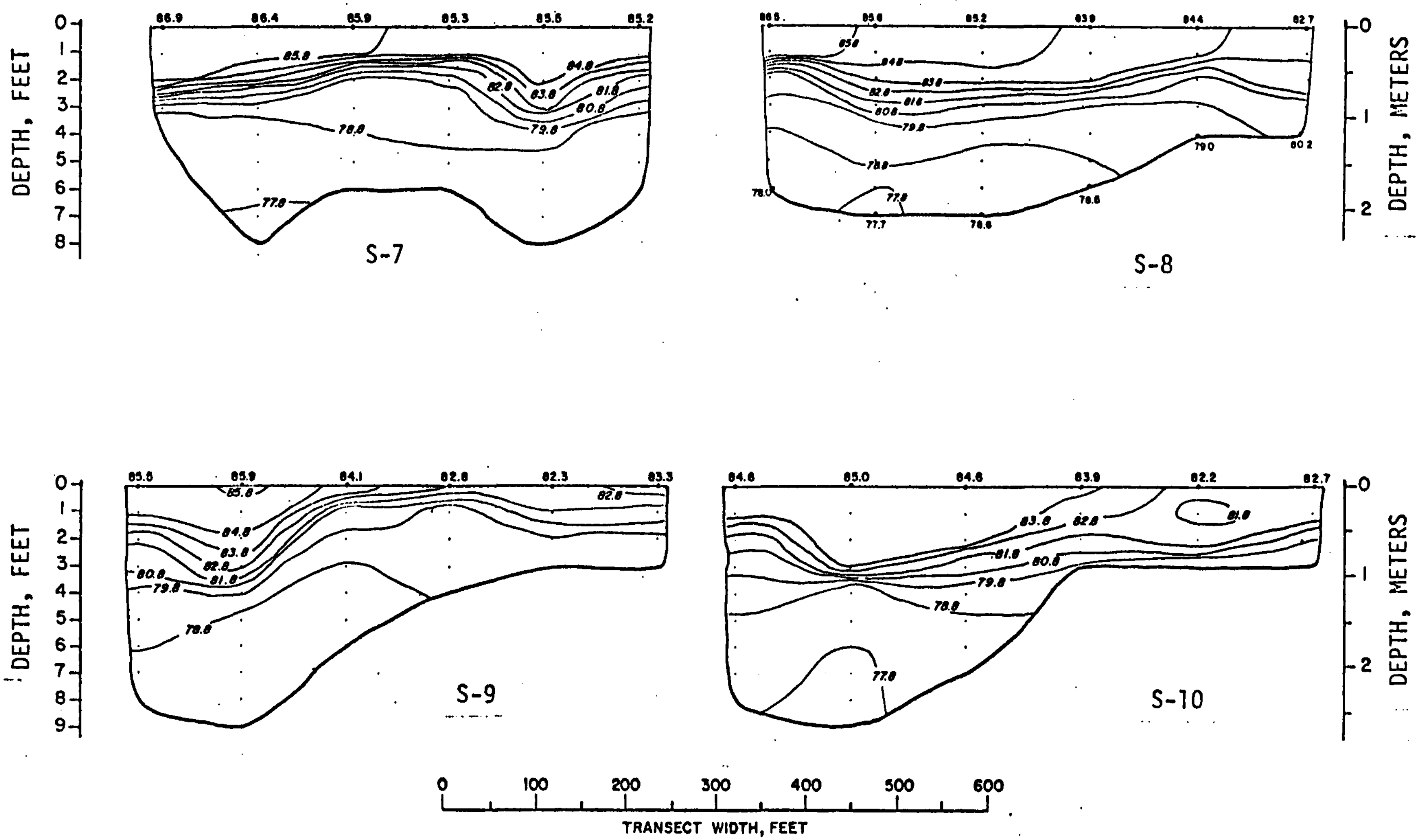
Appendix Figure B-10. Longitudinal surface thermal profile (°C) from August 26, 1976. Merrimack River Summary Report, 1979.



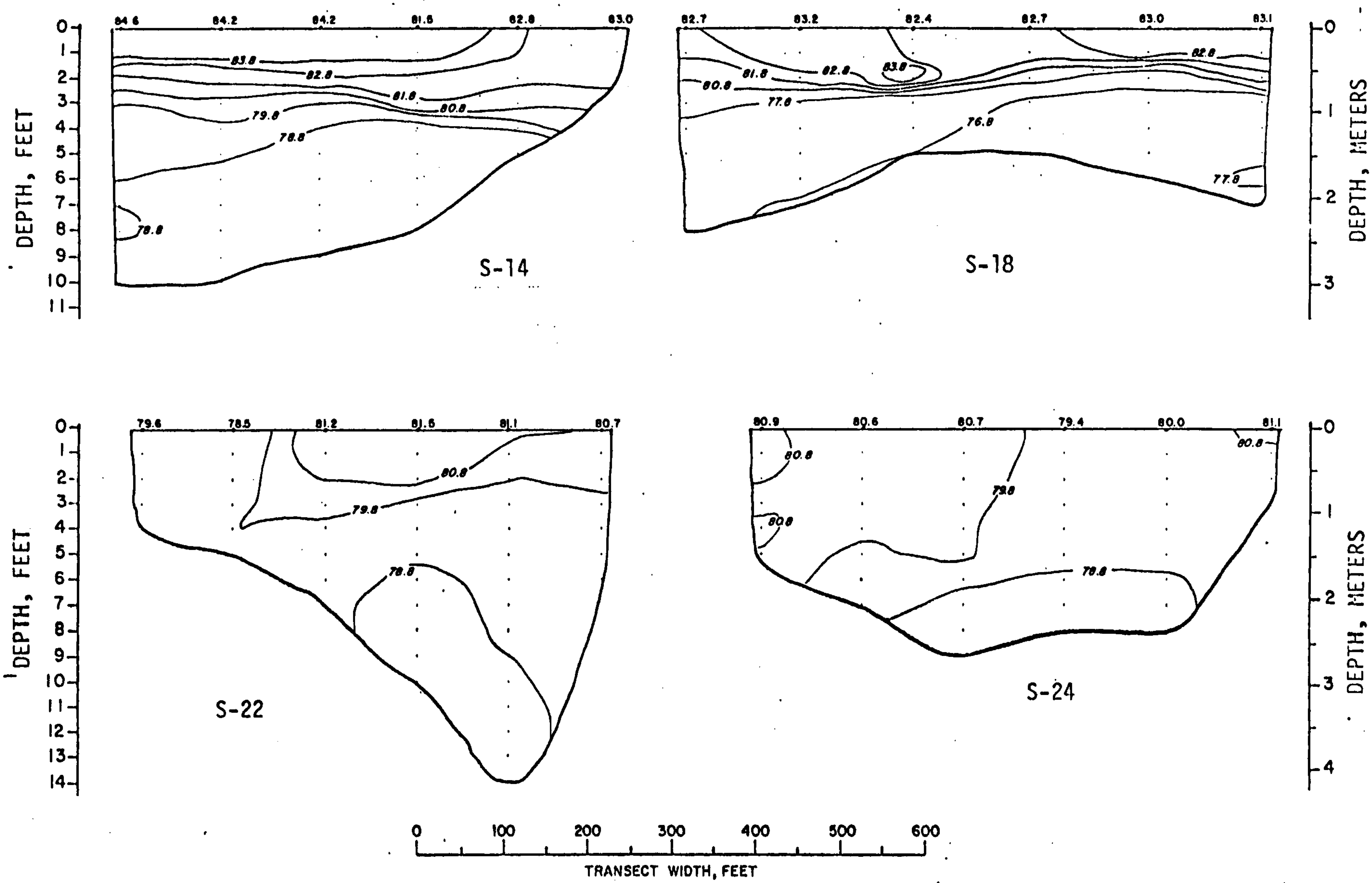
Appendix Figure B-11. Thermal profiles (°F), June 26, 1975.
Merrimack River Summary Report, 1979.



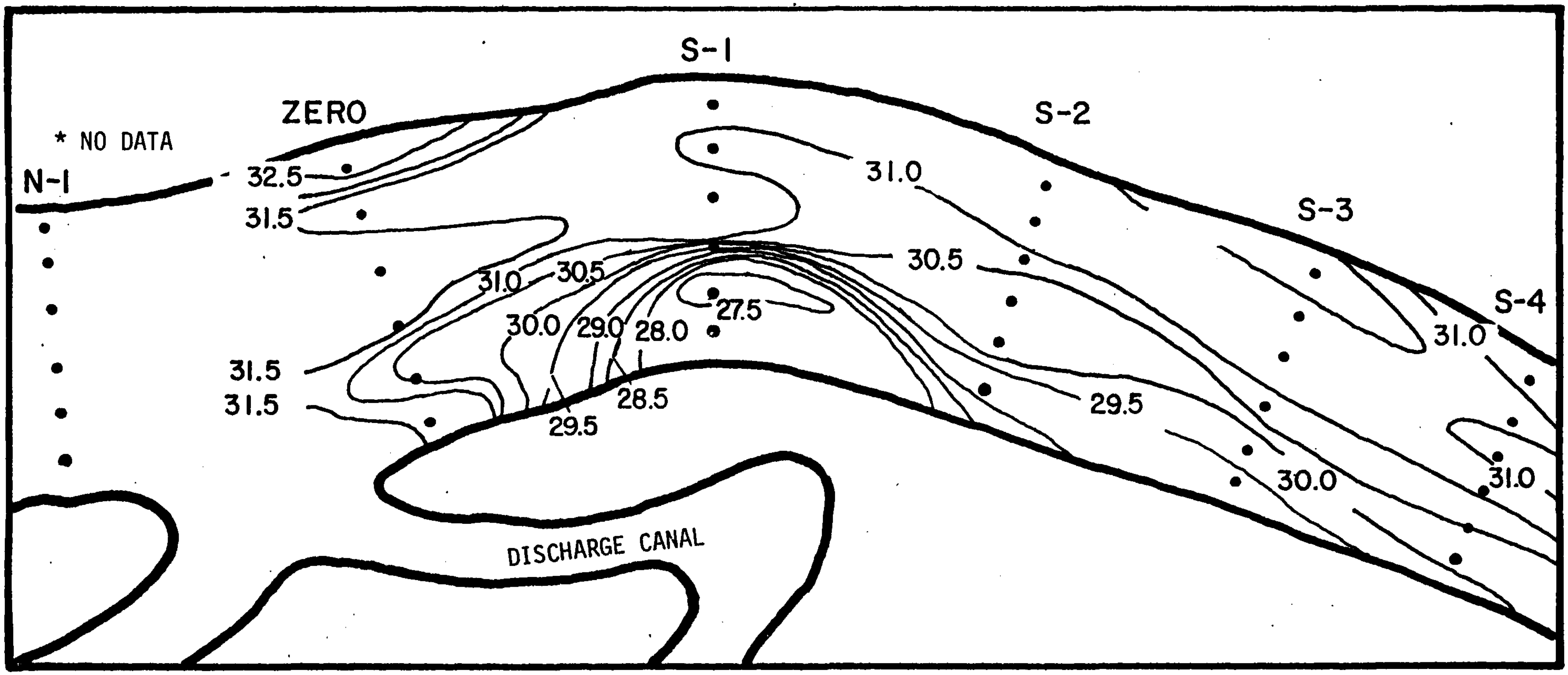
Appendix Figure B-11. (Continued)



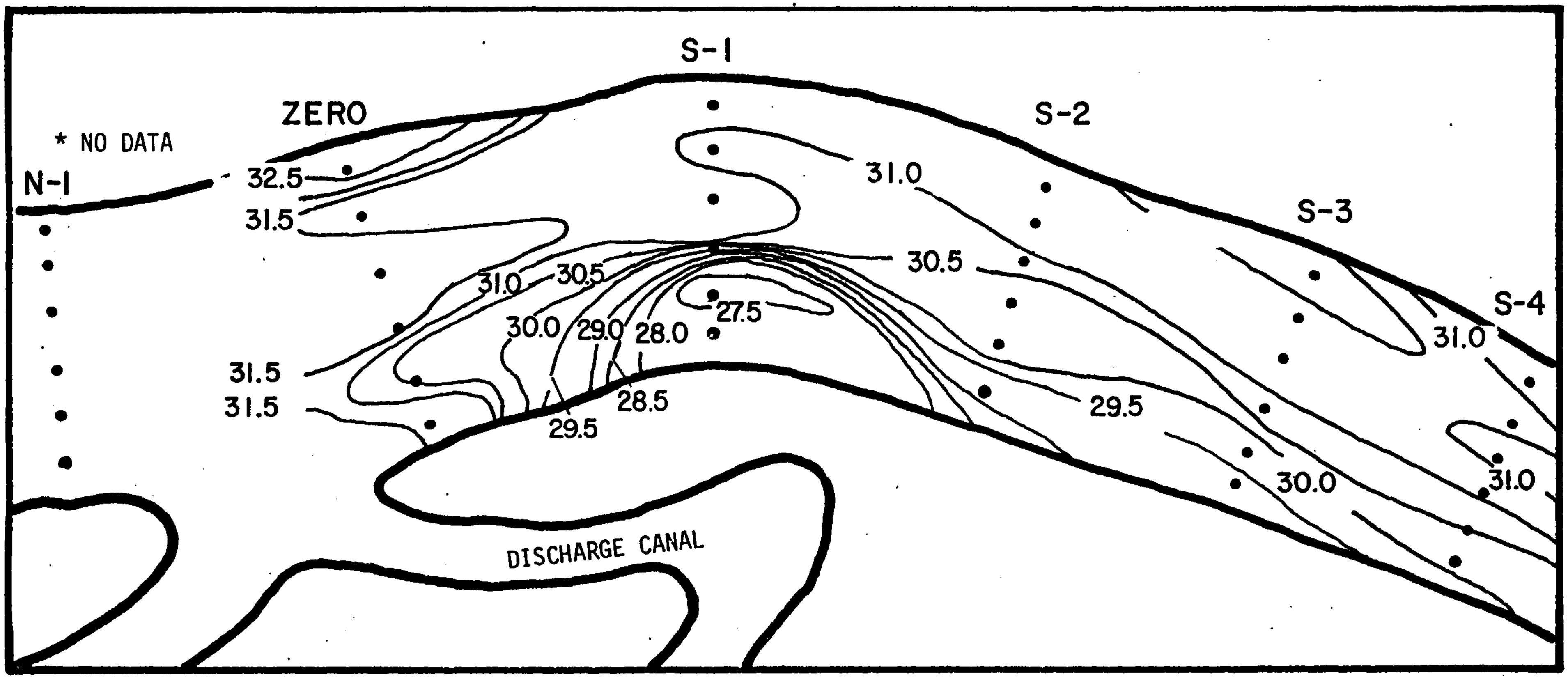
Appendix Figure B-11. (Continued)



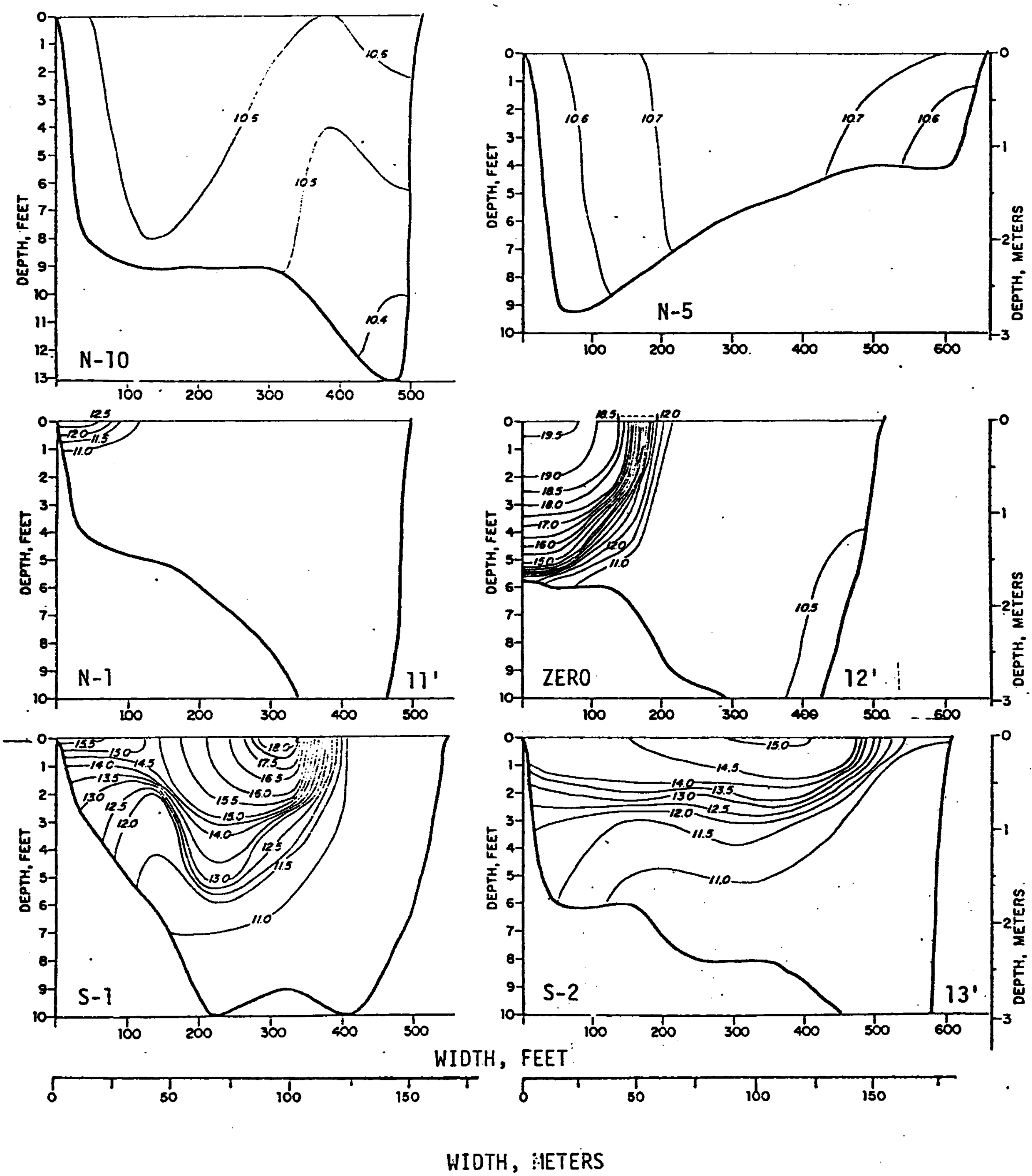
Appendix Figure B-11. (Continued)



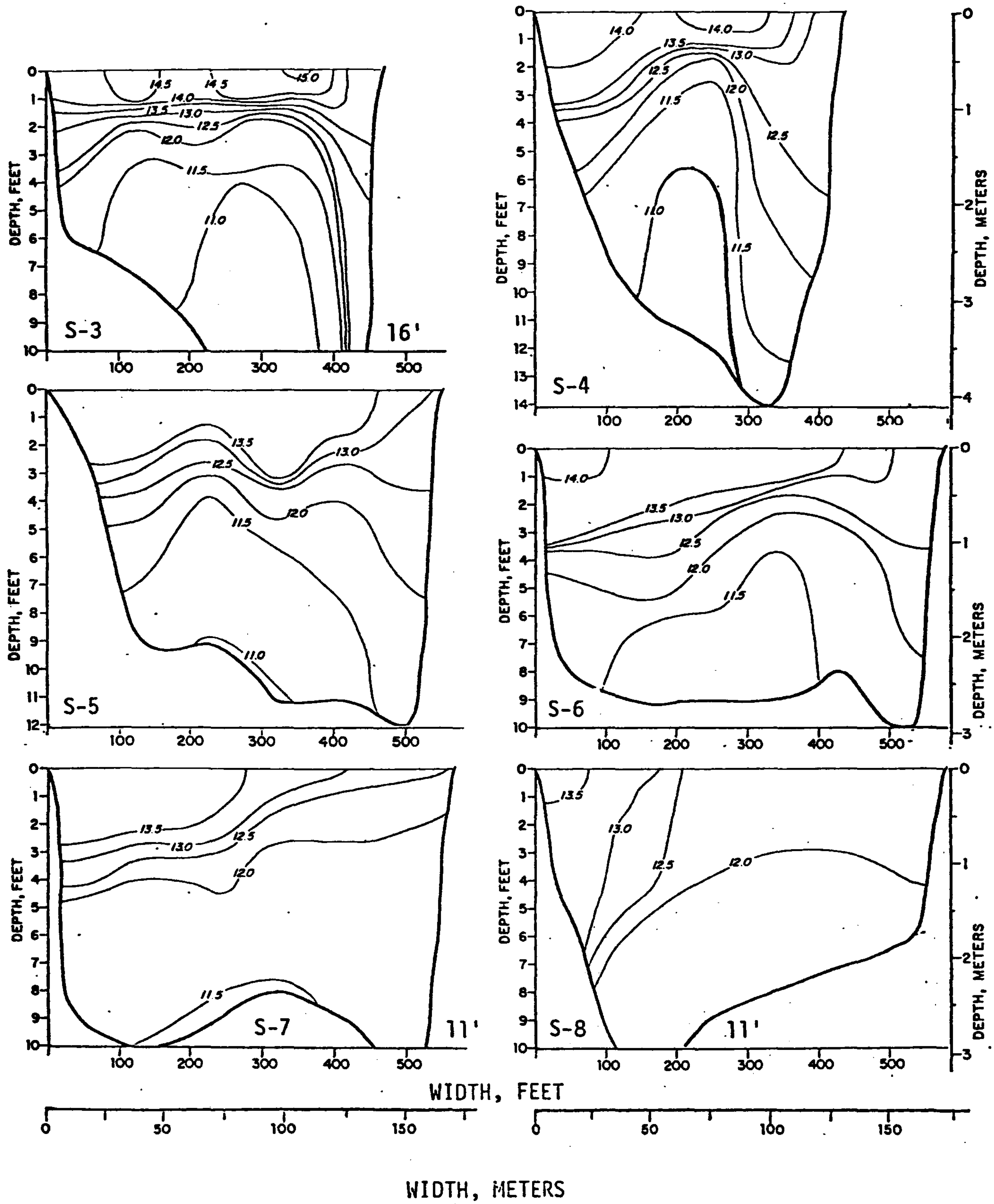
Appendix Figure B-12. Longitudinal surface thermal profile (°C) from June 26, 1975. Merrimack River Summary Report, 1979.



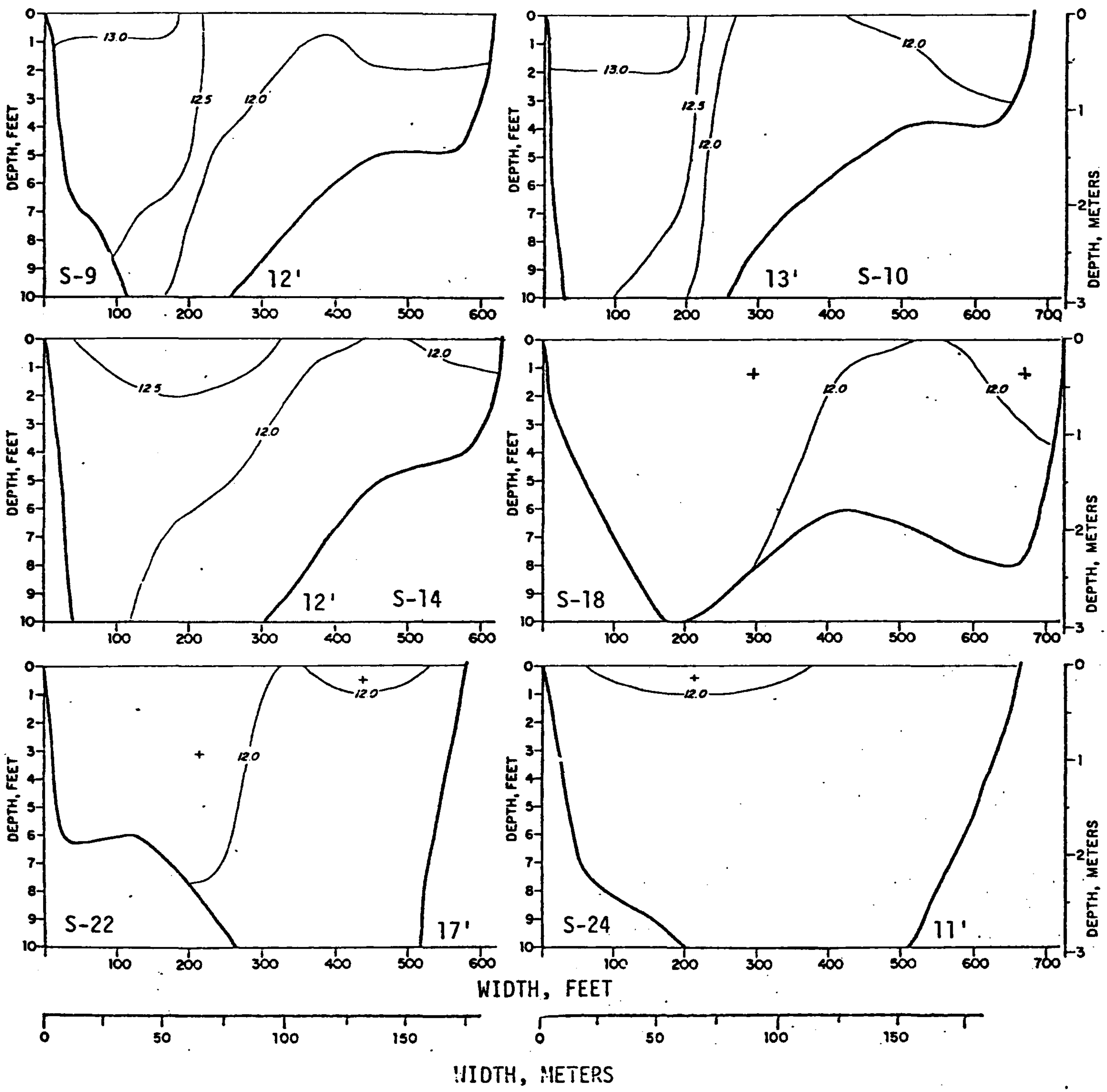
Appendix Figure B-12. Longitudinal surface thermal profile (°C) from June 26, 1975. Merrimack River Summary Report, 1979.



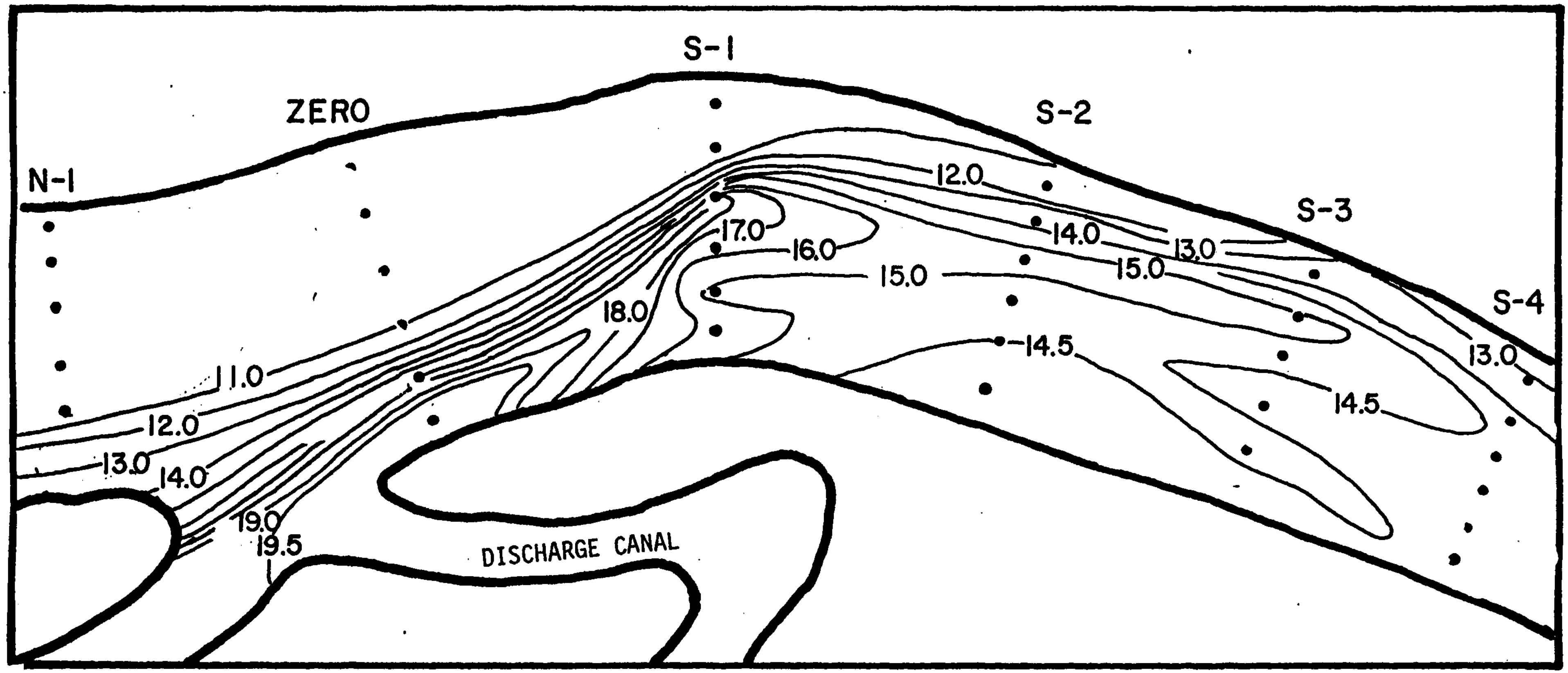
Appendix Figure B-13. Thermal profiles (°C), October 13, 1976.
Merrimack River Summary Report, 1979.



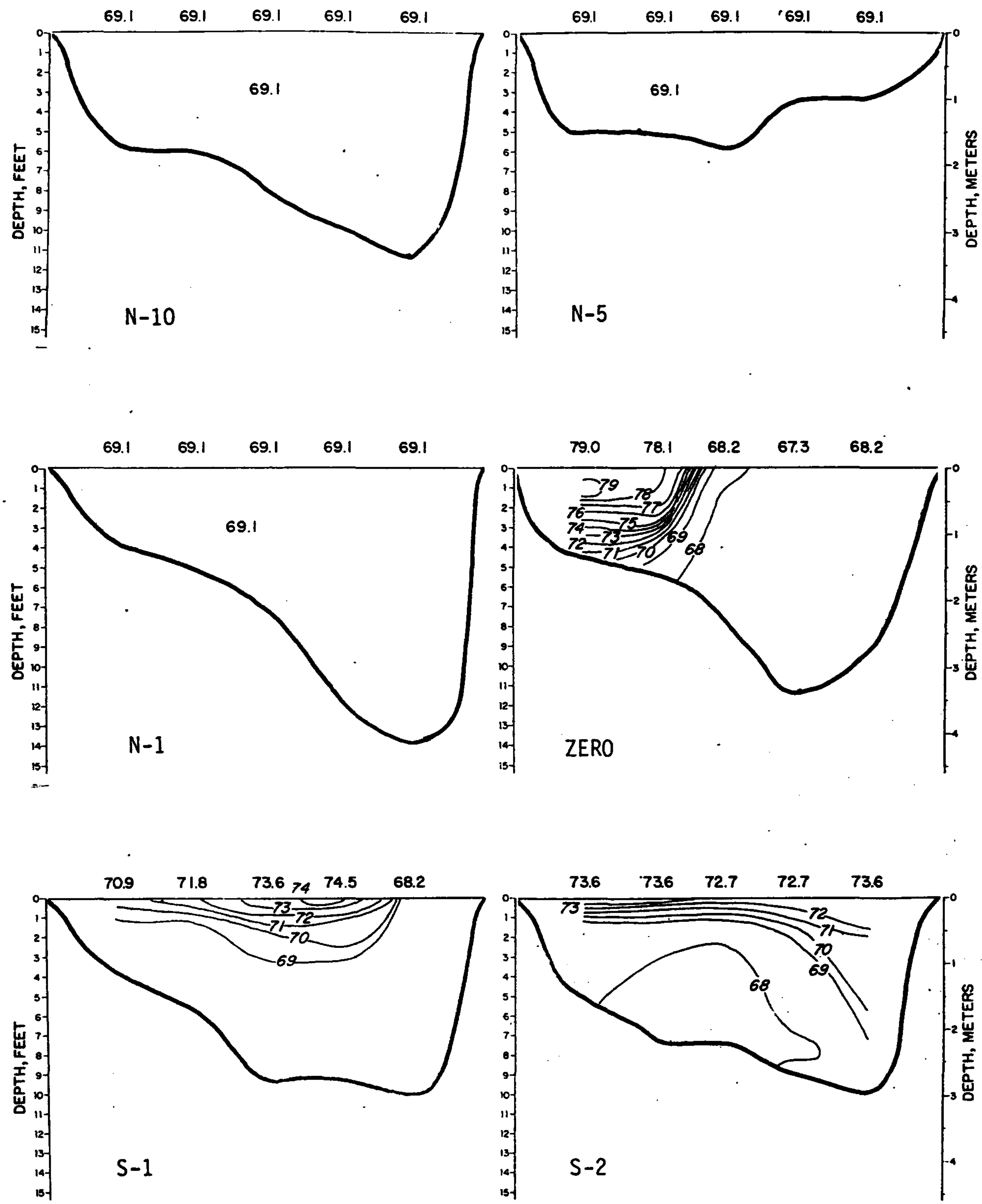
Appendix Figure B-13. (Continued)



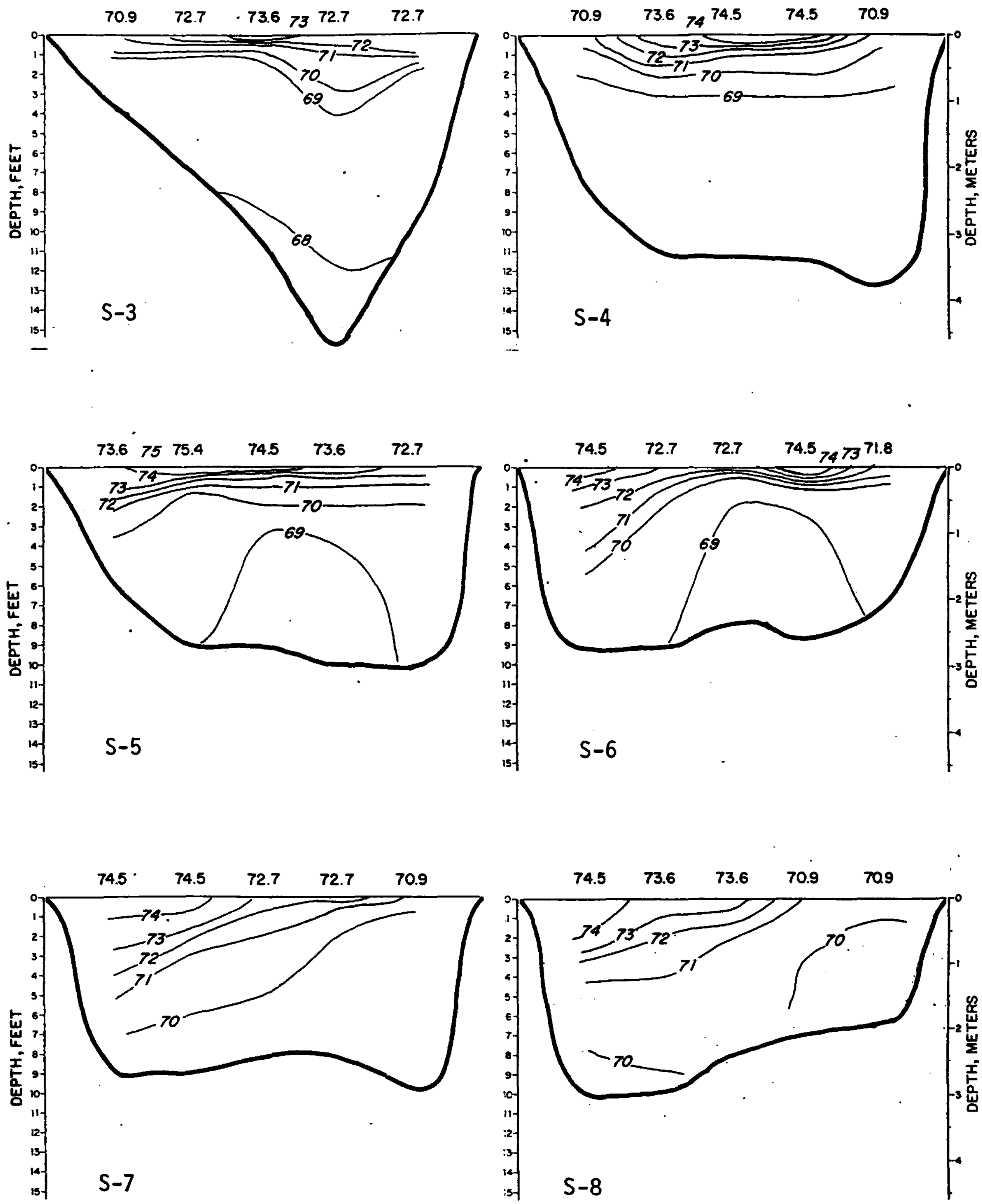
Appendix Figure B-13. (Continued)



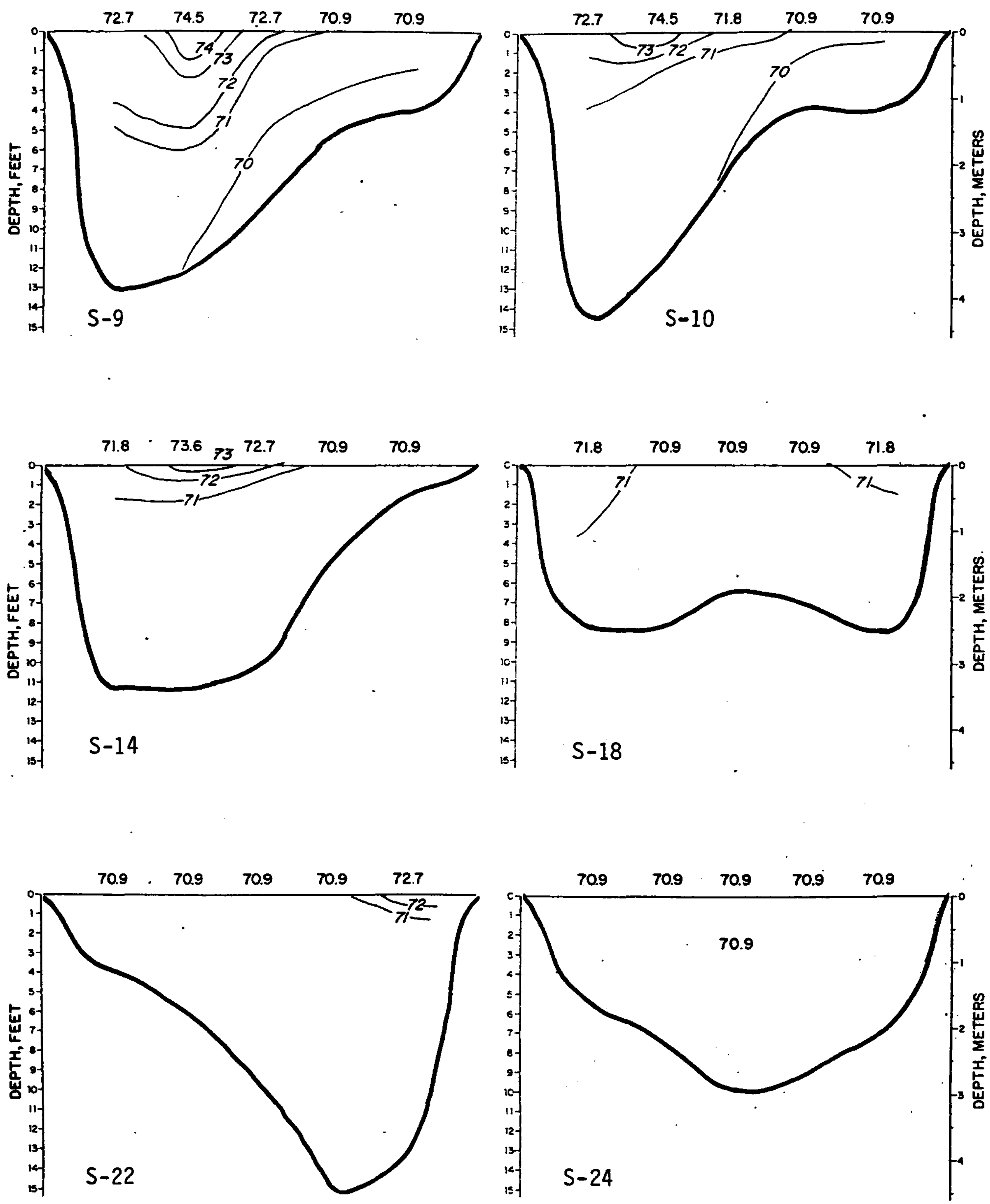
Appendix Figure B-14. Longitudinal surface thermal profile (°C) from October 13, 1976. Merrimack River Summary Report, 1979.



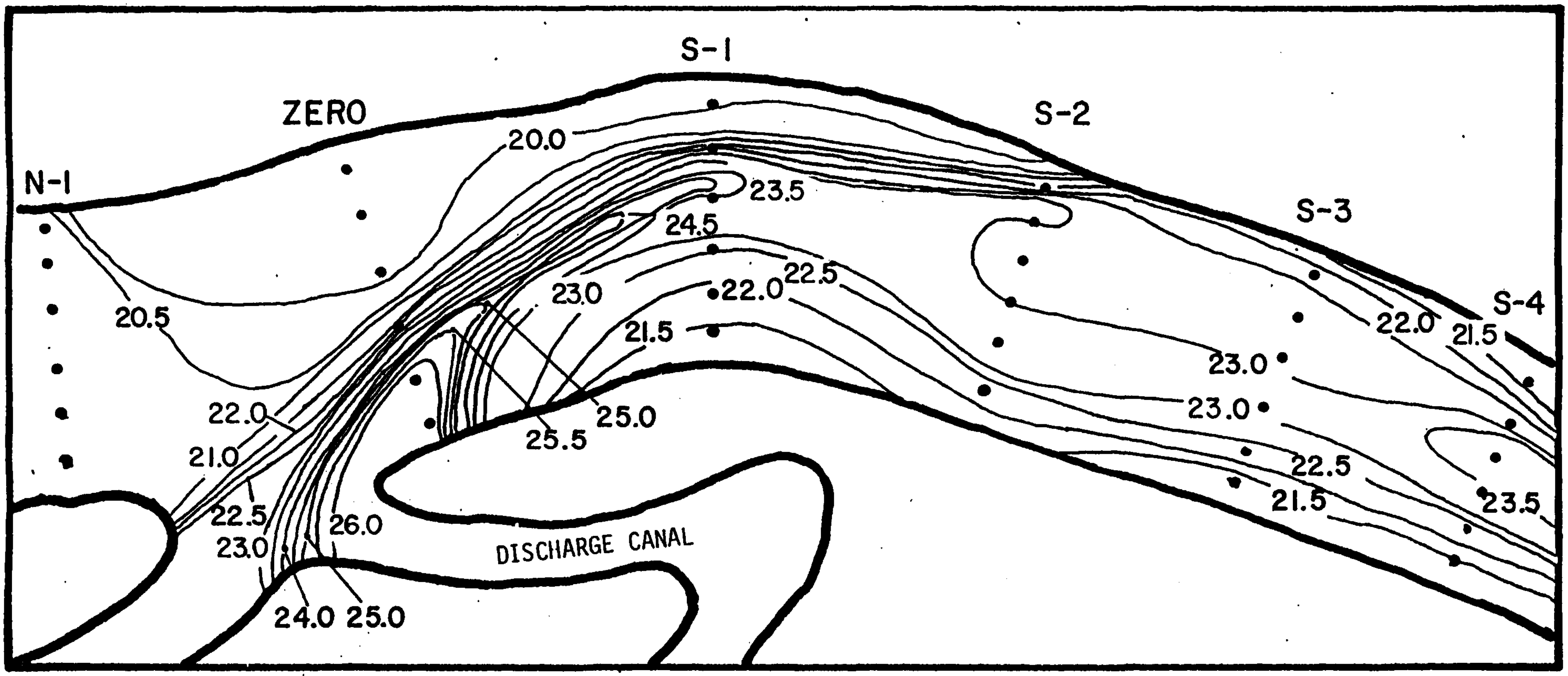
Appendix Figure B-15. Thermal profiles (°F), July 7, 1972.
Merrimack River Summary Report, 1979.



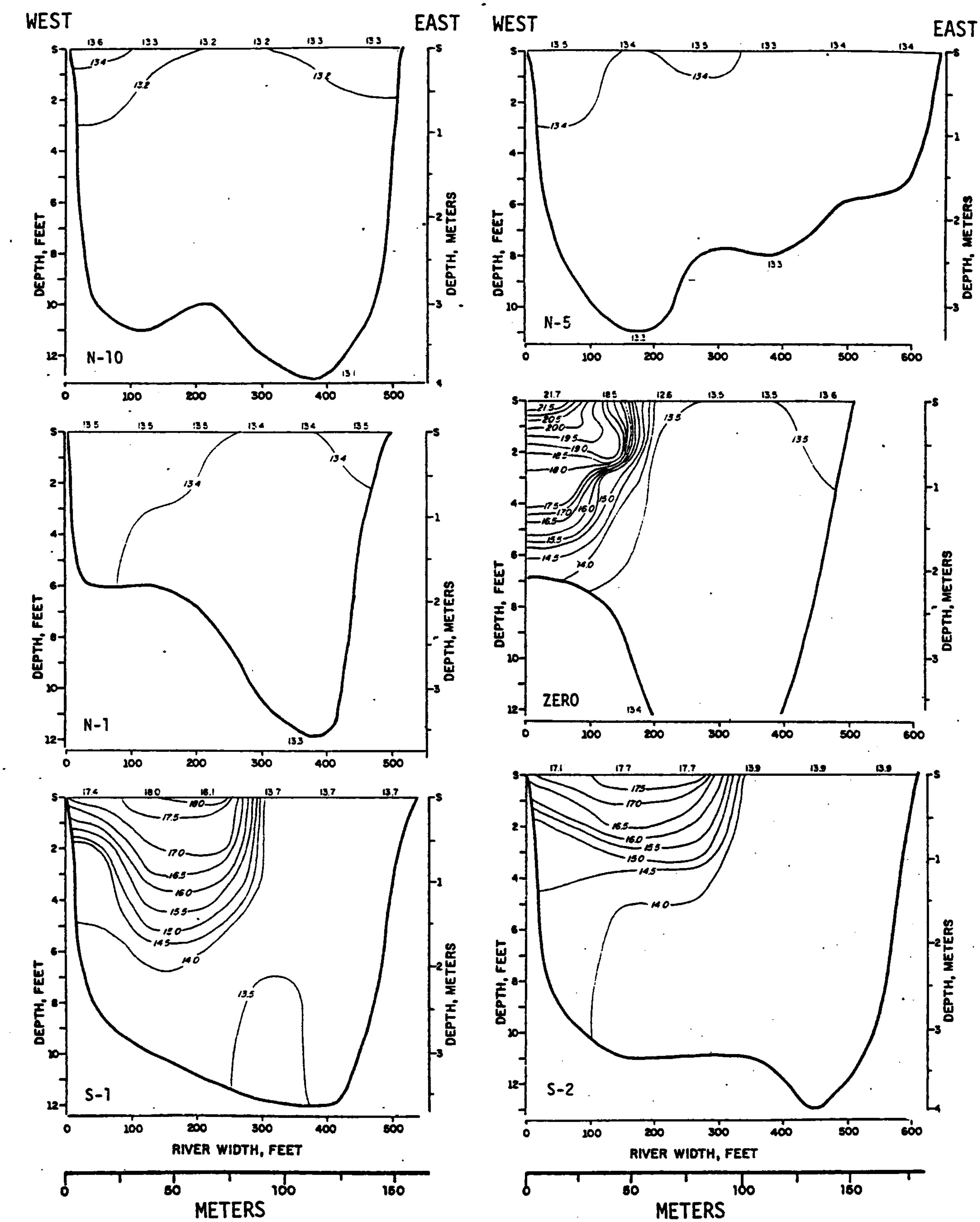
Appendix Figure B-15. (Continued)



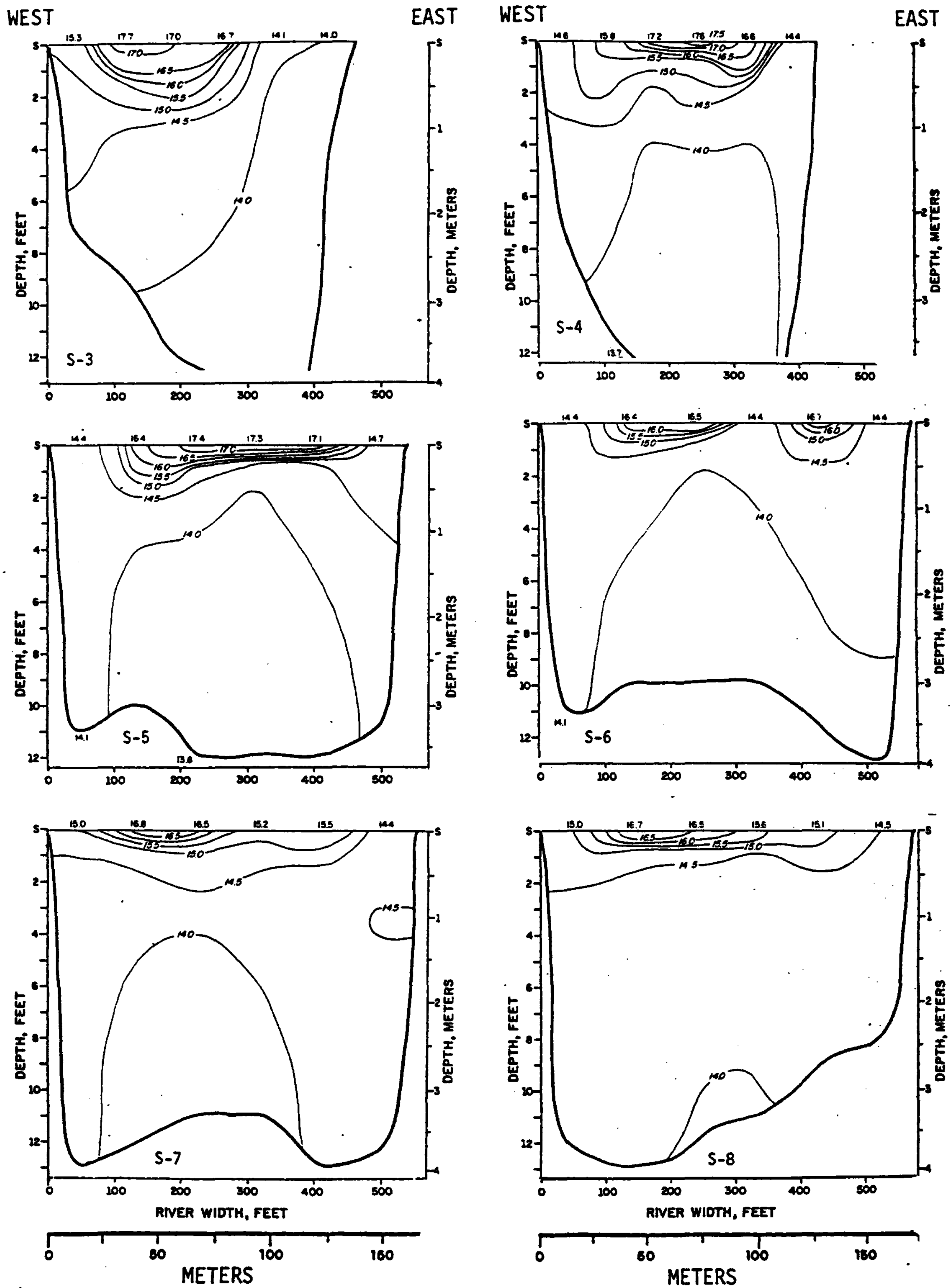
Appendix Figure B-15. (Continued)



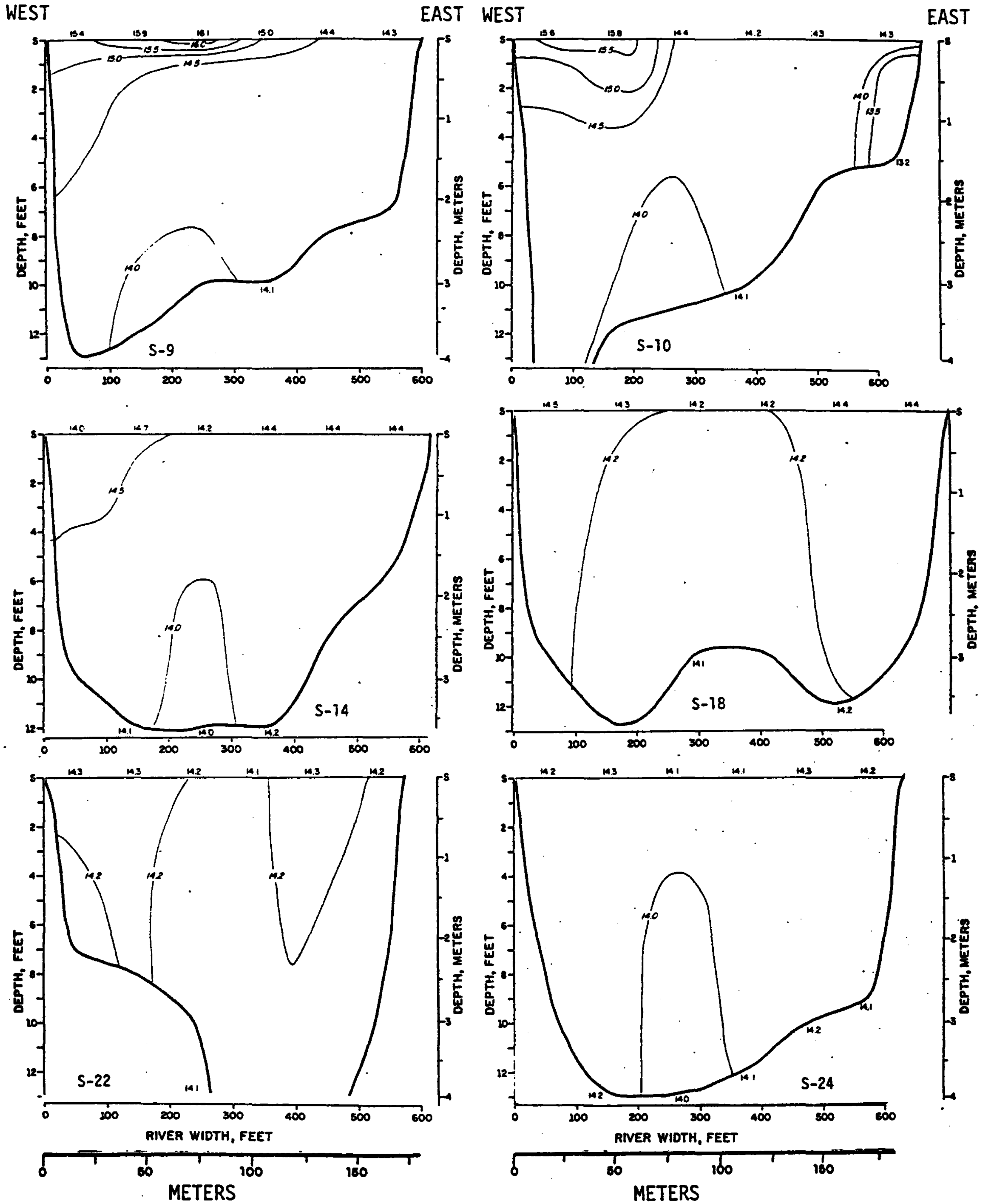
Appendix Figure B-16. Longitudinal surface thermal profile (°C) from July 7, 1972. Merrimack River Summary Report, 1979.



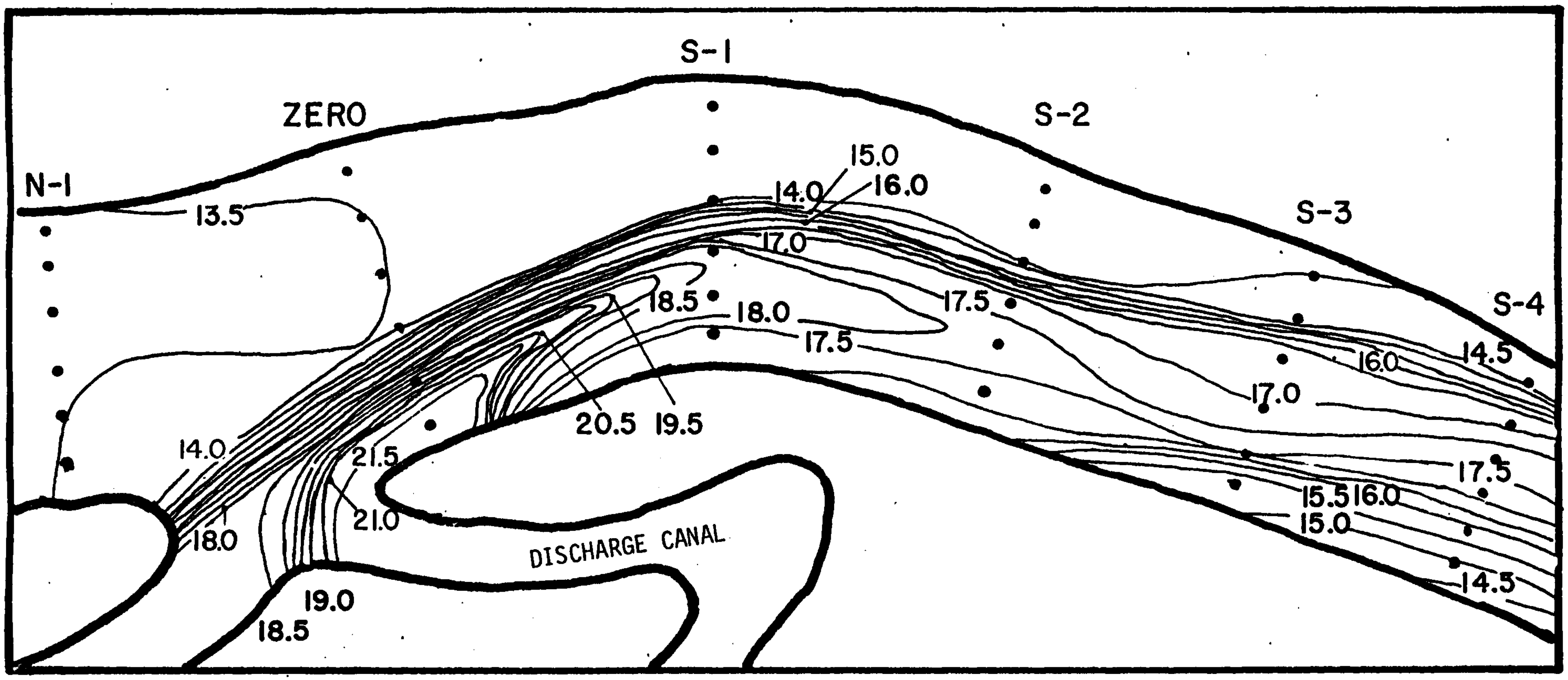
Appendix Figure B-17. Thermal profiles (°C), September 28, 1977. Merrimack River Summary Report, 1979.



Appendix Figure B-17. (Continued)



Appendix Figure B-17. (Continued)



Appendix Figure B-18. Longitudinal surface thermal profile (°C) from September 28, 1977. Merrimack River Summary Report, 1979.

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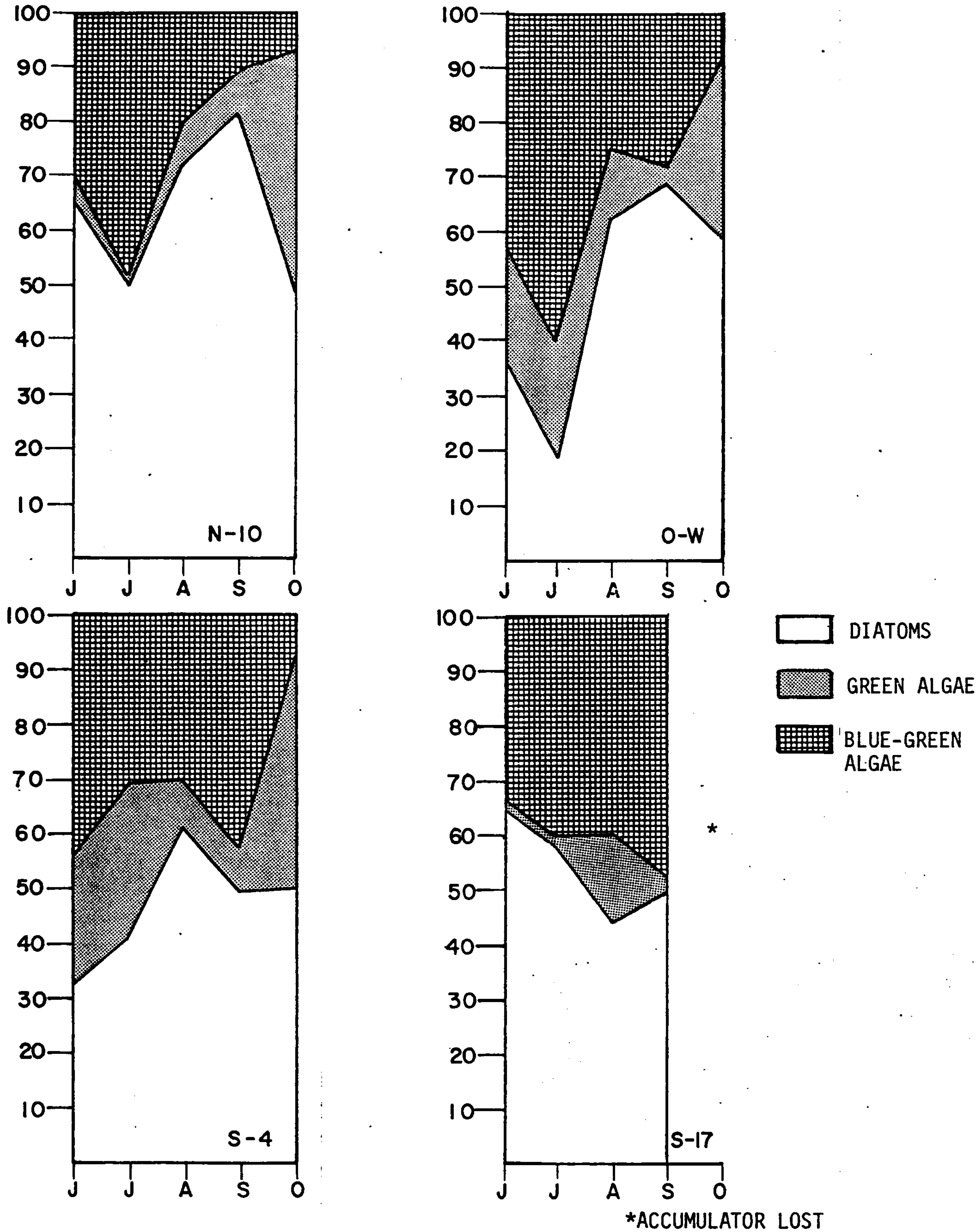
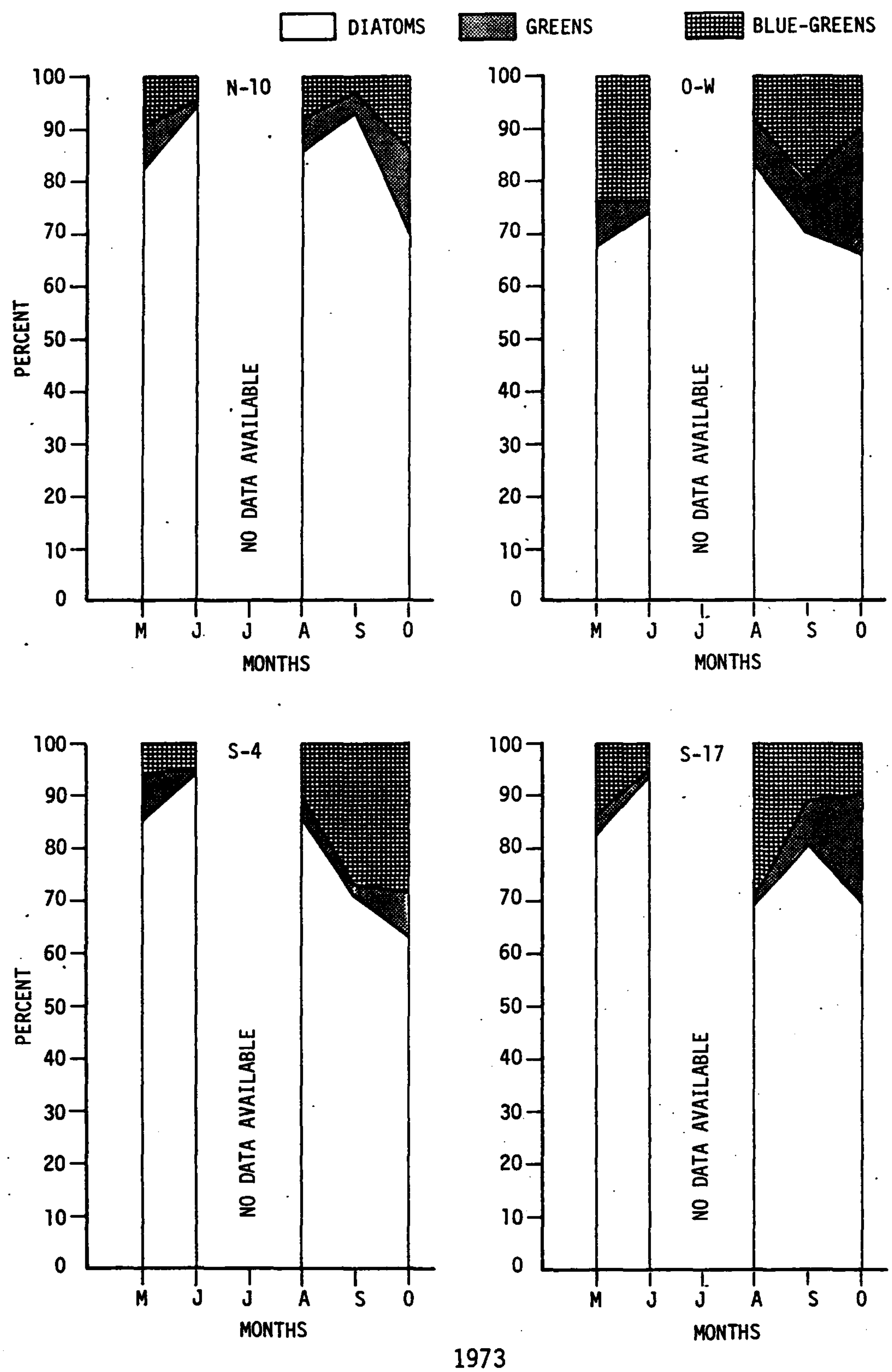
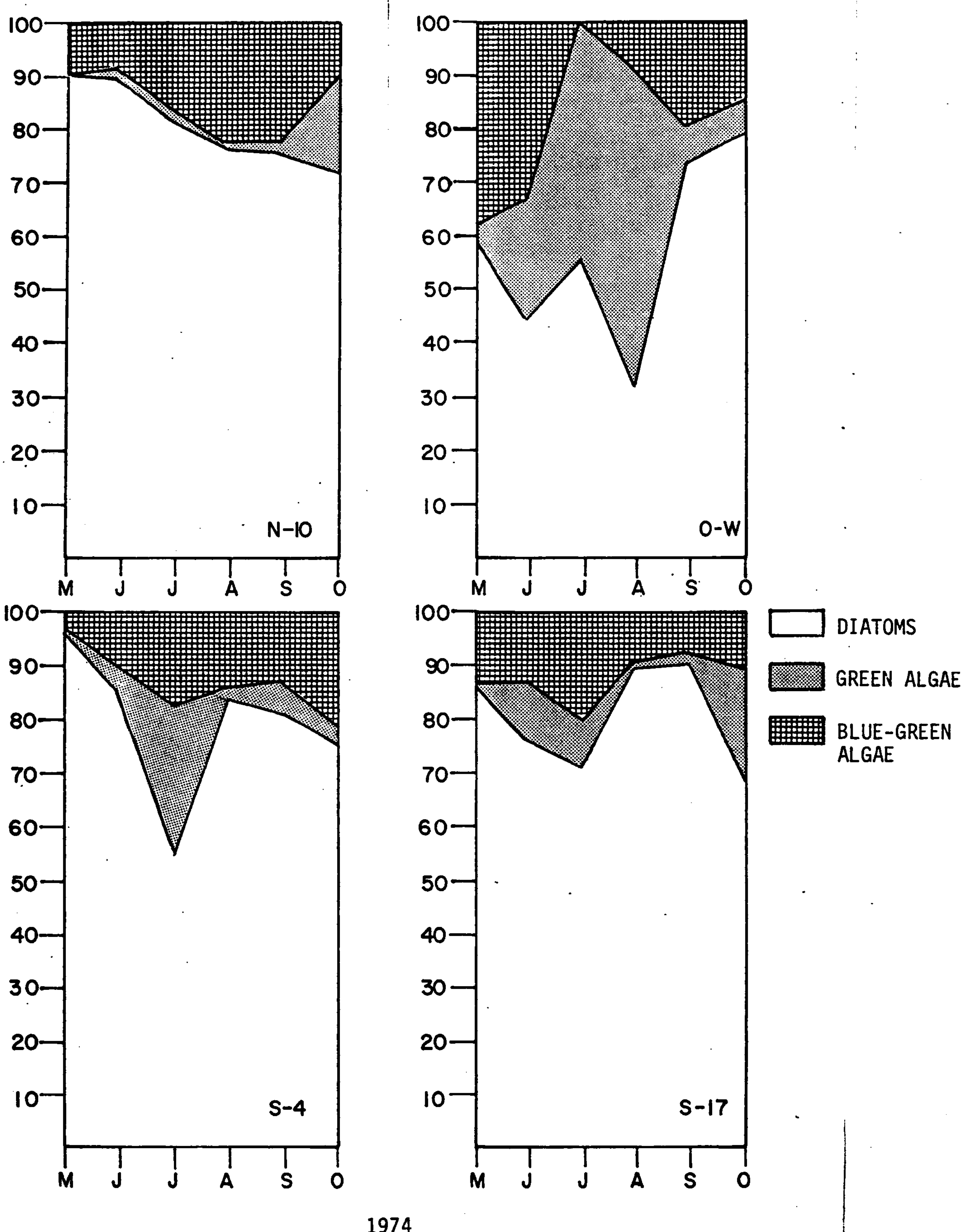
APPENDIX C



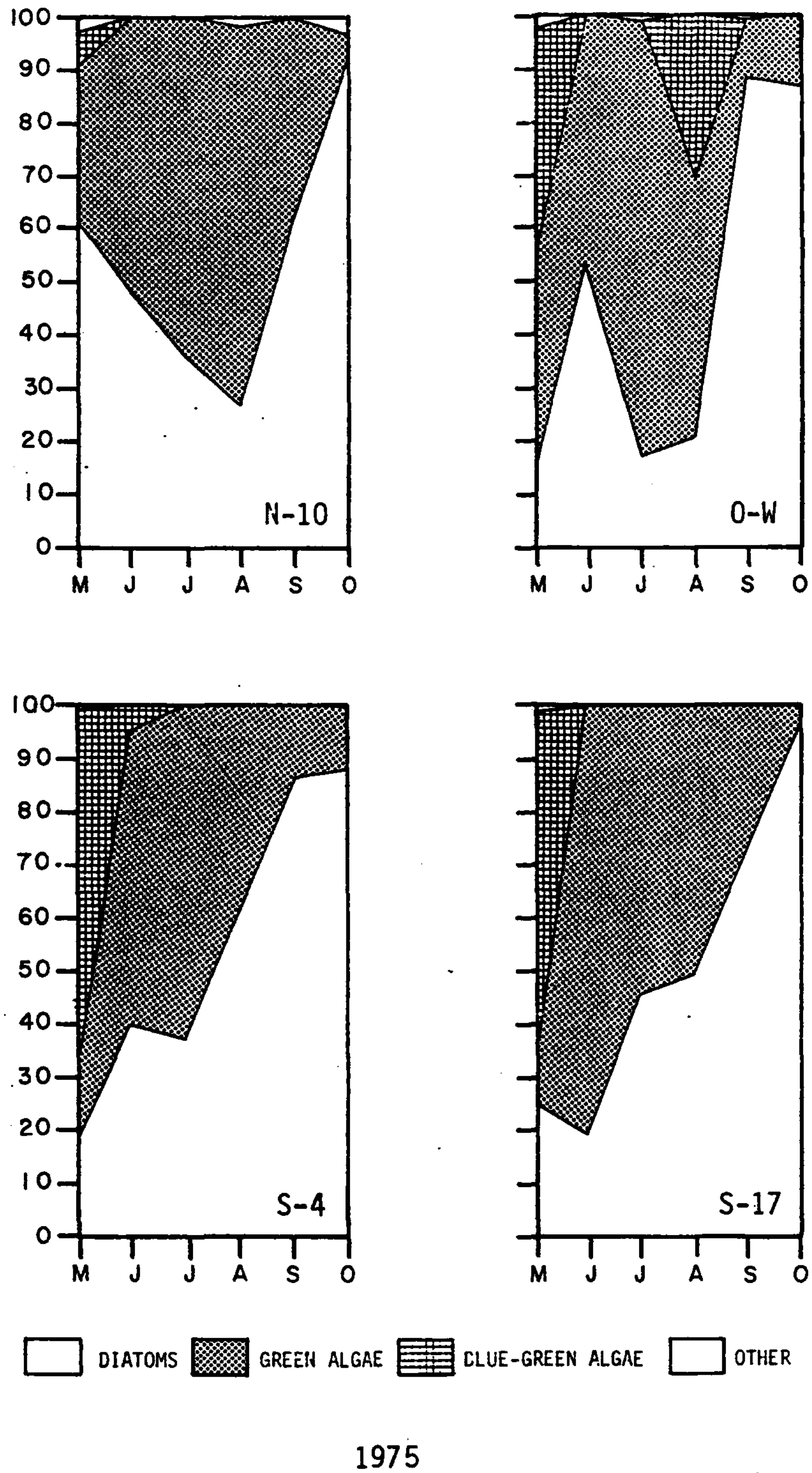
Appendix Figure C-1. Cumulative percent composition of periphyton communities allowed to colonize artificial substrates for one month at four Hooksett Pond stations, 1972 through 1978. Merrimack River Summary Report, 1979.



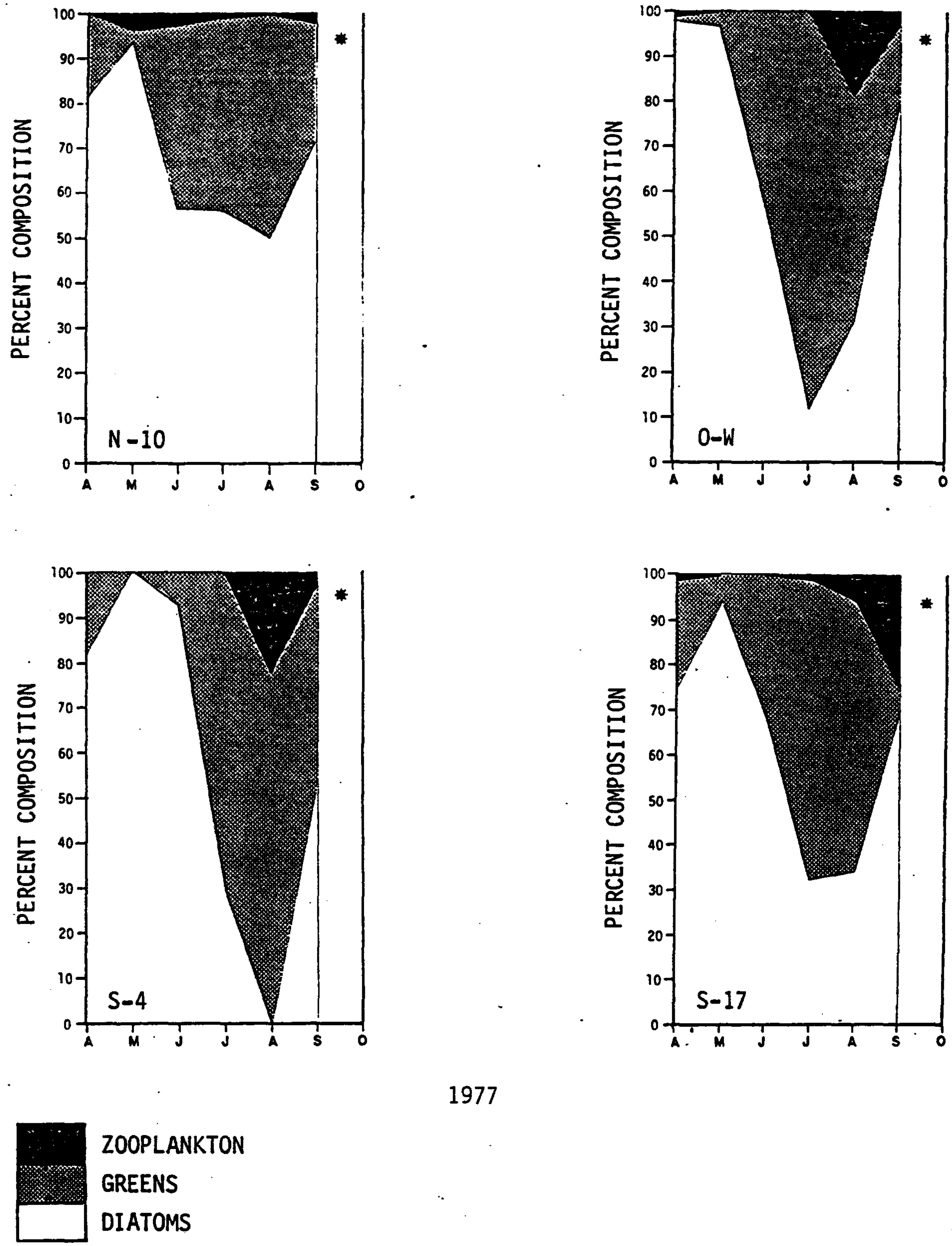
Appendix Figure C-1. (Continued)



Appendix Figure C-1. (Continued)



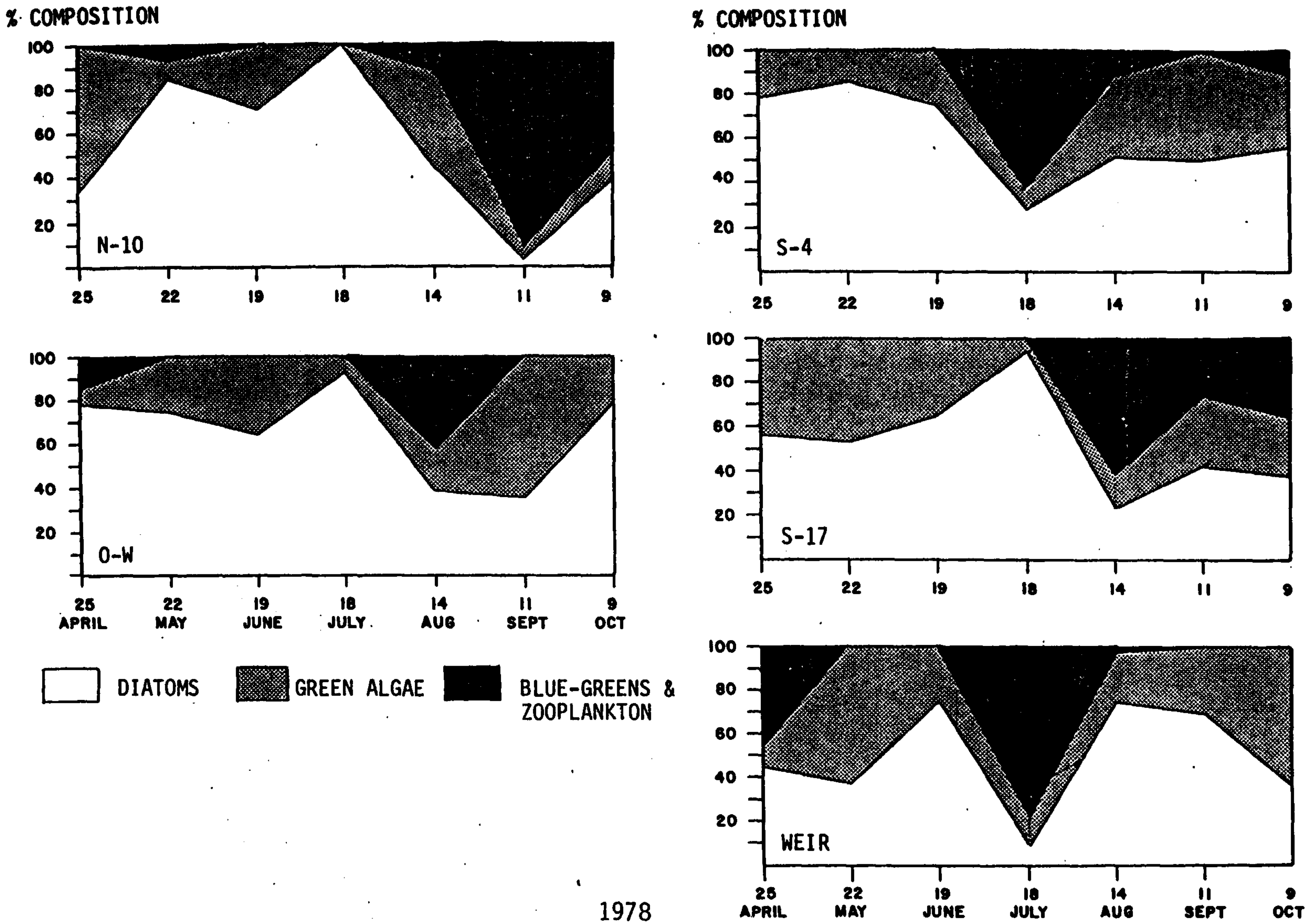
Appendix Figure C-1. (Continued)



* ACCUMULATORS WASHED OUT IN OCTOBER

* slides lost at all stations

Appendix Figure C-1. (Continued)



Appendix Figure C-1. (Continued)

APPENDIX TABLE C-1. TAXONOMIC INVENTORY OF PHYTOPLANKTON COLLECTED FROM 1967 THROUGH 1978 SAMPLING SEASONS, HOOKSETT POND, MERRIMACK RIVER, NEW HAMPSHIRE. MERRIMACK RIVER SUMMARY REPORT, 1979.

	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978
Chlorophyta											
Chlorophyceae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Actinastrum sp.								✓			
Ankistrodesmus sp.								✓	✓	✓	✓
Arthrodesmus sp.								✓			
Asterococcus sp.								✓			
Bulbochaete sp.								✓		✓	
Chlamydomonas sp.								✓			
Cladophora sp.								✓	✓	✓	✓
Closterium sp.								✓	✓	✓	✓
Coelastrum sp.									✓	✓	✓
Cosmarium sp.								✓	✓	✓	✓
Crucigenia sp.									✓		✓
C. tetrapedia											✓
Desmidium sp.								✓	✓	✓	✓
Dictyosphaerium sp.								✓	✓		
Euastrum sp.								✓	✓	✓	✓
Eudorina sp.			✓	✓	✓			✓	✓	✓	✓
E. elegans										✓	
Golenkinia sp.											✓
Hyalotheca sp.								✓	✓	✓	✓
Hydrodictyon reticulatum								✓	✓	✓	✓
Kirchneriella sp.									✓		✓
Micrasterias sp.								✓	✓	✓	✓
Microspora sp.						✓	✓	✓	✓	✓	✓
Mougeotia sp.				✓			✓	✓	✓	✓	✓
Netrium sp.								✓	✓	✓	
Oedogonium sp.								✓	✓	✓	✓
Palmodictyon sp.					✓			✓	✓	✓	
P. varium											✓
Pandorina sp.			✓					✓			
Pediastrum sp.			✓	✓			✓	✓	✓	✓	✓

Continued

APPENDIX TABLE C-1. (Continued)

	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978
Pleurotaenium sp.								✓	✓	✓	✓
Quadrigula sp.											✓
Q. closteroides											✓
Scenedesmus sp.			✓	✓	✓			✓	✓	✓	✓
Schroederia sp.								✓			
Selenastrum sp.								✓	✓	✓	✓
Sphaerocystis sp.								✓	✓	✓	✓
Spirogyra sp.			✓		✓	✓	✓	✓	✓	✓	✓
Spirotaenia sp.								✓	✓	✓	✓
Spondylosium sp.								✓	✓	✓	✓
Staurastrum sp.			✓				✓	✓	✓	✓	✓
Stigeoclonium sp.				✓				✓	✓	✓	
Ulothrix sp.			✓	✓	✓			✓		✓	✓
Volvox sp.											✓
Xanthidium sp.								✓			✓
Zygnema sp.								✓	✓		✓
Chrysophyta											
Bacillariophyceae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Actinella puntata											✓
Amphora sp.								✓	✓	✓	✓
Asterionella sp.			✓	✓	✓	✓	✓	✓	✓	✓	
A. formosa											✓
Cocconeis sp.								✓	✓	✓	✓
Cyclotella sp.										✓	✓
Cymbella sp.								✓	✓	✓	✓
Diatoma sp.			✓	✓				✓		✓	
Eunotia sp.									✓	✓	✓
Fragilaria sp.			✓	✓	✓			✓	✓	✓	✓
Frustulia sp.											✓
Gomphonema sp.								✓	✓	✓	✓
Gyrosigma sp.								✓	✓	✓	✓
Melosira sp.						✓	✓	✓	✓	✓	✓
M. varians										✓	✓

Continued

APPENDIX TABLE C-1. (Continued)

	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978
Meridion sp.								√	√	√	√
Navicula sp.			√		√			√	√	√	√
Nitzschia sp.								√	√		√
Pinnularia sp.								√	√	√	√
Stauroneis sp.								√	√	√	√
Surirella sp.								√	√	√	√
Synedra sp.								√	√	√	√
Tabellaria sp.			√	√	√	√	√	√	√	√	√
Chrysophyceae					√	√		√	√	√	√
Chrysosphaerella sp.					√			√	√	√	√
Dinobryon sp.					√			√	√	√	√
D. cylindricum											√
Mallomonas sp.								√		√	√
Rhipidodendron sp.										√	
Synura sp.					√			√	√	√	√
Xanthophyceae	√	√	√						√	√	√
Botrydium sp.											√
Tribonema sp.									√	√	
Cyanophyta	√	√	√	√	√	√	√	√	√	√	√
Anabaena					√			√	√	√	√
Anacystis					√		√	√	√	√	
A. aeruginosa							√				
Arthrospira									√		
Gomphoshaeria								√			
Lyngbya			√		√			√	√	√	√
Merismopedia								√	√	√	√

Continued

APPENDIX TABLE C-1. (Continued)

	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978
Oscillatoria sp.			✓			✓	✓	✓	✓	✓	✓
Plectoema sp.								✓			
Polycystis sp.			✓								
Pyrrophyta											
Dinophyceae	✓	✓			✓	✓		✓	✓	✓	✓
Ceratium sp.					✓			✓	✓	✓	✓
C. hirundinella											✓
Peridinium sp.								✓	✓	✓	✓
Rhodophyta					✓	✓					
Audouinella sp.					✓						

APPENDIX TABLE C-2. MEAN MONTHLY AMBIENT (N-10) CHLOROPHYLL a CONCENTRATIONS (µg/l) AND CHANGES IN CHLOROPHYLL a CONCENTRATION FROM AMBIENT TO THREE DOWNSTREAM STATIONS, 1972 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

	1972							1973							1974						
	APR	MAY	JUN	JUL	AUG	SEP	OCT	APR	MAY	JUN	JUL	AUG	SEP	OCT	APR	MAY	JUN	JUL	AUG	SEP	OCT
N-10 µg/l	1.52	1.87	2.96	4.01	7.65	10.60	3.02	2.41	2.19	3.06	5.36	8.60	15.39	2.49	1.76	2.46	4.92	9.42	23.45	5.67	2.21
O-W Δµg/l	0.00	-0.33	-0.60	-0.53	-1.93	-0.74	+0.01	-0.27	-0.02	-0.33	-1.92	-1.67	-3.55	+0.06	-0.33	-0.16	-2.42	-3.36	-6.94	-1.16	-0.39
S-4 Δµg/l	-0.10	+0.02	-0.33	-0.23	+0.03	+1.51	+0.12	-0.08	+0.35	-0.42	-1.42	-1.14	-1.57	+0.22	+0.09	-0.10	-0.33	+0.02	-1.21	-0.47	-0.02
S-17 Δµg/l	-0.07	-0.11	+0.22	+0.64	+1.39	+2.75	+0.18	+0.03	+0.28	+0.56	+0.95	+0.51	+0.60	+0.03	+0.01	+0.01	+0.77	+1.51	-1.97	+0.77	+0.11

	1975							1976							1977						
	APR	MAY	JUN	JUL	AUG	SEP	OCT	APR	MAY	JUN	JUL	AUG	SEP	OCT	APR	MAY	JUN	JUL	AUG	SEP	OCT
N-10 µg/l	1.82	2.13	4.69	5.20	5.49	2.42	1.78	1.64	1.36	4.53	6.72	2.69	1.58	2.18	0.77	2.17	2.80	4.47	3.61	2.33	2.76
O-W Δµg/l	-0.01	+0.20	-1.04	-1.85	-2.21	-0.41	-0.06	-0.03	-0.10	-1.57	-2.30	-0.66	-0.07	-0.77	-0.05	-0.39	-0.48	+0.16	+0.32	+0.05	-0.90
S-4 Δµg/l	+0.15	-0.07	-0.64	-1.47	-1.75	-0.06	0.00	+0.16	-0.06	-0.40	-1.13	-0.50	-0.17	-0.87	+0.03	-0.41	+0.11	-0.13	+0.87	-0.01	-0.68
S-17 Δµg/l	+0.03	-0.06	-0.02	-0.06	+1.17	-0.26	+0.12	+0.03	-0.02	-0.30	-1.00	-0.28	-0.04	-0.29	+0.07	+0.15	+0.52	+0.02	+1.10	+0.37	-0.17

	1978						
	APR	MAY	JUN	JUL	AUG	SEP	OCT
N-10 µg/l	1.20	1.36	1.59	4.61	3.13	2.86	1.77
O-W Δµg/l	-0.27	-0.61	-0.24	-1.21	-0.64	-0.02	-0.19
S-4 Δµg/l	-0.12	-0.32	-0.29	-0.02	-0.04	+0.69	-0.47
S-17 Δµg/l	-0.08	+0.05	+0.17	+0.03	-0.28	+0.26	+0.36

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APPENDIX D

APPENDIX TABLE D-1. ANNUAL MEAN DENSITY (INDIVIDUALS/m^2) OF DOMINANT TAXA COLLECTED FROM PONAR AND ARTIFICIAL MULTIPLATE SAMPLES 1972 TO 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

		1972				1973				1974				1975			
		N-10	ZERO	S-4	S-17	N-10	ZERO	S-4	S-17	N-10	ZERO	S-4	S-17	N-10	ZERO	S-4	S-17
PONAR	Annelida	1035	580	1585	338	5460	2645	5555	6169	5103	2993	3605	6344	6720	2928	8857	8141
	Mollusca	64	49	40	159	72	113	196	291	255	172	270	778	531	244	342	686
	Diptera	1600	903	1445	931	7863	2341	4982	975	3535	2843	2751	1343	572	514	996	493
	Other	18	32	66	473	408	102	89	406	309	153	41	348	265	125	625	310
	Total	2717	1564	3135	1901	13803	5201	10822	7841	9205	6161	6667	8812	8088	3811	10820	9630

		1976				1977*				1978*			
		N-10	ZERO	S-4	S-17	N-10	ZERO	S-4	S-17	N-10	ZERO	S-4	S-17
PONAR	Annelida	875	523	695	1001	997	2179	1950	2428	1347	1670	2123	1880
	Mollusca	351	219	210	191	1089	841	630	783	771	470	516	1125
	Diptera	106	223	60	229	248	745	516	516	286	502	414	284
	Other	63	86	201	89	348	875	1437	919	189	385	363	596
	Total	1395	1051	1166	1510	2682	4640	4533	4646	2594	3087	3416	3885
ARTIFICIAL MULTIPLATES	Ephemeroptera					424	260	279	170	159	277	237	144
	Trichoptera					1174	652	804	500	426	782	365	334
	Diptera					1750	2493	2078	1982	404	436	586	269
	Other					1002	1086	787	1147	166	239	99	461
	Total					4350	4491	3948	3799	1154	1733	1287	1209

*represents a mean from two stations; all other means represent three stations.

APPENDIX TABLE D-2. PERCENT COMPOSITION BY WEIGHT AND PERCENT VOLATILES OF SEDIMENT SAMPLES COLLECTED AT BENTHIC MACROINVERTEBRATE SAMPLING STATIONS, 1977 AND 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

	JUNE					AUGUST					OCTOBER				
1977	GRAVEL	SAND	MUD	GRAPHIC MEAN (PHI VALUE)	PERCENT VOLATILES	GRAVEL	SAND	MUD	GRAPHIC MEAN (PHI VALUE)	PERCENT VOLATILES	GRAVEL	SAND	MUD	GRAPHIC MEAN (PHI VALUE)	PERCENT VOLATILES
N-10-W	0	99.3	0.7	3.1	1.0	0.2	98.7	1.1	3.2	2.6	1.0	98.6	0.5	2.9	0.9
N-10-M	1.9	98.0	0.1	0.8	0.4	1.2	98.7	0.1	1.0	0.4	7.7	92.2	0.1	0.6	0.4
O-W	2.1	97.3	0.6	2.7	1.6	4.3	95.4	0.3	1.5	1.3	0.1	99.7	0.2	2.9	0.9
O-M	2.7	97.3	0	1.3	0.3	1.4	98.6	0	0.8	0.5	1.3	98.6	0.1	1.0	0.4
S-4-W	0.5	99.0	0.5	3.1	1.3	1.0	99.2	0.7	3.2	1.9	0	95.1	4.9	3.3	6.8
S-4-M	0.7	99.2	0.1	1.1	0.4	0.4	99.6	0	1.0	0.5	1.3	98.7	0	1.1	0.4
S-17-W	0.3	99.2	0.5	3.2	1.1	0	99.2	0.8	3.2	1.6	0	98.8	1.2	3.0	5.2
S-17-M	0.8	99.2	0	1.4	0.4	0.6	99.3	0.1	1.4	0.4	0.8	99.2	0	1.5	0.4
1978															
N-10-W	0	78.7	21.3	3.5	1.6	1.6	61.8	36.6	3.9	2.5	0.7	60.3	39.0	3.7	2.9
N-10-M	0.1	99.9	0	1.5	0.3	0	99.7	0.3	1.6	0.4	0.7	99.0	0.3	1.8	0.3
O-W	0.1	83.7	16.2	3.3	0.9	1.3	61.7	37.0	3.7	0.1	0.9	76.4	23.5	3.5	2.5
O-M	0.5	99.5	0	0.9	0.5	3.0	96.8	0.2	1.1	0.5	0.7	99.0	0.3	1.1	0.5
S-4-W	0.2	80.2	19.6	3.4	1.7	0.1	91.0	8.9	3.2	0.7	0.4	97.2	2.4	3.2	1.2
S-4-M	0.9	99.0	0.1	1.0	0.5	0.5	99.2	0.3	1.2	0.4	1.4	98.2	0.4	1.0	0.5
S-17-W	0	87.4	12.6	3.4	0.8	0.3	82.4	17.3	3.3	0.8	0.1	70.6	29.3	3.9	2.1
S-17-M	0.6	99.4	0	1.6	0.4	0.5	99.2	0.3	1.5	0.4	2.0	97.4	0.5	1.4	0.5

APPENDIX TABLE D-3. BENTHIC MACROINVERTEBRATES OBSERVED IN PONAR (P) AND ARTIFICIAL MULTIPLATE (M) SAMPLES, HOOKSETT POND, MERRIMACK RIVER, NH, 1972-1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

	1972				1973				1974				1975				1976				1977				1978			
	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17
Porifera																												
Spongillidae												P																
Coelenterata																												
Hydra sp.							P	P	P							P												
Platyhelminthes																												
Turbellaria			P	P	P		P	P	P	P	P	P	P	P	P	P			P	P	PM	PM	PM	PM	PM	PM	PM	PM
Nematoda			P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	PM	PM	PM	PM	PM	PM	PM	PM
Nemertea	P	P							P	P		P	P	P	P	P												
Bryozoan statoblast									P	P			P	P	P	P												
Annelida																												
Oligochaeta	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	PM	PM	PM	PM	PM	PM	PM	PM
Lumbriculidae																	P	P										
Tubificidae																												
Aulodrilus piqueti																				P								
Aulodrilus americanus																			P									
Immature specimens																												
without capilliforms																	P	P	P	P	P	P	P	P				
with capilliforms																	P	P	P	P	P	P	P	P				
Limnodrilus claparedeianus																	P	P	P	P								
Limnodrilus hoffmiesteri																	P	P	P	P	P	P	P	P				
Limnodrilus profundicola																	P	P	P	P	P	P	P	P				
Limnodrilus udermianus																				P								
Peloscolex sp.																			P									
Potamothrix vejdovskyi																	P	P	P	P	P	P	P	P				
Tubifex tubifex																	P			P								
Tubifex newaensis																	P											
Niadidae																												
Allonais sp.																												
Arctenonais lomondi																	P		P	P	P	P	P	P				
Nais spp.									P	P	P	P	P	P	P	P			P				P					
Paranais spp.																		P										
Piquetiella michiganensis																	P	P	P	P	P	P	P	P				
Pristinia spp.																				P								
Ripistes parasita																												
Slavina sp.									P	P	P	P	P	P	P	P												
Specaria josinae																		P	P	P	P	P	P	P				
Stylaria spp.									P	P	P	P	P	P	P	P	P				P	P		P				
Stylaria lacustris																				P	P	P	P	P				
Hirundinea	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
Glossiphoniidae																												
Dina sp.									P			P	P		P	P												
Helobdella sp.									P	P	P	P	P	P	P	P	P	P	P	P	P	PM	PM	P	PM	P	P	
Placobdella sp.									P			P	P	P														

Continued

APPENDIX TABLE D-3. (Continued)

	1972				1973				1974				1975				1976				1977				1978			
	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17
Mollusca																												
Gastropoda																												
Ancylidae																												
***Ferrissia* sp.**									P	P			P	P							PM	PM	M	P	M			
Amnicolidae																												
***Amicola* sp.**					P	P	P	P	P	P	P	P	P	P	P	P	P		P		PM	P	P	PM				
***Lyrogyrus* sp.**											P	P	P	P	P	P						M	M					
Physidae																												
***Physa* sp.**							P	P				P	P		P	P												
Planorbidae																												
***Helisoma* sp.**	P			P		P	P	P	P			P	P	P	P	P					P	P	PM	PM	P	P	P	P
Vivipareidae																												
***Campeloma* sp.**	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Pelecypoda																												
Sphaeriidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P					P	PM	P	P	P	P	P	P
***Pisidium* sp.**									P	P	P	P	P	P	P	P			P									
***Sphaerium* sp.**									P	P	P	P	P	P	P	P	P	P	P	P								
Unionidae									P	P	P	P	P	P	P	P												
***Anodonta* sp.**		P																										
Elliptio complanatus	P	P	P	P	P	P	P	P			P	P	P				P	P	P	P	P	P	P	P	P	P	P	P
Arthropoda																												
Arachnida																												
Hydracarina	P	P	P	P		P	P	P	P	P	P	P	P	P	P	P		P		P	PM	PM	PM	PM	P	P	P	P
Crustacea																												
Cladocera													P								PM	PM	PM	PM	M	M	PM	PM
Copepoda													P	P	P	P												
***Argulus* sp.**									P																			
Ostracoda													P															
Isopoda			P	P		P		P				P																
Asellidae																												
Asellus racovitzai racovitzai													P		P	P				P	P		P		P			
Amphipoda												P																
Gammaridae																												
***Gammarus* sp.**					P																							
Talitridae																												
Hyalella azteca										P	P		P		P	P	P	P		P	P	P	M	P	P			
Decapoda																	P		P		P							

Continued

APPENDIX TABLE D-3. (Continued)

	1972				1973				1974				1975				1976				1977				1978			
	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17
Insecta																												
Ephemeroptera																												
Baetidae		P				P		P		P	P	P	P	P	P	P												
Baetis sp.																										M	M	M
Centroptilum sp.																		P		P	PM	PM	PM	PM	PM	M	PM	PM
Pseudocoleon sp.																									M	M	M	
Baetiscidae																												
Baetisca sp.										P			P															
Caenidae																												
Caenis sp.																			P		PM	PM	PM	P	PM		P	P
Ephemeridae																												
Hexagenia sp.													P							P	P							
Ephemerellidae																												
Ephemerella sp.					P	P	P	P	P	P	P		P	P	P					P	PM	M	M	M	M	M	M	M
Heptageniidae																												
Stenonema sp.					P	P				P					P			P			M	M	PM	M	M	M	M	M
Leptophlebiidae																												
Paraleptophlebia sp.							P				P								P									
Polymitarcidae																												
Ephoron sp.	P	P	P	P		P		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Siphlonuridae																												
Ameletus sp.									P	P	P	P																
Isonychia sp.																					M	M	M	M	M			M
Plecoptera																												
Perlidae																												
Perlesta sp.																					M	M	M	M	M			P
Paragnetina sp.																								M				
Isoperla sp.																												M
Isogenous sp.																												M
Taeniopterygidae																												
Taeniopteryx sp.																						M	M	M				
Megaloptera																					M							
Corydalidae																												
Nigronia sp.																					M							
Sialidae																												
Sialis sp.									P					P	P		P				P		PM	P	P	P	P	
Neuroptera																												
Sisyra sp.																					M			M				
Hemiptera																												
Dytiscidae												P	P	P	P	P												
Rhantus sp.																						P						
Lepidoptera															P						PM			P				
Odonata																												
Anisoptera																												
Corduliidae																												
Tetragoneuria sp.																												M
Epicordulia sp.			P																									
Gomphidae																												
Argiogomphus sp.																										P	P	
Dromogomphus sp.																			P	P	P	P	P					
Gomphus sp.		P	P	P	P	P	P	P		P	P	P	P	P	P	P	P	P	P			P						
Stylurus sp.																							P	P	P		P	
Libellulidae	P																											
Macromia sp.															P							M	P					
Macromiidae																												
Didymops sp.					P						P				P										P			
Zygoptera																												
Coenagrionidae	P												P						P									
Anomalagrion sp.																	P											
Chromagrion sp.													P	P														
Nehalennia sp.																					PM	PM	PM	PM				M
Ischnura sp.																	P											
Lestidae																												
Lestes sp.								P																				

Continued

APPENDIX TABLE D-3. (Continued)

	1972				1973				1974				1975				1976				1977				1978			
	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17
Coleoptera																												
Dryopidae																												
Helichus sp.				P																	P	P		P				
Elmidae			P	P			P				P			P		P												
Ancyronyx sp.	P			P												P												
Dubraphia sp.	P		P	P	P	P	P	P	P		P	P	P	P	P	P	P	P		P	P	P	PM	P	P	P	P	P
Gyrinidae																												
Gyrinus sp.																						M		M				
Hydrophilidae																												
Berosus sp.												P	P							P		P						
Psephenidae																												
Psephenus sp.																					M		M	M				
Trichoptera		P		P											P													
Glossosomatidae																												
Hydropsychidae	P		P	P	P	P		P						P														
Cheumatopsyche sp.					P	P			P	P	P				P						PM	PM	PM	PM	PM	PM	PM	PM
Hydropsyche sp.																									M	M	M	M
Diplectrona sp.																		P										
Hydroptilidae					P	P			P	P	P	P	P								P	P	P	P	M	M		M
Pupae																					M	M		PM		M	P	
Agraylea sp.												P									M	M	M	M	PM	M	M	M
Ithytrichia sp.																					M							
Oxyethira sp.									P																			
Ochrotrichia sp.												P																
Odontoceridae																												
Psilotreta sp.																										M		
Leptoceridae	P				P	P		P			P		P	P	P	P												
Arthripsodes sp.									P	P	P	P																
Ceraclea sp.																							M	M		PM	P	PM
Leptocella sp.									P																			
Oecetis sp.																					PM	PM	PM	P	P		P	
Limnephilidae								P																				
Nyctiophylax sp.																										M		
Pseudostenophylax sp.																				P								
Pycnopsyche sp.																												
Molannidae				P																								
Philopotomidae																												
Chimarra sp.																						M	M	M	M	M		
Phryganeidae																												
Phryganea sp.																	P											
Psychomyiidae				P	P			P	P			P	P	P		P								M				
Lype sp.																	P			P	M	PM	PM	M	M	M	M	M
Neureclipis sp.										P							P								M			
Phylocentropus sp.									P	P		P						P	P	P	P	P	P	P	PM	PM	PM	PM
Phylocentropus pupae																									P			
Polycentropus sp.																	P					M						
Psychomyia sp.									P			P	P	P	P	P												

Continued

APPENDIX TABLE D-3. (Continued)

	1972				1973				1974				1975				1976				1977				1978			
	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17	N10	0	S4	S17
Diptera																												
Pupae	P	P	P	P																	M	M	M	M	PM	PM	PM	PM
Ceratopogonidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
Palpomyia gp. spp.																									P	P	P	P
Chaoboridae																												
Chaoborus sp.										P													P	P				
Chironomidae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	PM	PM	PM	PM	PM	PM	PM	PM
Chironominae																												
Chironomus sp.	P		P		P	P	P	P	P	P	P	P		P	P	P		P			P	P	P	P	P	P	P	P
Cladotanytarsus sp.																		P		P	PM	PM	M	PM	PM	PM	PM	PM
Cryptochironomus spp.	P	P	P	P					P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	PM	PM	P
Dicrotendipes spp.													P					P			PM	PM	PM	PM	PM	PM	PM	P
Endochironomus sp.													P								P							
Glyptotendipes spp.													P	P	P	P	P	P	P	P								
Microtendipes sp.																										P		P
Micropsectra sp.																								P				
Parachironomus spp.																		P	P	P	P				PM	M	PM	
Paratanyarsus spp.																		P							P			
Polypedilum spp.									P				P	P	P	P	P	P	P	P	PM	PM	PM	PM	PM	PM	PM	PM
Pseudochironomus sp.														P		P		P		P					P	P	P	
Rheotanytarsus spp.																	P		P	P			P	P			M	P
Tanytarsus sp.																		P			PM	PM	PM	PM	PM	PM	P	PM
Tribelos sp.									P	P	P	P	P	P	P	P					P		P		P			
Orthocladinae														P														
Cricotopus sp.													P		P	P	P	P	P	P	M	M	M	M	M	M	M	M
Eukiefferiella sp.																	P								M	M	M	M
Paraorthocladius sp.																									P	P	P	P
Psectrocladius sp.																									M	M		
Microcricotopus sp.																		P										
Psectrocladius sp.															P	P												
Rheocricotopus sp.																	P	P			P				P	P	P	PM
Thienemanniella sp.																									P	M	M	M
Tanypodinae		P	P										P		P													
Ablabesmyia sp.																	P	P		P	PM	PM	PM	PM	M			M
Clinotanypus sp.																		P										
Conchapelopia sp.																					M	M	M	M	PM	M	M	M
Pentaneura sp.	P	P	P	P	P	P	P	P	P	P	P	P	P	P														
Procladius									P	P	P	P	P	P	P	P	P	P	P	P	P	PM	PM	P	P	P	P	P
Macropelopia sp.																									PM	PM	P	P
Empididae						P																M						
Psychodidae																												
Psychoda sp.													P		P								P					
Rhagionidae																												
Atherix sp.													P															
Simuliidae																					M	M		M	M	M	M	M
Tabanidae																												
Crysops sp.													P															
Tabanus sp.									P				P															
Tipulidae																												
Antocha sp.																					M	M		M				
Total number of Taxa Ponars	20	18	22	25	24	25	21	27	45	39	37	45	60	46	51	46	43	43	39	48	55	49	51	51	41	30	36	32
Multiplates																					34	38	36	35	33	35	26	30

APPENDIX E

APPENDIX TABLE E-1. PERCENT COMPOSITION OF HOOKSETT POND FISH BASED ON ELECTROFISHING AND SEINING. MERRIMACK RIVER SUMMARY REPORT, 1979.

	1967[1]	1968[1]	1971	1972	1973	1974	1975	1976	1977[2]	1978[2]
Anguiliidae										
American eel	0.5	0.3	0.8	1.4	2.0	2.2	3.1	1.3	0.4	
Clupeidae										
American shad										<0.1
Salmonidae										
Rainbow trout			0.2			0.1				
Atlantic salmon										
Brook trout			0.2							
Osmeridae										
Rainbow smelt									<0.1	
Esocidae										
Chain pickerel	1.0	1.5	0.3	0.8	1.0	0.6	0.3	0.4	0.2	0.3
Cyprinidae										
Golden shiner	5.3	11.2		0.6	1.5	0.9	0.9	0.6	14.8	9.0
Common shiner		<0.1	31.3			0.6			17.2	11.9
Spottail shiner						0.4			2.6	4.9
Notropis sp(p).				3.1	0.1		3.2	2.6	<0.1	
Fallfish		0.1	0.5	3.5	1.0	0.9			7.9	19.3
Semotilus							2.8	0.2		
Catostomidae										
White sucker	10.8	15.6	10.8	5.6	0.6	7.5	8.3	6.4	3.4	2.9
Ictaluidae										
Yellow bullhead	1.4	1.7	0.2	0.1	0.3	0.3	0.8	1.1	0.6	>0.1
Brown bullhead	18.9	8.8	3.4	4.1	3.0	1.1	3.2	1.2	0.8	0.1
Madtom sp(p)[3]		<0.1	0.2		0.2		0.2	0.6	0.1	>0.1
Percichthyidae										
White perch	<0.1	0.2	0.2	0.1	0.2				0.1	0.2
Centrarchidae										
Redbreast sunfish	4.2	5.6	2.1	6.7	11.2	10.0	13.8	20.4	6.8	2.5
Pumpkinseed	33.9	27.5	26.1	48.5	53.5	51.2	42.7	42.2	34.2	29.9
Bluegill				0.2		0.1	0.1		1.1	<0.1
Smallmouth bass	2.1	2.2	1.8	1.2	7.8	5.0	2.2	14.3	4.8	1.1
Largemouth bass	0.1	0.1	1.4	7.7	1.7	11.7	11.2	4.7	3.2	5.9
Percidae										
Johnny darter						0.2	0.1	0.4	<0.1	0.1
Yellow perch	21.7	25.3	20.6	16.4	15.9	7.1	7.1	3.6	2.2	11.8
Walleye	<0.1									

[1] adapted from Wightman 1971, methods included fyke netting, gillnetting and electrofishing

[2] seining replaced electrofishing in 1977

[3] Species identification of madtoms is questionable prior to 1977; both Margined and Tadpole madtom have been collected in Hooksett Pond during 1977 and 1978.

APPENDIX TABLE E-2. PERCENT COMPOSITION OF HOOKSETT POND FISH BASED ON FYKE NETTING. MERRIMACK RIVER SUMMARY REPORT, 1979.

	1967[1]	1968[1]	1969[1]	1972	1973	1974	1975	1976	1977	1978
Anguiliidae										
American eel	0.5	0.3	0.4	0.5	1.1	0.1	0.2	0.2		0.1
Salmonidae										
Rainbow trout							<0.1			
Atlantic salmon										0.1
Brook trout							<0.1			
Esocidae										
Chain pickerel	1.0	1.5	2.3	1.4	2.0	0.6	0.6	0.2	0.2	1.2
Cyprinidae										
Golden shiner	5.7	10.2	10.1	0.4	0.4	0.7	1.2	1.0	0.6	2.6
Common shiner		<0.1							0.2	0.1
Spottail shiner						0.3			0.4	
Fallfish		0.1	0.2			0.4	0.4	0.1	0.9	1.6
Semotilus spp.										
Catostomidae										
White sucker	10.9	14.8	22.8	12.1	16.2	24.6	17.9	23.6	36.6	19.8
Ictaluridae										
Yellow bullhead	1.6	1.8	2.6	1.5	4.3	1.2	1.4	0.8	0.7	2.6
Brown bullhead	19.0	8.6	13.0	46.0	28.9	21.2	35.6	30.5	12.9	14.4
Madtom[2]					<0.1		0.3	0.1	0.4	0.5
Percicthyidae										
White perch	0.1	0.2	0.5	2.5	1.7	4.7	3.0	3.7	2.3	4.2
Centrarchidae										
Redbreast sunfish	4.1	5.6	3.0	0.6	3.1	2.7	4.5	5.7	2.2	8.4
Pumpkinseed	32.9	28.4	19.5[3]	15.5	18.9	25.4	19.9	16.4	20.8	24.3
Smallmouth bass	2.4	2.0	4.4	5.5	8.6	5.4	4.5	5.0	7.8	9.6
Largemouth bass		<0.1	0.3	0.1	<0.1	0.1	0.6	0.1	1.0	
Percidae										
Yellow perch	21.8	26.4	20.8	14.0	14.6	12.2	9.9	12.7	13.1	10.4
Walleye	<0.1	<0.1	<0.1		<0.1		<0.1			0.1

[1]adapted from Wightman, 1971.
[2]Species identification of madtoms is questionable prior to 1977; both margined and tadpole madtom have been collected in Hooksett Pond during 1977 and 1978.
[3]reported as common sunfish

APPENDIX TABLE E-3. CATCH PER TUCKER TRAWL TOW OF LIVE AND DEAD ICHTHYOPLANKTON COLLECTED AT THE MERRIMACK GENERATING STATION INTAKE STRUCTURES AND THE DISCHARGE CANAL, 1975 TO 1977. MERRIMACK RIVER SUMMARY REPORT, 1979.

	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD
Intake Structure												
SUNFISH												
1975	0	0	0	0	0	3.0	0	2.6	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0.5	0	0.6	0	0	0	0	0
Unidentified Species												
1975	0	0	0	0	0	0	0.1	0	0	0	0	0
Discharge Canal												
SUNFISH												
1975	0	0	0	0	0	0	1.6	2.6	0	0	0	0
1976	0	0	0	0	0.8	0	13.3	0.7	7.1	1.6	0.2	0
1977	0	0	0	0	12.4	0.2	167.8	19.1	31.3	9.0	0.3	0
LARGEMOUTH BASS												
1976	0	0	0	0	0	0	0	0.1	0	0	0	0

Sunfish = *Lepomis* spp.

1733.4

APPENDIX TABLE E-4. 1978 ICHTHYOPLANKTON ENTRAINMENT COLLECTIONS SUMMARIZED BY DATE. MERRIMACK RIVER SUMMARY REPORT, 1979.

DATE	TIME START	TIME END	WATER TEMPERATURE (°C) SURF	WATER TEMPERATURE (°C) BTM	VOLUME OF WATER FILTERED (m^3)	LARVAE CAPTURED QUANTITY	LARVAE CAPTURED SPECIES
5/23	1225	1427	15.5	15.4	71.8	0	
	1428	1955	15.5	15.4	204.2	0	
	1955	2350	NA	NA	117.4	0	
5/24	2350	0350	NA	NA	143.6	11	White sucker
	0353	0750	14.7	14.6	148.0	0	
	0754	1154	15.7	15.5	149.6	0	
	1205	1605	16.1	15.7	143.6	0	
	1615	2005	15.1	15.0	143.6	0	
	2005	2400	NA	NA	146.8	4	White sucker
5/25	0005	0400	14.6	14.6	146.8	3	White sucker
	0405	0805	14.7	14.7	149.9	0	
5/31	1200	1600	21.6	21.5	149.9	2	Golden shiner
						2	Unidentifiable
	1605	2000	21.2	21.2	146.8	1	Unidentifiable
	2005	2400	20.6	20.6	146.8	78	*Notropis* spp.
						19	Golden shiner
						3	Johnny darter
						2	White sucker
6/1	0005	0400	20.1	20.1	146.8	10	Golden shiner
	0405	0800	19.9	19.9	146.8	0	
	0800	1200	23.2	23.0	149.9	1	Johnny darter
6/8	0850	1215	18.7	18.5	128.0	0	
	1215	1605	19.2	19.1	143.6	0	
	1610	2000	18.8	18.8	143.6	0	
	2000	2400	18.8	18.8	149.9	17	*Notropis* spp.
						10	Golden shiner
						3	Johnny darter
						2	White sucker

(Continued)

APPENDIX TABLE E-4. (Continued)

DATE	TIME		WATER TEMPERATURE (°C)		VOLUME OF WATER FILTERED	LARVAE CAPTURED	
	START	END	SURF	BTM	(m^3)	QUANTITY	SPECIES
6/9	0000	0430	18.3	18.0	149.9	11	Golden shiner
						1	*Notropis* sp.
	0435	0730	18.0	17.6	109.3	0	
	2000	2400	NA	NA	149.9	1	Golden shiner
6/13	0830	1155	17.9	17.9	128.0	0	
	1200	1600	18.2	18.2	149.9	0	
	1600	1955	17.2	17.2	146.8	0	
	2000	2400	16.9	17.0	149.9	6	Golden shiner
6/14	0005	0400	16.3	16.5	146.8	23	Golden shiner
						3	Unidentifiable
						1	*Notropis* sp.
	0400	0815	17.5	17.5	140.5	3	Golden shiner
6/15	0900	1200	17.0	17.0	17.8	0	
	1200	1600	17.9	17.9	20.3	0	
	1600	2000	17.5	17.5	20.7	0	
	2000	2400	16.7	16.7	20.7	0	
6/16	0000	0400	16.3	16.3	20.7	1	Golden shiner
	0400	0600	16.3	16.3	5.2	0	
6/28	0900	1200	25.2	25.1	116.4	0	
	1200	1600	25.3	25.3	199.5	0	
	1600	2000	24.4	24.3	119.5	0	
	2000	2400	24.3	24.4	119.5	0	
6/29	0000	0400	23.6	23.6	119.5	2	*Lepomis* spp.
						1	Golden shiner
	0400	0800	23.8	23.8	119.5	0	
	0800	1200	25.7	25.6	119.5	0	
	1200	1600	25.9	25.9	119.5	14	*Lepomis* spp.
	1600	2000	24.9	24.8	192.9	3	*Lepomis* spp.
	2000	2400	24.2	24.2	192.9	1	*Lepomis* sp.

(Continued)

APPENDIX TABLE E-4. (Continued)

DATE	TIME START	TIME END	WATER TEMPERATURE (°C) SURF	WATER TEMPERATURE (°C) BTM	VOLUME OF WATER FILTERED (m³)	LARVAE CAPTURED QUANTITY	LARVAE CAPTURED SPECIES
6/30	0000	0400	23.2	23.3	192.9	2	*Lepomis* spp.
						2	Golden shiner
						1	*Notropis* sp.
						1	Unidentifiable
	0400	0800	23.4	23.4	192.9	1	Largemouth bass
7/5	0900	1200	22.4	22.3	160.2	0	
	1200	1600	23.9	23.9	213.6	6	*Lepomis* spp.
	1600	2000	22.1	22.1	213.6	0	
	2000	2400	21.5	21.5	213.6	2	*Lepomis* spp.
						1	Golden shiner
7/6	0000	0400	20.9	20.9	213.6	0	
	0400	0800	21.5	21.4	213.6	1	Golden shiner
	0800	1200	23.0	23.0	216.1	0	
	1200	1600	24.9	24.7	230.6	0	
	1600	2000	23.9	23.9	230.6	0	
	2000	2400	23.5	23.5	230.6	0	
7/7	0000	0400	23.1	23.1	230.6	0	
	0400	0800	22.7	22.7	230.6	4	*Lepomis* spp.
7/10	0850	1200	24.7	24.7	141.3	0	
7/21	0845	1600	28.0	28.0	605.2	0	
	1600	2000	26.9	27.1	230.6	0	
	2000	2400	26.5	26.6	230.6	0	
7/22	0000	0400	26.5	26.6	230.6	0	
	0400	0800	26.7	26.8	230.6	0	
7/25	1745	2000	27.4	27.5	140.4	0	
	2000	2400	26.4	26.4	249.6	0	

(Continued)

APPENDIX TABLE E-4. (Continued)

DATE	TIME		WATER TEMPERATURE (°C)		VOLUME OF WATER FILTERED	LARVAE CAPTURED	
	START	END	SURF	BTM	(m^3)	QUANTITY	SPECIES
7/26	0000	0400	23.8	23.8	249.6	1	Margined madtom
	0400	0800	25.2	25.2	249.6	0	
	0955	1200	26.4	26.4	130.0	0	
	1200	1600	26.8	26.8	249.6	0	
	1600	2000	26.3	26.3	249.6	0	
	2030	2400	25.9	25.9	218.4	0	
7/27	0000	0400	25.5	25.5	249.6	0	
	0400	0900	25.4	25.4	312.0	0	
	0930	1200	23.4	23.4	218.4	0	
	1200	1600	26.6	26.5	249.6	0	
	1630	2000	25.8	25.7	161.2	0	
	2000	2400	25.6	25.6	249.6	0	

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APPENDIX TABLE E-5. NUMBER AND TOTAL LENGTH (mm) OF FINFISH IMPINGED DURING 48 SAMPLING HOURS PER WEEK AT MERRIMACK STATION UNITS I AND II, 1976 AND 1977. MERRIMACK RIVER SUMMARY REPORT, 1979.

		JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
		NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH
Rainbow smelt	1976									1	75									1	85				
	1977																			1	85				
Pickerel	1976																								
	1977							1	290																
Golden shiner	1976							1	80	5	65							1	80						
	1977							9	70	18	70	2	175					1	NA						
Bridle shiner	1976									1	65														
	1977																					16	70	1	75
Common shiner	1976									1	70	6	120					1	55						
	1977	2	80			2	80	135	80									1	NA						
Spottail shiner	1976			2	95	5	95					2	90												
	1977																								
Shiners	1976																			2	65				
	1977					1	80	15	80	7	80									2	NA				
Fallfish	1976							1	60			1	110												
	1977																								
White sucker	1976											4	265	3	385	1	180								
	1977									2	280	1	410			1	NA								
Yellow bullhead	1976			2	90	3	170			2	165														
	1977							1	120																
Brown bullhead	1976	1	55	1	80	5	100	16	95	32	100	7	110	2	150	9	155	1	190						
	1977							6	130	12	145	1	150	1	115	7	NA	1	NA						
Bullhead sp(p).	1976																								
	1977																								
Tadpole madtom	1976																					3	65	2	60
	1977	1	55																						
Margined madtom	1976									2	100									2	95				
	1977									1	60														
White perch	1976											1	285	1	230										
	1977																								
Redbreast sunfish	1976									1	190	1	190									1	130		
	1977																								
Pumpkinseed	1976					5	95	3	95	8	65	1	45			2	120	1	205	13	90	5	95		
	1977	2	60	1	60	2	125	10	130							2	NA	1	NA	1	NA				
Sunfish	1976															1	40	1	35						
	1977					1	40	3	110			1	150			1	NA	1	NA						
Smallmouth bass	1976			4	80					1	85			1	60	1	50			1	100				
	1977															1	50			1	100				
Largemouth bass	1976			1	65															2	125	1	80		
	1977																								
Yellow perch	1976			8	135	9	125	27	100	2	95	9	155	3	180	3	170			5	160	1	80		
	1977	3	130			2	125	10	90	3	170	1	140			3	NA			1	NA				
Unidentified	1976							1	60			1	NA			1	220								
	1977															1	NA								

APPENDIX TABLE E-6. SUMMARY OF FISH ENTRAPMENT MONITORING FOR UNITS I AND II, MERRIMACK STATION, JUNE THROUGH OCTOBER, 1978. MERRIMACK RIVER SUMMARY REPORT, 1979.

	JUNE		AUGUST		SEPTEMBER		OCTOBER	
	NO.	LENGTH RANGE (mm)	NO.	LENGTH RANGE (mm)	NO.	LENGTH RANGE (mm)	NO.	LENGTH RANGE (mm)
Golden shiner	3	71-86	0		0		1	130
Common shiner	2	55-95	0		0		0	
Spottail shiner	0		0		0		0	
Fallfish	3	100-200	1	87	0		0	
White sucker	1	461	0		0		0	
Yellow bullhead	1	170	0		0		0	
Brown bullhead	10	71-204	6	145-170	0		0	
Margined madtom	1	151	0		0		0	
Pumpkinseed	1	59	0		1	43	1	31
Smallmouth bass	1	280	0		0		0	
Largemouth bass	1	28	1	78	0		0	
Yellow perch	2	260-281	2	194-243	0		0	
American shad	0		0		0		1	91

APPENDIX TABLE E-7. FISH TOXICITY STUDY, 1975. MERRIMACK RIVER SUMMARY REPORT, 1979.

AUGUST 22 - SEPTEMBER 4

SPECIES	LOCATION	TOTAL TESTED	NUMBER DEAD DURING 3-DAY ACCLIMATION	NUMBER DEAD IN REMAINDER OF TEST	NUMBER UNACCOUNTED	NUMBER ALIVE	MORTALITY* INDEX
Smallmouth bass	Intake	10	9	1	-	0	1.00
Yellow perch		11	11	0	-	0	1.00
Pumpkinseed		51	51	0	-	0	1.00
Smallmouth bass	Discharge	10	5	0	1	4	0.00
Yellow perch		6	5	0	1	0	1.00
Pumpkinseed		20	20	0	-	0	1.00

SEPTEMBER 4-17

SPECIES	LOCATION	TOTAL TESTED	NUMBER DEAD DURING 3-DAY ACCLIMATION	NUMBER DEAD IN REMAINDER OF TEST	NUMBER UNACCOUNTED	NUMBER ALIVE	MORTALITY* INDEX
Smallmouth bass	Intake	11	0	1	5	5	0.17
Yellow perch		18	5	7	3	3	0.70
Pumpkinseed		20	1	10	4	5	0.67
Smallmouth bass	Discharge	12	1	1	1	9	0.10
Yellow perch		20	11	3	6	0	1.00
Pumpkinseed		20	10	1	7	2	0.33

SEPTEMBER 17-29

SPECIES	LOCATION	TOTAL TESTED	NUMBER DEAD DURING 3-DAY ACCLIMATION	NUMBER DEAD IN REMAINDER OF TEST	NUMBER UNACCOUNTED	NUMBER ALIVE	MORTALITY* INDEX
Smallmouth bass	Intake	8	0	0	-	8	0.00
Yellow perch		32	1	3	-	28	0.10
Pumkinseed		38	1	5	-	32	0.14
Smallmouth bass	Discharge	12	0	12	-	0	1.00
Yellow perch		26	8	16	1	0	0.94
Pumpkinseed		32	10	17	1	4	0.81
Restocked from intake to discharge after fish kill							
Smallmouth bass		3	0	0	-	3	0.00
Yellow perch		15	1	9	1	4	0.69
Pumpkinseed		16	1	1	-	14	0.07

$$\text{* Mortality index} = \frac{\text{Number dead}}{\text{Total} - \left(\text{Dead during acclimation}\right) - \text{Unaccounted}}$$

APPENDIX TABLE E-9. FISH TOXICITY STUDY, 1977. MERRIMACK RIVER SUMMARY REPORT, 1979.

JULY 19 - AUGUST 1

SPECIES	LOCATION	TOTAL TESTED	NUMBER DEAD DURING 3-DAY ACCLIMATION	NUMBER DEAD IN REMAINDER OF TEST	NUMBER UNACCOUNTED	NUMBER ALIVE	MORTALITY INDEX*
Smallmouth bass	Intake	8	0	1	4	3	0.25
Yellow Perch		3	2	1	0	0	1.00
Pumpkinseed		30	11	8	0	11	0.42
Smallmouth bass	Discharge	4	1	0	0	3	0.00
Yellow Perch		5	5	0	0	0	0.00
Pumpkinseed		22	13	4	0	5	0.44

AUGUST 15 - 30

SPECIES	LOCATION	TOTAL TESTED	NUMBER DEAD DURING 3-DAY ACCLIMATION	NUMBER DEAD IN REMAINDER OF TEST	NUMBER UNACCOUNTED	NUMBER ALIVE	MORTALITY INDEX*
Smallmouth bass	Intake	3	0	2	0	1	.67
Yellow Perch		24	2	21	1	0	1.00
Pumpkinseed		19	0	0	1	18	0.00
Smallmouth bass	Discharge	7	2	1	3	1	0.50
Yellow perch		5	5	0	0	0	0.00
Pumpkinseed		22	22	0	0	0	0.00

$$* \text{ Mortality index} = \frac{\text{Number dead}}{\text{Total} - \left(\begin{matrix}\text{Dead during}\\ \text{acclimation}\end{matrix}\right) - \text{Unaccounted}}$$

APPENDIX TABLE E-10. MEAN BACK-CALCULATED LENGTHS (mm) AT ANNULUS FORMATION FOR SMALLMOUTH BASS. MERRIMACK RIVER SUMMARY REPORT, 1979.

STATION	ANNULUS	1967*	1968*	1969*	1975	1976	1977	1978
North	1	NA	NA	111.8	117.6	128.3	89.6	101.0
	2	152	149.9	185.4	164.8	169.4	130.1	152.1
	3	213	198.1	223.5	206.3	210.9	176.4	197.9
	4	267	259.1	294.6	256.2	258.6	229.9	244.8
	5	348	309.9	307.3	298.0	293.5	281.5	287.6
	6	358	350.5	358.1	322.0	272.7	304.9	321.0
	7	384	396.2	388.6	333.5	362.3	NA	339.0
South	1	104.1	91.4	109.2	118.3	145.1	103.4	104.5
	2	167.6	139.7	167.6	164.0	180.7	159.0	150.6
	3	218.4	228.6	213.4	207.8	212.9	211.2	202.2
	4	274.3	266.7	292.1	252.4	237.7	249.9	246.7
	5	337.8	287.0	317.5	298.5	257.8	286.4	285.0
	6	275.9	363.2	NA	326.0	335.0	318.9	324.5
	7	NA	NA	NA	363.5	316.0	352.2	383.0

* Adapted from Wightman (1971)

APPENDIX TABLE E-11. MEAN BACK-CALCULATED LENGTHS (mm) AT ANNULUS FORMATION FOR PUMPKINSEED. MERRIMACK RIVER SUMMARY REPORT, 1979.

STATION	ANNULUS	1967*	1968*	1969	1975	1976	1977	1978
North	1	58.4	66.0	66.0	71.7	94.5	56.2	64.8
	2	99.1	101.6	109.2	97.1	122.0	87.6	94.4
	3	147.3	144.8	144.8	120.2	146.1	118.8	116.9
	4	NA	180.3	170.2	147.6	164.7	140.8	135.3
	5	NA	NA	NA	170.0	171.4	158.8	153.6
	6	NA	NA	NA	182.1	178.6	171.1	170.1
South	1	60.9	73.7	63.5	71.0	91.0	79.8	78.4
	2	109.2	101.6	119.4	101.4	118.2	108.5	104.2
	3	134.6	147.3	144.8	132.1	141.1	130.8	123.6
	4	180.3	172.7	175.3	158.8	160.2	145.8	140.7
	5	NA	NA	NA	175.2	177.9	158.9	158.3
	6	NA	NA	NA	185.4	184.9	171.0	172.6

* Adapted from Wightman (1971)

APPENDIX TABLE E-12. MEAN BACK-CALCULATED LENGTHS (mm) AT ANNULUS FORMATION FOR YELLOW PERCH. MERRIMACK RIVER SUMMARY REPORT, 1979.

STATION	ANNULUS	1967*	1968*	1969*	1975	1976	1977	1978
North	1	91.4	94.0	94.0	118.3	128.1	92.0	104.2
	2	134.6	142.2	142.2	143.9	159.9	118.2	127.7
	3	193.0	180.3	180.3	169.5	185.9	141.3	154.6
	4	226.1	218.4	210.8	195.0	208.2	169.1	177.3
	5	254.0	248.9	NA	212.9	223.3	196.9	201.4
	6	274.3	NA	NA	233.0	241.1	217.6	223.2
	7	NA	NA	NA	239.0	259.6	236.7	233.7
	8	NA	NA	NA	272.2	265.6	254.0	241.6
South	1	94.0	88.9	94.0	110.8	149.7	113.4	111.1
	2	124.0	134.6	139.7	137.3	167.8	134.9	136.0
	3	177.8	175.2	172.7	165.5	181.2	155.3	160.7
	4	228.6	213.4	208.3	185.7	194.6	177.2	184.0
	5	254.0	231.1	NA	205.0	212.2	194.8	199.3
	6	274.3	264.2	NA	210.9	220.6	217.0	219.1
	7	NA	NA	NA	233.5	217.7	231.8	231.3
	8	NA	NA	NA	255.0	227.5	238.0	NA

* Adapted from Wightman (1971)

APPENDIX TABLE E-13. LENGTH-WEIGHT RELATIONSHIPS FOR SMALLMOUTH BASS. MERRIMACK RIVER SUMMARY REPORT, 1979.

YEAR	STATION	Log C	n	r	N
1972	N-10-E	-6.58	3.19	.89	42
	N-10-W	-5.88	2.94	.98	48
	S-3-E	-6.22	3.07	.97	20
	S-2-W	-6.34	3.11	.99	42
1973	N-10-E	-4.19	2.77	.92	3
	N-10-W	-5.59	3.30	.98	48
	S-3-E	-4.93	3.02	.99	52
	S-2-W	-5.77	3.37	.98	30
1974	N-10-E	-5.24	3.17	.99	35
	N-10-W	-3.43	2.45	.99	4
	S-3-E	-5.24	3.17	.99	47
	S-2-W	-4.08	2.69	.98	52
1975	N-10-E	-5.12	3.12	.99	55
	N-10-W	-4.15	2.73	.99	10
	S-3-E	-4.99	3.06	.99	52
	S-2-W	-4.60	2.91	.99	8
1976	N-10-E	-5.06	3.11	.99	6
	N-10-W	-3.95	2.63	.90	26
	S-3-E	-4.59	2.90	.96	22
	S-2-W	-4.86	2.42	.96	39
1977	N-10-E	NC	NC	NC	1
	N-10-W	-6.05	3.48	1.00	4
	S-3-E	-4.47	2.84	.99	48
	S-2-W	-5.17	3.14	1.00	5
1978	N-10-E	-4.67	2.93	1.00	33
	N-10-W	-4.87	3.02	0.99	11
	S-3-E	-5.15	3.13	1.00	73
	S-2-W	-5.53	3.27	0.99	21

NC - Not Calculated

APPENDIX TABLE E-14. LENGTH-WEIGHT RELATIONSHIPS FOR PUMPKINSEED. MERRIMACK RIVER SUMMARY REPORT, 1979.

YEAR	STATION	Log C	n	r	N
1972	N-10-E	-6.90	3.44	.90	27
	N-10-W	-6.05	3.05	.93	33
	S-3-E	-6.13	3.12	.98	39
	S-2-W	-5.60	2.88	.92	187
1973	N-10-E	-5.17	3.25	.95	8
	N-10-W	-5.07	3.17	.94	40
	S-3-E	NC	NC	NC	97
	S-2-W	-5.31	3.28	.89	128
1974	N-10-E	-4.92	3.13	.96	69
	N-10-W	-3.61	2.54	.81	6
	S-3-E	-4.07	2.75	.96	133
	S-2-W	-3.64	2.57	.90	322
1975	N-10-E	-4.83	3.08	.97	89
	N-10-W	-4.72	3.03	.97	77
	S-3-E	-4.03	2.70	.95	101
	S-2-W	-4.46	2.91	.98	217
1976	N-10-E	-2.18	1.89	1.00	2
	N-10-W	-4.14	2.76	.97	33
	S-3-E	-4.35	2.86	.77	40
	S-2-W	-4.05	2.72	.95	237
1977	N-10-E	-5.07	3.19	.99	13
	N-10-W	-5.43	3.34	.98	28
	S-3-E	-5.57	3.40	.99	27
	S-2-W	-4.93	3.13	.98	81
1978	N-10-E	-3.92	2.68	.96	16
	N-10-W	-5.26	3.28	.98	13
	S-3-E	-4.72	3.04	.98	67
	S-2-W	-4.99	3.15	.98	217

NC - Not Calculated

APPENDIX TABLE E-15. LENGTH-WEIGHT RELATIONSHIPS FOR YELLOW PERCH. MERRIMACK RIVER SUMMARY REPORT, 1979.

YEAR	STATION	Log C	r.	r	N
1972	N-10-E	-6.55	3.16	.93	63
	N-10-W	-6.53	3.16	.96	111
	S-3-E	-5.81	2.85	.97	22
	S-2-W	-6.35	3.09	.93	113
1973	N-10-E	-4.16	2.67	1.00	2
	N-10-W	-4.78	2.92	.95	49
	S-3-E	-3.83	2.51	.81	87
	S-2-W	-5.29	3.13	.84	41
1974	N-10-E	-3.90	2.56	.93	86
	N-10-W	NC	NC	NC	1
	S-3-E	-6.18	3.56	.96	83
	S-2-W	-5.07	3.08	.95	117
1975	N-10-E	-4.84	2.97	.96	93
	N-10-W	-4.49	2.82	.96	107
	S-3-E	-4.49	2.82	.95	69
	S-2-W	-3.75	2.48	.93	12
1976	N-10-E	NC	NC	NC	0
	N-10-W	-4.75	2.92	.98	132
	S-3-E	-4.64	2.92	.76	11
	S-2-W	-3.57	2.42	.84	75
1977	N-10-E	-6.30	3.60	.96	6
	N-10-W	-5.05	3.06	.98	22
	S-3-E	-4.65	2.90	.79	17
	S-2-W	-4.92	3.10	.97	42
1978	N-10-E	-4.02	2.63	.96	72
	N-10-W	-5.48	3.22	.99	16
	S-3-E	-4.37	2.76	.98	32
	S-2-W	-5.37	3.20	.99	32

NC - Not Calculated